Government of Canada
Gouvernement du Canada

Ottawa, Canada

High Definition Television Colloquium
La télévision à haute définition Colloque
'85

Volume 1 of 2
Volume 1 de 2

Canada

High Definition Television
Colloquium 85

Télévision à Haute Définition
Colloque 85

2/

Second international colloquium on new television systems: HDTV '85 :

Ottawa, Canada, May 13-16, 1985 =

Deuxième colloque international sur les nouveaux systèmes de télévision: TVHD '85 :

Ottawa, Canada, du 13 au 16 mai 1985 /

COLLOQUIUM PROCEEDINGS

A Post-Colloquium Proceedings will be published in order to include the summaries of the discussions in the Workshops.

1./International Colloquium on New Television Systems: HDTV '85 (2nd : 1985 : Ottawa)/

LES ACTES DU COLLOQUE

Les Actes du colloque seront publiés après le colloque, afin d'inclure les résumés des délibérations qui auront eu lieu dans les ateliers.

Additional copies of the Colloquium Proceedings are available at $30 Canadian per two volume set. Please make cheques or money orders payable to **CBC/HDTV'85** and send your request to:

Elmer H. Hara
Chairman,
HDTV Colloquium Program Committee

Department of Communications
Room 638
300 Slater Street, Ottawa, Ontario
Canada, K1A 0C8

On peut se procurer des exemplaires supplémentaires des actes du colloque à raison de 30$ canadiens pour la série des deux volumes. Veuillez établir votre chèque ou mandat à l'ordre de **CBC/HDTV'85**. Les commandes doivent être adressées à:

Elmer H. Hara
Président
Comité du programme du colloque de la TVHD

Ministère des Communications
Bureau 638
300, rue Slater, Ottawa, Ontario
Canada, K1A 0C8

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SECOND INTERNATIONAL COLLOQUIUM
ON
NEW TELEVISION SYSTEMS: HDTV'85

Ottawa Congress Centre

- All Abstracts are in English and French.
- Simultaneous English-French interpretation will be provided for the presentation of papers.
- Papers with an asterisk (e.g. 2.10* F. Delmas, "Colour Slide ...") are written in French.
- Papers with two asterisks (e.g. 3.5** E. Dubois & S. Ericsson, "Digital Coding ...") are written in both English and French.
- Papers with three asterisks have Abstracts only. Their texts will be included in the Post-Colloquium Proceedings which will also contain the Workshop Summaries.

PROGRAM

Monday, May 13, 1985

07:30 - 09:30	**REGISTRATION**	
OPENING SESSION	Chairperson	K. Davies, CBC
09:30 - 09:40	**OPENING ADDRESS**	K. Hepburn, Assistant Deputy Minister (Technology & Industry), Department of Communications
09:40 - 10:05	**KEYNOTE SPEAKER**	G. Gougeon, Vice President of Engineering, Canadian Broadcasting Corporation
SESSION 1. NEEDS	Chairperson	D. MacLean, DOC
10:05 - 10:30	1.1***	T. Fujio, "The Present State of HDTV: What it takes and what should be done." NHK, Japan
10:30 - 10:50	**COFFEE BREAK**	
10:50 - 11:15	1.2***	W. Habermann, "The HDTV-Studio Standard Project: Status of Discussion and Position in Europe", Chairman of EBU Working Group V1-HDTV
11:15 - 11:40	1.3***	J. Flaherty, "HDTV Standardization Activities in the United States", CBS, USA
11:40 - 12:05	1.4	F. Spiller, "The Content of HDTV: A New Creative Challenge", Francis Spiller Associates, Canada
12:05 - 13:00	**LUNCH**	

SESSION 2-A. TECHNOLOGY; Psychophysics Chairperson D. Phillips, DOC

13:00 - 13:20	2.1	W. Glenn & K. Glenn, "HDTV Colorimetry", New York Institute of Technology, USA
13:20 - 13:40	2.2***	P. Hearty, "Limitations of Current Psychophysical Approaches to Display Evaluation", Department of Communications, Canada
13:40 - 14:00	2.3***	D. Kline & H. Mathias, "A Look at the Characteristics of Film in Relation to the Needs of HDTV for Theatrical Production", USA
14:00 - 14:40	2.4***	A. Kaiser & D. Morss III, "Direct Comparison of 35 mm Film and High Definition Television", CBS Technology Center & CBS Engineering and Development, USA
14:40 - 15:00	**COFFEE BREAK**	

SESSION 2-B. TECHNOLOGY; Cameras and Displays and Recorders Chairperson S. Quinn, CBC

15:00 - 15:20	2.5	B. Stanski, "Some Noise Aspects of HDTV Cameras", University of Dortmund, FRG
15:20 - 15:40	2.6	G. Mahler, "The Display Problem of HDTV", HHI, FRG
15:40 - 16:00	2.7***	K. Morita & T. Kataoka, "Color Picture Display System for High-Definition Television", Matsushita Electric Industrial Co., Ltd., Japan
16:00 - 16:20	2.8	K. Takashasi, M. Umemoto, Y. Etoh, S. Mita, S. Nagahara, H. Noguchi, H. Ogiwara & M. Greenwood, "Color Television and Digital VTR for High Definition Television Use", Central Research Laboratory, Hitachi; Hitachi Denshi, Japan & Canada
16:20 - 16:40	2.9	G. Smith, "Recording HDTV - Present and Future", SONY, USA
16:40 - 17:00	2.10**	F. Delmas, J. Chambaut, M. Artigalas & M. Favreau, "Colour Slide Scanners for High Definition TV", Thomson Video Equipment, France
18:00 - 20:00	**TOUR & RECEPTION**	(Optional: only a limited number of tickets are available.)

Tuesday, May 14, 1985

SESSION 2-C. TECHNOLOGY; Systems Chairperson L. Cheveau, CBC

08:45 - 09:05	2.11*	R. Melwig, "HDTV: A Slow Revolution", CCETT, France
09:05 - 09:35	2.12***	B. Nabati, "Using a Videodisc as a Medium for High-Resolution Fixed Images", Centre Mondiale Informatique et Ressources Humaine, France
09:35 - 10:05	2.13	J. Gaspar, "Interlace Scan Artifacts", McDonnel Douglas Astronautics Co., USA
10:05 - 10:25	**COFFEE BREAK**	

SESSION 3-A. SYSTEMS; Scanning and Coding Chairperson M. Akgun, DOC

10:25 - 10:50	3.1	N. Tanton, I. Childs & C. Sandbank, "Compatibility Consideration for HDTV Sources and Displays", BBC, UK
10:50 - 11:15	3.2	C. Billotet, H. Sauerberger & L. Stenger, "HDTV - Alternatives in Fieldrates and Conversion to 50 Hz", Deutsche Bundespost, FRG
11:15 - 11:40	3.3***	B. Wendland, "A Scanning Scheme for a New HDTV Standard", University of Dortmund, FRG
11:40 - 12:05	3.4	G.M.X. Fernando, D. Parker & P. Saraga, "Investigations on Raster Conversions for HDTV Displays", Philips, UK
12:05 - 12:30	3.5	S. Ericsson & E. Dubois, "Digital Coding of High Quality TV", INRS, Canada
12:30 - 13:30	**LUNCH**	

SESSION 3-B. SYSTEMS & DELIVERY; EDTV, HDTV Chairperson G. Chouinard, DOC

13:30 - 14:10	3.6**	H. Mertens & D. Wood, "The European Approaches to Better Quality in Television", Technical Centre, EBU
14:10 - 14:30	3.7***	G. Crowther, "European MAC: A Component Maker's Viewpoint", Mullard, UK
14:30 - 14:50	3.8***	J. Lowry, "The Evolution of B-MAC into a fully Compatible EDTV System", Digital Video Systems/Scientific-Atlanta, Canada
14:50 - 15:10	3.9	C. Rhodes, "The Further Evolution of B-MAC Signal Format for HDTV Broadcasting", Scientific-Atlanta, USA
15:10 - 15:30	3.10***	R. Morcom, "Enhanced C-MAC: The Evolutionary Approach", IBA, UK
15:30 - 15:50	**COFFEE BREAK**	

SESSION 3-B. SYSTEMS & DELIVERY; EDTV, HDTV (continued) Chairperson D. Garforth, CBC

15:50 - 16:10	3.11	G. Reitmeier & C. Carlson, "An Adaptive Extended-Definition MAC Television System", RCA, USA
16:10 - 16:30	3.12	Y.S. Kao & L.N. Lee, "An Evolutionary Approach to HDTV based on Motion-Adaptive Image Processing Techniques", COMSAT, USA
16:30 - 16:50	3.13***	J. Kumada, "Developmental State of Various HDTV Equipment Including the MUSE System", NHK, Japan
16:50 - 17:10	3.14***	J. Nadan, "Two-Channel NTSC-Compatible HDTV Transmission Methods", Philips, USA
18:30 - 22:30	**BANQUET**	Reception Area

Wednesday, May 15, 1985

SESSION 3-C. SYSTEMS & DELIVERY; Optical Techniques Chairperson M. Sablatash, DOC

08:45 - 09:10	3.15	G. Heydt, "Optical Fiber Networks with HDTV Capability", HHI, FRG
09:10 - 09:35	3.16	R. MacDonald & D.K.W. Lam, "Photoconductive Broadband Switching for HDTV", Department of Communications, Canada
09:35 - 09:55	**COFFEE BREAK**	

SESSION 4. POLICY, STANDARDS & IMPACT Chairperson K.Y. Chang

09:55 - 10:20	4.1	Y. Tadokoro, "High-Definition Television: Towards a Worldwide Standard", NHK, Japan
10:20 - 10:45	4.2***	K. Powers, "High Definition Production Standards: How broad their application?", RCA, USA
10:45 - 11:10	4.3***	H. Payne, "Heroics in Policy Advising: The Australian experience in planning broadcasting services by national satellites." DOC, Australia
11:10 - 11:50	4.4***	P. Lyman, "HDTV: Who pays for the dream?", Nordicity, Canada
11:50 - 13:00	**LUNCH**	

COLLOQUIUM WORKSHOPS

Wednesday, May 15, 1985

WORKSHOP 1. 13:00 - 17:00

APPLICATIONS AND OPERATIONAL NEEDS Moderator to be arranged.

"HDTV: Who Needs It?"

- addressing the wide range of possible applications of HDTV, user expectations compared to present systems, economic implications on operations.

WORKSHOP 2. 13:00 - 17:00

SYSTEMS AND STANDARDS Moderator R. Zavada, Eastman Kodak, USA

"Evolution or Resolution?"

- addressing the emerging forces in systems and standards, approaches to a common standard, its urgency, whether the 1125 line system will become the de-facto standard.

WORKSHOP 3A. 13:00 - 15:00

TECHNICAL - PRODUCTION Moderator M. Blandford, CBC, Canada

"Practicality vs. Creativity"

- addressing how end-use impacts on production techniques, technical bottlenecks, impact of new equipment requirements, production costs, training costs, impact on small operations.

WORKSHOP 3B. 15:00 - 17:00

TECHNICAL - DISPLAY Moderator W. Habermann, IRT, FRG.

"Image of the Future"

- addressing needs for various applications, impact of digital processing, prospects of competing technologies, psychophysical aspects, impact of sound, the "ideal" in commercial and home systems.

18:30

SPEAKERS' DINNER National Arts Centre Restaurant

Thursday, May 16, 1985

WORKSHOP 3C. 9:00 - 11:30

TECHNICAL - DISTRIBUTION Moderator V. Reed, Skyline Cablevision, Canada

"Which Way to the Viewer?"

- addressing cable, broadcast and DBS technologies, impact on compatibility, stereo-sound, whether fibre optic transmission is the prerequisite for mass distribution.

WORKSHOP 4. 9:00 - 11:30

SOCIO-ECONOMIC Moderator P. Lyman, Nordicity Group, Canada

"HDTV: Who Pays for the Dream?"

- addressing the market for HDTV, perception of HDTV's value and its relative cost, the importance of compatibility, impact on consumer video products, on cinemas, whether EDTV is good enough or all that can be afforded.

CLOSING PLENARY SESSION Chairperson O. Roscoe, Telesat Canada
13:30 - 15:00

DEUXIÈME COLLOQUE INTERNATIONAL
SUR
LES NOUVEAUX SYSTÈMES DE TÉLÉVISION: TVHD 1985

Centre des congrès d'Ottawa

- Tous les résumés sont en versions française et anglaise.
- Une traduction simultanée en anglais et en français sera disponible lors des conférences.
- Les articles indiqués par un asterisque (e.g. 2.10* F. Delmas, "Les Analyseurs...") sont en version française.
- Les articles indiqués par deux asterisques (e.g. 3.5**, E. Dubois et S. Ericsson, "Codage numérique...") sont en version française et anglaise.
- Les articles indiques par trois asterisques dont le résumé seulement apparaît dans le premier volume disponible des Actes, de même que les rapports soumis par les ateliers.

PROGRAMME

le lundi 13 mai 1985

0730-0930	INSCRIPTION
OUVERTURE DU COLLOQUE	(Modérateur: K. Davies, Société Radio Canada)
0930-0940	MOT DE BIENVENUE K. Hepburn, sous-ministre adjoint (technologie et industrie), Ministère des Communications
0940-1005	TÊTE D'AFFICHE G. Gougeon, Vice Président, Ingénierie, Société Radio Canada
SESSION n° 1. LES BESOINS	(Modérateur: D. Maclean, Ministère des Communications)
1005-1030	1.1*** T. Fujio, "État actuel du système TVHD - Necessités et imperatifs." NHK, Japon
1030-1050	PAUSE CAFÉ
1050-1115	1.2*** W. Habermann, "Projet de norme sur les studios de TVHD: État des discussions et position en Europe." Rapporteur du groupe de travail V1-HDTV de l'UER

1115-1140	1.3*** J. Flaherty, "Activités de normalisation de la TVHD aux États-Unis." CBS, E.-U.
1140-1205	1.4 F. Spiller, "Contenu de la TVHD: nouveau défi à la créativité." Francis Spiller Associates, Canada
1205-1300	DÉJEUNER

SESSION n° 2A — **TECHNOLOGIE: la psychophysique** (Modérateur: D. Phillips, MDC)

1300-1320	2.1 W. Glenn et K. Glenn, "Colorimétrie en Télévision a Haute Définition." New York Institute of Technology, E.-U.
1320-1340	2.2*** P. Hearty, "Limites des méthodes psychophysiques actuelles d'évaluation de l'image." MDC, Canada
1340-1400	2.3*** D. Kline et H. Mathias, "Aperçu des caractéristiques du cinéma par rapport aux besoins de TVHD dans la production commerciale (États-Unis)." Panavision, E.-U.
1400-1440	2.4*** A. Kaiser et D.F. Morss III, "Comparaison directe du film 35mm à la Haute Définition (TVHD)." CBS Technology Center & CBS Engineering and Development, E.-U.
1440-1500	PAUSE CAFÉ

SESSION n° 28 — **LA TECHNOLOGIE: les caméras, les écrans et les enregistreuses**

(Modérateur: S. Quinn, Société Radio Canada)

1500-1520	2.5 B. Stanski, "Caractéristiques de bruit des caméras de TVHD." Université de Dortmund, RFA
1520-1540	2.6 G. Mahler, "Problématique des écrans de TVHD." IHH, RFA
1540-1600	2.7*** K. Morita et T. Kataoka, "Système d'affichage en couleur pour la télévision à la Haute Définition." Matsushita Electric Industrial Co., Japon
1600-1620	2.8 K. Takahashi, M. Umemoto, Y. Etoh, S. Mita, S. Nagahara, H. Noguchi, H. Ogiwara., M. Greenwood, "Caméra de télévision couleurs et magnétoscope numérique pour la télévision à haute définition." Laboratoire central de recherche, Hitachi Ltée., Hitachi Denshi, Japon et Canada
1620-1640	2.9 G. Smith, "Enregistrement de la TVHD - Présent et avenir." Centre technologique Sony Inc., E.-U.
1640-1700	2.10** F. Delmas, J. Chambaut, M. Artigalas, M. Favreau, "Les analyseurs de diapositives couleurs à haute définition." Thompson Vidéo Equipement, France
1800-2000	VISITE ET RECEPTION (Optionel: nombre limité de billets disponibles)

le mardi 14 mai 1985

SESSION n° 2C — **LA TECHNOLOGIE: systèmes** (Modérateur: L. Cheveau, SRC)

0845-0905	2.11* R. Melwig, "La TVHD: Une révolution lente." CCETT, France
0905-0935	2.12*** B. Nabati, "Utilisation d'un vidéodisque comme support d'images fixes de haute résolution." CMIRH, France
0935-1005	2.13 J. Gaspar, "Défauts associés au balayage entrelacé." McDonnell Douglas Astronautics Co., EU
1005-1025	PAUSE CAFÉ

SESSION n° 3A	**SYSTÈMES: balayage et codage** (Modérateur: M.B. Akgun, MDC)	
1025-1050	3.1	N.E. Tanton, I. Childs, C.P. Sandbank, "Considérations liées à la compatibilité des sources et des supports de présentation." BBC, U.K.
1050-1115	3.2	C. Billotet, H. Sauerberger et L. Stenger, "TVHD - nouvelles fréquences de trame et conversion à 50 Hz." Deutsche Bundespost, RFA
1115-1140	3.3***	B. Wendland, "Système de balayäge pour une nouvelle norme TVHD." Université de Dortmund, RFA
1140-1205	3.4	G.M.X. Fernando, D.W. Parker et P. Saraga, "Recherches sur la conversion de trame pour présentation sur écran de télévision à haute définition." Philips, U.K.
1205-1230	3.5	E. Dubois et S. Ericsson, "Codage numérique des signaux de télévision de haute qualité." INRS, Canada
1230-1330	DÉJEUNER	
SESSION n° 3B	**SYSTÈMES ET DISTRIBUTION: EDTV, HDTV** (Modérateur: G. Chouinard, MDC)	
1330-1410	3.6**	H. Mertens et D. Wood, "Les voies européenes vers la télévision de meilleur qualité." Centre Technique, UER
1410-1430	3.7***	G. Crowther, "Système MAC européen: Point de vue d'un fabricant." Mullard, U.K.
1430-1450	3.8***	J. Lowry, "Évolution du B-MAC vers un système de TVHD totalement compatible." Digital Video Systems/Scientific Atlanta, Canada
1450-1510	3.9	C. Rhodes, "Évolution supplémentaire de la structure des signaux B-MAC pour radiodiffusion TVHD." Scientific Atlanta, E.-U.
1510-1530	3.10***	R. Morcom, "Système C-MAC amélioré - Conception progressive." IBA, U.K.
1530-1550	PAUSE CAFÉ	
	SYSTÈMES ET DISTRIBUTION: EDTV, HDTV (suite)	
	(Modérateur: D. Garforth, SRC)	
1550-1610	3.11	G. Reitmeir et C. Carlson, "Système adaptable de télévision à composantes analogiques multiplexées et a extension de definition." RCA, E.-U.
1610-1630	3.12	Y.S. Kao et L.N. Lee, "Conception progressive d'une norme TVHD basée sur les techniques de traitement de l'image avec compensation de mouvement." COMSAT, E.-U.
1630-1650	3.13***	J. Kumada, "État du développement de différents systèmes TVHD, y compris le système MUSE." NHK, Japon
1650-1710	3.14***	J. Nadan, "Méthodes de transmission TVHD à deux canaux, Compatible NTSC." Philips, E.-U.
1830-2230	BANQUET - Salle de reception	

le mercredi 15 mai 1985

SESSION n° 3C	**SYSTÊMES ET DISTRIBUTION: techniques optiques**
	(Modérateur: M. Sablatash, MDC)
0845-0910	3.15 G. Heydt, "Réseaux à fibres optiques à capacité de TVHD." IHH, RFA
0910-0935	3.16 R. MacDonald et D.K.W. Lam, "Commutation à large bande par photo-conduction pour télévision à haute définition." MDC, Canada
0935-0955	PAUSE CAFÉ
SESSION n° 4	**POLITIQUE, STANDARDS ET IMPACT** (Modérateur: K.Y. Chang)
0955-1020	4.1 Y. Tadokoro, "Télévision haute définition: vers une norme internationale." NHK, Japon
1020-1045	4.2*** K.H. Powers, "Normes relatives à la production haute définition: Quelle est l'étendue de leur champ d'application?" RCA, E.-U.
1045-1110	4.3*** H. Payne, "Visées audacieuses: l'expérience de l'Australie dans la planification de services de radiodiffusion par satellites domestiques." MDC, Australie
1110-1150	4.4*** P. Lyman, "La TVHD: Qui paie la note du rêve?" Nordicity, Canada
1150-1300	DÉJEUNER

ATELIERS DU COLLOQUE

le mercredi 15 mai 1985

ATELIER 1
1300-1700

Applications et besoins (Modérateur: indeterminé)

"La TVHD: Pourquoi?"

- Toutes les applications possibles de la TVHD, les attentes de l'utilisateur par rapport aux systèmes actuels, les implications économiques.

ATELIER 2
1300-1700

Systèmes et normes (Modérateur: R. Zavada, Eastman Kodak, E.-U.)

"Evolution ou résolution?"

- Les nouveaux développements en matière de systèmes et de normes, les possibilités d'une norme commune, la nécessité de s'entendre rapidement; le système de 1125 lignes deviendra-t-il la norme?

ATELIER 3a
1300-1500

Technique - Production (Modérateur: M. Blandford, SRC)

"Aspects pratiques vs. créativité"

- Les répercussions sur les techniques de production, les impasses techniques, l'impact des nouveaux besoins d'équipement, les coûts de production et de formation et l'impact sur les petites exploitations.

ATELIER 3b
1500-1700

Technique - Affichage (Modérateur: W. Habermann, IRT, RFA)

"L'image de l'avenir"

- La nécessité des diverses applications, l'impact du traitement numérique, les perspectives des technologies concurrentes, les aspects psychophysiques, l'impact du son, le système "idéal" pour l'équipement commercial et grand public.

1830 DINER DES CONFÉRENCIERS - Restaurant du Centre Nationale des Arts

le jeudi 16 mai 1985

ATELIER 3c 0900-1130

Technique - Distribution (Modérateur: V. Reed, Skyline Cablevision, Canada)

"Comment atteindre le téléspectateur"

- Le câble, la diffusion traditionelle, la diffusion directe par satellite, l'impact sur la compatibilité, le son stéréo; la fibre optique est-elle la condition préalable à la distribution à grande échelle?

ATELIER 4 0900-1130

Socio-économie (Modérateur: P. Lyman, Nordicity Group, Canada)

"La TVHD: qui paie ce rêve?"

- Le marché de la TVHD, la perception de sa valeur et de son coût relatif, l'importance de la compatibilité, l'impact sur les produits vidéo grand public, sur le cinéma; la EDTV convient-elle ou est-ce seulement un pis-aller?

le jeudi 16 mai 1985

SÉANCE PLÉNIÈRE DE FERMETURE (Modérateur: O. Roscoe, Télésat Canada)
1330-1500

NEW TELEVISION TECHNOLOGY DEMONSTRATIONS

Tuesday, May 14,1985 & Wednesday, May 15,1985	Thursday, May 16,1985
9:00	9:00
10:00	10:00
11:00	11:00
13:00	
14:00	
15:00	
16:00	

DEMONSTRATIONS DES NOUVELLES TECHNOLOGIES DE TÉLÉVISION

mardi,14 mai 1985 et mercredi,15 mai 1985	jeudi,16 mai 1985
0900	0900
1000	1000
1100	1100
1300	
1400	
1500	
1600	

THE PRESENT STATE OF HDTV - WHAT IT TAKES AND WHAT SHOULD BE DONE

Takashi Fujio
Director General of Research

NHK Science & Technical
Research Laboratories

1.1

ABSTRACT

In the information society of the future television will be assigned to an ever more important position as an imaging system and a video communication system fundamental to the information industry. After the digitization of TV signals was achieved, extensive picture processing, including in the temporal frequency domain, has become possible by manipulation of TV signals. All the future imaging systems would be based on television technology. From this point of view, an HDTV system proposed by NHK was designed to make it a total broadcasting system from program production and transmission to reception in homes, bearing in mind the all-round system which will be able to create a future image culture.

Presently, all the HDTV equipment including a receiver with 40-inch CRT has been completed by NHK. Early in 1984, the MUSE signal system was developed for DBS and it is used for experimental HDTV broadcasting at the Tsukuba Exposition site. A quality system converter from the HDTV with 60 Hz field to existing TV with 50 Hz field was also developed and demonstrated successfully in January of this year at the IWP 11/6 in Tokyo.

NHK has done all this to realize an ultimate TV broadcasting with single standard throughout the world, which promises the unification of the world into one "television community" in the next generation. Engineers of today are responsible to hand over a splendid video system to engineers of tomorrow. Broadcasters of the eighties should cooperate and direct their effort to the establishment of a unified HDTV system without sticking on conventional ideas which will obstruct an advance and progress of the system in the future.

ÉTAT ACTUEL DU SYSTEME HDTV - NÉCESSITÉS ET IMPÉRATIFS

Takashi Fujio,
Directeur général de la recherche
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RÉSUMÉ

Dans la société consommatrice d'information de l'avenir, la télévision se verra accorder un rôle de plus en plus important comme système d'imagerie et systèmes de communication vidéo essentiel à l'industrie de l'information. Après la numérisation des signaux de télévision, la manipulation de ces signaux, y compris dans le domaine temporel, rend possible le traitement détaillé de l'image. Tous les systèmes d'imagerie éventuels seraient basés sur la technologie de la télévision. De ce point de vue, un système HDTV proposé par le laboratoire de la NHK a été conçu pour en faire un système de radiodiffusion intégral comprenant la production, la transmission et la réception au foyer des programmes, tout en tenant compte d'un ensemble de facteurs qui permettront la création de la culture de l'imagerie de l'avenir.

Tout le matériel de HDTV a déjà été mis au point par le laboratoire de la NHK, y compris un récepteur comportant un TRC de 40 pouces. Dans les débuts de l'année 1984, le système MUSE a été mis au point pour la radiodiffusion directe par satellite et il est utilisé à titre expérimental pour la radiodiffusin de TVHD à l'exposition de Tsukuba. Un convertisseur de système de grande qualité permettant le passage de la trame TVHD 60 Hz à la trame TV 50 Hz a été également mis au point et a fait l'objet d'une démonstration réussie en janvier de l'année courante dans le cadre des travaux du groupe de travail intérimaire 11/6 à Tokyo.

Le laboratoire de la NHK a effectué tous ces travaux pour obtenir un système de télévision basé sur une seule norme internationale promettant l'unification des cultures pour former une seule "communauté télévisuelle" dans la prochaine génération. Les ingénieurs d'aujourd'hui sont tenus de remettre aux ingénieurs de demain un système vidéo splendide. Les radiodiffuseurs des années 80 doivent coopérer et diriger leurs efforts vers l'établissement d'un système TVHD unifié sans s'accrocher aux idées conventionnelles qui bloquent les progrès éventuels du système.

The HDTV-Studio Standard Project
Status of Discussions and Position in Europe

1.2

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ABSTRACT

In September 1984 the CCIR IWP 11-6 had received for consideration various proposals - originated by the EBU, Japan and USA - on potential choices of parameters to be included in a CCIR Recommendation possibly agreed upon at the CCIR Final Meeting October 1985. The most controversial item contained therein was the field rate, where differing requirements, in particular the mandatory conversion to existing standards set diverging priorities. The level of quality reached in standards conversion from one particular HDTV-standard candidate into the conventional standards was considered to be the fundamental and decisive attribute for its acceptance.

Among the variants in question the conversion of a 60 Hz field rate into 50 Hz found particular attention. Combined efforts in Europe, Japan and USA were made to provide the appropriate program material and the sophisticated hardware for arranging the conversion itself and demonstrations and subjective tests on the quality achieved. The paper will give a survey of these activities intended for the beginning of 1985, present the results of the tests and possibly enlarge on conclusions drawn from them.

PROJET DE NORME SUR LES STUDIOS DE TVHD

ÉTAT DES DISCUSSIONS ET POSITION EN EUROPE

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1.2

RÉSUMÉ

En septembre 1984, le Groupe de travail intérimaire 11-6 du CCIR avait reçu pour fins d'étude diverses propositions formulées par l'Union européenne de radiodiffusion (UER), le Japon et les Etats-Unis concernant les paramètres susceptibles d'être inclus dans l'avis du CCIR que pourrait arrêter la Réunion finale du CCIR en octobre 1985. L'élément le plus controversé du document était la fréquence de trame. En effet, la divergence des besoins sur ce plan - en particulier la conversion obligatoire aux normes existantes - fait que les priorités sont différentes pour les uns et pour les autres. Le niveau de qualité de la conversion entre une certaine proposition de norme de télévision à haute définition (TVHD) et les normes classiques a été jugé l'élément fondamental et décisif de l'acceptation de cette norme de TVHD.

Parmi les variantes proposées, la conversion d'une fréquence de trame de 60 Hz à 50 Hz a particulièrement retenu l'attention. Des efforts concertés ont été faits en Europe, au Japon et aux Etats-Unis pour fournir la programmation utile et le matériel sophistiqué nécessaires à la conversion proprement dite et aux démonstrations et essais subjectifs de la qualité obtenue. Le document passera en revue ces activités qui sont prévues pour le commencement de 1985; il présentera aussi les résultats des essais et s'étendra possiblement aux conclusions qui en sont tirées.

HDTV STANDARDIZATION ACTIVITIES IN THE UNITED STATES

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1.3

ABSTRACT

Since there is wide spread agreement in the U.S. for the need for a single world wide HDTV production standard, the Advanced Television Systems Committee (ATSC) was formed in May, 1983, to study high definition, enhanced, and improved television systems. This work towards a high definition television production standard has been conducted by the ATSC. The ATSC has been coordinating its efforts with those of the EBU and other broadcasting unions throughout the world in order that a worldwide HDTV production standard may be achieved.

The ATSC recently adopted recommendations for a high definition production standard. These recommendations have been submitted to the U.S. State Department in preparation for the final meetings of CCIR Study Group 11 to be held in Geneva in October, 1985.

The recommendations of the ATSC will be reported and their implications on a worlwide HDTV standard will be considered. The need for such a standard in the mass communications environment of the 21st Century will also be discussed.

ACTIVITÉS DE NORMALISATION DE LA TVHD AUX ÉTATS-UNIS

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CBS Engineering and Development Department

RÉSUMÉ

Etant donné qu'on s'entend généralement aux États-Unis sur la nécessité d'établir une seule norme mondiale de production TVHD, le Advanced Television Systems Committee (ATSC) Comité d'étude des systèmes de télévision avancés) a été créé en mai 1983 pour étudier les systèmes de télévision à haute définition, améliorés et avancés. L'ATSC a dirigé les travaux susmentionnés visant la formation d'une norme de production de télévision à haute définition. Il a coordonné ses efforts avec ceux de l'Union européenne des radiodiffuseurs et d'autres unions de radiodiffusion du monde entier en vue d'en arriver à une norme mondiale de production TVHD.

Dernièrement, l'ATSC a présenté au ministère d'État des États-Unis des recommendations sur une norme de production de télévision à haute définition, en prévision des réunions finales de la Commission d'études du CCIR qui se tiendront à Genève en octobre 1985.

Dans sa commission, M. Flaherty décrit les recommendations de l'ATSC et leurs implications sur une norme TVHD mondiale. Il traite aussi de la nécessité d'adopter une telle norme dans le milieu des communications de masse du 21ième siècle.

THE CONTENT OF HDTV
(A New Creative Challenge)

1.4

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ABSTRACT

During the last few years a great deal of attention has been focussed on the technological aspects of HDTV, yet the success or failure of HDTV will eventually be determined by the content it will provide and the consumers reaction to that content.

In the light of this it is essential to direct attention to the kinds of opportunities which HDTV offers to content creators and to better understand the characteristics of HDTV as a new window for visual communication and expression.

In general, HDTV offers an enhanced capacity for visual presentation, but is this likely to alter the established ways of producing films and television programs? Will it result in more "live" programming or will it increase the content creator's desire to manipulate still further the elements of the video process? Will it aid the evolution of computer-driven video systems and result in more varied uses for video imagery? Will it promote more interactive uses of television and will it turn both the creators and consumers of content from the present, essentially passive, use of the electronic media?

HDTV provides a unique opportunity to reassess the value and role of television not only as a means of creative expression but as a means of communication, and as a source of information.

In exploring such issues it is useful to try and establish where and how HDTV fits into the overall evolution of electronic communications. For example, will it develop as a supplement to existing radio and television broadcasting and film, or will it provide for an entirely new and more powerful content creation and delivery system eclipsing many of the established systems?

Most important of all, how is HDTV likely to be received by the consumer and how much is the consumers reaction likely to be affected by the content and services offered and the formats in which they will be provided.

If the great potential of HDT is to be realized it is vital to marshall our content creation resources as energetically as we are deploying our technological capabilities.

CONTENU DE LA TVHD
(Nouveau défi à la créativité)

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1.4

RÉSUMÉ

Au cours des dernières années, on s'est attaché surtout aux aspects techniques de la TVHD. Pourtant, ce sont le contenu et la réaction du public à ce dernier qui décideront ultimement du succès ou de l'échec de la télévision à haute définition.

Il est donc essentiel d'envisager les diverses possibilités que la TVHD offre aux créateurs de contenu et de mieux comprendre les particularités de ce nouveau créneau de communication et d'expression visuelles.

Dans l'ensemble, la TVHD offre une meilleure présentation visuelle. Mais cette caractéristique modifiera-t-elle réellement les moyens usités de production des films et des émissions de télévision? Donnera-t-elle lieu à un plus grand nombre d'émissions "en direct" ou est-ce qu'elle accentuera le désir des créateurs de contenu de manipuler davantage les éléments du processus vidéo? Est-ce que la TVHD stimulera l'évolution des systèmes vidéo informatisés et produira des usages plus variés de la vidéo? Favorisera-t-elle des utilisations plus interactives de la télévision et détournera-t-elle tant les créateurs que les consommateurs de contenu de l'utilisation essentiellemente passive qu'ils font présentement du média électronique?

La TVHD fournit une occasion unique en son genre de réévaluer la valeur et le rôle de la télévision, non seulement comme moyen d'expression créative mais comme médium de communication et source d'information.

Pour bien explorer ces questions, il importe d'essayer d'établir où et comment la TVHD s'insère dans l'évolution générale des communications électroniques. Par exemple: deviendra-t-elle un complément de la radio, de la télévision et du cinéma ou est-ce qu'elle offrira un système de création et de distribution de contenu tout à fait nouveau et plus puissant qui éclipsera nombre des systèmes établis?

Ce qui importe avant tout, c'est l'accueil que le consommateur réservera à la TVHD et l'incidence qu'auront le contenu, les services offerts et leur présentation sur la réaction des consommateurs.

Si l'on veut exploiter le riche potentiel de la TVHD, il est capital de rallier nos ressources de création de contenu avec autant d'énergie que nous en déployons du côté technique.

THE CONTENT OF HDTV
(A NEW CREATIVE CHALLENGE)

Frank Spiller
Francis Spiller Associates

INTRODUCTION

HDTV represents yet another, albeit important, step in the continuing attempts to improve the quality of the television image.

But does this evolutionary process go beyond mere image enhancement? How does it affect the established content creation processes, and what kinds of content are likely to be displayed on the new high definition formats which science and technology seek to create.

What renders such questions difficult is that those working to create electronic systems often have very little ongoing contact with those who create content. This is not of course a deliberate avoidance, it is just that the disciplines involved are so different. The result is that content creators usually face the question of whether or not the new system can improve the creation, distribution, and exhibition of content after it has been proven as a workable electronic system.

But the issue is not just a matter of different operational practices, or a sequential separation in development and use, content creators look at the results of technological development in different ways. As a recent study has observed, there is a clear difference between the way the technologist and the content producer regards a visual image. "I was discussing the problem (of picture quality) with a leading producer...I pointed to a photograph of a television screen on the wall and asked the deliberately vague question: 'Taking this picture, for instance, how would you define it?....He turned to look at it and, to my utter surprise, he started walking away from it. If I had been asked the same question I would have walked towards it, to examine in detail what it is made of...the immediate reaction of the humanist and the technologist were exactly opposite... there had really been no communication between us...he was interested in one thing, I in another.*

As the development and introduction of various types of enhanced electronic images progresses and intensifies it becomes increasingly important to not only recognize these differences in perception but to use them more effectively in system design and use.

What I want to explore in the following paper is how HDTV might affect the way content is presently conceived and created, whether it offers any potential for the introduction of new types of content, and to what extent new forms of distribution and exhibition might alter the consumers use of content.

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* Extracted from Technical Frontiers of Television by Raymond Wilmotte, IEEE Trans, BC-22, Number 3, September 1976 and quoted in Toward a Better Picture? by Pat Hawker IBA, Intermedia May 1982.

THE CREATIVE COMPONENTS

By and large all content is created out of relatively simple elements. There are, in fact, perhaps only three elements which the creator of content can manipulate either separately or in some combination. These elements are sounds, images, and time.

These elements have provided the essential underpinnings of the content creation process for our modern means of electronic communications. Furthermore, it can be shown that these elements apply whether we are dealing with radio broadcasting, motion pictures, television, or the latest computer-driven content creation processes. What is also interesting is that one is able to ascribe various emphases to these elements depending on the medium under consideration.

For example, radio is based on the creative manipulation of sounds. In the early days of radio it simply reproduced sounds of real events, whether these were the conveying at a distance of the sounds of a great occasion, like a visit of some notable personage, or the transmission of a sports event or a theatrical performance. In the early days then, radio was not seen so much as a creative medium for its own sake but merely a way of delivering sounds at a distance.

It was some time before radio discovered a way of presenting sounds so as to create an emotional effect out of the elements of the medium itself. The creative power of radio, therefore, increased in direct proportion to the number of ways provided for sound to be manipulated. Certainly, this was due to a gradual improvement in sound quality, a search which is still continuing, but it is also due to the facilities available to record and edit programs so as to juxtapose the elements in ways which take advantage of the nature of the sound itself whether voice or music, and by the timeframe in which the sound elements are presented.

About the same time that this was happening in radio the motion picture film was continuing to evolve. Here the emphasis was not on sound but visuals. One has only to look back at the early silent films to recognize the importance of the visual structure, and more particularly the important element of visual motion. In a way the silent motion picture was the "theatre-of-mime" in a new setting.

Like radio, however, the creative use of the cinema, even in the silent motion picture days, began increasingly to depend on the ability to manipulate the content in new ways. Out of this search for new ways of constructing the images came the art of editing. Interestingly enough, this focus on the image has been, and continues to be, an essential component of the cinema and the motion picture. Even after the advent of recorded sound, and the introduction of dialogue, music, and sound effects, motion picture production has retained its concern for the image as the primary element in the creative process.

From a content creation viewpoint radio broadcasting thus came to rely on the creative juxtaposition of sounds, whereas film has remained primarily a process of juxtaposing images.

These perspectives provide an interesting entry into a consideration of the evolution of the television medium. Television suddenly provided the facility to convey images over distances. Its early fascination was in being able to see an event taking place in real time. Unlike the motion picture then, the early emphasis was not on the creative manipulation of images but on their effective display at a distance in real time.

Only when recording equipment became available was it possible to contemplate the use of some of the disciplines which had been used in radio and motion pictures, that is the ability to manipulate the sound and visual elements before delivering them to the consumer.

The most important characteristic of television was that while it was a visual medium it did not provide the reproductive capability of the still picture or the motion picture film. At the same time the visual element was still more compelling than the sound element. For these reasons and others, such as the way television was financed, the television medium became, in a sense, a product of time. It was not so much the sounds and images of television that mattered but the time over which these elements were presented.

Perhaps, because television captured our imagination with its ability to deal in real time, the time factor came to dominate the way in which its content was created and presented. Granted the programs were an assembly of visual and sound elements but this assembly had to fit a precise time allocation. The faster, more abrupt, editing techniques which superseded the quiet fades and dissolves of the earlier motion pictures grew out of television's preoccupation with its use of time. It had to find a dramatic way to overcome its visual limitations. Denied the rich images of motion pictures, television had to focus on smaller parts of a scene.

Quite naturally, more abundant close-ups became the norm, but even beyond this the creators of television looked for compelling visual objects, simple symbols that provided the connective tissue of the program. It is out of the constraints inherent in the television medium that the rapid fire juxtaposition of the simple images of commercial messages emerged as a way of creating a high emotional impact. A more sophisticated form of this evolutionary process is reflected in the current popularity of music videos.

In each case the content producer has sought out the primary attributes of the medium and has attempted to use these in imaginative ways to create a high emotional impact. The order of creative sophistication achieved with any one medium takes time however. At first, the new medium tends to borrow heavily from the existing art forms. Only after much experience and experimentation has been acquired is it possible to begin to perceive the particular attributes of the newest medium. Ironically, it is often only when another medium has been introduced which offers competition to the existing medium that the inherent attributes of the older medium are found. One might say that this has been the case with radio when television arrived. As well, Motion pictures could be said to have encouraged greater experimentation in the live theatre while themselves benefitting from the challenge of television.

Given these kinds of insights, where does this put HDTV in this overall scale of media developments? Before considering HDTV specifically, it is useful to look at a few more elements in the overall equation.

CONTENT AND THE CONSUMER

From the consumer's point of view all of these somewhat esoteric theories about the cration of content are generally irrelevant. Aside from a very few, most consumers simply react to what they see and hear in terms of their particular desires of the moment. If they want to be entertained they want to find something that is entertaining. If they want to be informed they look for information, and more and more they are looking for specific types of information.

The consumer also wants to receive the content as simply and easily, and as cheaply as possible. Furthermore, there are ample signs that the consumer wants to bring the content exhibition process more and more under his or her direct control.

So generally speaking, the consumer usually has something in mind when instituting a search for content. Because of the increasing array of choices of content (even though this may be somewhat illusory*) the consumer is likely to choose the content which is most entertaining that is to say, it is highly effective in its task of creating an emotional effect, or is

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* In spite of the increasing capacity of the electronic system the program and service exhibition processes are primarily governed by mass market philosophies so that real consumer choice is still limited.

highly informative, that is to say it has been prepared so as to present the information in the most lucid way.

Even the most uninformed user of content makes certain important distinctions about content. For example, most television viewers understand very well the difference between a motion picture, a regular television program and a made-for-TV movie. Similarly, radio listeners discern the difference between a recorded program and a live program even if they are not told. Most movie goers can tell the difference between sequences which are actually shot on location and those which are re-enacted with realistic settings but with the aid of special effects.

What is important is that while the user of content does not necessarily understand the process by which the elements of a program are structured, he or she has a feeling for the very different impact created by different content creation techniques.

It follows that the various ways in which the creators of content have manipulated the creative elements in the various media create discernible differences in expectations on the part of the users of content. Basically, the consumer of content expects something different from a movie than from a regular television program and something different from radio than from a cassette recording.

But what is expected is not entirely due to the way the creative elements of content production are manipulated. The environment in which the content is "consumed" is also of importance. For example, there is a vast difference between viewing a movie in a darkened theatre than on a television screen in a family environment, perhaps punctuated by household activities going on all around. Similarly, listening to recordings on a hi-fi system in the home is very different from listening to the sounds of radio as background to other activities such as jogging with a Sony Walkman. What is perhaps a tribute to the creators of the content is that much of the effect desired is retained. A motion picture film still has tremendous drawing power when viewed on television even though it was designed for a much larger screen, and the effect of popular music is retained even though its power and range is diminished by inferior listening devices.

This also suggests that the consumer is willing to sacrifice reception quality for convenience while still being moved by the results of the skill with which the creator has manipulated the creative elements. This is not to suggest that the consumer goes through a kind of conscious process of analyzing these creative elements but rather that the power of the medium in the hands of a skilled content creator does not necessarily diminish in the consumer's eyes if the exhibition apparatus is of less than desirable quality.

Nevertheless, there does seem to be an increasing level of consumer discrimination and a desire for greater video and audio impact. For example, studies in Japan have shown that cable television viewers much prefer conventional film and television images to alpha-numeric or static graphic displays. It would appear that this reaction is directly related to the lack of mobility in the simpler visual presentations inasmuch as they lack the dynamic visual stimulus which is provided by regular film and television programs. On the other hand, it would seem that dynamic computer graphics do offer the necessary visual stimulus, hence their growing popularity as elements of conventional film and television production.

In a similar way the fidelity of new sound systems, such as those made possible by laser discs, or even the internalized effect created by the Sony Walkman, all represent alternative ways that the consumer can obtain improved audio stimulus as well.

What seems to be happening at the consumer level is that the new technologies are providing consumers with more listening and viewing options. It seems highly likely that the consumer would like to have more content diversity, perhaps with different content matched more effectively to the various exhibition systems, but given the general lack of content diversity, or the greater cost of seeking the ultimate in content exhibition, is prepared to make compromises.

Nevertheless, one can expect to encounter discerning consumers when it comes to the evaluation of image quality. Unless the high definition image offers a marked improvement over present television images it seems unlikely that the average consumer will be motivated to upgrade the in-home exhibition equipment.

In this respect it is well to remember the experience with three-dimensional movies. Introduced too soon and offering an uncertain and questionable improvement in the viewing experience the idea failed before its promoters could demonstrate that its eventual potential was greater than the early compromises suggested. The key is that whether or not the concept had potential it needed to reflect a quantum leap in the viewing experience to gain acceptance with the public. By contrast, the Sony Walkman radio, which like 3D movies required the user to "wear" an apparatus, provided an order of improvement in the listening experience sufficient to overcome this inconvenience.

It should also be recognized that the <u>consumer</u> is not only gaining more control over the exhibition of audio and video content, the <u>creator</u> is losing control over the environment in which the content is viewed or listened to by the consumer.

This situation raises some difficult problems for the content creators. For example, what standards should be used in the content creation process? Should one take into account the fact that a high proportion of motion picture film exhibition will continue for a long time to be via a conventional television receiver, or should the intention be to exploit to the full the capabilities of the most ideal cinema environment. In this respect, the television producer probably has an easier time with this issue than the movie producer. At least one is facing consumers who by and large own standardized television receivers.

On the other hand, conventional television viewing has become a kind of de-facto standard. This shows up quite dramatically in respect of cable community channels. In this case, it is highly desirable to accept different content creation values than those used in conventional television yet viewers are so accustomed to the conventional television content that they are more likely to reject any change of a format as being unsatisfactory or inferior. Only when the format is drastically changed, for example, in the case of a computer display, does the consumer bring a different value system to an assessment of the content exhibition process.

There are, of course, several ways of looking at these kinds of problems. The simplest way is to work towards the evolution of the ultimate terminal device which would embody a whole range of viewing and listening experiences. To an extent, this has been achieved by attempting to elevate the conventional home television receiver to a multipurpose display unit. Unlike the sound reproduction apparatus in the home which can range all the way from a simple portable AM/FM radio to complex stereo equipment, the conventional television receiver has become the ubiquitous terminal device even though the compromises which this entails are already proving to be unsatisfactory.

In fact, much of the effort which is going into receiver design considerations in relation to HDTV appear to be destined to try and preserve the notion of a composite visual reception device in the home. What seems to be at stake is whether the compromises needed to maintain this ubiquity is likely to have an adverse effect on the creation and exhibition of many diverse forms of content and the choice by the consumer of differing listening and viewing experiences.

CONTENT DISTRIBUTION

Given the broad technical innovations that are occurring in both the creation, distribution and exhibition of content it would seem essential to retain at least two primary objectives: 1) to allow the consumer to select from a variety of content availabilities and to select an appropriate means of listening to and viewing the content. 2) to allow content creators the maximum facility to identify and select the most appropriate distribution and exhibition opportunities.

It can be seen that this type of reasoning does not leave very much scope for compromise. Ideally, the viewer must have real choice in content while at the same time being able to maximize the value of that choice through an appropriate range of reception facilities.

Similarly, the content creator must be able to have a high expectation that the user will at least have the option to be able to receive and "consume" the content as close as possible to the manner envisaged by the content creator. This suggests that a communication process is involved representing a path directly from a content creator to the user. This concept has much less to do with "broadcasting" than it has with the newer systems of electronic distribution where more and more the identity of the actual user, and the nature of his or her needs, are fulfilled by the content creator through a distribution process more approaching a point-to-point delivery system. Rather than content delivery to the broad undifferentiated audience accepted by broadcasting one is now moving to more selected forms of delivery whether through coded broadcast signals or via cable systems or telephone networks.

If this basic principle of content delivery becomes more practical and acceptable through the results of technological development it becomes more important to ensure that an appropriate reception or terminal device is available to receive the content so that it can achieve the intended impact.

In the light of this it is unfortunate that the term "high definition television" tends to drive one to think in terms of conventional "television" systems, whereas what we are really considering is a <u>high definition video image.</u> Once one is freed from the television connection it is possible to take a more balanced view of the broad potential application of improved image resolution systems.

THE IMPLICATIONS FOR HDTV

a) Initial Development

Given the natural propensity to look at new developments in the light of existing experience it is clear that HDTV builds more easily on the philosophy of motion picture imagery than it does on television. As we have seen, motion picture creation concepts have always been heavily oriented to visual expression and what HDTV promises is an alternative way to achieve the visual rendition that has, up to now, been associated primarily with photographic film.

It follows from this that the advantages of electronic image manipulation, coupled with the improved image rendition, promises to offer both creative and economic advantages to the established motion picture production processes.

Everything seems to point to the fact that HDTV offers the potential to sustain the motion picture creator's intentions in a video form. Rather than being diminished by conventional TV, motion pictures can retain their power and effect while taking full advantage of the electronic production and distribution facility.

Such an objective is not likely to be realized if too many compromises are accepted in the distribution and exhibition systems in the interests of making them more compatible with conventional television distribution and reception apparatus.

This is not a criticism of conventional television but simply a recognition that its present purpose and impact have been achieved because of the particular characteristics of the current viewing experience. Furthermore, some of this impact could be modified if its content is presented on a larger screen.

An example of this is the HDTV technologist's pride in the sensation of reality which is possible with HDTV. This factor may however create a negative impact in certain situations. For example, will television viewers really want to watch even more vivid and realistic pictures of the violence, tragedies, and anguish already seen on their screens as part of regular news programs?

This is not to suggest that television content could not be displayed on an HDTV format but that in using this type of exhibition the television content creator must be aware of the potential differences in the exhibition experience.

These considerations point to the value of a scale of options when considering video exhibition systems. Furthermore, these options should embrace a range of video exhibition possibilities which range all the way from the video telephone through to teleconferencing, conventional TV, and high definition video. What this would recognize is that we are providing the consumer with a range of video reception opportunities which approaches the range becoming available in audio listening and which can be more effectively matched to the user's requirements and life-style. At the same time, we are moving closer and closer to the point where content creators may wish to exercise much more control and influence over the form of exhibition to be allowed for the content.

b) Subsequent Utilization of HDTV

The preceding assessment of the application and use of HDTV accepts that at first there will be a normal tendency to base initial HDTV utilization on familiar forms. As has been pointed out, HDTV is more easily related to motion picture practices than to those of television. This attitude will probably only last through the initial stages. The subsequent development and use of HDTV will, as has been the case with all other new media, tend to focus on developing the particular attributes of HDTV for their own sake.

It is only possible to speculate on what the results of this second phase of content development will be. Nevertheless, it is vitally important to build into the present HDTV technology development the facility to embrace a number of content creation and exhibition options.

It is interesting to note that HDTV can provide the means of bringing together the present somewhat separate skills involved in motion picture production and television production. As well, it promises to provide for a more successful amalgamation of computer-based technology with the two preceding media forms. The result of this is not likely to herald the demise of conventional television nor that of conventional motion pictures but rather to foster the emergence of a new level of audio visual experience which embodies the carefully studied construction associated with motion pictures, and its emphasis on the visual form, with the immediacy and the rigid time disciplines of television, making possible the inclusion of content with preplanned as well as live segments.

At the same time there will be possibilities for interactive video experiences which not only preserve the consumer's increasing control over the exhibition of content but enables the user to become an integral part of the audio video experience.

This latter development could build on the fact that the television viewers habits are changing. One might say that the consumer is now creating his or her own content through the application of available in-home technology.

For example, the widespread use of converters is enabling viewers to move rapidly back and forth across many cable channels, selecting in the process parts of several programs to form a very personal assembly of content.

The time shifting of programs with VCRS and the increasing ability to remove, ("zap"), commercial messages all reflects a growing consumer autonomy.

What this means is that the creator of HDTV content cannot necessarily expect to replicate the controlled exhibition experience of the cinema nor the so-called passive viewing of regular television.

All this points to the need for an imaginative use of HDTV which reflects the technological opportunity and accepts the new power in the hands of the consumer. In this respect the demonstrated capabilities of videodisc as an effective interactive technology in the hands of imaginative content creators provides a vision of the new skills which will be needed to exploit the potential of HDTV. It also suggests the new types of viewing environment which may evolve.

Others have already drawn attention to the value of HDTV in providing for the exhibition of art, its potential role in medicine and education, in widescreen teleconferencing, in photography and printing, and in many other applications where precise visual imagery are necessary to heighten the communications value of the medium.

These considerations not only involve the exploitation of the characteristics of HDTV but involve more extensive considerations of the kind of environments in which high definition video will be exhibited. Clearly, these exhibition opportunities will range all the way from the introduction of new types of electronic cinema to the assessment of the impact of high definition videos in a conventional household setting. In effect, the viewing environment is becoming a more critical part of the content creation process.

CONCLUSIONS

If HDTV is to provide new and improved creative opportunities for content providers it must be regarded as a new phase in the development of the electronic exhibition process. While HDTV obviously takes its roots from conventional television the introduction of this new form should not be compromised by modelling it on the principles of existing television services. This is not say that the ultimate form of HDTV will not be arrived at through a succession of evolutionary stages but to argue for a strongly future-oriented approach to HDTV development. The objective must be to advance to the use of a high definition video image which is neither film or television but a new form of content expression providing, amongst other things, an interactive capability.

It can be seen that these desirable goals must be capable of realization irrespective of the delivery technology which is chosen.

To achieve such an objective it is essential to bring together the perceptions of the content creators, the innovative capabilities of the technologist, and the future needs and expectations of consumers.

Such an approach should also leave open the question as to whether the ultimate in high definition video can become a household exhibition concept or not. The major goal should be to seek a form of electronic video expression which clearly represents a quantum jump in the presentation of video information.

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HDTV COLORIMETRY

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ABSTRACT

High definition television should be designed based on a complete knowledge of the performance of the visual system in color. This provides design data for providing the visual system with all of the information it can perceive at a minimum bandwidth. Extensive psychophysical measurements have been made in order to gather these data. These measurements generally have results expressed as threshold contrast sensitivity for gratings of luminance or isoluminance complementary color pairs.

The data presented will include contrast sensitivity of luminance and color as a function of spatial frequency and temporal frequency. Also included will be measurements of the oblique effect in color and luminance. Temporal changes in an image produce masking which acts both forward and backward in time. The changes in luminance and color sensitivity caused by masking effects will be presented. At higher spatial frequencies isoluminance color gratings may be perceived as black and white gratings.

The system implications of the above data will be discussed. This includes the relative bandwidths of color difference signals; the choice of the color axes of the wider and narrower bandwidth color; the preferred sampling pattern to take advantage of the oblique effect; the temporal requirements for presentation of color and luminance; and the signal processing that takes advantage of color ambiguities at high spatial frequency color.

COLORIMÉTRIE EN TÉLÉVISION À HAUTE DÉFINITION

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RÉSUMÉ

La conception de la télévision à haute définition doit se fonder sur des connaissances approfondies du système visuel en couleur. On obtient ainsi des données de conception permettant de donner au système visuel toutes les informations qu'il est en mesure de percevoir avec une largeur de bande minimale. De très nombreuses mesures psychophysiques ont été prises afin de recueillir ces données. Les résultats de ces mesures sont habituellement exprimés en sensibilité différentielle pour les réseaux géométriques de lignes parallèles de luminance ou de paires de couleurs complémentaires de même luminance.

Les données présentées comprennent la sensibilité différentielle de luminance et de couleur en fonction de la fréquence spatiale et de la fréquence temporelle. Les mesures de l'effet oblique en couleur et en luminance sont également incluses. Les modifications temporelles d'une image produisent un effet de masquage qui agit à la fois en avance et en retard dans le temps. Les changements de luminance et de sensibilité chromatique causés par les effets de masquage sont présentés. A des fréquences spatiales élevées, les réseaux géométriques de lignes parallèles de couleurs de même luminance peuvent être perçus comme des réseaux en noir et blanc, tandis que les réseaux de lignes jaunes et bleues peuvent être perçus comme des réseaux de lignes rouges et vertes. La sensibilité différentielle de ces ambiguités est présentée.

Les répercussions des données ci-dessus sur le système sont discutées. Cette discussion englobe les largeurs de bande relatives des signaux différence de couleur; le choix des axes chromatiques des couleurs de grande et de faible largeur de bande; le diagramme d'échantillonnage préféré permettant de prendre avantage de l'effet oblique; les exigences temporelles touchant la présentation de la couleur et de la luminance et le traitement des signaux qui tire profit des ambiguïtés chromatiques aux couleurs de fréquence spatiale élevée.

HDTV Colorimetry

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Introduction

In this paper we shall discuss color as it applies to HDTV. First, let us consider how an HDTV system differs from television systems that have been designed in the past.

Compared with standard NTSC or PAL transmission systems, the most obvious difference is field of view. People tend to view an image at a distance which optimizes the information processed by the visual system within the field of view. The visual system has much better acuity in the fovea (at the center of the field of view) than in the periphery. In fact, about half of the neurons in the visual cortex are devoted to processing the information in the central 2^{o} of the field of view. To increase the fraction of the image that is within this 2^{o}, the viewer "backs up" until there starts to be significant loss in visual response at the limiting resolution of the image. Extensive studies of viewing habits indicate that the distance at which people find the best compromise is where the limiting resolution of the display appears to be about 20 cycles per degree. This is about 7 screen heights for standard television and about 3.5 screen heights for 35 mm motion pictures and for HDTV. Viewed at this distance, as recommended, HDTV should really be called "wide screen" television. The field of view is larger, however, the number of TV lines per millimeter on the viewer's retina is the same as for 525-line television. For extending television designs to HDTV, we need first to consider what visual parameters depend on field of view.

Modulation Transfer Functions (MTF's) Dependence on Temporal Frequency and Field of View

Performance of the human visual system can be quantified by psychophysical measurements of the minimum contrast needed for an observer to differentiate a grating pattern from a homogeneous field of the same space-average luminance. In the laboratory, patterns to be detected have often been sine-wave luminance gratings of varying spatial frequencies. Similar measurements can be made for gratings of complementary colors in which luminance has been held constant, "isoluminance chromaticity gratings". In this case, the measurement reflects the amount of color (saturation) needed for an individual to differentiate the grating pattern from a homogeneous gray background of the same space-average luminance. Earlier studies have addressed similar questions, but with luminance levels and fields of view that are much less than those of current television monitors.[1,2] Kelly and his colleagues[3,4] have published extensive data on detection of both luminance and isoluminance chromaticity (red-green) sine-wave gratings. As this work was done with red-green color pairs chosen to average a saturated yellow, it is difficult to apply the findings to color television.

We have repeated many of the measurements of modulation thresholds for luminance and isoluminance chromaticity gratings using parameters that were more suited to design of a high-definition television imaging system. We have measured thresholds over the spatial frequency range for television viewing values and have used gratings of complementary color pairs that average to illuminant "C" white rather than to a saturated yellow. These measurements were also made using luminance levels and fields of view that are appropriate for normal television viewing conditions.

In the experiments to be described, we used the "method of adjustment"[5] to obtain modulation thresholds. An observer adjusted the contrast of luminance (Y) sine-wave gratings of varying spatial frequencies displayed on a television screen. For isoluminance chromaticity gratings, the saturation of the red-cyan (R-Y) or blue-yellow (B-Y) color bars was adjusted. Space-average luminance for both chromaticity and luminance gratings was approximately 1000 td.

Thresholds were obtained for static (DC) gratings and for gratings that varied temporally in counter-phase alternation at 2, 10, 15 and 30 Hz. Figure 1 shows modulation transfer functions averaged over 3 observers for static and temporally modulated luminance gratings (Y) and isoluminance chromaticity gratings (R-Y, B-Y). All temporal frequencies were tested at two fields of view: $4.5^{\circ} \times 6^{\circ}$ and $18^{\circ} \times 24^{\circ}$ (hereafter referred to as 6° and 24° fields, respectively, in accordance with the horizontal dimension). Where the results for the 6° field showed a difference from the 24° field, data are depicted by a dashed line. Figure 1 shows that for luminance gratings the field-of-view effect is limited to static gratings of low spatial frequency. This finding contrasts strongly with results shown for blue-yellow gratings. Here the wider field of view increases low spatial frequency perceptibility for static as well as flickering gratings up to a temporal rate of 15 Hz. (At 30 Hz, perception is so poor even for the 24° field, that further

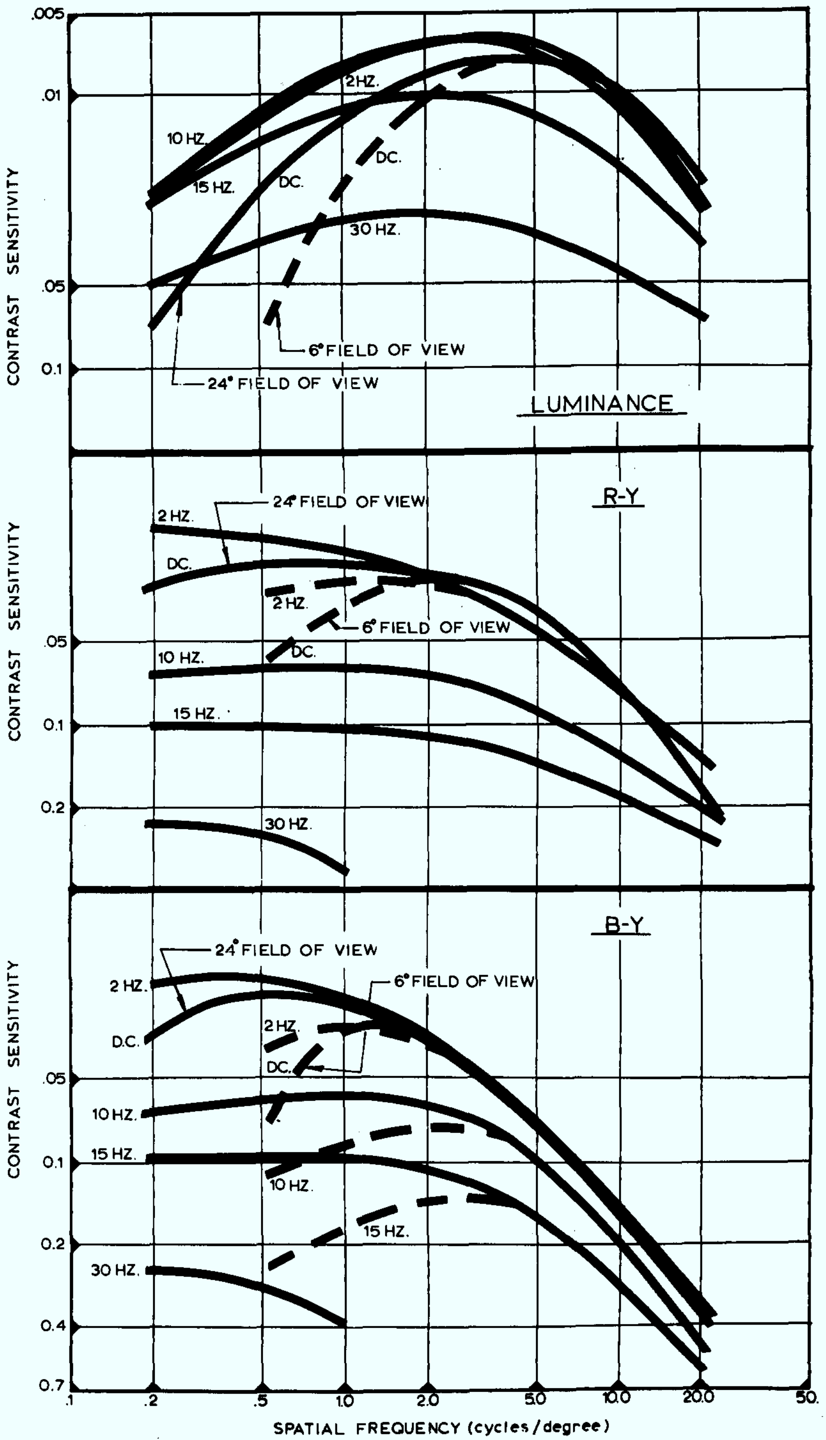


FIG. 1 MTF'S FOR STATIC AND TEMPORALLY MODULATED (2-30 HZ.) LUMINANCE, R-Y (RED-CYAN) AND B-Y (BLUE-YELLOW) GRATING. DASHED LINES SHOW WHERE 6° FIELD DATA DIFFER FROM 24° DATA.

degradation by a smaller field would be undetectable with these measurements). The results for red-cyan gratings are more similar to those for luminance with the field-of-view effect limited to DC and to gratings flickering at the slowest (2 Hz) temporal rate. Note that for all three conditions the effect of increasing field size is to improve sensitivity to low, but not high, spatial frequencies. The lack of effect for high spatial frequencies was expected since these spatial frequencies can only be detected in the central few degrees of the visual field.

Figure 1 also demonstrates the differing effect of temporal modulation on perception of luminance gratings compared with perception of isoluminance chromaticity gratings. In Figure 1, for low spatial frequencies (less than 1 cy/deg) there is a relative enhancement, in sensitivity for perception of luminance gratings at temporal modulation rates up to 15 Hz, relative to that for static gratings. At the higher spatial and temporal frequencies (above 10 cy/deg and 15 Hz) perception is degraded. The highest temporal rate, 30-Hz, degrades perception at all spatial frequencies.

Comparing sensitivity for DC and flickering chromaticity gratings, we noted that in general temporal modulation degraded, rather than enhanced, sensitivity, especially of low spatial frequency chromaticity gratings. The only exception to this finding was a slight enhancement of 2 Hz flickering gratings, for both color pairs, over sensitivity for the DC grating. The temporal degradation is similar for both blue-yellow and red-cyan gratings.

Neural conduction in the visual system is generally slower along pathways that transmit color information than along those that transmit luminance information.[6] This fact may underly the observation that temporal variables affect perception of achromatic and chromatic patterns differently. For example, low temporal frequency modulation facilitates perception of a low spatial frequency luminance gratings, however, the same condition will degrade perception of an isoluminance low spatial frequency chromaticity grating. Similarly, 15 Hz counter-phase alternation degrades perception of isoluminance chromaticity gratings at all spatial frequencies by about the same amount as a 30 Hz flicker degrades perception of luminance gratings.

Chrominance Resolution

Since HDTV will be a new system we can re-evaluate the proportions of luminance and of wide and narrow-band color primaries to be used. The NTSC color television system design was based on the fact that the visual system has better resolution in luminance than in color. Because of the limitations of bandwidth and compatibility, there were

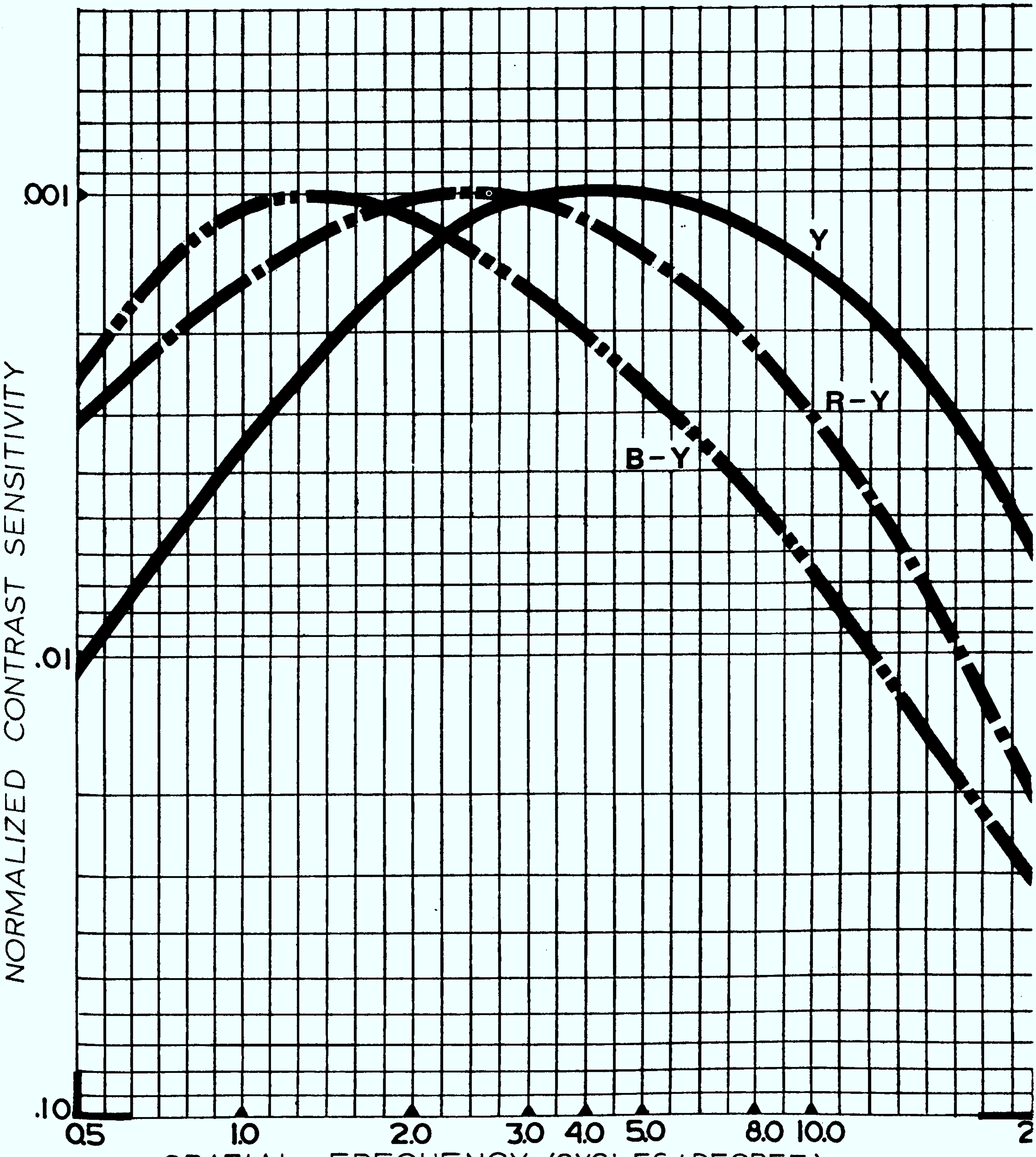


FIG. 2 NORMALIZED MTF'S FOR STATIC LUMINANCE (Y) AND ISOLUMINANCE CHROMATICITY (R-Y),(B-Y).

significant compromises in the resolution allocated to color. With inadequate color resolution the choice of the chromaticity of the high resolution and low resolution color signals was related more to the need to depict flesh tones accurately at edges rather than to match the performance of the visual system. With adequate color resolution, the proper proportions for allocating luminance and color information need to be determined.

Preliminary testing with various color pairs passing through illuminant "C" white on the CIE diagram showed that the maximum perceptible color resolution was for red-cyan gratings, and the minimum resolution, for blue- yellow gratings. These results verify the proportions and maximum and minimum color coordinates recommended by NHK[7] based on a similar study by Sakata and Isono.[8]

As with luminance gratings, sensitivity to stationary gratings composed of these color pairs decreases at both high and low spatial frequencies. However, in color, the peak sensitivity is for gratings of lower spatial frequencies than is the case in luminance.

In Figure 2, the static curves of Figure 1 have been normalized with each peak set to .01 so that the different absolute sensitivities of the human visual system to the luminance and two chromaticity gratings are not apparent. To estimate relative limiting resolutions we compared the high spatial frequencies of these three curves at 30% of peak response. The R-Y resolution (10 cy/degree) was about half that of Y (20 cy/degree), and the B-Y resolution, (5 cy/degree) about one quarter that of Y. If an imaging system were designed without the need for color resolution compromises, the color signals would have resolutions both vertically and horizontally in about these proportions with respect to Y.

We have noticed in measuring the color contrast thresholds for isoluminance chromaticity gratings, that at the higher spatial frequencies the gratings appeared to be black and white, rather than colored. The perception of a black and white grating could not be eliminated by adjustments in brightness difference between the color pairs. This effect had also been observed by Granger.[9] We repeated the threshold measuremenst of isoluminance chromaticity gratings asking the observers to indicate the saturation at which they observed colored gratings rather than black and white ones. We then compared the spatial frequency at which the normalized curves were at 30% of peak response, as we did for the curves in Figure 2. These points were lower in spatial frequency than the corresponding point on the luminance curve by about a factor of 3 for red-cyan or green-magenta, and by about a factor of 5 for blue-yellow gratings.

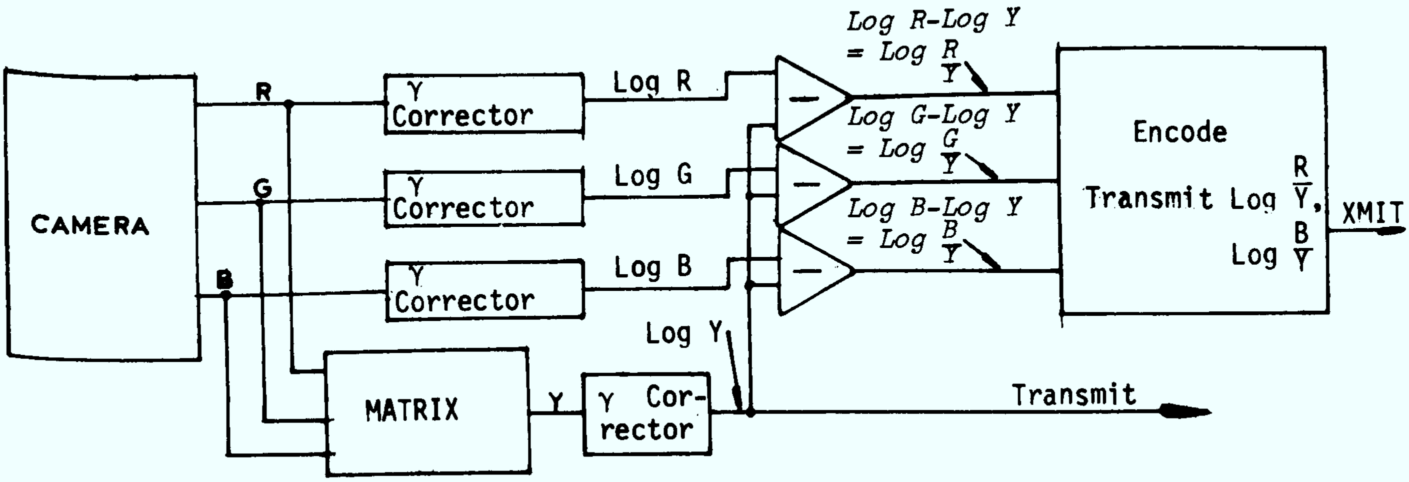
This observation suggests the possibility of adding the highest spatial frequency color information to luminance (since this information is undistinguishable from luminance). This would then allow a reduction of the bandwidth required for R-Y and B-Y.

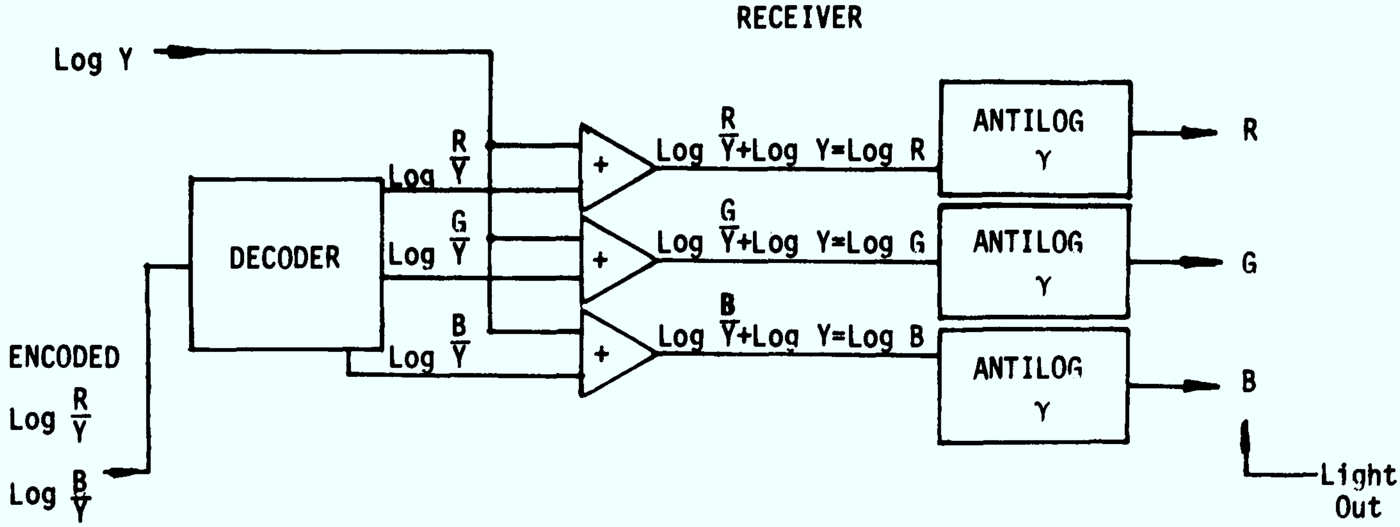
Maintaining Color Signals Independent of Luminance

It is well known that the NTSC and PAL systems do not transmit color as isoluminance color signals. As a result of this in saturated colors, a large portion of the luminance is carried by the narrow band color signals resulting in poor resolution. Color should be transmitted completely independent of luminance if we are to have good luminance contrast in saturated colors and also not have color inaccuracies caused by gamma correction. The following analysis will show that current processing is not far from an isoluminance color system and could be made so with rather small changes in gamma correction and signal processing.

Gamma correction for transmission or digital encoding often causes artifacts in color images. The traditional analysis of color difference signals assumes a linear system. If signals are maintained as linear signals for transmission or digitizing, both noise and contouring become more visible at low brightness portions of the grey scale since the visual system is logarithmic.

Let us suppose that we were going to design a system in an ideal world where we could start all over and use whatever processing we wanted. First, we would transmit signals that are the log of brightness signals. This is based on the fact that the visual system is logarithmic (obeys Weber's Law). Noise or contouring from digitizing would, therefore, be minimized since it would be equally visible at all brightness levels. Secondly, we would depict color by the proportions of the primaries. These signals would then represent saturation and hue, independent of luminance. These proportions would be multiplied by broad-band luminance in the receiver to give R, G & B signals. The following block diagram shows the processing necessary to do this:





The above processing is very similar to the processing now used. The purpose of gamma correction has been assumed to be to correct for nonlinearities in the cathode-ray tube. In fact, the gamma correction in the camera is very close to the gamma necessary to convert a linear signal into a log signal. Figure 3 shows a comparison of the transfer curve producing a gamma of 1/2.2 compared with that producing the log of the input. The camera transfer characteristic could be changed to this gamma with a slight change in its gamma correction. The gamma in the cathode-ray tube is very close to the gamma necessary to convert a log signal to a linear light output. It could be changed to this with very slight modifications to the gamma of the receiver's final video amplifiers. The remainder of the processing is exactly the same as current processing except that the luminance gamma correction is done after summing linear R, G & B signals to produce Y.

In the display the "contrast" control varies the gain of log Y. Consequently, it varies the gamma of the luminance output of the display without changing the color. This is a very desirable feature, since it has been shown that the displayed gamma should be varied as a function of surround illumination to give the proper subjective impression of brightness.[10,11] It has also been demonstrated that the proportions of the colors should not be varied as a function of surround illumination to produce the proper hue and saturation.[12] Both of these conditions can be satisfied by adjusting the "contrast" control only, with this signal processing.

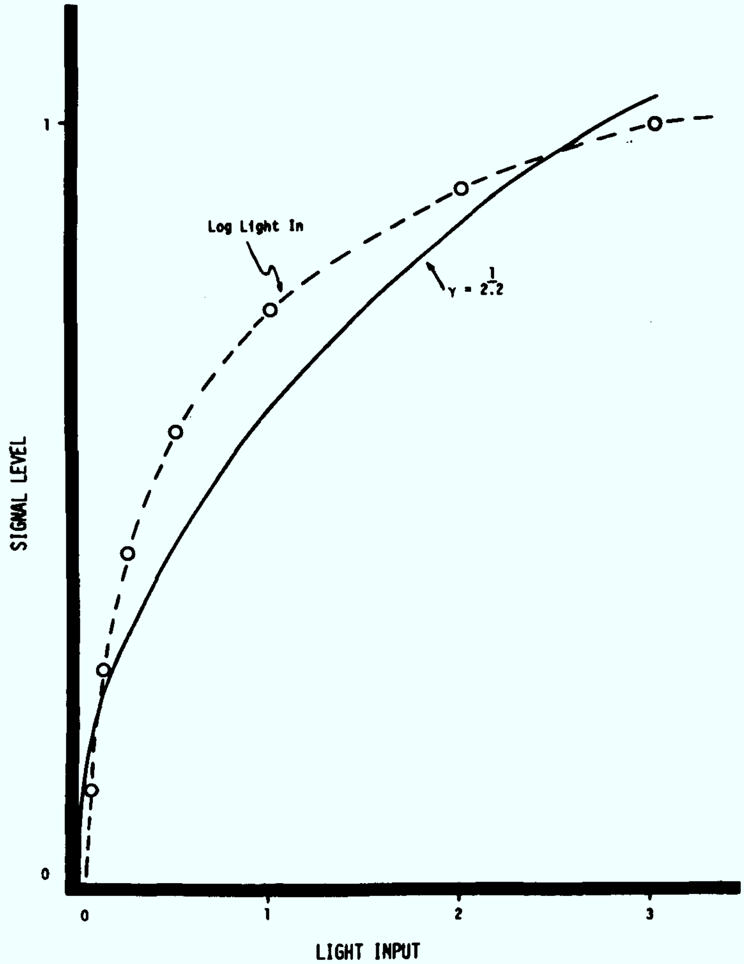


Figure 3. Transfer curves of signal level vs. light input for of 1/2.2 compared with signal level = log light input.

Image Sampling

As the information content of HDTV will be higher than that of present systems, there will be a greater need for bandwidth conservation. Present color systems have already conserved some bandwidth by taking advantage of the visual system's limited acuity for differences in chromaticity as compared with luminance. Because of the need for a considerable further reduction in bandwidth, other effects must be studied to make it possible to eliminate more information that the visual system cannot see before the signal is transmitted. One system for reducing bandwidth uses diagonal sampling. Black and white halftone printing has always used this technique which takes advantage of the "oblique effect" reported in the vision literature.[13] We have found that this effect also exists in color and similar techniques may be used to reduce the bandwidth of color signals.

A television image is normally sampled in the vertical direction by the scan lines. The increased use of digital stores has also resulted in horizontal sampling of the image.

The idea of "offset" or diagonal sampling has often been proposed[14] and a CCD camera chip using this type of sampling has been developed.[15] If the same number of pixels is sampled cardinally as diagonally, the information content of the image remains the same. Diagonal sampling would thus appear to offer no particular advantage for image resolution, were it not for the "oblique effect". This well-documented visual effect refers to the reduction in perceptibility of patterns that are oriented obliquely (at 45^{o} or 135^{o}) relative to those that are horizontally or vertically oriented.[13]

The sources of the oblique effect are both optical (lens/cornea) and neurophysiological. When the optical source has been ruled out by correcting viewers for optical astigmatism, the remaining poorer resolution of diagonal than cardinal gratings has been attributed to neurophysiological mechanisms. Experiments that bypass the optics of the eye by using a laser to form interference fringes directly on the retina have also demonstrated an "oblique effect". This finding suggests an orientational inequality in the visual nervous system.[16]

Our work on this phenomenon has focussed on measuring modulation transfer functions of individual observers using sine-wave luminance and isoluminance chromaticity gratings that were oriented in both cardinal (90^{o}, 180^{o}) and both diagonal (45^{o}, 135^{o}) directions. Using the procedures described under "Modulation Transfer Functions", we have measured modulation thresholds across a wide range of spatial frequencies: 0.6 cy/deg through 36 cy/deg. Figure 4 shows averaged modulation transfer functions for cardinally and obliquely oriented gratings. The curves reflect the mean sensitivity based on eight observers. For high spatial frequencies the anisotropy observed represents about 1/2 octave, i.e., $\sqrt{2}$, reduction in resolution at the same contrast sensitivity for obliquely oriented luminance and chromaticity gratings, relative to cardinally oriented gratings. This is a somewhat higher ratio than has been reported in the vision literature. It may be a result of measuring subjects with astigmatism corrected by their optometrists, rather than using the most accurate correction possible, as is generally done in vision research.

We can use the oblique effect to reduce the number of pixels in the image. The result of using diagonal sampling with half the number of pixels is diagrammed in Figure 5. This figure shows a polar plot of the resolution of the visual system at 30%

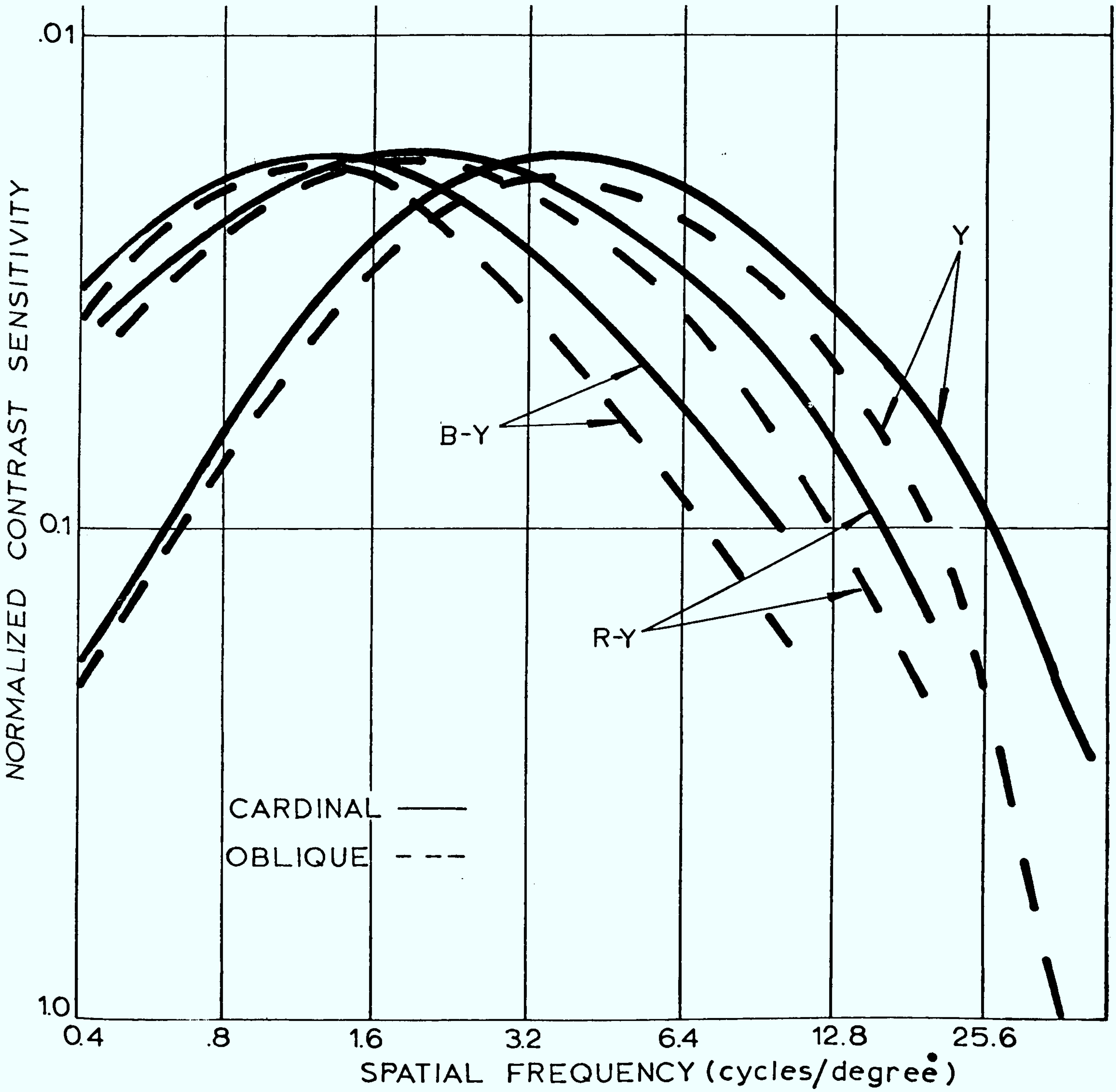


FIG.4 NORMALIZED MTF'S FOR CARDINALLY (SOLID LINE) AND DIAGONALLY (DASHED LINE) ORIENTED GRATINGS (LUMINANCE Y, CHROMATICITY, R-Y, B-Y)

of its peak sensitivity. Superimposed is a plot of a normal television display using 480 x 680 pixels and a Kell factor loss of .7. Also shown is the plot of a display using 480 x 340 pixels with diagonal sampling and a Kell factor of .8 by using appropriate processing. Pre and post-filtering as reported by Wendland and Schroeder[17] have achieved Kell factors in excess of .8. They also report a subjective improvement in apparent sharpness for luminance diagonal sampling that agrees very closely with our predictions based on oblique effect measurements.

Our measurements, in addition, predict a corresponding effect in color that can be used to reduce color bandwidth.

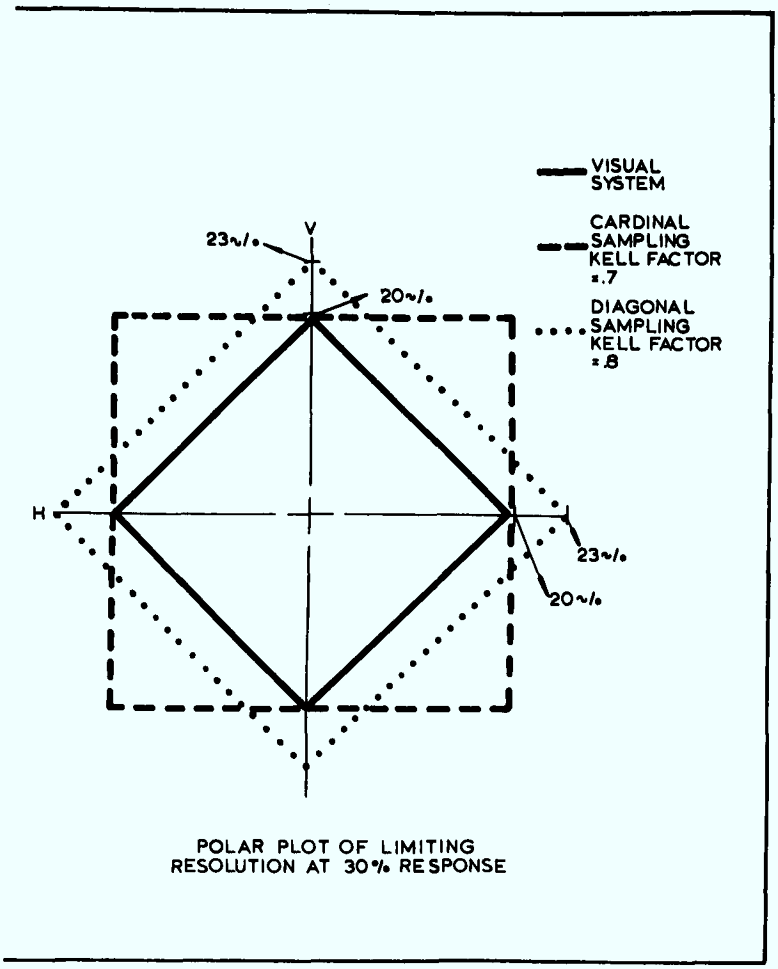


Figure 5

Display of Temporally Changing Information

HDTV places a significant pressure on the need for reducing bandwidth. The largest reduction in bandwidth can be achieved by challenging the assumption that all information in the signal must be sent at the same frame rate. Studies of the spatiotemporal performance of the visual system have shown that, particularly with a wide field of view, low spatial frequency information will be important, especially for color information. Peripheral vision has good temporal response but poor spatial resolution. With HDTV, a wider field of view will stimulate more in the peripheral field. Therefore, temporal resolution (i.e., good motion rendition) becomes at least as important as good spatial resolution for creating a realistic image. Good temporal resolution translates into a high frame rate. The following set of experiments suggest that a high frame rate is essential only for low spatial frequency luminance information. Perception of color information is relatively slow at all spatial frequencies. Perception of high spatial frequency (detail) luminance information and detail color seem to require long duration central visual processing, before perceptual realization. Current work in neurophysiological primate vision and human psychophysical studies have made it possible to design systems which match the information temporal rates for different spatial frequencies of luminance and color to that of the visual system. This process results in considerable conservation of bandwidth (a factor of about 2.5 in luminance and about 4 in color).

The long "time constants" in the visual pathways that process luminance detail and color information probably cause the phenomenon of visual "masking". This is a reduction in perceptibility of a target produced by a transient change in luminance that occurs either just before, or just after visual presentation of the target stimulus. In television images an example of visual masking is the impairment in perception of detail information that is produced by scene changes.[18] It also occurs during motion in an image. The explanation advanced for masking is that neural activity in the sustained, or slower, visual channel is "pre-empted" by that in transient, or more rapid, channels en route to central visual processing areas.[19] Inasmuch as the viewer may "fill in" the missing information, or at least does not see what is masked, this phenomenon seems to lack a reassuring subjective validity. However, magicians have unwittingly demonstrated masking very nicely by using hand motion-induced transients to degrade visual perception, thereby leading to the observation that the hand is often "quicker than the eye." The following series of experiments demonstrate how visual masking degrades perceptibility of sine-wave luminance and isoluminance chromaticity gratings at varying spatial frequencies.

Figure 6 diagrams the temporal relationships between two stimuli that were used to study masking. We used a .1 sec exposure of off-the-air TV as a mask, i.e., to interfere with perception of a sine-wave grating target presented either just before or just after the mask. Target duration varied from 17-2000msec. The observer adjusted the grating contrast, or saturation in the case of color, until it was barely perceptible. When the TV image occurs prior to the sine-wave grating, there is "forward masking"; when it follows presentation of the grating, "backward masking".

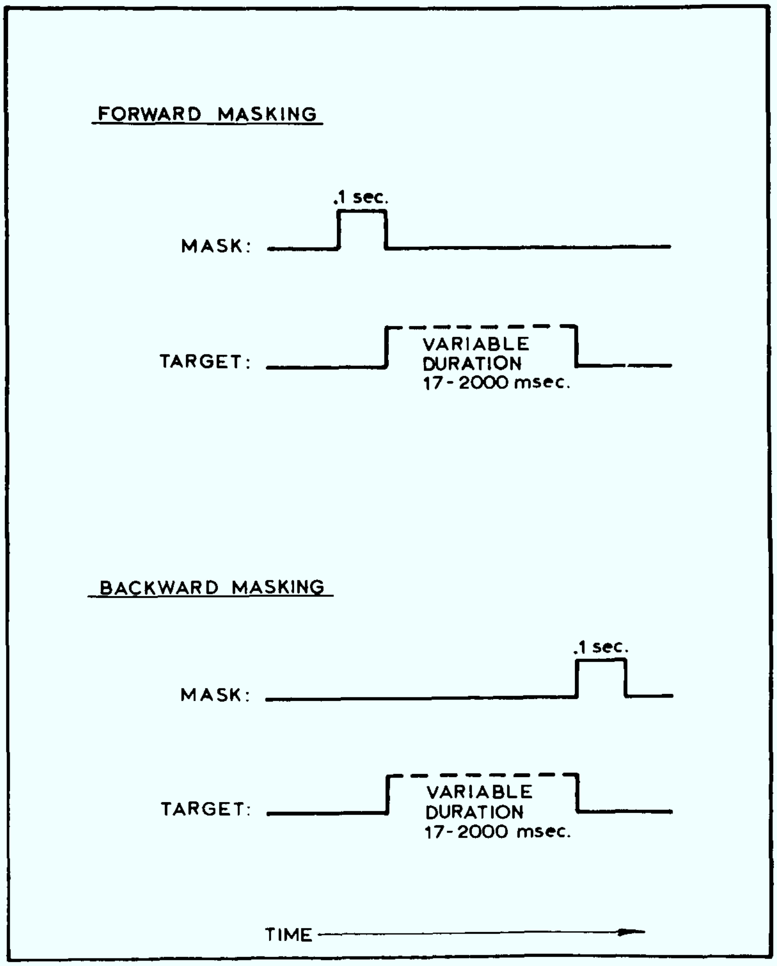


Figure 6: Experimental paradigm for masking studies.

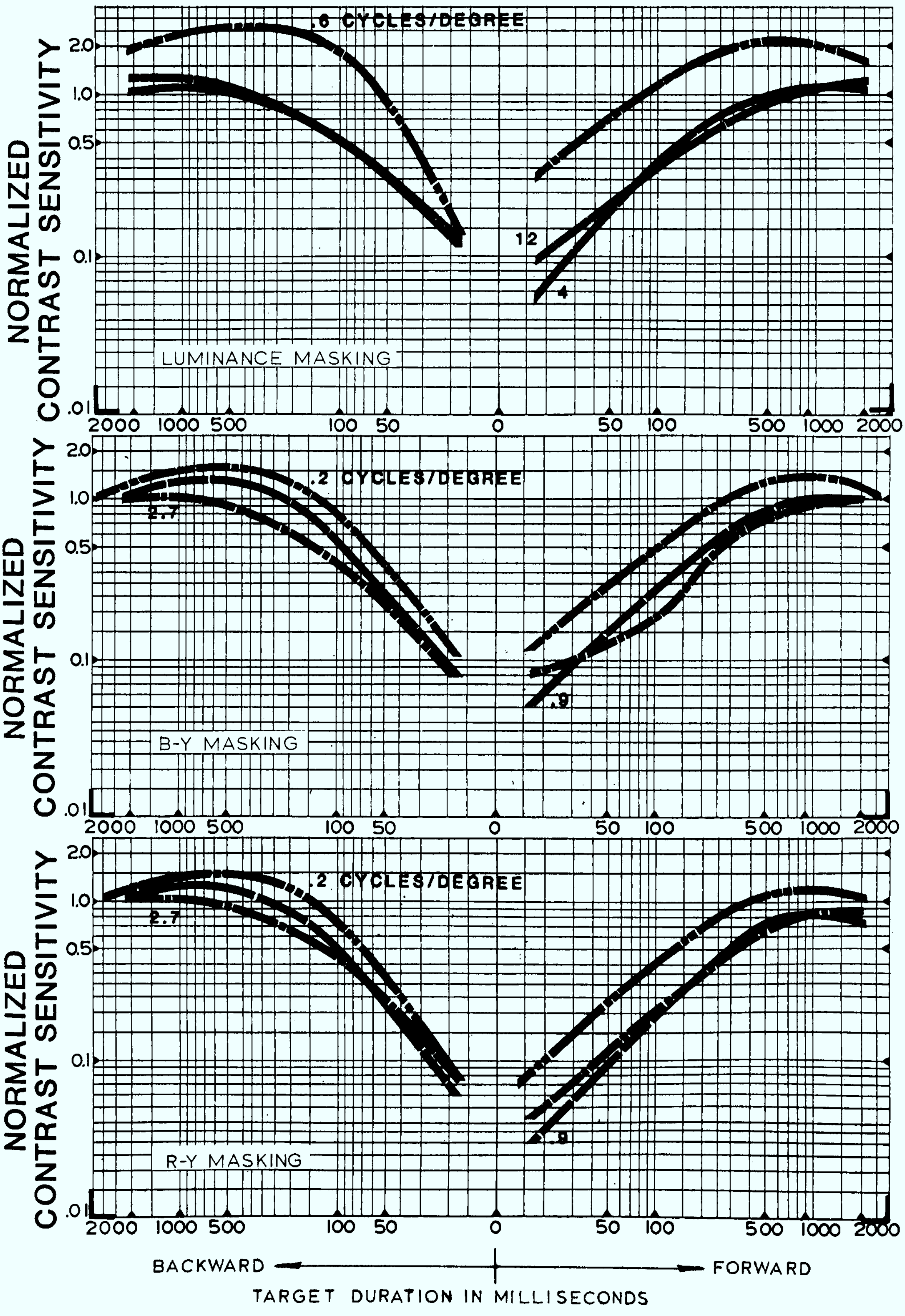


FIG. 7 MASKING OF PERCEPTION OF LUMINANCE AND ISOLUMINANCE CHROMATICITY GRATINGS OF VARYING DURATION AND SPATIAL FREQUENCY BY .1 SECOND MASKING.

Curves in Figure 7 have been normalized to 1.0 against each observer's "steady-state" condition. Luminance gratings of spatial frequencies at or above 4 cy/degree were masked for longer durations than were the coarser gratings at .6 cy/degree. Masking was also shown when chromaticity gratings were viewed, although in this case perceptibility was not affected by the spatial frequency of the target grating. The masking effects did not differ significantly for the red-cyan and blue-yellow color pairs.

The observed reduction in perceptibility when the target was presented either just before or just following the masking stimulus is, in fact, a combined effect. It is due partly to the brief target duration, as well as to the target's temporal proximity to the mask. Comparisons of sensitivity for masked with unmasked targets of varying duration give an idea of the magnitude of the "pure" masking effect. The "pure" masking component for a factor of two reduction in perceptibility corresponds to about 80 msec., backward masking and about 150 msec. forward masking, for gratings of all spatial frequencies in both luminance and chromaticity.

If the viewer fixates a static portion of the image and a moving object causes a transient within the field of view, the combined backward and forward masking effects prevent perception of detail for about 250 msec. This explains the results previously reported by Seyler and Budrikis[18] in their study of the delay in the perception of detail after scene changes.

The present study suggests that for moving images while fixating, a frame rate of 5 frames per second should be adequate for the detail luminance and detail color in stationary portions of an image. On the basis of these measurements, we have constructed a television system to display low resolution information at 60 fields per second interlaced with detail information displayed at 7.5 frames per second. The result is a system that compares favorably in motion rendition with a standard television display.

Our color measurements indicate an even greater potential saving in bandwidth of color signals. A complete system using lower rates for color is under construction.

Conclusions

The wider field of view of HDTV places a relatively higher importance on low spatial frequency information in both luminance and color. It also makes flicker and motion rendition at low spatial frequencies relatively more visible.

The fact that HDTV is a new system makes it possible to design the system with a better match of the relative resolution of color on luminance. It also makes it possible to use better signal processing and gamma correction in order to provide a color signal which is independent of luminance.

The increased bandwidth that HDTV would normally require can be greatly reduced by diagonal sampling of both luminance and color information. It can also be reduced by the proper use of spatial filtering at both the camera and display and by sending detail luminance and color information at reduced frames rates.

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LIMITATIONS OF CURRENT PSYCHOPHYSICAL APPROACHES TO DISPLAY EVALUATION

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2.2

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ABSTRACT

In developing improved communications systems, such as high-definition television, it is common practice to use some form of psychophysical assessment to guide design decisions. The assessment procedures used, of course, vary from study to study. In some cases, for example, measures of human sensitivity to contrast are used to guide decisions about optimum resolution. In other cases, measures of viewer satisfaction are used to guide decisions about optimum aspect ratio.

Although these psychophysical studies vary in type, complexity, and visible formality, each is a specific test involving particular combinations of measure, viewer, stimulation, and circumstance. Consequently, the meaning and generality of study outcomes are implicitly limited. Unfortunately, these limitations are not always clear to those reading the study reports.

The present paper examines several research issues in high-definition television design and summarizes the results of existing studies that relate to these issues. In this context, it explores the strengths and limitations of various psychophysical measures and methods and demonstrates the kinds of conclusions they can support.

The paper then outlines a new theoretical approach and explores its implications for understanding human perceptual and judgemental processes. This approach differs from others in that it is particularly sensitive to the issues raised in the discussion of psychophysical measures and methods. In closing, the paper develops some of the implications of the approach for research in display evaluation.

LIMITES DES MÉTHODES PSYCHOPHYSIQUES ACTUELLES D'ÉVALUATION DE L'IMAGE

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RÉSUMÉ

Au cours du développement de systèmes de communication améliorés tels la télévision à haute définition (TVHD), il est d'usage d'employer une forme quelconque d'évaluation psychophysique qui guidera les décisions relatives à la conception. Les méthodes d'évaluation employées varient bien entendu d'une étude à l'autre. Dans certains cas, par exemple, des mesures de la perception humaine du contraste servent à orienter les décisions touchant la meilleure résolution. Dans d'autres cas, des mesures de la satisfaction du spectateur sont utilisées pour établir le rapport de largeur à hauteur d'image optimal.

Bien que ces analyses psychophysiques varient en genre, en complexité et en schèmes perceptuels, toutes consistent en un test précis comportant des combinaisons particulières de mesures, de spectateurs, de stimulations et de conditions. Par conséquent, la signification et la portée des résultats sont forcément restreintes. Malheureusement, ceux qui lisent ces rapports ne saisissent pas toujours ces limites.

Le présent document examine plusieurs sujets de recherche en conception de la télévision à haute définition et il résume les constatations des études produites à leur propos. Dans cette optique, il relève les points forts et les limites des diverses mesures et méthodes psychophysiques et montre le genre de conclusions qu'elles sont susceptibles de fournir.

Il brosse également les grandes lignes d'une nouvelle approche théorique et en examine l'utilité pour comprendre les schèmes humains de perception et de jugement. Cette approche diffère des autres en ce qu'elle accorde un sens particulier aux questions soulevées dans la discussion des mesures et des méthodes psychophysiques. En conclusion, l'article aborde certaines applications de cette approche dans la recherche sur l'évaluation de l'image.

A LOOK AT THE CHARACTERISTICS OF FILM IN RELATION TO THE NEEDS OF HDTV FOR THEATRICAL PRODUCTION, USA

2.3

Don Kline & Harry Mathias

ABSTRACT

In order for HDTV to more nearly provide the viewing experiences of film, it needs to satisfy more criteria than simply achieving equivalent resolution.

This paper looks at some of those considerations, such as; dynamic range, comparative gamma and temporal effects.

APERCU DES CARACTÉRISTIQUES DU CINÉMA PAR RAPPORT AUX BESOINS DE TVHD DANS LA PRODUCTION COMMERCIALE (ÉTATS-UNIS)

Don Kline et Harry Mathias

2.3

RÉSUMÉ

Pour procurer des sensations visuelles plus proches de celles du cinéma, il ne suffit pas que la TVHD offre strictement une résolution équivalente. Elle doit satisfaire à bien d'autres critères.

Le présent document examine un certain nombre de ces aspects, entre autres: la gamme dynamique, la gamma relatif et les effets temporels.

DIRECT COMPARISON OF 35mm FILM AND HIGH DEFINITION TELEVISION

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2.4

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ABSTRACT

In January 1985, CBS will conduct a test at the CBS film studios in Studio City, California to produce the first direct comparison of 35mm film and High Definition Television. Over the course of a week, a variety of objective test material and subjective scenes will be shot simultaneously on a high quality 35mm camera and on a HDTV system operating at 1125 lines, 60Hz., 2:1 interlace, and 5:3 aspect ratio.

Each scene will be set up so that horizontal and vertical sizes will be identical for both images when projected. In addition, the director of photography will adjust the film and HDTV cameras to achieve identical image characteristics such as depth of field.

Comprehensive test material as well as scenic material representative of a broad range of cinematographic circumstances will be photographed during the production.

The results of the production will be used for direct comparative evaluation using film and electronic projection systems. The material will also be used for the evaluation of the ongoing development of HDTV film recording systems and HDTV telecines.

This paper will report on the methods used to produce the test material and the results obtained.

COMPARAISON DIRECTE DU FILM 35 mm A LA TÉLÉVISION À HAUTE DÉFINITION (TVHD)

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2.4

RÉSUMÉ

En janvier 1985, CBS procédera à un essai dans ses studios de cinématographie de Studio City (Californie), afin d'obtenir la première comparaison directe entre film 35 mm et télévision à haute définition (TVHD). Pendant une semaine, des scènes devant servir à des essais objectifs et subjectifs seront filmées simultanément par une caméra 35 mm de grande qualité et par un système TVHD qui produira une trame de 1 125 lignes, à 60 Hz avec entrelacement de 2/1 et rapport d'image de 5/3.

Chaque scène sera tournée de manière que les dimensions horizontales et verticales des deux images soient identiques au moment de la projection. En outre, le directeur de la photographie réglera les caméras 35 mm et de TVHD de manière à obtenir des caractéristiques d'image identiques, par exemple la même profondeur de champ.

Des scènes types de toutes sortes ainsi que des scènes illustrant une vaste gamme de prises de vues de cinéma seront filmées pendant la production.

Les résultats serviront à une évaluation comparative directe au moyen de systèmes de projection cinématographique et de projection électronique. La matière sera aussi utilisée pour évaluer le développement actuel des systèmes d'enregistrement cinématographique de TVHD et les systèmes de télécinéma TVHD.

Le rapport fait état des méthodes employées pour produire la matière des tests et des résultats obtenus.

CARACTÉRISTIQUES DE BRUIT DES CAMÉRAS DE TVHD

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2.5

RÉSUMÉ

Le rapport signal/bruit est un paramètre important de qualité des caméras de télévision à haute définition (TVHD). Le présent document décrit une analyse du bruit tenant compte des possibilités et des limites d'amélioration du rapport signal/bruit (S/N).

Il est montré qu'une caméra de TVHD dans laquelle le courant du signal dans le canal du vert varie entre 300 et 350 nA présente un rapport signal/bruit compris entre 35 et 37 dB. Ce rapport est suffisamment élevé pour donner l'impression d'une image exempte de bruit. Le rapport subjectif signal/bruit pondéré équivalent varie entre 53 et 54 dB.

L'insertion d'un bobinage de Percival optimal entre le tube analyseur et le préamplificateur peut améliorer le rapport S/B d'environ 3 ou 4 dB. L'amélioration subjective est d'environ 1 à 2 dB.

Le filtrage vertical et le filtrage en diagonale pour obtenir un balayage d'image exampt d'erreur y sont aussi discutés des points de vue de leurs répercussions sur le rapport S/B. L'amélioration apportée par le filtrage vertical est d'environ 3 dB tandis que le filtrage en diagonale produit une amélioration de 6 dB.

Pour donner l'impression d'une image exempte de bruit, il faut un éclairage d'intensité suffisante. Il est montré que l'intensité usuelle de l'éclairage des studios, laquelle se situe entre 500 et 2 000 lx suffit pour donner l'impression d'une image exempte de bruit produite par une caméra de TVHD.

Les propriétés d'une caméra de TVHD sont décrites et comparées à celles d'une caméra classique. La qualité de l'image est illustrée au moyen de diapositives montrant des photographies d'image-moniteur.

SOME NOISE ASPECTS OF HDTV-CAMERAS

2.5

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ABSTRACT

The S/N-ratio is an important quality characteristic for HDTV-Cameras. In this paper a noise analysis is described, within the possibilities and limits of an improvement relating to S/N-ratio are discussed. It is shown that a HDTV-Camera with a green channel signal current of (300...350)nA yields a (35...37)dB S/N-ratio. This S/N-ratio is sufficiently high for a noise free picture impression. The equivalent subjective weighted S/N-ratio is (53...54)dB. The application of an optimum percival-coil between pick-up tube and pre-amplifier can improve the S/N-ratio by about (3...4)dB. The subjective improvement is about (1...2)dB. Vertical and diagonal filtering for error free picture scanning are discussed with respect to influences on S/N-ratio. The improvement by vertical filtering is about 3 dB whereas the diagonal filtering results in a 6 dB improvement.

For a noise free picture impression sufficient lighting intensity is required. It is shown that the standard studio lighting intensity of (500...2000)lx is sufficiently high to give a noise free picture impression in connection with a HDTV-Camera. The properties of an installed HDTV-Camera are described and compared to a conventional camera. The picture quality is demonstrated by some monitor-photographs.

1. Introduction

For the construction of HDTV-Systems it is necessary to employ high resolution colour TV cameras. A very important quality characteristic of a HDTV-Camera is its signal-to-noise (S/N) ratio. In this paper a noise analysis for HDTV-Cameras with different picture scanning is described. These are

- HDTV-Camera with standard picture scanning
- HDTV-Camera with vertical filtering
- HDTV-Camera with diagonal filtering

For these Camera-types sufficient lighting intensity for a noise free picture impression is calculated.

In addition to this the characteristics of a constructed HDTV-Camera are described.

2. Picture Scanning

Figure 1 shows the picture pickup process in a TV camera. The picture with its three dimensional brightness function s(x,y,t) is represented by an optical system on the target of the pick-up tube. The output signal b(x,y,t) of the pickup tube is vertically scanned with the line distance d.

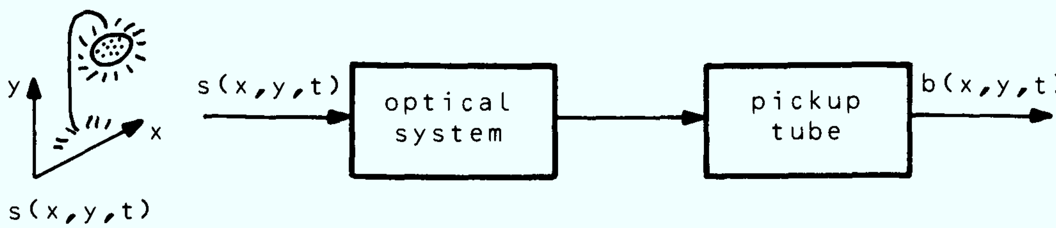

Figure 1: Picture pickup process in a TV camera

Figure 2 a) shows the point spread function b(x,y,t) of the camera with the assumption of a circular modulation transfer function /1/. Its three-dimensional Fourier spectrum $B(f^x,f^y,f^t)$ is shown in Figure 2 b). The scanned picture signal $b_\perp(x,y,t)$ and its periodic Fourier-spectrum $B_\perp(f^x,f^y,f^t)$ is shown in Figs. 2 c) and 2 d). It is obvious from Fig. 2 d) that there is an overlapping (aliasing) between the periodic spectra if sampling frequency $f_s{}^y = 1/d$ is less than $2f_c{}^r$, with $f_c{}^r$ the cutoff frequency of the camera before scanning.

Vertical resolution is distorted by these aliasing effects. The degradation of vertical resolution is quantitatively described by the Kell factor. But in the case of a high-line-number camera, which has 1250 lines we can tolerate some areas of aliasing (as shown in Fig. 3 a)) /1/. With proper vertical and horizontal filtering, we are allowed to transmit this error-free signal with 625 lines (Figs. 3 b) and 3 c)). After transmission, the video signal can be retransformed by a vertical interpolating filter into a high-line-number signal with 1250 lines.

The picture can be reconstructed without irritating line structures by a flat-field monitor out of this error-free signal, with a monitor transfer function $H_M(f^y)$ as in Fig. 3 d). With these techniques, the picture quality can be improved and vertical resolution is increased within a given standard bandwidth; the Kell factor is overcome /1/.

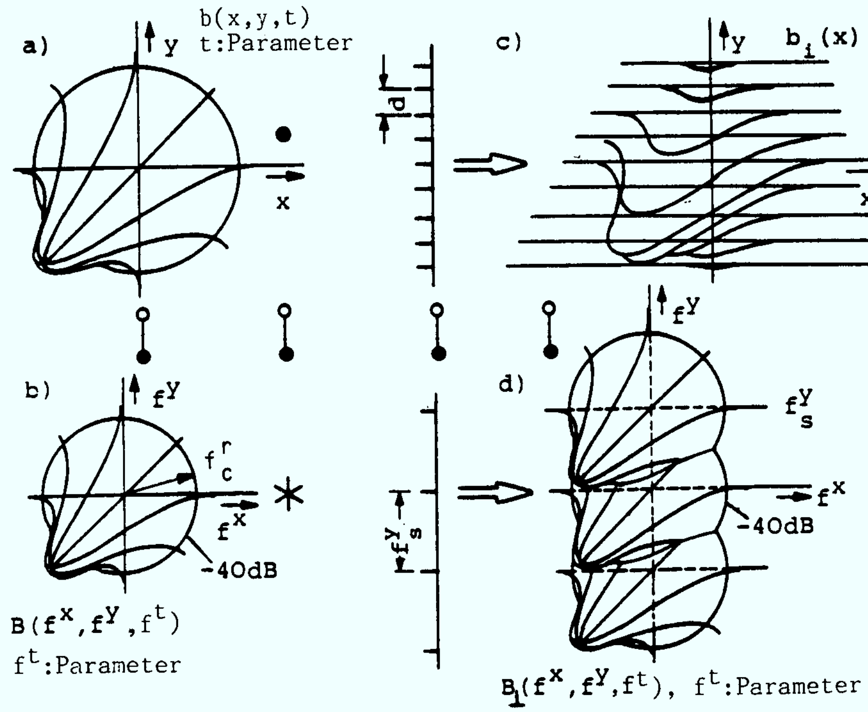

Figure 2: Picture signal $b(x,y,t)$, sampled signal $b_i(x)$ and their spectra /1/

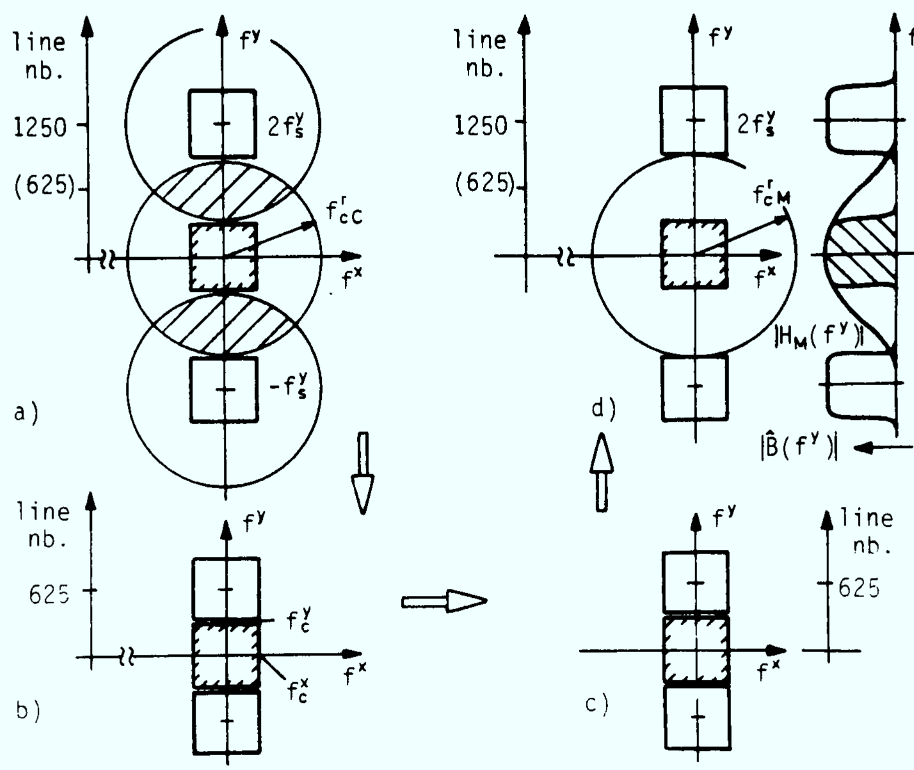

Figure 3: Alias-free scanning and flat-field reproduction /1/

With proper planar filtering in the diagonal direction, resolution can be further improved in the horizontal direction by offset sampling (Fig. 4) /1/. Again, we start with a high-line-number camera and by prefiltering in f^{ξ}- and f^{η}-direction, we get a basic area that is bordered by a diagonally orientated square. This basic spectrum can be transmitted with half the line number without any error.

At the receiver end the signal is retransformed by an interpolating digital filter into a high-line-number signal. This high-line-number signal can be reconstructed at the monitor screen without irritating line structures (flat field).

This concept gives increased horizontal resolution. With a spatial sampling frequency f_s^x, an error-free sampling with an orthogonal sampling scheme needs a cutoff frequency $f_c^x < 1/2 f_s^x$.

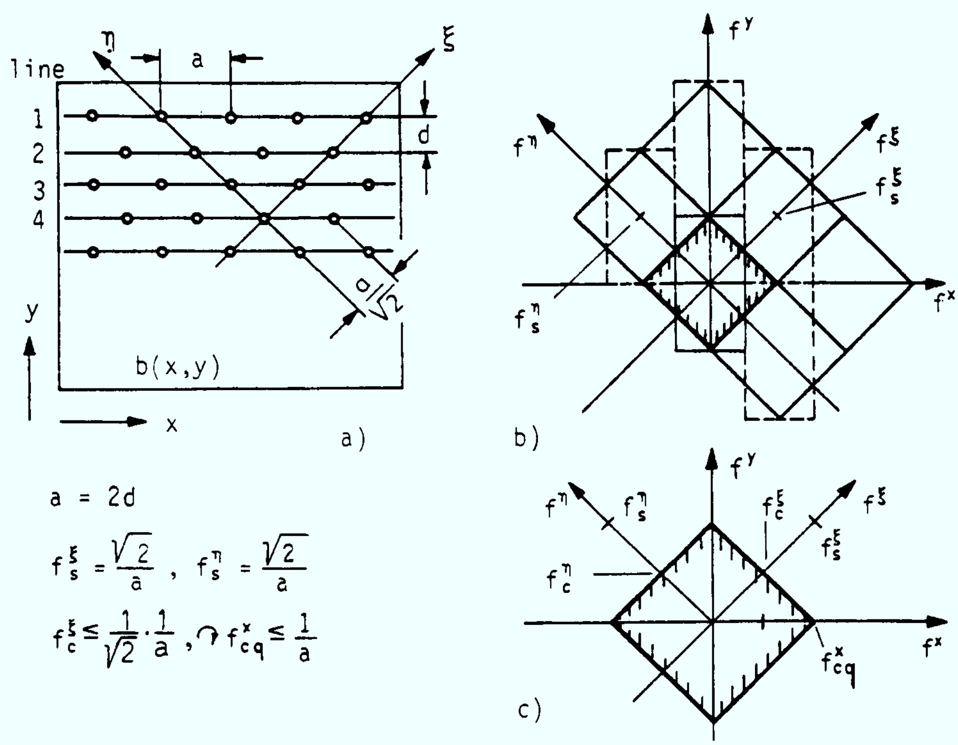

Figure 4: Offset sampling, spectra /1/

With offset sampling, using a diagonal prefilter, the horizontal cutoff frequency for error-free sampling can be twice as high, that is, $f_c^x = f_s^x$. This improvement of resolution in horizontal direction is accompanied by some loss in diagonal direction. However, the human eye is somewhat more sensitive to vertical and horizontal structures than to diagonal structures. In addition, there is a higher probability for horizontally and vertically orientated structures in pictures /2,3,4/.

3. Concepts for HDTV-Cameras

Picture scanning errors and techniques for error free picture scanning yield camera concepts, which are shown in Fig. 5.

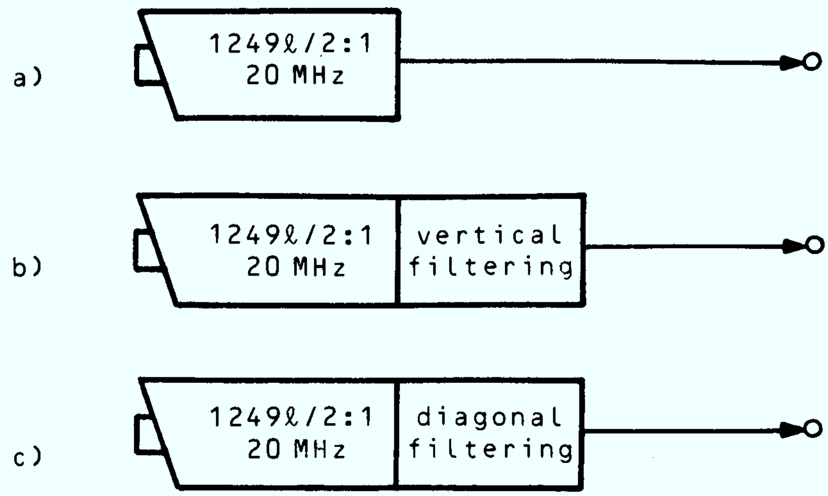

Figure 5: Concepts for HDTV-Cameras
a) Camera with standard picture scanning
b) Camera with vertical filtering
c) Camera with diagonal filtering

In each case we start with a high-line-number camera with 1249 lines for example and a bandwidth of 20 MHz. Fig. 5 a) shows a HDTV-Camera with standard picture scanning. This camera concept suffers from picture scanning errors, which are described in chapter 2.

Error free picture scanning is possible with camera concepts shown in Fig. 5 b) and 5 c). These camera concepts use a high-line-number camera with vertical filtering and diagonal filtering, respectively. An important characteristic of picture quality in TV-systems is given with S/N-ratio. In this connection camera noise is of special importance. The noise-behavior of the different concepts for HDTV-Cameras in Fig. 5 is described in the next chapter. In addition to this the sufficient lighting intensity for a noisefree picture impression is calculated.

4. Noise-behavior of different camera concepts

4.1 Camera with standard picture scanning

A camera with direct connection between pickup tube and pre-amplifier leads to a noise-spectrum, which is shown in Figure 6 /5/.

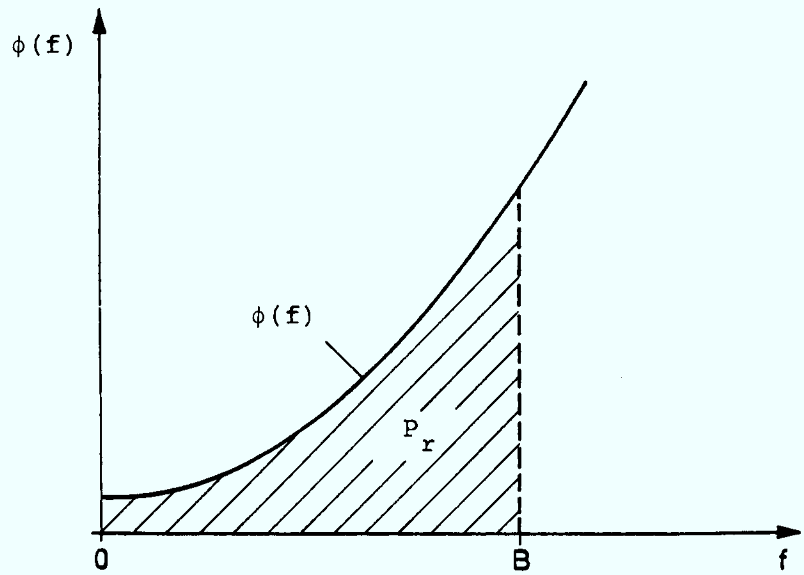

Figure 6: Noise spectrum of a camera with direct connection between pickup tube and pre-amplifier

The noise spectrum is described by

$$\phi(f) = k_1 + k_2 f^2 \tag{1}$$

k_1 and k_2 are constants, which include characteristics of the pickup tube and the pre-amplifier; f is the video frequency. The noise power is equivalent to the area between $\phi(f)$ and the f-axis and is given with the video bandwidth B by

$$P_r = \int_0^B \phi(f)df = \int_0^B (k_1+k_2 f^2)df = k_1 B + k_2 B^3/3 \tag{2}$$

For high video bandwidth (B > 5 MHz) it is $k_1 B \ll k_2 B^3/3$ and we get with $k = k_2/3$

$$P_r \approx kB^3 \tag{3}$$

With the signal current I_s and the signal power $P_s = I_s^2$, so the signal-to-noise (S/N) ratio becomes

$$\frac{S}{N} = \frac{P_s}{P_r} = \frac{I_s^2}{kB^3} \tag{4}$$

This equation shows, that the S/N-ratio is a crucial problem in the development of a HDTV-Camera. When we are going from a standard camera with a signal bandwidth of B = 5 MHz for example to a HDTV-Camera with B = 20 MHz, and the same signal current I_s, the S/N-ratio decreases about 18 dB.

For a noise free picture impression S/N may not fall short of a limit value. The noise visibility limit in a HDTV-system with a bandwidth of B = 20 MHz, a viewing distance of 3 x picture height and an aspect ratio of 5 : 3 is about (37...39)dB /6,7/. This value is valid for the luminance. In a camera with Saticon-pickup tubes S/N ratio in the luminance channel is about 2,7 dB better than S/N ratio in the green channel /8/. With reference to the green channel the noise visibility limit is about (35...37) dB. This value is obtainable with a signal current of (300...350) nA in the green channel /9/.

The subjective weighted S/N-ratio can be calculated with a proper noise weighting function for a HDTV-system /6,7/. For a noise free picture impression we get a subjective weighted S/N-ratio of about (53...54) dB /9/.

For signal processing following the pre-amplifier output a S/N-ratio better than the noise visibility limit is desirable. This is possible with a higher signal current I_s for example. But in that case the camera required a higher lighting intensity. An improvement of S/N-ratio is also possible by application of a percival-coil between pickup tube and pre-amplifier /10/. An optimum percival-coil can improve the S/N-ratio by about (3...4) dB. The subjective improvement is about (1...2) dB /8,11/.

4.2 Camera with vertical filtering

A camera with direct connection between pickup tube and pre-amplifier leads to a two-dimensional noise-spectrum /12/, which is shown in Figure 7 /11/.

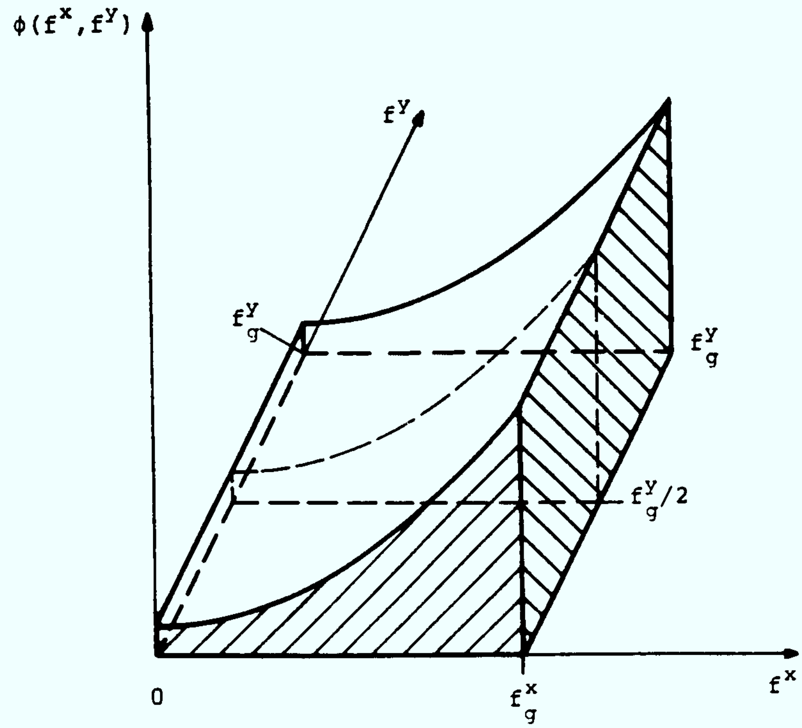

Figure 7: Two dimensional noise-spectrum $\phi(f^x, f^y)$; f^x and f^y are spatial frequencies

The two-dimensional noise-spectrum /12/ is described by

$$\phi(f^x, f^y) = k_1 + k_2(f^x)^2 \tag{5}$$

k_1 and k_2 are constants; f^x and f^y are spatial frequencies. In f^y-direction $\phi(f^x, f^y)$ is constant, because the noise-contributions of the different lines are not correlated.

In this representation the noise power is equivalent to the volume between $\phi(f^x, f^y)$ and the (f^x, f^y)-plane and is given by

$$P_r = \int_0^{f_g^y} \int_0^{f_g^x} \phi(f^x, f^y)\, df^x\, df^y = \int_0^{f_g^y} \int_0^{f_g^x} [k_1 + k_2(f^x)^2]\, df^x\, df^y \tag{6}$$

$$P_r = f_g^y \cdot [k_1 f_g^x + k_2 (f_g^x)^3/3] \tag{7}$$

Following vertical filtering with $f^y = f_g^y/2$ (Fig. 7) yields the noise power

$$P_{rv} = (f_g^y/2)\cdot[k_1 f_g^x + k_2(f_g^x)^3/3] = P_r/2 \qquad (8)$$

This result shows that vertical filtering reduces noise power to the half. With unchanged signal power the improvement in S/N-ratio is 3 dB.

4.3 Camera with diagonal filtering

The effect of diagonal filtering on noise is shown in Figure 8.

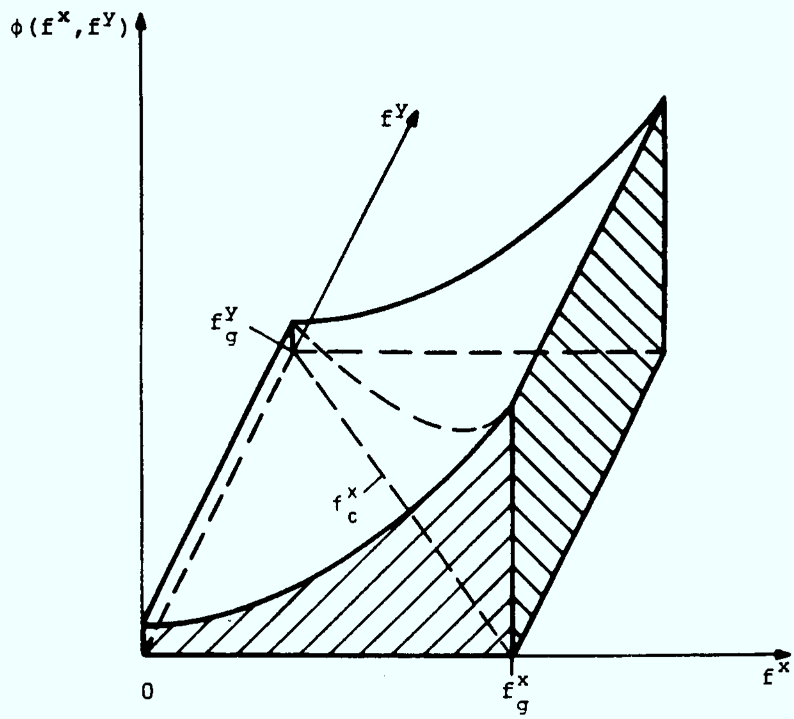

Figure 8: Noise-spectrum $\phi(f^x,f^y)$ and diagonal filtering

The cut-off frequency f_c^x is given by

$$f_c^x(f^y) = -(f_g^x/f_g^y)\cdot f^y + f_g^x \qquad (9)$$

and leads to the noise power

$$P_{rd} = \int_0^{f_g^y}\int_0^{f_c^x(f^y)} [k_1 + k_2(f^x)^2]\, df^x\, df^y = f_g^x f_g^y k_1/2 + f_g^y(f_g^x)^3 k_2/12 \qquad (10)$$

With diagonal filtering and $f_g^x = f_g^y$ we get the noise power

$$P_{rd}(f_g^x = f_g^y) = [k_1(f_g^x)^2]/2 + [k_2(f_g^x)^4]/12 \tag{11}$$

Without diagonal filtering the noise power is given by (equation 7)

$$P_r(f_g^x = f_g^y) = k_1(f_g^x)^2 + k_2(f_g^x)^4/3 \tag{12}$$

With (12) we have

$$\frac{P_{rd}}{P_r} = \frac{1}{4}\left[1 + \frac{1}{1 + (k_2/k_1)(f_g^x)^2/3}\right] \tag{13}$$

Generally it is $(k_2/k_1)(f_g^x)^2/3 \ll 1$ and the noise power following diagonal filtering becomes

$$P_{rd} \approx P_r/4 \tag{14}$$

This result shows that diagonal filtering reduces noise power about to a quarter of the original noise power. With unchanged signal power the improvement in S/N-ratio is about 6 dB.

4.4 Summary of the results

The noise-behavior of the different camera concepts is shown in Figure 9. Represented is the ratio P_r/P_{rs} (noise power/standard noise power) as a function of the ratio B/B_s (bandwidth/standard bandwidth) for direct connection between pickup tube and preamplifier. In this case the noise power P_r is proportional to the third power of the bandwidth B ($P_r \sim B^3$). Curve a) is a camera with standard picture scanning, curve b) a camera with vertical filtering and curve c) a camera with diagonal filtering. The camera with vertical filtering yields half the noise power and the camera with diagonal filtering a quarter of the noise power compared to a camera with standard picture scanning.

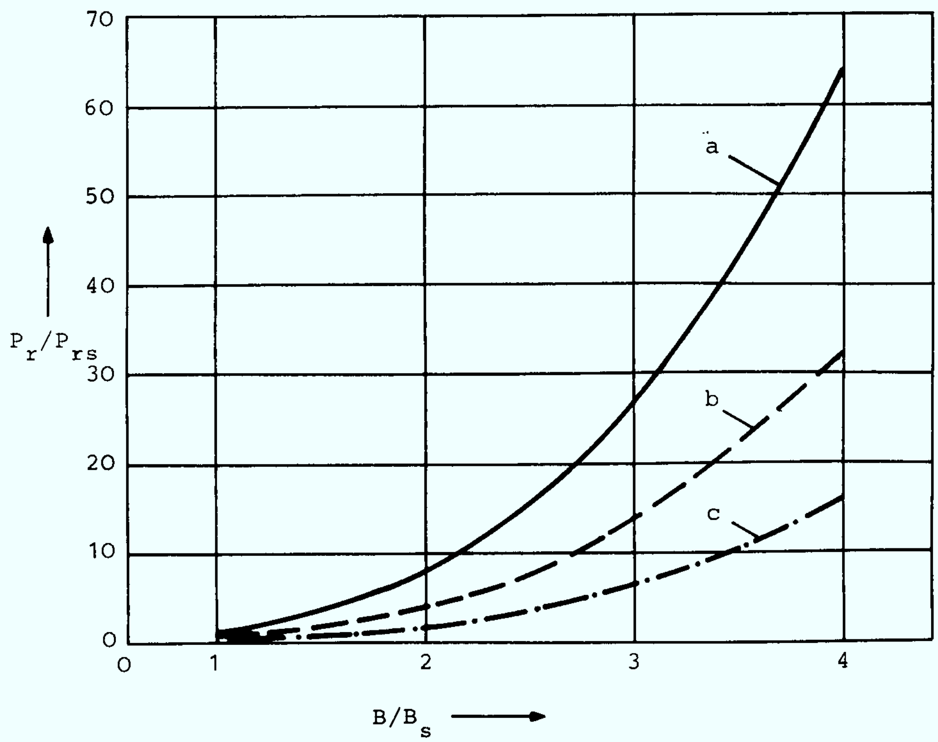

Figure 9: Noise-behavior of the different camera concepts

5. Light requirement

The light requirement of a HDTV-Camera is determined by the S/N-ratio for a noise free picture impression. For this a Saticon-camera with direct connection between pickup tube and pre-amplifier requires a lighting intensity of (500...2000)lx /9/. This corresponds roughly to the lighting intensity of standard studios. But here we have to note that standard lighting intensity includes a "reserve", because for a standard Camera a lighting intensity of about (300...1000)lx is sufficiently high to give a noise free picture impression. When we apply this reserve of standard lighting intensity, a HDTV-camera requires no additionally light to give a noise free picture impression.

A reduction of lighting intensity for a HDTV-Camera to about (300...1500)lx is possible by application of an optimum percival-coil between pickup tube and pre-amplifier /8/. By this a reserve is given compared to the lighting intensity of present standard TV studios. In this case we can reduce the aperture of the camera objective lens about one or two steps.

Vertical filtering improves S/N-ratio about 3 dB. In this case half of the original signal power is sufficiently high to give a noise free picture impression and we can reduce the signal current of the pickup tube to $I_{sv} = I_{so}/\sqrt{2}$; I_{so} is the original signal current without vertical filtering. Signal current is proportional to the lighting intensity of the scene. A reduction of lighting intensity about $1/\sqrt{2}$ to (300...1500)lx is possible and gives with unchanged aperture of the camera lens a noise free picture impression. On the other hand with un-unchanged lighting intensity a reduction of camera lens aperture about one step is allowed.

Diagonal filtering improves S/N-ratio about 6 dB. In this case a quarter of the original signal power is sufficiently high to give a noise free picture impression and we can reduce the signal current of the pickup tube to $I_{sd} = I_{so}/2$. A reduction of lighting intensity about 1/2 to (300...1000)lx is possible and gives with unchanged aperture of the camera lens a noise free picture impression. On the other hand with unchanged lighting intensity a reduction of camera objective aperture about two steps is allowed.

The results in lighting intensity for the different camera concepts are shown in Figure 10.

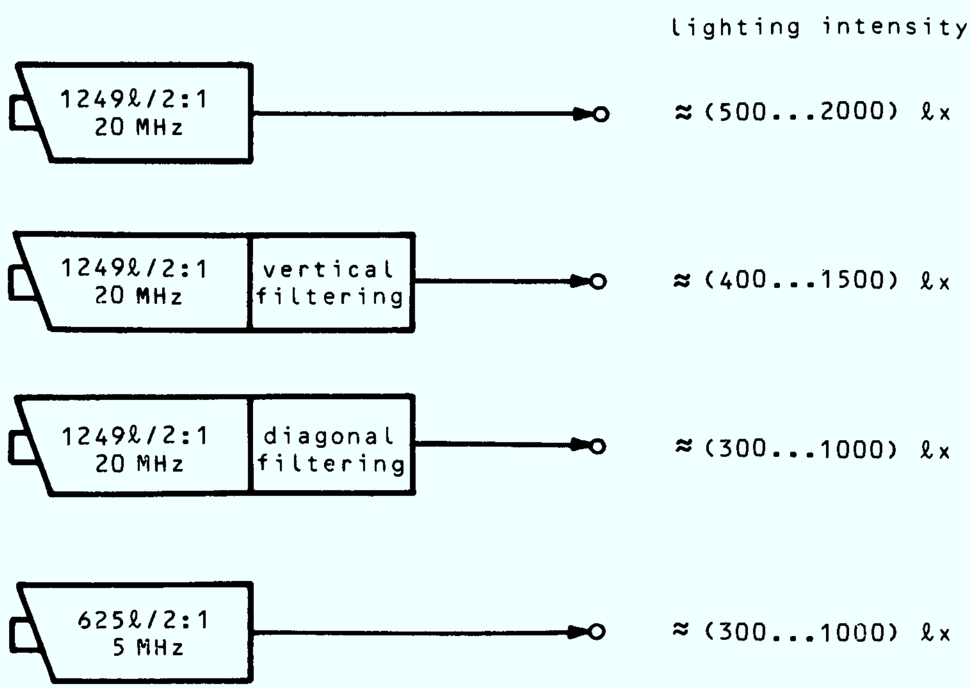

Figure 10: Required lighting intensity for different camera concepts

6. Description of a HDTV-Camera

At the University of Dortmund we have constructed a laboratory model of a HDTV-Camera /5,8,9,11/. It is based on a standard "KCN" camera which has been supplied by "Bosch-Fernseh". Additionally "Bosch-Fernseh" supported the camera conversion in the beginning. The characteristics of this first European HDTV-Camera are shown in table 1.

Table 1: Camera characteristics

pickup tubes	1-inch-Saticon (special development, "Heimann GmbH")
aspect ratio	4 : 3
Video bandwidth (3 dB) R, G, B	20 MHz
horizontal resolution	800 TV lines per picture high
modulations depth	20 % at 800 TV lines (without aperture correction)
S/N-ratio	35 dB (green channel unweighted; 350 nA signal current) 53 dB (luminance, weighted)
operating modes	interlace 2 : 1 - 1249 lines, 25 Hz frame frequency - 1049 lines, 30 Hz frame frequency progressiv scanning - 625 lines, 50 Hz frame frequency - 252 lines, 60 Hz frame frequency

The resolution capability of this camera in connection with a high line number monitor (Mitsubishi C6911E) is shown in Fig. 11 a). For comparison Fig. 11 b) shows the resolution capability of a standard camera in connection with a PAL-consumer monitor.

a)

b)

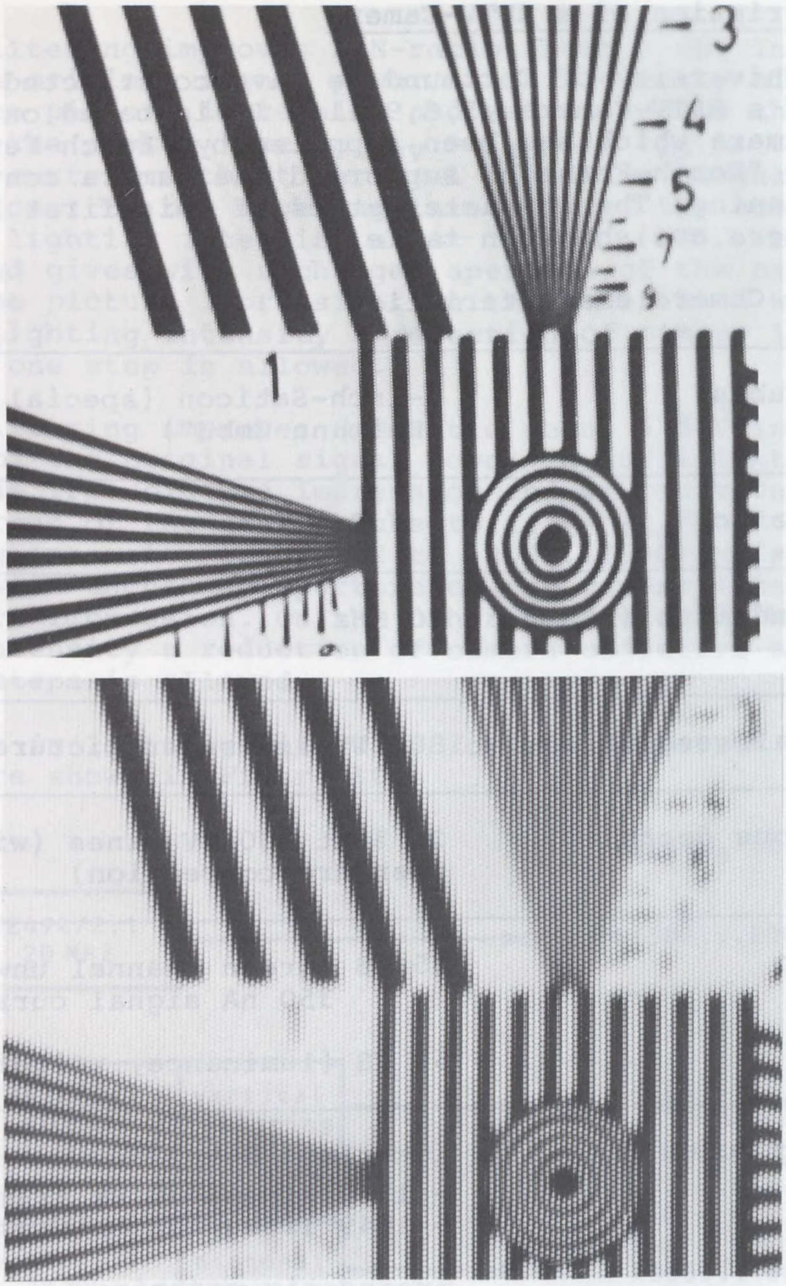

Figure 11: Resolution capability
a) HDTV-Camera (1249 l/2:1) in connection with a high line number monitor (Mitsubishi C6911E)
b) Standard camera (625 l/2:1) in connection with a PAL-consumer monitor

The reproduction of a naturally scene with the HDTV-Camera is shown in Fig. 12 a). For comparison Fig. 12 b) shows the same scene with a standard camera.

a)

b)

Figure 12: Reproduction of a naturally scene
a) HDTV-Camera (1249 l/2:1) in connection with a high line number monito: (Mitsubishi C6911E)
b) Standard camera (625 l/2:1) in connection with a PAL-consumer monitor

7. Summary

Some noise aspects of HDTV-Cameras are described in this paper. A S/N-ratio of (35...37)dB in the green channel is sufficiently high for a noise free picture impression. Vertical and diagonal filtering for error free picture scanning are discussed with respect to influences on S/N-ratio. The improvement by vertical filtering is about 3 dB wheras the diagonal filtering results in a 6 dB improvement. The standard studio lighting intensity is sufficiently high to give a noise free picture impression in connection with a HDTV-Camera. In addition to this the characteristics of a constructed HDTV-Camera are described.

Acknowledgment

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PROBLÉMATIQUE DES ÉCRANS DE TVHD

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2.6

RÉSUMÉ

La projection constitue le plus gros obstacle que doit surmonter l'introduction de la télévision haute définition (TVHD) sur le marché de la consommation. La haute définition ou d'autres moyens d'amélioration de la qualité de l'image exposée par des systèmes perfectionnés ne pourront percer que si l'on parvient à produire des écrans de plus grandes dimensions et de plus haute résolution. Une amélioraton notable de l'impression de présence et de réalité (téléprésence), suffisante pour justifier les efforts consacrés à la mise au point de nouveaux systèmes, pourraient être obtenue à l'aide d'un écran de 100 pouces, à standard de 1 000 lignes et à luminance adéquate.

Les CRT à projection directe offrent une solution pour les moniteurs uniquement. Des tubes de 30 pouces à rapport largeur-hauteur de 5/3 et à définition de 800 - 1 000 lignes sont aujourd'hui disponibles. Des écrans à plasma, électroluminescents, fluorescents et à cristaux liquides ont été construits pour une projection directe sur de grands panneaux plats, mais aucun d'eux ne répond à la fois à toutes les spécifications de taille, de définition, de couleur et de mouvement.

La technologie de projection permet de répondre aux exigences d'ordre dimensionnel. Des projecteurs de télévision à haute définition ont été mis au point au Japon à partir d'écrans conventionnels. Une définition à 800 lignes TV a été réalisée. Un écran de projection frontale à gain élevé (10) est nécessaire pour produire une luminance suffisante. En principe, les systèmes de projection par valve de lumière autorisent un haut rendement lumineux. Le contrôle de la lumière s'effectue par polarisation ou par diffraction. Comme pour les diapo-projecteurs, la lumière provient de lampes de grande intensité et le contrôle s'exerce à la diapositive. Dans le cas de la polarisation, l'élément de commande peut être constitué d'un cristal électro-optique ou de cristaux liquides. En ce qui a trait à la diffraction, la couche de contrôle, qui peut être un élastomère ou un film fluide transparent, est placée à l'intérieur d'un système de projection à champ sombre (projection optique de Schlieren). Il existe un tube à canon unique qui ne possède qu'une couche de contrôle et qu'un seul système optique pour les trois couleurs primaires, ce qui permet la conception d'un téléviseur compact, sans problème d'homologation. Les projecteurs disponibles se caractérisent par un flux lumineux de 1 000 lumens et une définition à 600 lignes. Il a été démontré que des améliorations pouvaient être apportées. L'application à la TVHD de la technologie de projection par valve lumineuse semble très prometteuse.

THE DISPLAY PROBLEM OF HDTV

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2.6

ABSTRACT

The display problem has turned out the most serious obstacle to the introduction of high definition TV to the consumer market. HDTV or even less pronounced quality improvements by enhanced systems would be fully acknowledged only by displaying the picture on screens of both larger size and higher resolution. A dramatic improvement in the impression of presence and reality ("Telepresence") justifying the efforts of the new system would be possible by 100"displays resolving 1000 TV lines with sufficient luminance.

Direct view CRT's offer a solution for monitor purpose only. 30"tubes with 5:3 aspect ratio have become available providing 800-1000 TV lines resolution. Plasma displays, electroluminescent displays, vacuum fluorescent displays and liquid crystal displays have been constructed for direct view large flat panels but none of them can meet the requirements of size, resolution, color, and motion simultaneously.

A projection technology offers the solution to the size demand. HDTV projectors have been developed in Japan using the conventional 3-CRT design. A resolution of 800 TV lines has been achieved. A high gain front projection screen (gain>10) is required for providing sufficient luminance. In principle, light-valve projection systems could achieve high light output. The light controlling element may act by polarisation or diffraction. Similar to slide projectors, the light comes from high intensity lamps, and the controlling element takes the place of the slide. For the polarisation case this may be an electro-optic crystal or liquid crystals. For the diffraction case the control layer is placed inside a dark field (schlieren-optical) projection system and may be an elastomer material or a fluid transparent film. A single gun version is using only one control layer and one optical system for all three primary colors thus allowing a compact design without registration problems. Available projectors deliver more than 1000 lumens and nearly 700 TV lines resolution. It has been shown that improvements are possible. The light-valve technology appears to be a promising technology for HDTV applications.

INTRODUCTION

Presently HDTV cameras are already available on the market delivering R,G,B-signals with 30 MHz bandwidth and resolving at least 1000 TV lines (500 line pairs per picture height). Furthermore it has been shown in our institute and elsewhere that these signals could be transmitted digitally and disseminated to the consumers without degradation via single-mode optical fiber networks using component coding. Thus the real bottle-neck for the system appears at the receiving end with the problem of displaying the transmitted picture information adequately.

Indeed, the display problem has turned out the most serious obstacle to the introduction of high definition TV to the consumer market. HDTV or even less pronounced quality improvements by enhanced systems (EDTV) would be fully acknowledged only by displaying the picture on screens of both larger size and higher resolution. A dramatic improvement in the impression of presence and reality ("Telepresence") justifying the efforts of a new service would result if the field of view could be increased to a value being possible with 100" displays of sufficient luminance and 1000 TV lines resolution allowing a viewing distance of again 100".

The possible maximum number of picture elements which a feasible consumer display device would be capable to display in the future should determine the information capacity to be demanded from a HDTV transmission system. The average viewing distance at the receiving end has to be assumed constant for all systems, say D = 2.5 m (100"). So the dimensions of the displayed picture elements should be assumed to be correspondingly fixed, i.e. 1.25 x 1.25 mm² for D = 2.5 m according to experience and subjective tests. Under these conditions, the required display area has to be proportional to the number of picture elements transmitted by the systems. Fig. 1 shows how by this reasoning different picture sizes are related to different systems. Standard TV allows only a small window to the real world to be transmitted, the field of view being limited to 10° vertical (D = 5.5 H) and 14° horizontal according to 0.2 million picture elements for R,G, and B respectively. A 27" screen diagonal would be adequate for D = 2.5 m. On the other hand, our ultimate goal of Telepresence could be reached by a large screen display of 1.6 million pixels while the screen diagonal equals the viewing distance (D = 2H with aspect ratio 3:5). The field of view then becomes 28° vertical, 45° horizontal. With such a wide angle system the whole scene may be transmitted and displayed instead

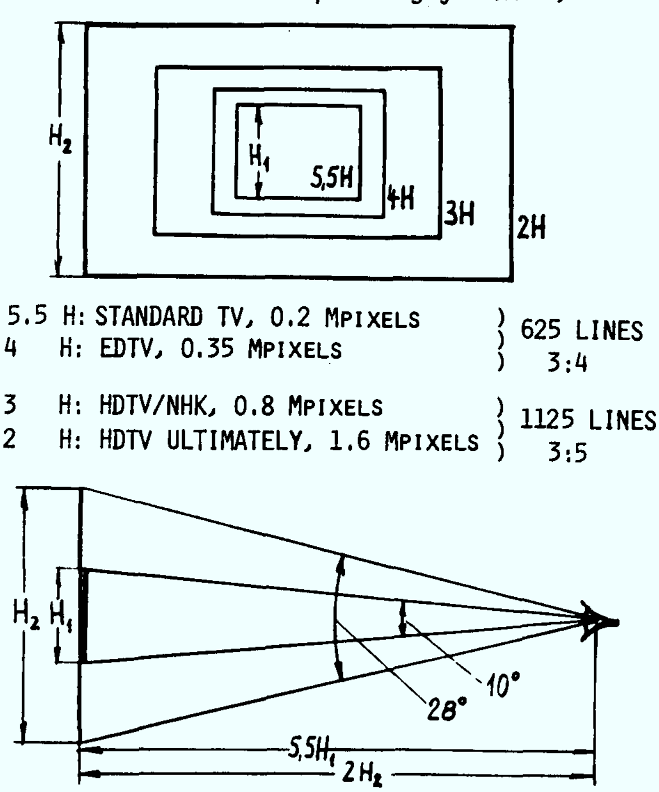

Fig. 1: With viewing distance fixed, different picture sizes are related to different TV-standards

of a window segment. Again, it should be emphasized that those large pictures normally must not be merely enlarged versions of the picture segments selected for standard TV. The increased information capacity has to be used for transmitting the ambient scene of the segment.

Summarizing, a display for use in a HDTV receiver allowing the telepresence viewing distance of D = 2 H should have the following features:

High resolution	:	1000 TV lines
Large screen	:	100" diagonal
Good luminance	:	$\geq$ 170 cd/m² (50 ft-L)
Good contrast ratio	:	$\geq$ 1:100
Full color and motion capability		

Moreover, for consumer application a moderately priced compact design, long life, and simple service are required. Considerable improvements have recently been made of conventional display technologies for HDTV, especially in Japan, but the aforementioned consumer device is still not available.

The next sections will give a survey of relevant display technologies, their state-of-the-art and future aspects. We devide these technologies into direct view and projection displays. The direct view displays may be emissive (active) or non-emissive (passive). Correspondingly the projectors may be of the CRT-type or the light-valve type. The latter will be treated in some detail, because - to our opinion - the light-valve technology appears to be a promising display technology for HDTV applications.

DIRECT VIEW DISPLAYS

EMISSIVE DISPLAYS

The prevalent technology of highest performance is still the classic shadow mask CRT. The technology had reached considerable maturity since years. Nevertheless further improvements of electron optics, deflection and cathodes have been made resulting in smaller spot size even with high beam current. This is being applied in a delta gun, dot shadow mask tube with 0.34 mm pitch for 30" 3:5 format HDTV-monitors now on the market. We have observed resolutions of 800-1000 TV lines and sufficient convergence accuracy with these monitors. Color purity appears to be a problem and accordingly the yield of tubes of adequate performance is low. Recently even a 40" version was reported and shown. Its weight is 85 kg. This seems to be the upper limit of dimensions which could be practically achieved by the technology. For monitor purposes the size is quite acceptable.

Naturally one hopes to find the solution to the HDTV large screen among the famous flat panels which often had been announced and could be "hung on the wall". We should mention the flat panel CRT's, e.g. the guided beam device of Credelle[1]. A target size of 75 x 100 cm² (50" diagonal) had been postulated, but not yet reached. The principle size limitation is given by the enormous air pressure onto the large vacuum vessels. Plasma displays, thin-film electroluminescent display, and vacuum fluorescent displays have been constructed for direct view large flat panels but none of them can meet the requirements of size, resolution, color, and motion simultaneously.

NON-EMISSIVE DISPLAY

The conventional liquid crystal technology has been steadily improved and has already entered the color display market for small pocket TV receivers. Recently a 2" receiver with 17,600 cells for each primary color has become available. These cells are addressed by an active thin-film transistor matrix. The standard method of changing the direction of polarization of a linearly polarized light wave by twisted nematic liquid crystal molecules is used. The electric fields supplied by the active matrix control this effect. One transistor is required for each cell. But the number of gray scale steps achieved is rather low. Another principle difficulty of liquid crystals was their slow response. This problem has been fairly solved with the new designs.

Large liquid crystal flat panels have also been announced and described. Mitsubishi reported about their "Crystal Color" display [2]. They are using modules of LCD panels having 8 x 64 pixels. These are assembled to build up full size screens up to 2.9 x 4.6 m² with 256,000 pixels total. Each pixel cell is made of three subcells for R, G and B. The pixel pitch is 7.2 mm, so the average viewing distance should be 15 m. The device is not intended for home use. Similar screens are being shown at the Tsukuba Exposition '85.

PROJECTION DISPLAYS

CRT PROJECTORS

A projection technology offers the solution to the size demand. But until recently the principle lack of brightness, contrast and resolution being inherent drawbacks of projected TV pictures had not been overcome sufficiently. During the years the situation has changed somewhat. The conventional 3-CRT design has now been improved to such an extent that successful applications to HDTV could be shown. Also the high brightness light-valve projectors - to be described later - have been considered for HDTV.

New high resolution electron guns have been constructed for the projection tubes. The electron optical system was improved by an additional focus lens to overcome the blooming of the scanning spot at high brightness. Liquid cooling of the faceplates is now generally applied to allow high phosphor power densities. The projection optical system had to be improved accordingly. The refractive lens type of projectors are now being used exclusively and high performance lenses combining high resolution and high aperture have been designed. Indeed, the degradation of the resolution achieved on the CRT faceplates by the projection lens is a problem when a high aperture is required for high brightness. Presently good f/1.0 lenses sufficient for standard TV and excellent f/1.8 lenses for HDTV projectors have become available. Furthermore special high gain screens are developed being a compromise of directivity (limited viewing angle) and gain necessary for providing sufficient luminance from the still low light output even with the new projector designs.

After all, the new generation of standard TV projectors for home use comes with up to 65" rear projection screens as compact designs. They are using 7" tubes with 5" raster format. The screens (Fresnel-diffuser-lenticular type) have a gain of about 5.

The new Sony projector for HDTV offered for sale has a resolution of at least 800 lines per picture height and a luminance of 140 cd/m² (40 ft-L) on a 120" front projection screen with a gain of 12. 9"projection tubes are used. A contrast ratio of 40:1 is achieved if no ambient light is present. The 1125 lines/60 Hz standard with an aspect ratio of 3:5 has been successfully presented with this equipment during several occasions. For the 1985 Montreux Symposium a HDTV projector with a 200" screen will be shown.

LIGHT-VALVE PROJECTORS

CRT projectors are still suffering from their low light output due to the principle of producing the light from the energy of the electron while that beam also has to address the pixels and is responsible for the available resolution. Even with the reduced blooming effect of modern tubes a high drive operation is not allowed for high resolution and lens aperture is limited. Therefore the light flux from CRT projectors is being limited to a value of around 150 lumens and the high gain front projection screens mentioned above are necessary to meet the luminance requirement. Apart form their bulky construction not convenient for home use the high gain screens have a limited range of view. For the wide field of view, being the purpose of HDTV, low gain screens or even a matte white wall should be preferred.

Another projection technology is then required combining high resolution and very high light output. A light flux of at least 1000 lumens should be available for a 100" screen HDTV projection.

With light-valve devices the two different tasks of producing light and achieving high resolution (i.e.addressing a maximum number of pixels) are separated and may be optimized indepently. So the principle of light valve projection appears promising. The main advantage is that a controlling element modulates a light beam coming from an external source which can therefore be of high intensity. The light controlling element could act by absorption like a slide in a slide projector. This would be impracticable due to the problem of power dissipation.The controlling element may act without power dissipation by changing the state of polarization of the light or by diffraction. The gating of light according to the two principles is sketched in Fig. 2.

For the polarization case the element has to be placed between two crossed polarizers within a projection system. Liquid crystals or electro-optic crystals with birefringence controlled by electric fields may be used. Each picture element on the control layer must be modulated indepently by the video signal. This is the problem of addressing.

For the diffraction case the element is placed into the optical path of a dark field (schlieren-optical) projection system, i.e. between a pair of matched masks which block the light if no diffraction is effected. The control layer material may be a fluid transparent film or an elastomer material. The surface of the control layer is to be deformed by electric fields into optical phase gratings which are amplitude modulated according to the intensity of the picture elements. Again the problem of addressing appears. It would not be sufficient to create surface structures according to the finest details of the picture. When using the diffraction effect - unlike to the polarization effect - even finer structures are required to form an adequate grating. Each picture element must comprise at least one period of a grating raster, i.e. a spatial carrier frequency f_c is required of

$$f_c > 2f_s$$

where f_s ist the highest frequency component present in the spatial spectrum of the picture on the control layer.

A lot of different light valve devices had been designed and explored in the past, some have reached a production status. Those of relevance to TV applications are ordered in Table 1 according to the physical effect of the control layer and to the method of addressing used.

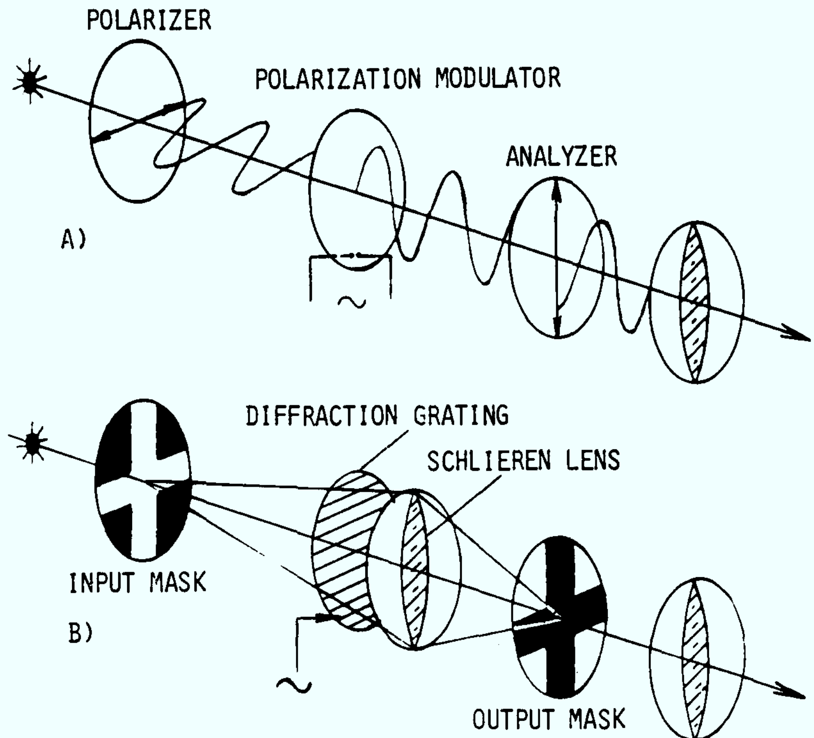

Fig.:2: Principles of electronic light control used in light valves:
a) varying the state of polarization
b) diffraction by controlled phase gratings

CONTROL-LAYER		ADDRESSING		
EFFECT	MEDIUM	ELECTRON BEAM	OPTICAL	MATRIX
DIFFRACTION	FLUID FILM	EIDOPHOR [3] GENERAL ELECTR. [4]		
	ELASTOMER	–	RUTICON* [5]	GLENN* [6]
CHANGING POLARISATION	LIQUID CRYSTALS	–	HUGHES [7]	HUGHES* [8]
	ELECTRO-OPTIC CRYST.	TITUS (SODERN) [7]	PHOTOTITUS* [10]	

* EXPERIMENTAL

Table 1: Light valve principle for use in TV displays

Electron-Beam-Addressing

The conventional and most widely applied method of addressing is by an electron beam. Then the control layer has to be placed inside a vacuum tube. The well established TV projectors using diffraction gratings from Gretag in Switzerland ("Eidophor") and from General Electric should be mentioned first. A fluid film is scanned by the electron beam according to the TV line raster. Its surface is deformed by the charge pattern deposited by the beam. The deformations are modulated by the video signal which is accomplished through defocus modulation (Gretag) or deflection modulation of the beam (GE). Whereas the Eidophor is a very bulky 3-gun design for R,G,B with light output of at least 7000 lumens which could never been envisaged for home use, the General Electric projector is a single-gun version. After an invention of Glenn [4] there is only one control layer and one optical system for all three primary colors thus allowing a compact design without registration problems. The construction is illustrated in Fig. 3. The single-gun principle is a spatial frequency division multiplexing using three different phase gratings as carriers, one is horizontal for green, and two others are vertical with different periods for controlling red and blue. Available projectors deliver more than 1000 lumens light output from a 1300 W xenon lamp, and a 1023 scan line version provides a resolution of nearly 700 lines per picture height. Modified with an anamorphic lens a projector was demonstrated at the 1983 Montreux Symposium by General Electric displaying a HDTV picture with 3:5 aspect ratio. We at Heinrich-Hertz-Institut in Berlin have made a thorough investigation over the past three years about the single-gun light valve system and it appears that further improvements of picture quality for HDTV applications and higher light efficiency could be achieved.

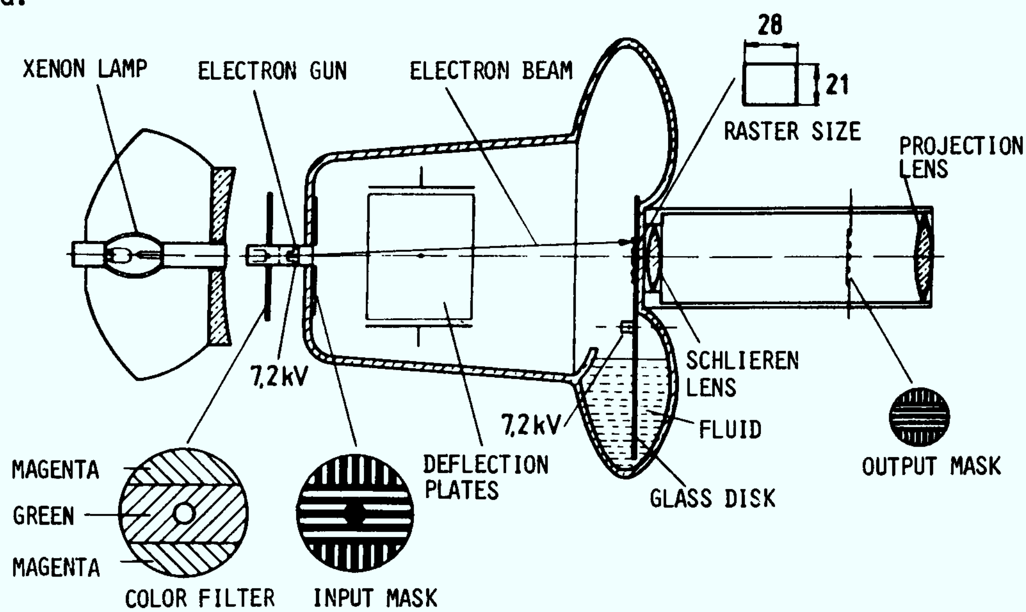

Fig. 3: The single-gun light valve projection system of General Electric

Another light-valve device using the Pockels effect is also addressed by an electron beam. The electro-optic crystal is a KD_2PO_4 plate operated just above its Curie temperature (about -50°C) and in a reflection mode optical system. A constant current scanning electron beam is used and the video signal is applied between the target plate and a grid placed in front of it. The electron beam functions as a flying-spot short circuit between the grid and the point of impact on the target. Control voltages of 100 V are required. The device has been invented by Marie[9] under the name of "Titus" (an acronym for Tube Image a Transparence Variable Spatio-temporelle) and has been commercialized as the "Sodern Visualization System". Applications to HDTV projections have not yet been shown.

Optical Addressing

If the control layer is placed between conductive planes in series with a photoconductor layer an electric field pattern can be created by illuminating the photoconductor. So the optical addressing by a primary light (writing light) is possible when the reading light used in the light valve is prevented to reach the photosensor. Amorphous-Se, CdS, and single-crystal silicon photoconductors have been used. The primary image source may come from a small, very high resolution monochrome CRT or from a laser scanner.

Optical addressing had been applied to Pockels control layers mentioned above ("Phototitus"), but not for TV purposes. Optically addressed control layers using the diffraction principle have been developed with a metallized elastomer. The metallized surface is deformed and acts as a flexible mirror within a reflection-mode light valve system.

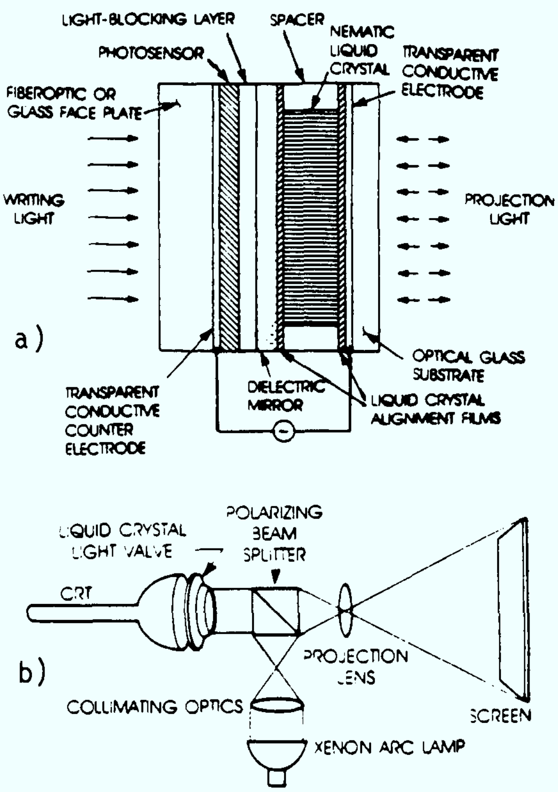

Fig. 4: The optically addressed liquid crystal light valve of Hughes:
a) Light valve element
b) Optical system for projection

Optically addressed liquid-crystal-light valves using the polarization principle have been successfully developed by Hughes Aircraft Company [7]. Large screen monochromatic projection displays of this type are widely used in military command-control centers. The light-valve element and its application in a reflection-mode optical system is shown in Fig. 4. The combination of a fiberoptic CRT and the liquid-crystal light valve can result in a resolution of 1000 TV lines. A "second generation" of these light valve are being developed at the Hughes Research Labs while applying the silicon photoconductor. Higher resolution and faster time response are claimed.

Matrix Addressing

The active matrix already a common technique for addressing direct view liquid crystal displays is still in an early stage for light-valve control layers. Nevertheless it appears to be a very promising method for a future solid-state light valve element. If the line-at-a-time matrix addressing mode is applied the time response of the control layer will be matched and it would be possible to result in a kind of luminosity-hold type of TV display with the great advantage of flicker-free operation and high light efficiency. Less flicker compared to CRT's was already observed with the electron-beam addressed light valves described, but with active matrix addressing this could be much more improved. Furthermore the entire surface of the control layer can have a uniform raster being free from geometric distortion which is of considerable importance in matching light valves for color. Presently the required extreme density of the matrix elements on large VLSI chips is still a difficult problem of technology.

The research work of Glenn [6] should be mentioned in this connection. He is being engaged in constructing a solid-state light valve element using the metallized elastomer layer placed upon a large active matrix. Also recently Hughes Research Labs have applied a CCD array to addressing their liquid-crystal light valve.

CONCLUSION

When we are aiming at a HDTV system capable of transmitting pictures for "Telepresence" on large screens viewed from a distance of two times picture height, a single-mode optical fiber network is adequate for transmission and a projection technology is required for the HDTV receiver displaying the pictures with 100" diagonal and a resolution of 1000 lines per picture height and the projector should provide a high light output of at least 1000 lumens. For front projection a ceiling mount could be envisaged. Anyway, a compact and moderately priced design is necessary.

CRT projectors are already available with nearly sufficient resolution but their light output is limited due to principle reasons. So special high gain screen constructions with high directivity must be used with these projectors. These systems are bulky and costly, neither intended nor applicable for home use.

Light-valve projectors deliver very high light output, and bright pictures are achieved even with low gain screens. The electron beam addressed fluid film for diffraction control is successfully applied in equipments already on the market since years. The picture quality could be improved for HDTV applications. Solid-state addressed light-valve elements appears to be the most interesting future solution. This technology would avoid the problems of vacuum and electron optics, the difficulties of inserting a fluid of very low vapor pressure into the vacuum and the bombardment of electrons onto the fluid.

The display problem of HDTV receivers for consumer applications has not yet been solved. It's a problem of eminent economic importance and decisive for a success of the HDTV idea. It's the future challenge for the display industry!

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COLOR PICTURE DISPLAY SYSTEM FOR HIGH-DEFINITION TELEVISION

2.7

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ABSTRACT

The wide screen, high-definition television produces a crisper and higher resolution picture aiming at presenting a more attractive impression of "realism" to viewers thereby attempts to satisfy to the demands of the coming video generation. Research and development works in high-definition television (HDTV) system have been carried out at Matsushita Electric for thirteen years under the guidance of the NHK Science and Technical Research Laboratories (Japan Broadcasting Corporation). Comprehensive technological developments made to date include a high-definition camera with high-resolution Plumbicon pick-up tubes, a wide band contour corrector, a color encoder and decoder for composite signal transmission (HLO-PAL), a color encoder and decoder for Y-C components separate transmission, a high-definition video tape recorder, an SHF television receiver for DBS, a MUSE (Multiple Sub-Nyquist Sampling Encoding) decoder, and a variety of high-definition picture displays.

A picture display is one of the key components of a television system, because a viewer evaluates the television system he watches through the display. In this paper, details of recently developed displays for HDTV are described. Following a short review of our technological development in the field of high-definition picture displays, a 110 inch front-type projection display, a 55 inch rear-type projection display, and a 40 inch CRT display are described. Developmental displays made by Matsushita have been mainly used for visual evaluation of actual pictures in experimental HDTV systems. Relatively few numbers of developmental displays have been offered for systems investigation in high quality video transmission by optical-fibers, for computer video image composition, for use as a video display for electronic cinematography, and for educational use in closed circuit networks. Incidentally, there is the International Exposition, Tsukuba, 1985 (Tsukuba Expo '85), going on in Japan, where several displays are used to experiment broadcasting in HDTV.

SYSTÈME D'AFFICHAGE EN COULEUR POUR LA TÉLÉVISION À HAUTE DÉFINITION

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RÉSUMÉ

La télévision à grand écran et à haute définition produit une image plus nette, de meilleure définition, visant à donner une meilleure impression de "réalisme" aux téléspectateurs et essaie ainsi de satisfaire aux demandes de la génération vidéo montante. Des travaux de recherche et de développement sur la télévision à haute définition (TVHD) sont menés depuis treize ans à la compagnie Matsushita Electric, avec les conseils des laboratoires de recherche scientifique et technique de la NHK (Société de radiodiffusion du Japon). Les importants développements technologiques réalisés jusqu'ici comprennent une caméra à haute définition utilisant des tubes de captage Plumbicon de haute résolution, un correcteur de contours à large bande, un codeur et un décodeur pour la transmission de signaux composites (HLO-PAL), un codeur et un décodeur couleur pour la transmission séparée des composantes Y-C, un magnétoscope à haute définition, un récepteur de télévision SHF pour le service de radiodiffusion directe par satellite, un décodeur MUSE (sous-échantillonnage avec compensation de mouvement) et divers écrans d'affichage à haute définition.

L'affichage est l'un des éléments clés d'un système de télévision, car le spectateur évalue le système de télévision par l'image qu'il voit. La communication décrit en détal les écrans d'affichage récemment mis au point pour la télévision à haute définition. Après une courte revue de nos développements technologiques dans le domaines de l'affichage à haute définition suit une description d'un écran d'affichage de 110 pouves à projection par l'avant, d'un écran de 55 pouves à projection par l'arrière et d'un affichage à TRC de 40 pouces. Les écrans d'affichage mis au point par Matsushita ont été principalement utilisés pour l'évaluation visuelle d'images réelles dans les sytèmes en transmission vidéo de haute qualité par fibres optiques, pour la composition d'images vidéo par ordinateur, pour l'utilisation comme affichage vidéo pour la cinématographie électronique et pour des fins éducatives, dans des réseaux en circuit fermé. Il est à signaler que l'exposition internationale de Tsukuba (Expo 85), au Japon, montre l'utilisation de divers écran d'affichage pour la radiodiffusion expérimentale de télévision à haute définition.

COLOR TELEVISION CAMERA AND DIGITAL VTR FOR HIGH DEFINITION TELEVISION USE

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ABSTRACT

1. Introduction

As a next generation television system, NHK, Japan Broadcasting Corporation, is now promoting High Definition Television (HDTV) system which specifies the scanning lines of 1125, the interlace ratio of 2 to 1 and the aspect ratio of 3 to 5. The HDTV system has 4 to 5 times as much information as the present system and provides vivid pictures with an excellent resolution.

Hitachi has developed a camera, a VTR, a monitor and other equipments in accordance with the HDTV specifications.

This paper describes the 3-tube color studio camera, and the digital VTR for HDTV use.

2. HDTV Color Camera

2.1 Technical Features

The camera adopts a 14X zoom lens, and a 1-inch diode-gun SATICON which assures the limiting resolution of 1200 lines or more under the condition of 3-to-5 aspect ratio. Both are developed for HDTV use.

3. HDTV Digital VTR

3.1 Basic Composition and Technical Features

Since the frequency bandwidth of the HDTV signal is about 5 times as much as that of the present TV system, the original TV signal is converted to about 460 Mb/s digital codes in order to obtain a high quality picture after the analog-to-digital conversion. The converted super high speed signal is divided into 5 channels and recorded on the tape in parallel with 5 magnetic heads.

CAMÉRA DE TÉLÉVISION COULEURS ET MAGNÉTOSCOPE NUMÉRIQUE POUR LA TÉLÉVISION A HAUTE DÉFINITION

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RÉSUMÉ

1. Introduction

Le système de télévision de prochaine génération que propose maintenant la NHK, société d'État de de télévision du Japon, est un système de télévision haute définition (TVHD) à 1 125 lignes de balayage, entrelacement de 2/1 et rapport largeur-hauteur de 5/3. Le système TVHD présente quatre à cinq fois plus d'informations que le système actuel et fournit des images lumineuses d'excellente définition.

La compagnie Hitachi a mis au point une caméra, un magnétoscope, un téléviseur et d'autres équipements qui satisfont aux spécifications de la TVHD.

Le mémoire décrit la caméra couleurs de studio à 3 tubes et le magnétoscope numérique employés pour la TVHD.

2. Caméra couleurs de TVHD

2.1 Particularités techniques

La caméra comporte un zoom 14X et un tube analyseur SATICON d'un pouce de diamètre, qui assure une résolution de 1 200 lignes ou plus pour un rapport largeur-hauteur 5/3. Ces deux dispositifs ont été conçus pour la TVHD.

3. Magnétoscope numérique de TVHD

3.1 Composition de base et particularités techniques

Etant donné que la largeur de bande du signal TVHD est environ cinq fois plus grande que celle des systèmes de télévision actuels, le signal de télévision d'origine est converti en codes numériques d'environ 460 Mb/s afin d'obtenir une image de grande qualité après conversion analogique-numérique. Le signal converti de très grand débit est divisé en cinq canaux et enregistré sur bande par cinq têtes en parallèle.

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1. Introduction

As a next generation television system, NHK, Japan Broadcasting Corporation, is now promoting High Definition Television (HDTV) system[1)] which specifies the scanning lines of 1125, the interlace ratio of 2 to 1 and the aspect ratio of 3 to 5. The HDTV system has 4 to 5 times as much information as the present system and provides vivid pictures with an excellent resolution.

Hitachi has developed a camera, a VTR, a monitor and other equipments in accordance with the HDTV specifications.

This paper describes the 3-tube color studio camera, and the digital VTR for HDTV use.

2. HDTV Color Camera

2.1 Technical Features

Fig. 1 shows a block diagram of the HDTV color camera that uses the 3-tube system.

The camera adopts a 14X zoom lens, and a 1-inch diode-gun SATICON® which assures the limiting resolution of 1200 lines or more under the condition of 3-to-5 aspect ratio. Both are developed for HDTV use.

It is difficult to achieve a high accuracy of registration (0.025%) necessary for an HDTV camera only by a conventional lower order distortion compensation. The authors developed a new Digital Registration Correction (DRC) system[2)], which automatically compensates for a higher order distortion.

In addition, the mis-registration due to the variations of the chromatic aberration caused by zooming, focussing, and iris control of a lens cannot be neglected in the HDTV camera. We adopted a chromatic aberration corrector, which previously stores correction data in memory, reads out the data according to lens operations, applies them to the deflection circuit to control the scanning beam on the target of the pickup tube.

These two registration correction functions continuously guarantee an extremely high resolution.

As shown in Fig. 1, the camera head consists of the pickup tube driver (deflection and high voltage power supply), DRC circuit, chromatic aberration corrector, three preamplifiers as well as control computer, and is connected to the camera control unit with a camera cable.

The camera control unit consists of the three process amplifiers, and a sync generator, a monitor circuit, a registration measuring unit, and a contour corrector (2H, out-of-green system). Each process amplifier includes a cable compensator, a signal processing circuit, and a VDA (video distribution amplifier).

The camera utilizes the computer control system for major parameters to be able to cope with a camera auto-setup system in near future.

The appearance of the camera is shown in Fig. 2.

2.2 Digital Registration Correction System

The DRC system can compensate also for higher order mis-registrations generated in a pickup tube, by providing many discrete detection points in a picture as shown in Fig. 3(a). The camera has 19 detection points horizontally (every 1.34 μs) and 19 detection points vertically (every 32H).

In the DRC system, it is important to prevent the generation of picture shading by suppressing the abrupt changes of the scanning line density when generating a necessary smooth interpolation waveform from the serial data of the vertical detection points.

In the conventional linear interpolation method, the scanning line density changes abruptly at the data switching point and a stairstep shading is generated. This greatly degrades picture quality. The DRC system suppresses the generation of picture shading by using an analog filter, which provides the required interpolation waveform.

Fig. 3(b) shows a block diagram of the new DRC circuit. The correction data D_{11}, D_{12}, D_{13},--- stored in the data memory are read out in synchronism with the horizontal scanning repeatedly for a vertical data period of 32H. The data D_{21}, D_{22}, D_{23},--- are then read out 32 times as in the above. The readout data are digital-to-analog converted by the D/A converter and distributed through the multiplexer to the 19 vertical filters which correspond to the horizontal divisions. Each filter provides a vertically interpolated smooth correction signal. The filter output signals are sampled again by the multiplexer, passed through the horizontal filter, and supplied as the correction signal corresponding to each scanning line.

The vertical filters are the 5th order Bessel filters that have excellent phase characteristics. The cutoff frequency of the filter is set at 200 Hz to obtain the continuity between the data.

The correction accuracy of the DRC systm depends upon the number of data points, the quantizing level, and the maximum correction range. Our camera adopts 8-bit of quantizing and 3% of correction range. The overall correction accuracy of 0.025% is obtained over the entire picture frame in cooperation with the interpolation method which has a high accuracy of approximation, and the generation of picture shading is reduced to 1/7 to 1/8 times as much as the usual.

The registration measuring unit is also built into the camera to make an automatic registration adjustment possible, which greatly reduces the setup time to 2 to 3 minutes (in the relative setup mode). This has solved the big problem on camera operation.

2.3 Lens Chromatic Aberration Corrector

In general, the lens chromatic aberration can be corrected by compensating for the chromatic aberration of the R and B pictures relative to that of the G picture. Fig. 4 shows an example of the chromatic aberration. The vertical axis (ordinate) denotes the image height from the lens center, and the horizontal axis (abscissa) denotes the chromatic aberration relative to the G picture. The plus aberration expresses an expansion, and the minus aberration expresses a reduction, so that Fig. 4 shows the R and B pictures have a pincushion distortion relative to the G picture.

The aberration curve varies according to the lens operating conditions (zooming, focussing and iris control), and it is not advisable to store a large quantity of the correction data for all the cases. The number of data points for zooming is settled on 5, that for focussing on 4, and that for iris control on 3, and the correction data for the combination of these points are stored. The data for the intermediate point is obtained by the interpolation operation.

The correction data are divided into two components; one is a linear component (A) which expresses the tangent at the optical center 0, and the other is non-linear component (B) which expresses the remainder of the original curve minus the component (A). The component (A) corresponds to the deflection size, however, the component (B) corresponds to the pincushion (or barrel) distortion, so that a complicated correction waveform is required to compensate for the latter.

By various investigation of the aberraton curve, we found that the component (B) could be approximated by the 3rd order functon curve which was easily generated and that a sufficient correction accuracy could be obtained. The coefficient for each of the components (A) and (B) was decided by using the method of least squares to reduce the residual error to 0.01% or less.

Fig. 5 shows a block diagram of the lens chromatic aberration corrector. Three potentiometers (ZOOM, FOCUS, and IRIS) supply the signals which correspond to the respective operating conditions to the microcomputer. The microcomputer selects the data area including the lens operating conditions from the ROM, read out the correction data before and behind this data area, then executes the interpolation operation, and calculates the correction data for the lens operating conditions.

The linear interpolation method that requires a very short calculation time is employed. As a result, the circuit needs only 50ms or less calculation time, and can sufficiently follow the changes of the lens operating conditions, providing no sense of incongruity in a picture.

The output of the microcomputer is supplied to the multiplier which controls the amplitude of the correction waveform generator output.

The two outputs of the multiplier are added to the main deflection waveform in the adder to correct the chromatic aberration of the R and B pictures.

The chromatic aberration corrector can reduce the aberration to 1/4 to 1/6 times as much as that before correction, and can reach the target of 0.025%.

The specifications of the HDTV color camera we have developed is shown in Table 1.

3. HDTV Digital VTR

3.1 Basic Signal Processing and Technical Features

Fig. 6 shows the basic block diagram of the HDTV digital VTR we have developed. The HDTV three primary color signals are formed into a luminance signal component and two color signal components, each of which is converted to digital codes through the analog-to-digital converter.

Since the frequency bandwidth of the HDTV signal is about 5 times as much as that of the present TV system, the original TV signal is converted to about 460 Mb/s digital codes in order to obtain a high quality picture after the analog-to-digital conversion. The converted super high speed signal is divided into 5 channels and recorded on the magnetic tape in parallel with 5 magnetic heads.

The bit length on the magnetic tape becomes approximately 0.5 microns, therefore, the digital codes on the tape are susceptible to defects and noises of the tape. To solve the problem, the error correcting code is added before recording and the errors in the reproduced digital codes are automatically detected and corrected.

The magnetic head is not generally able to reproduce low frequency components. We have developed a new modulation processing system which converts the digital codes to the codes that have a little low frequency components by utilizing the characteristics of the video signal. The modulator output codes are recorded on the tape and the reproduced signals are again converted to the original digital codes by the demodulation processing.

The above error correction processing and the modulation/demodulation processing assure that the reproduced TV signals doesn't have picture degradation which is usually caused by the recording and reproduction processes. As a result, the reproduced picture quality depends only upon the sampling frequency and the quantizing level in the digital-to-analog conversion

3.2 Error Correction System

There are two types of errors in the reproduced signal;

1. Random Error: The error caused by noises due to the magnetizing characteristics of a tape and noises of the playback amplifier. This error usually occupies one bit of the digital code.

2. Burst Error: The error due to the dropout which is caused by the spacing between the magnetic head and tape due to a dirt or a scratch on the tape. This error usually occupies several ten to hundred bits of the digital code.

The higher the speed, that is, the wider the frequency bandwidth, the larger the effect of the noise in (1), and, the shorter the recorded wavelength and the narrower the recorded track width, by using the high density recording, the larger the effect of the noise in (1) as well as the effect of the dropout in (2).

On the other hand, since the HDTV digital VTR must record extemely large quantity of the data as described before, it is difficult to allocate enough bits for the error correcting code. However, the sync signal in the horizontal blanking period of the TV signal can be reinserted (regenerated) after the reproduction. We allocated the blanking period for recording the error correcting code instead of the horizontal blanking signal.

Fig. 7 shows the construction of the data block with the error correcting code added. As shown, the picture data are arranged in a unit called "subblock" and the error correcting code is added to every subblock. The data block with the error correcting code added is recorded on the tape in the direction of the arrow from the top subblock in Fig. 7.

Since the burst error on the tape occurs in the horizontal direction of the data block construction in Fig. 7, the error correction is calculated in the vertical direction. When the length of the subblock is selected longer than the predicted length of the burst error, the burst error can be handled as one word error in the vertical direction.

The code error at a upper bit provides a larger affect to picture quality, and the evaluation test of the HDTV signal shows that the affect of the code error can be almost completely removed when the error at the higher 4 bits is corrected.

To consider the result of this subjective evaluation, the error correction codes are applied to those upper bits.

Furthermore, two sets of the upper 4 bits from two adjacent words in the vertical direction are regarded as a new one word of 8 bits for error correction.

As the error correction code in the vertical direction, we adopted the "b-adjacent error correction code" which can correct erroneous codes in a word unit. By combining the new word of 8 bits described before with this error correction code, we could improve the error rate by one order.

3.3 Modulation Processing System

The DC component cannot be reproduced in a VTR recording/reproduction system owing to the frequency characteristics of the rotary transformer and the magnetic head. This results in a degradation of the reproduced signal waveform and is one of the main factor to generate the code error.

The modulation processing system converts the picture code having the DC component to the code having little DC component. In the HDTV digital VTR, a higher sampling frequency is used than the usual, therefore, more correlation between the pictures can be expected and the "8-8 mapping code" [3)] is applicable. The authors investigated to limit the number of continuing "1"s or "0"s (i.e. run length) so that the generation of the code error is further prevented.

Fig. 8 shows an example of the conversion of the TV signal to the "run length limited code". In the figure, (a) denotes the TV signal, and in (b), the sampled value is expressed by the natural binary code. When the code in (b) is reversed in every picture elements, the generation of the DC component is a little suppressed as shown in (c), however, it is not always possible ot prevent the generation of the DC component.

In the "8-8 mapping code", 256 levels of the 8-bit code are first rearranged in order of the weight of the word (the number of "1"s in one word), and these are made correspond to the level "0" to "255" of the picture (8-8 conversion). When the converted code is reversed in every picture elements, it seems, as shown in (d), that the numbers of "1"s and "0"s are often equal between the adjacent codes, and the generation of the DC component is moderately prevented. However, the code "1" or "0" continues between the adjacent codes as shown in (d).

After the investigation of the number of continuing "1"s or "0"s (run length) between the adjacent codes, it is found out that the number of words, i.e. the number of levels, usable at the run length of 6 is 196.

The "run length limited code" not only suppresses the DC component, but also reduces the what so called "maximum flux protect the occurrence of the code error since the effect of the non-linear waveform interference in the magnetic recording system is reduced.

The result of a practical recording and reproduction test proved the error rate is iproved by half an order in comparison with the case in which the run length is not limited.

The 196 levels at the run length of 6 are smaller than the 256 levels which can be expressed by 8 bits, so that the signal-to-noise ratio of the reproduced picture in this digital VTR is degraded from 59 dB. However, this is high enough and provides no big problems.

By developing the above error correction and modulation processing systems, we could reduce the error rate of the reproduced picture to 10^{-8} or less.

3.4 Specifications of HDTV Digital VTR

The appearance of the HDTV digital VTR we have developed is shown in Fig. 9. The right side rack includes the digital signal processing system and at the left side are located the tape transport and the signal processing system that extracts the clock signal and the digital data from the output signal of the magnetic head.

Table 2 shows the major specifications of the HDTV digital VTR. Both the tape speed and the rotating speed of the cylinder are twice as high as those of a conventional type C VTR, however, a conventional 1-inch video tape can be utilized.

4. Conclusion

The technologies on the HDTV color camera and digital VTR for the HDTV system was described.

An experimental model of the HDTV studio system by using these technologies surely satisfied the basic performance requirements.

The HDTV system is applicable to a broadcasting use as well as an industrial use, and further improvement in sensitivity of a camera, decrease in equipment size, and reduction in power consumption are expected.

The authors appreciate all the persons in NHK Science and Technical Laboratories who conducted us on the development of the HDTV system, and those in Canon, Ltd. who developed the zoom lens for HDTV use in cooperation with us.

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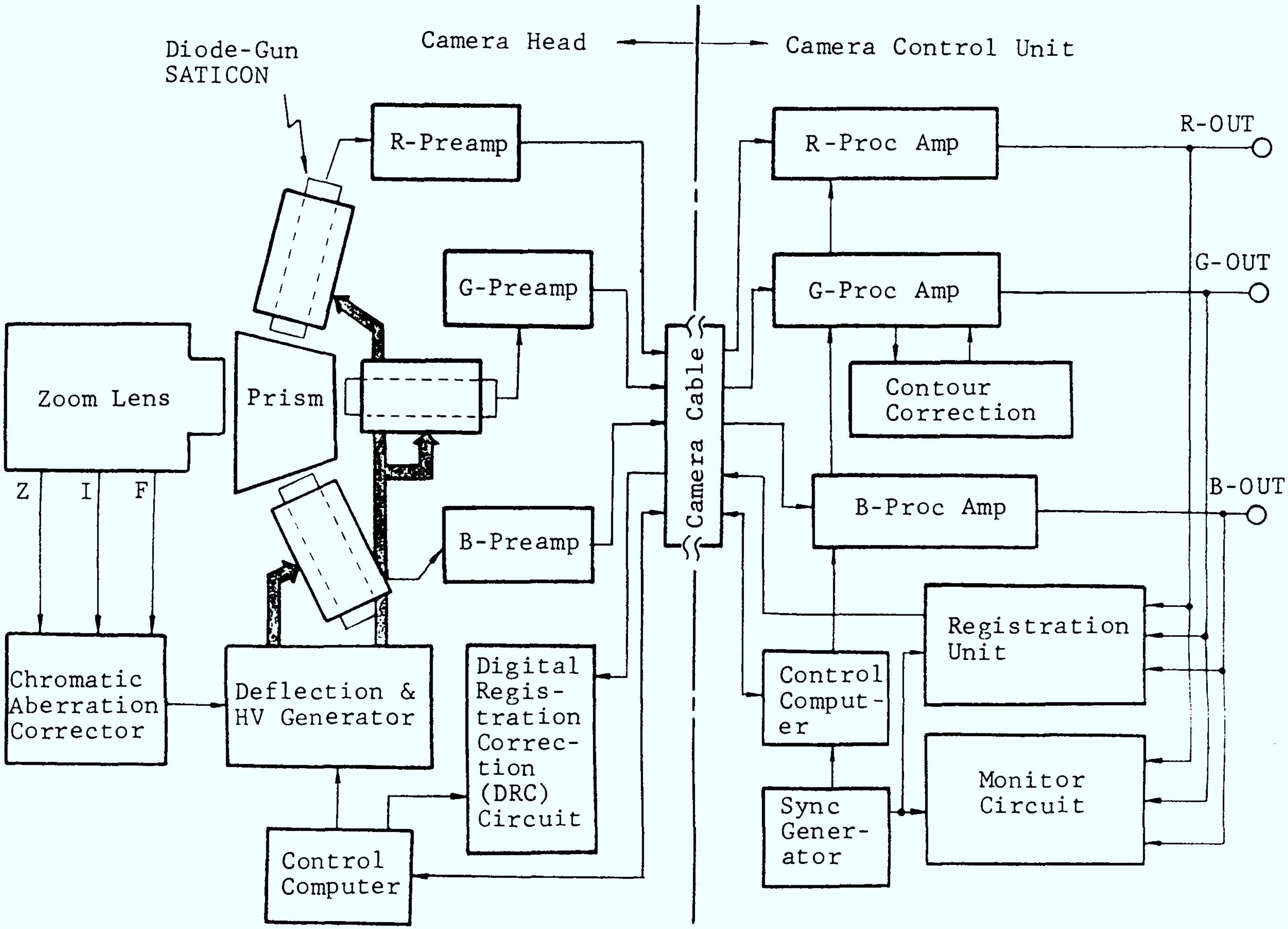

Fig. 1 Block Diagram of HDTV Color Camera

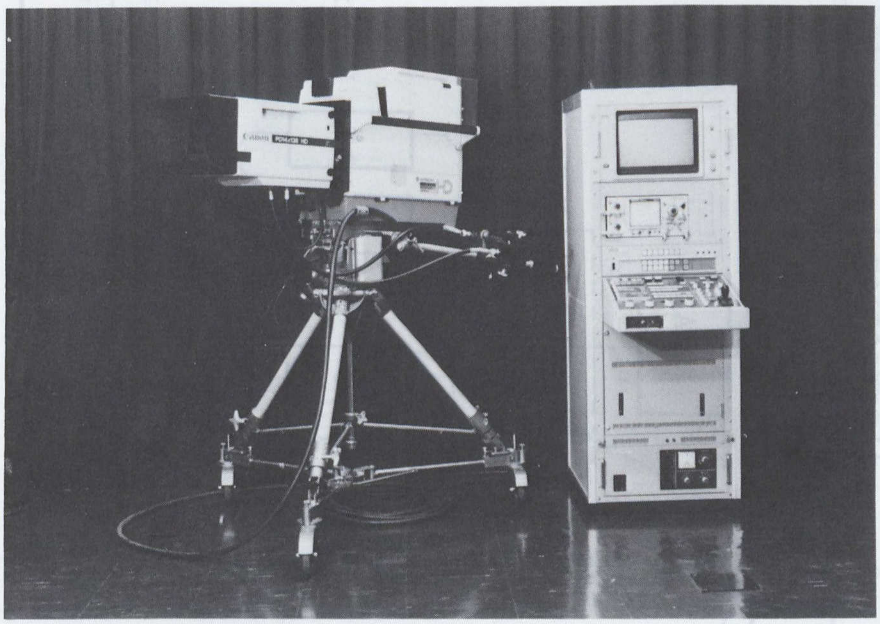

Fig. 2 Appearance of HDTV Color Camera

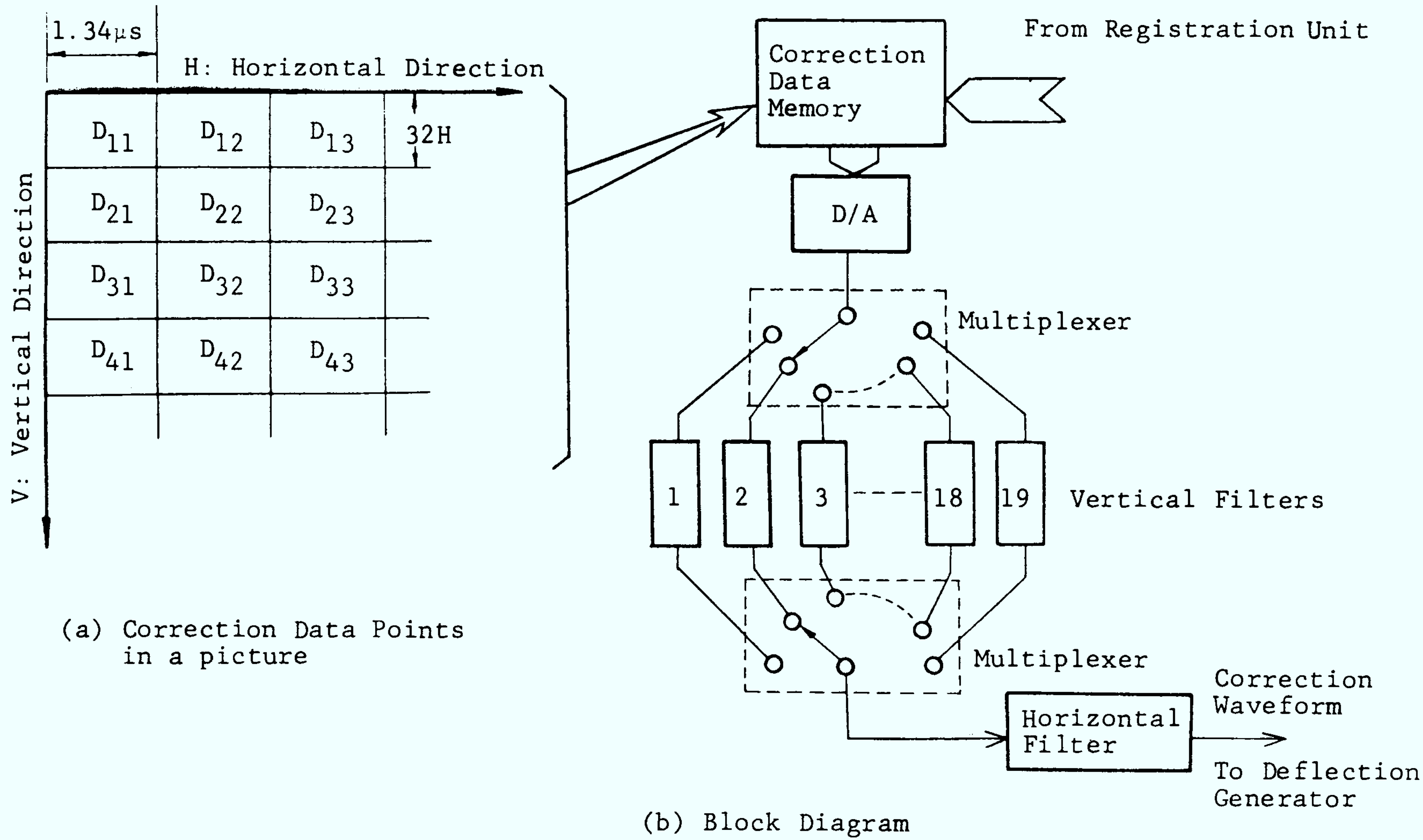

Fig. 3 New Digital Registration Correction (DRC) System

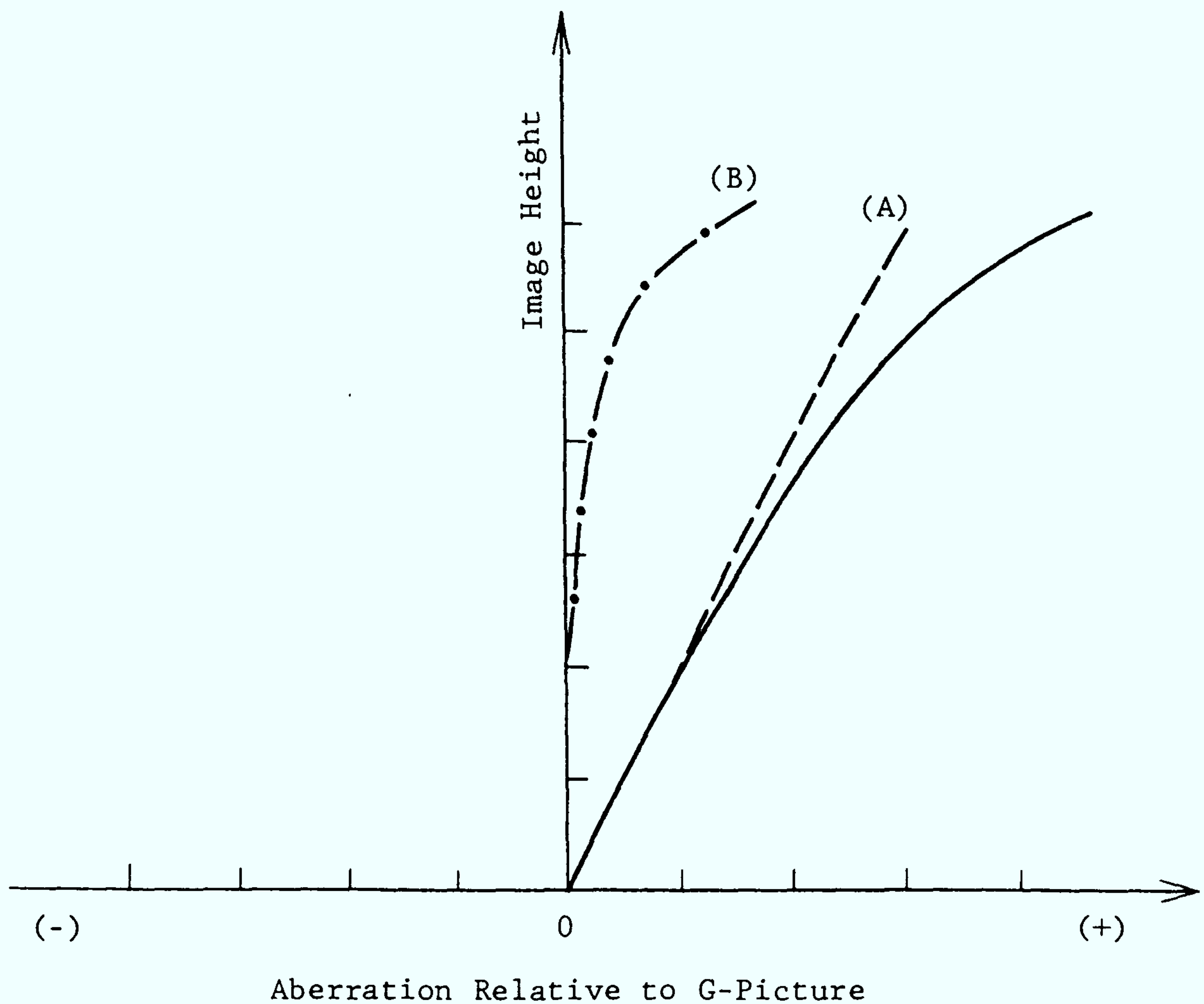

Fig. 4 An Example of Chromatic Aberration

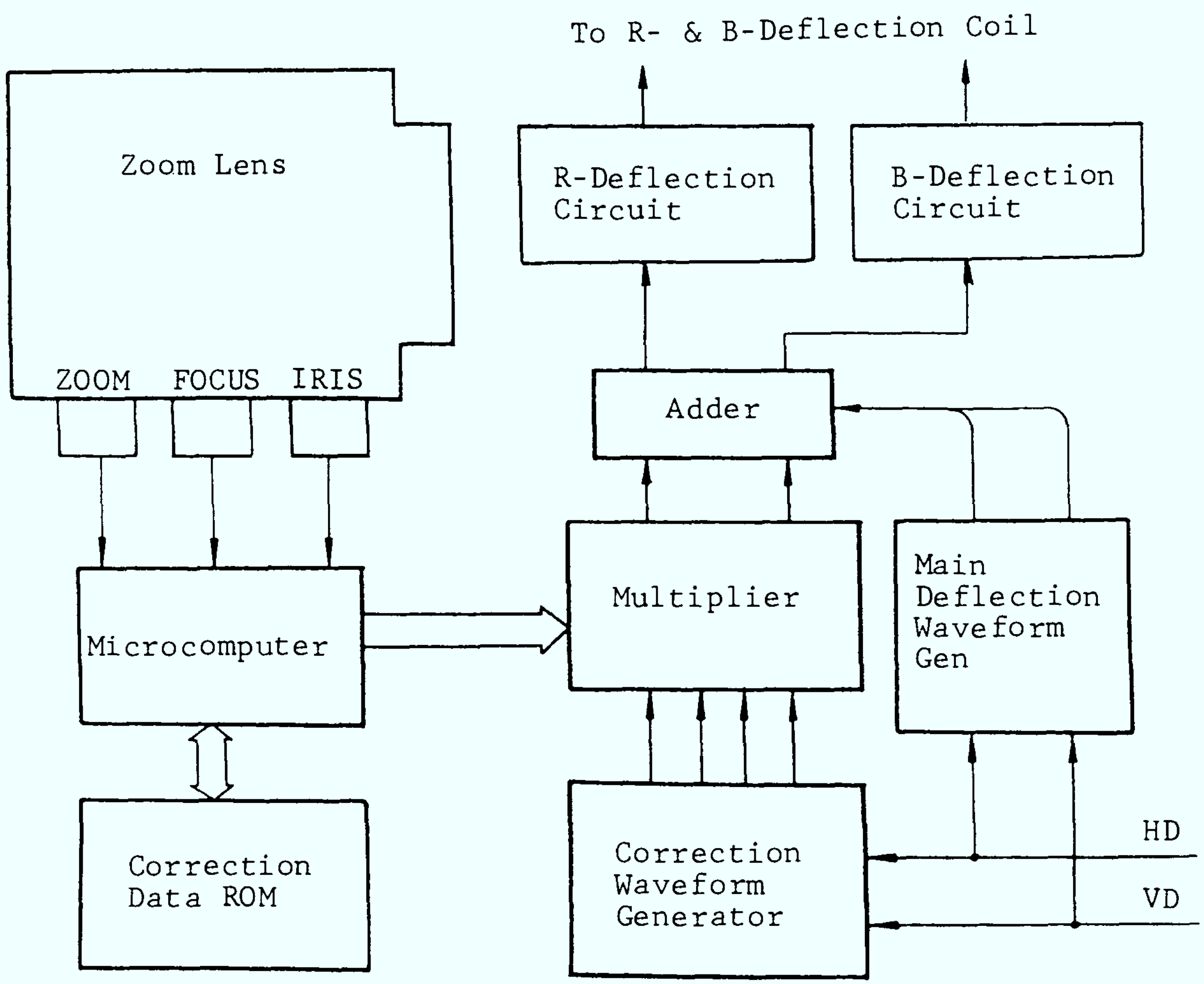

Fig. 5 Block Diagram of Lens Chromatic Aberration Corrector

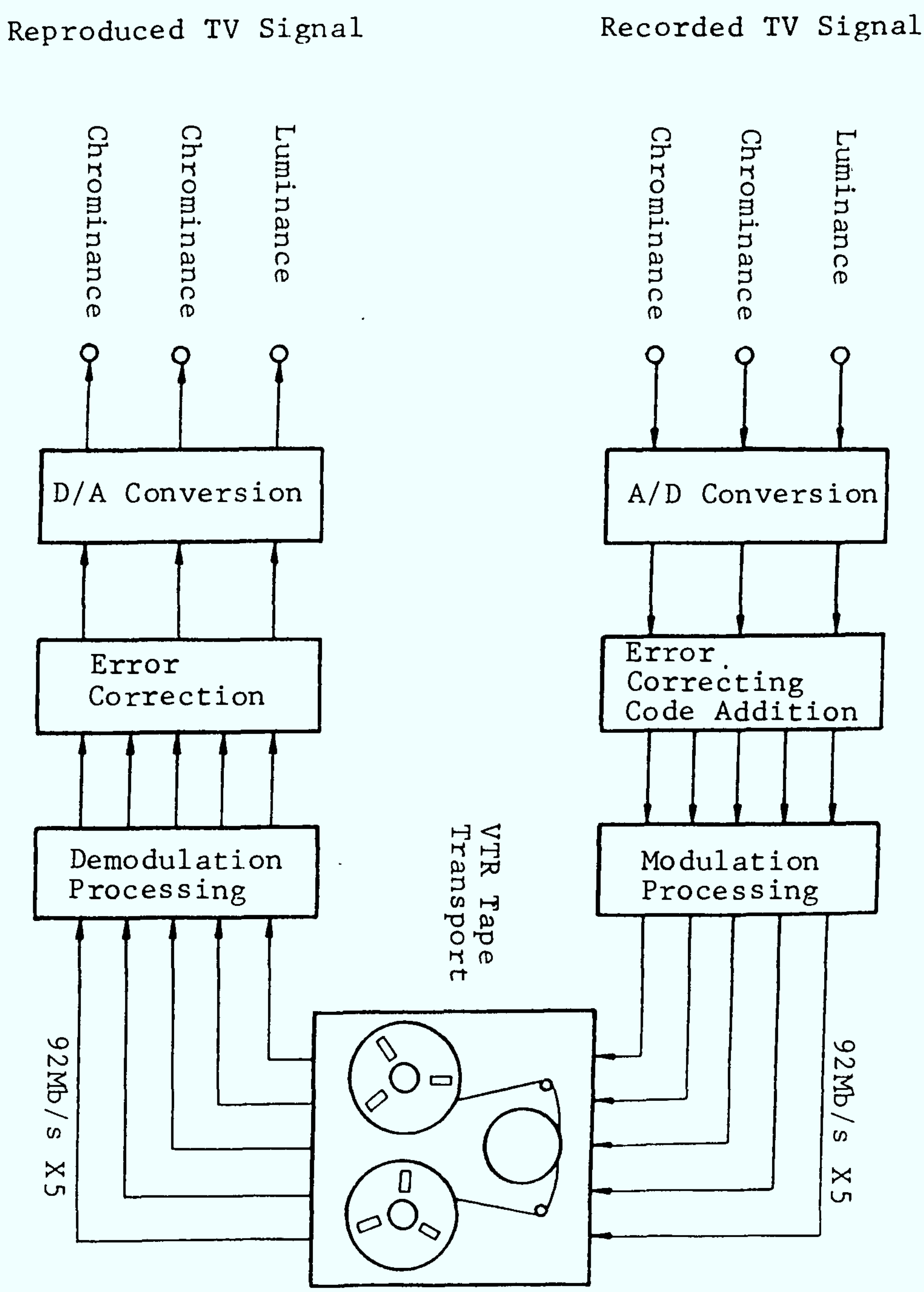

Fig. 6 Basic Block Diagram of HDTV Digital VTR

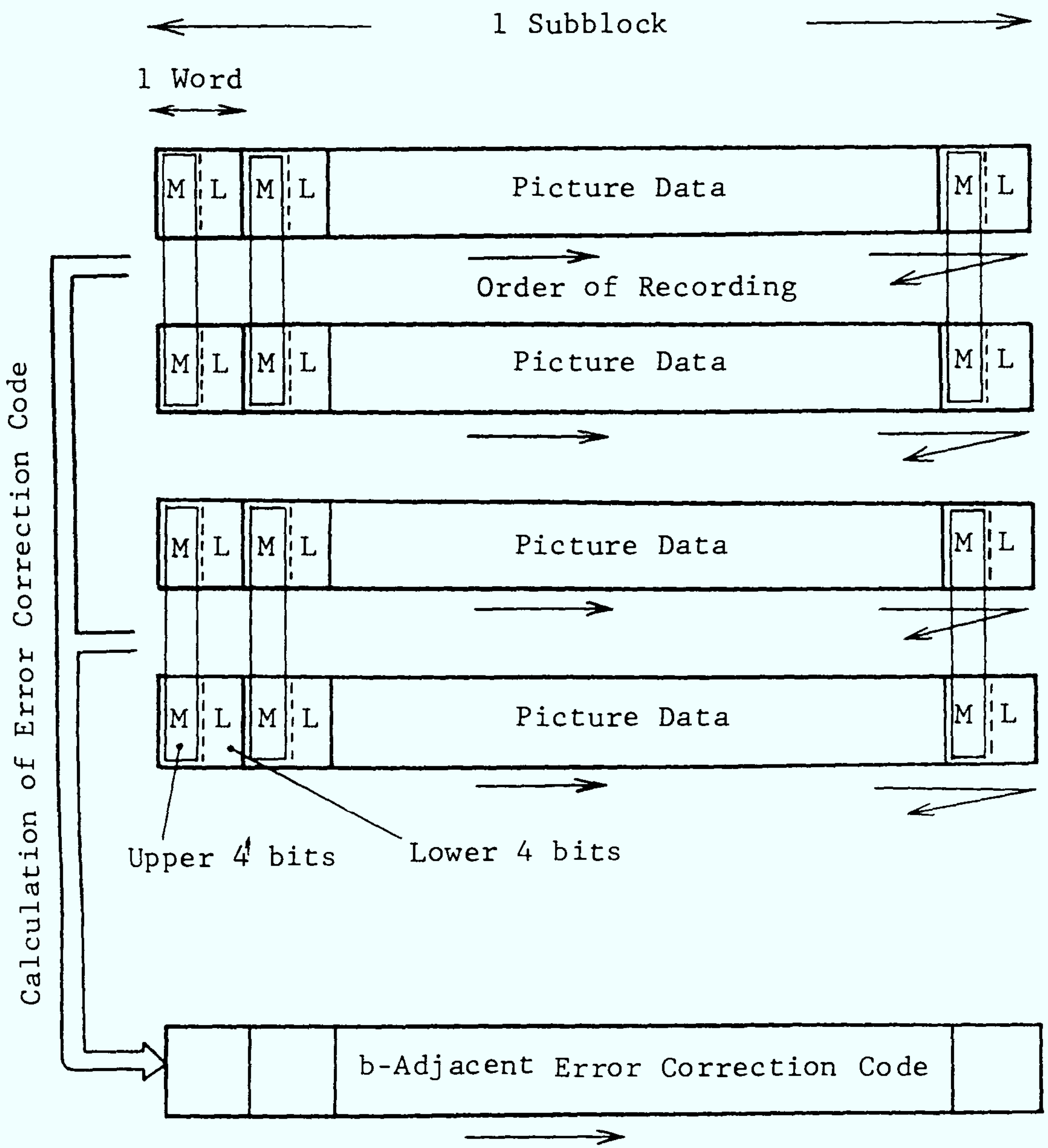

Fig. 7 Construction of Data Block

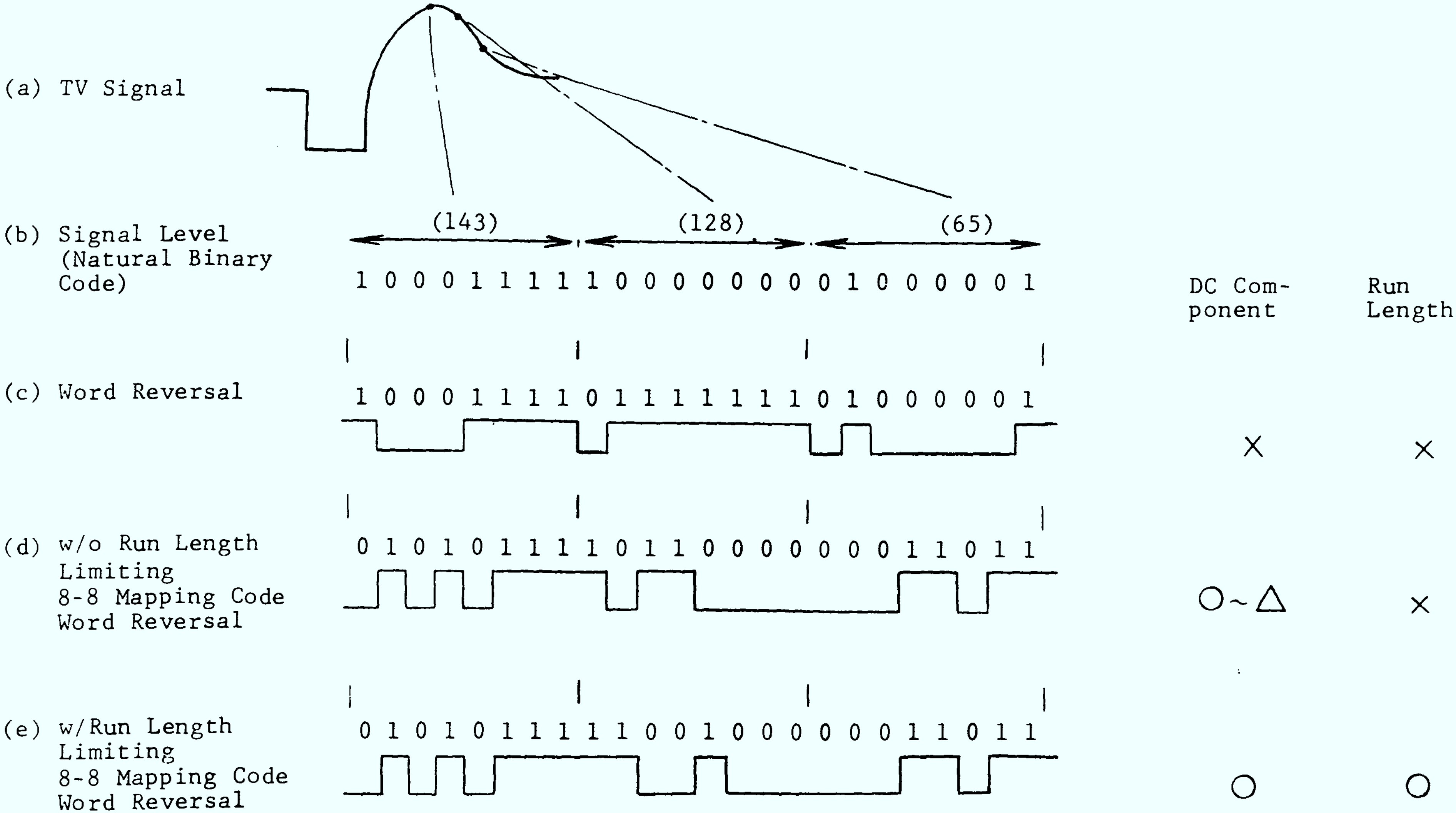

Fig. 8 Run Length Limited Code

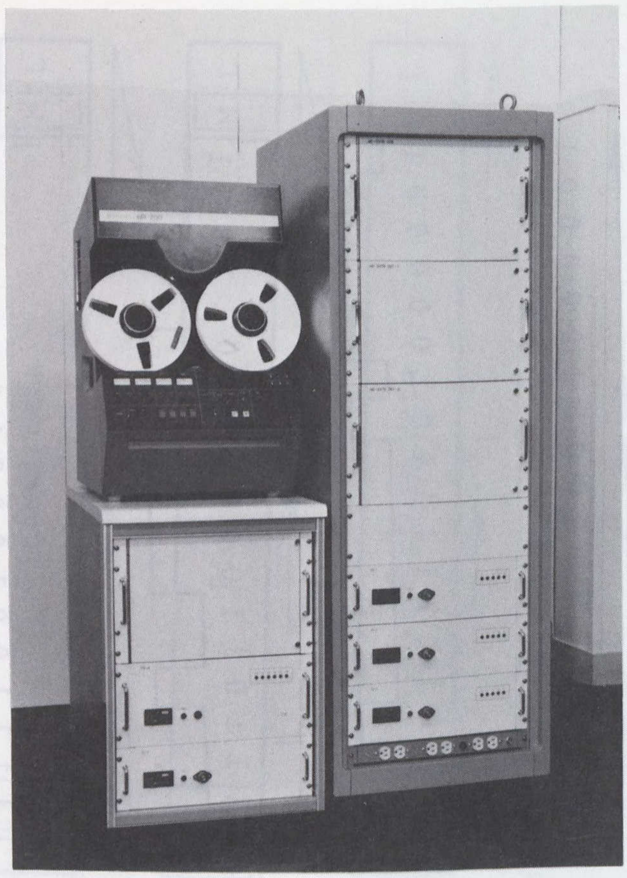

Fig. 9 Appearance of HDTV Digital VTR

Table 1 Specifications of HDTV Color Camera

Item		Specifications
Scanning Lines /Frame Frequency		1125 lines / 30 Hz
Pickup Tube		1" Diode-Gun SATICON
Sensitivity (S/N)		2000 lx, f2.8 (46 dB)
Limiting Resolution		1200 TV lines
Registration	System	Auto, Digital
	Accuracy	0.025% or less
Lens		14X zoom, f1.7
Chromatic Aberration Correction Accuracy		0.025% or less
Contour Corrector		Analog, 2H Out-of-green

Table 2 Specifications of HDTV Digital VTR

Recording System	Digital recording	
Tape Width	1-inch	
Tape Transport	Type C	
Tape Speed	48.8 cm/sec	
Cylinder Revolution	7,200 rpm	
Number of Channels	5	
Video Bandwidth	Luminance 20 MHz	Chrominance 5.5 MHz (Line sequential)
Sampling Frequency	46 MHz	11.5 MHz
Quantizing Bit	8 bits	8 bits
S/N	56 dB	56 dB

ENREGISTREMENT DE LA TVHD - PRÉSENT ET AVENIR

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2.9

RÉSUMÉ

Situation présente

La télévision à haute définition (TVHD) est intrinsèquement un système vidéo à composantes. C'est pourquoi, par souci d'une utilisation judicieuse de la largeur de bande et de simplicité, les signaux doivent être enregistrés en multiplex et multipiste. Pour obtenir un enregistrement multiplex, il faut un appareil à 3 ou 4 voies d'une largeur de bande exceptionnelle et d'une haute précision technique. Le document discute le traitement de signal particulier à la vidéo TVHD ainsi que la trame de bande (tape footprint) la mieux indiquée.

L'enregistrement de TVHD peut aussi se faire selon le procédé de conversion bande-film. Comme ce procédé est manifestement une composante primordiale du système dans son ensemble, le document décrit les appareils actuels d'enregistrement sur film par faisceau électronique.

Futur proche (3 à 5 prochaines années)

L'enregistrement vidéo numérique suscite actuellement un vif intérêt et beaucoup d'activité. Etant donné que l'on recherche ardemment la "transparence" dans les systèmes numériques d'enregistrement sur magnétoscope, il paraît évident qu'il faut aussi appliquer ce principe à la TVHD. Le document fait la comparaison entre les difficultés des techniques numériques et les réalités des méthodes analogiques.

Moyen terme (5 à 8 prochaines années)

La technique des disques optiques fait couler beaucoup d'encre actuellement dans les publications techniques. Une comparaison des trois techniques du vidéodisque (lecture seulement, "tirage" ("draw") et mémoire effaçable ("erasable") et de leur applicabilité à la TVHD sera aussi présentée. Les avantages et les caractéristiques des disques optiques sont explorés du point de vue de leurs applications en TVHD.

RECORDING HDTV - PRESENT AND FUTURE

2.9

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ABSTRACT

Present

HDTV is intrinsically a component video system. Therefore, for the sake of bandwidth efficiency and simplicity the signals must be recorded multi-channel and multi-track. To achieve the multi-channel recording, a machine with 3 or 4 channels of exceptional bandwidth and very precise mechanical construction, is required. The unique signal processing for HDTV video is discussed along with the appropriate tape footprint.

The tape-to-film conversion process is another method of recording HDTV. Since tape-to-film is obviously a very critical requirement to the whole system, the existing EBR (Electron Beam Recorder) will be described.

Near Term Future (3 to 5 Years)

Great interest is presently being shown and high level activity is underway relative to digital video recording. Since the implication of "transparency" for DVTR is strong, the natural extrapolation is for application to HDTV. A comparison between the difficulties of digital and the realities of analogue is presented.

Mid Term Future (5 to 8 Years)

Optical disc technology currently is much discussed in the technical news. Comparison of the three technologies, ROM, DRAW and ERASEABLE, and their applicability to HDTV will be presented. The advantages and features of the optical disc are explored with respect to applications to HDTV.

INTRODUCTION

For years engineers have worked diligently to improve the performance of television equipment for field, studio and transmission applications. Improvements have surely been dramatic from the earliest days of vacuum tubes, through the introduction of solid state devices to modern MSI and LSI circuitry.

While it is true there are today many new types of equipment, image quality improvements are on the flat part of the curve. After all, it is possible to achieve only so much with encoded systems of restricted bandwidth and limited number of scanning lines such as NTSC and PAL. While it is feasible to increase horizontal resolution with additional bandwidth, significant improvement of vertical resolution remains stalled unless, and only if, the number of scanning lines per picture is increased.

These factors led to experimentation that began at NHK as early as 1970. Through a very logical sequence of measurements and information gathering by empirical means, the 1125/60 standard was finally derived with its 5:3 aspect ratio.

At first, only cameras and monitors or displays were needed. (The word "only" is not used lightly here as there were significant technical difficulties in designing new yokes and circuitry for scanning and deflection, as well as pick-up and imaging tubes). In any case, the earliest work required simply acquisition and display to "see" what various changes in parameters would produce. For example, it has been shown that for normal viewing distances (equal to or greater than 3 times picture height), image sharpness does not improve significantly as scanning line quantity is increased beyond 1000. Thus the "1125" choice", while not maximum, approaches optimum because bandwidth, like money and time, is not available without bound in the real world.

PRESENT DAY HDTV RECORDING

The next step of the HDTV system evolution was to develop practical means for storage and retrieval of these high resolution images. We shall examine two existing methods for recording HDTV images.

Beginning with **tape**, let us consider some functions and features that exist in today's VTR that should be carried into HDTV. See figure 1.

For these reasons, the natural approach was to modify a "C" format machine. By using a proven tape transport, substantial design and manufacturing cost savings are possible. Ultimately these economies are passed on to the user.

Turning now to the signals to be recorded, we make another set of choices based on good engineering judgment. Since the eye is most sensitive to luminance or black and white information, we will elect to record a maximum practical baseband, some 20 MHz for G. The eye is less sensitive to chrominance information so in this case only up to 10 MHz each for two color signals, R & B, will be recorded. These are not purely R and B, but matrixed, with luminance being predominantly green.

HDTV REQUIRED VTR FUNCTIONS

1) INTERCHANGEABILITY

2) EDITABILITY

3) PICTURE IN SEARCH

4) MULTI GENERATION CAPABILITY

5) REASONABLE COST

FIGURE 1

While it is true we could record R, G, and B equi-band, and in some applications it may be desirable, the need is to provide all possible luminance information as well as enough chrominance to insure the eye is not "deprived".

The question now arises as to how we can provide 2 lesser channels (10 MHz) and 1 wider channel (20 MHz) with a "C" format type scanner. See figure 3.

If we use Time Division Multiplexing to divide the 20 MHz, G signal into 2 channels of 10 MHz each, and provide 2 more channels for R and B, each of 10 MHz, a total of 4 channels is required.

The 4 signals (transformed from 3) are now used to modulate 4 separate F.M. carriers and recorded by four heads mounted on a common scanner. See figure 4.

By using heads and, therefore, tracks of half the width of "C" format, it is necessary to increase reel-to-reel tape speed by only a factor of 2 to accommodate the 4 tracks per scanner revolution. Also, recall that since we require picture in shuttle, each head pass must be a full field and as a consequence, the video writing speed stays the same as "C" format -- approximately 26 m/sec. Thus an 11.75 inch tape reel will record/play 64 minutes at 48.3 cm/sec. reel-to-reel. Note, too, that provisions are made for two audio channels, control track and either time code or a 3rd audio channel.

Turning now to the playback system for HDTV, refer to figure 5.

The 4 signals R, G_1, G_2, and B are recovered from tape and proper equalization is established. After demodulation, the signals are then converted to digital. At this point, in the case of G_1 and G_2, time Division Demultiplexing and time base correction are applied. In addition, R and B are time base corrected and retimed relative to G. The machine outputs are, again, wideband G and two, narrower band color signals, R and B (or alternatively, Y, Cw, Cn).

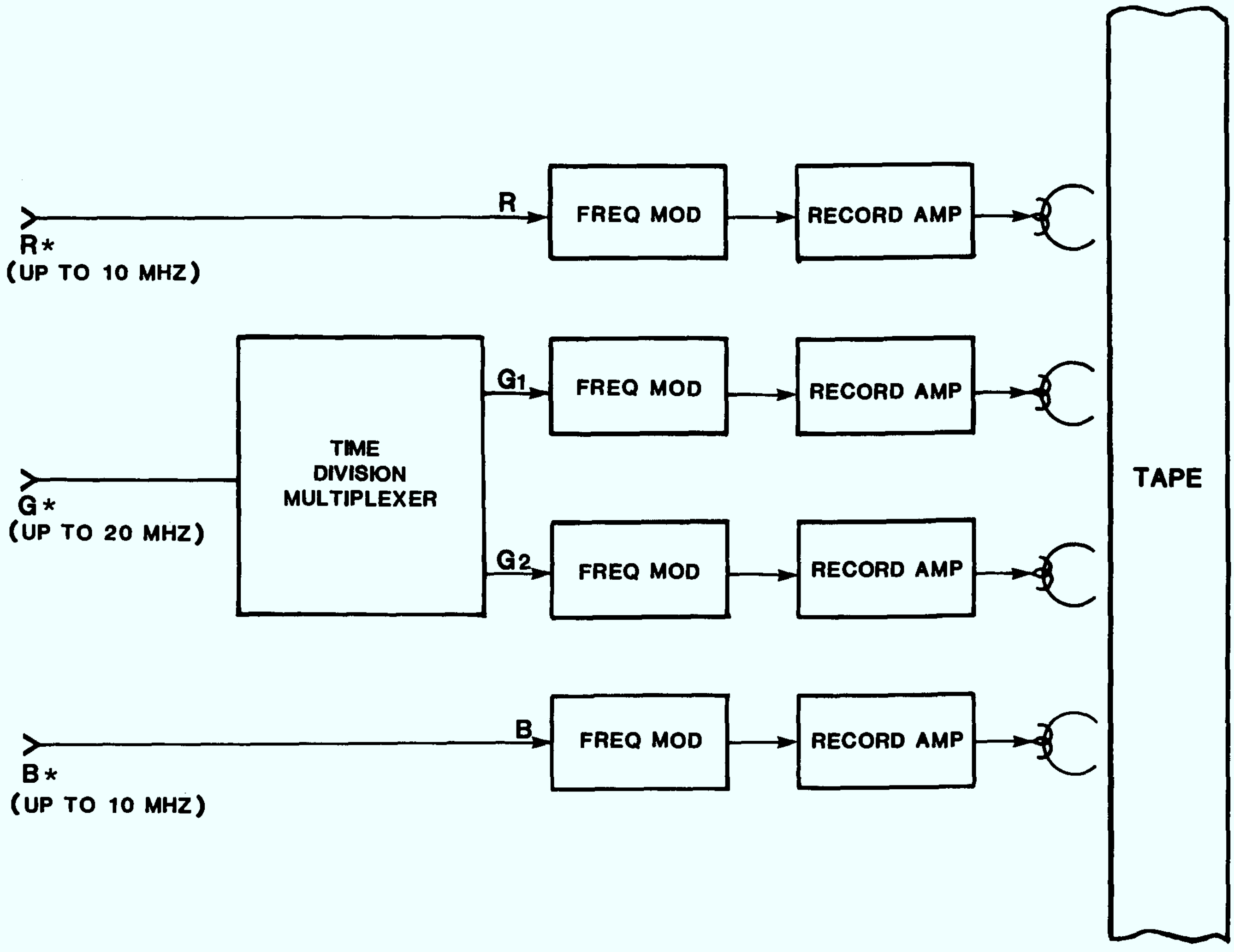
In summary, the format is fully as useful as "C". Even the edit capability is maintained since the same RS-422 machine control is utilized, insuring use of existing editing equipment.

One point of clarification: Only <u>within</u> the VTR does the signal deviate from 3 channel RGB. The I/O for all pieces of equipment (including VTR) is R/G/B.

Tape-to-film is the next major recording need in HDTV. It is accomplished with the **EBR, Electron Beam Recorder.** While the HDTV system permits image acquisition and post production, there are no complete answers as yet for electronic projection on a theater-size screen. Thus, it is absolutely essential to be able to expose 35MM film from HDTV. This is in order to use existing theaters, projection equipment and distribution. This transfer process takes 3 steps. Refer to figures 6, 7 and 8.

Firstly, recorded/edited images are reproduced (slower than real time) frame-by-frame in R-G-B sequence. Another special VTR is provided by a modification to type "C" for this purpose. See figure 6.

HDTV VTR RECORD SYSTEM



* ALTERNATIVELY [Y, Cw, Cn]

FIGURE 3

HDTV TAPE FOOTPRINT

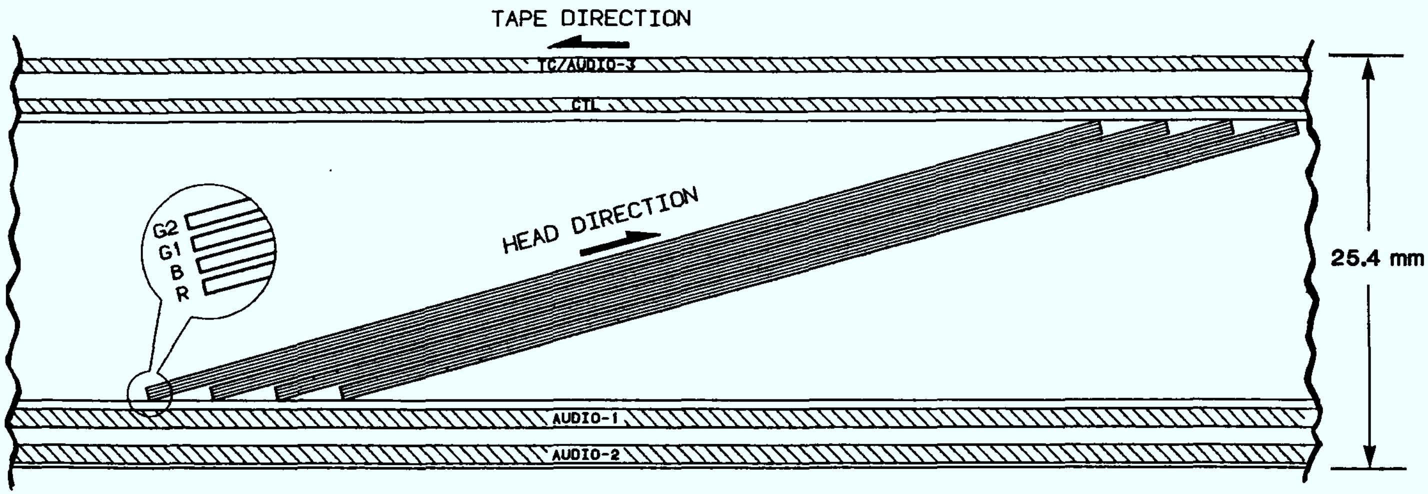


FIGURE 4

HDTV VTR PLAYBACK SYSTEM

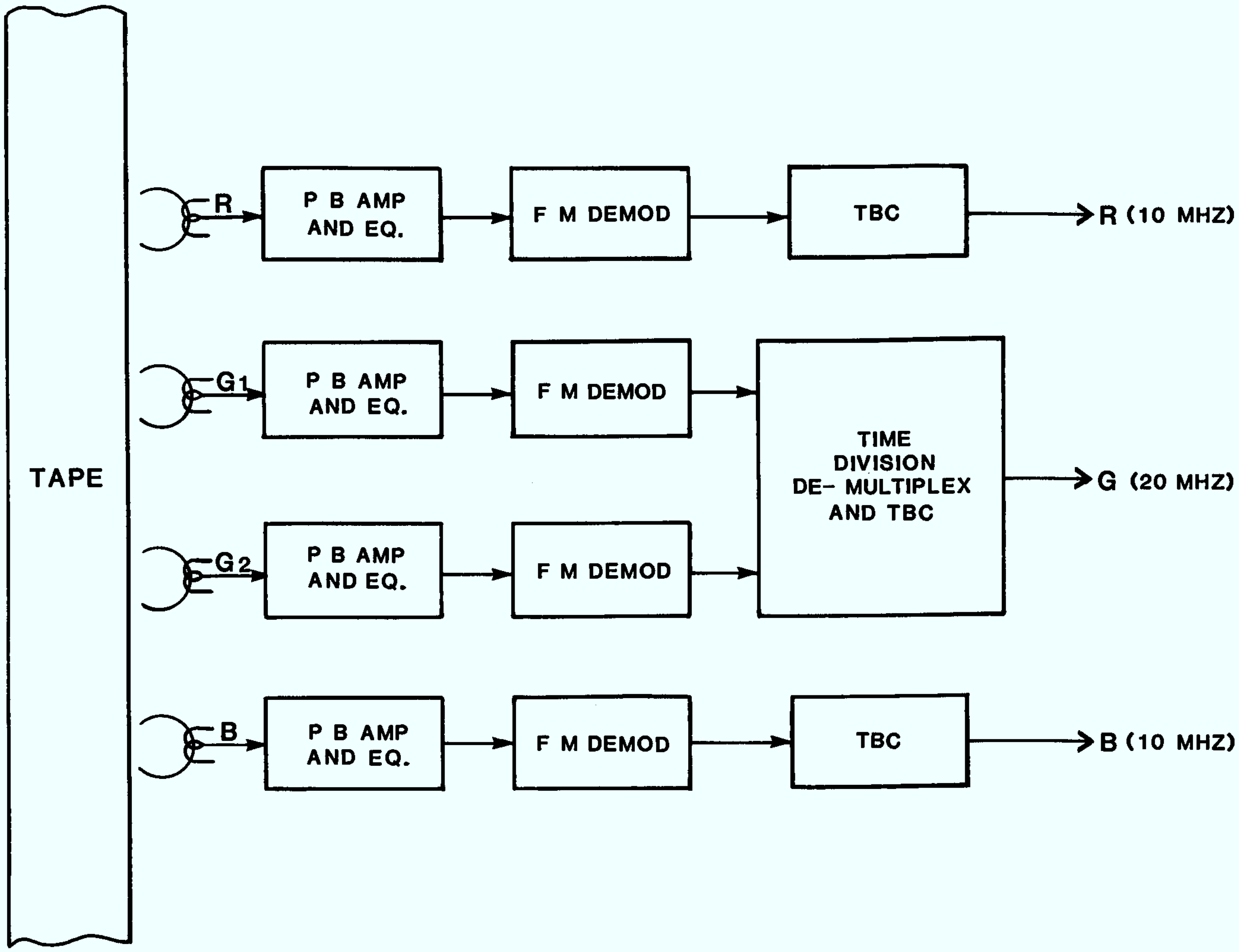


FIGURE 5

TAPE TO FILM BY EBR

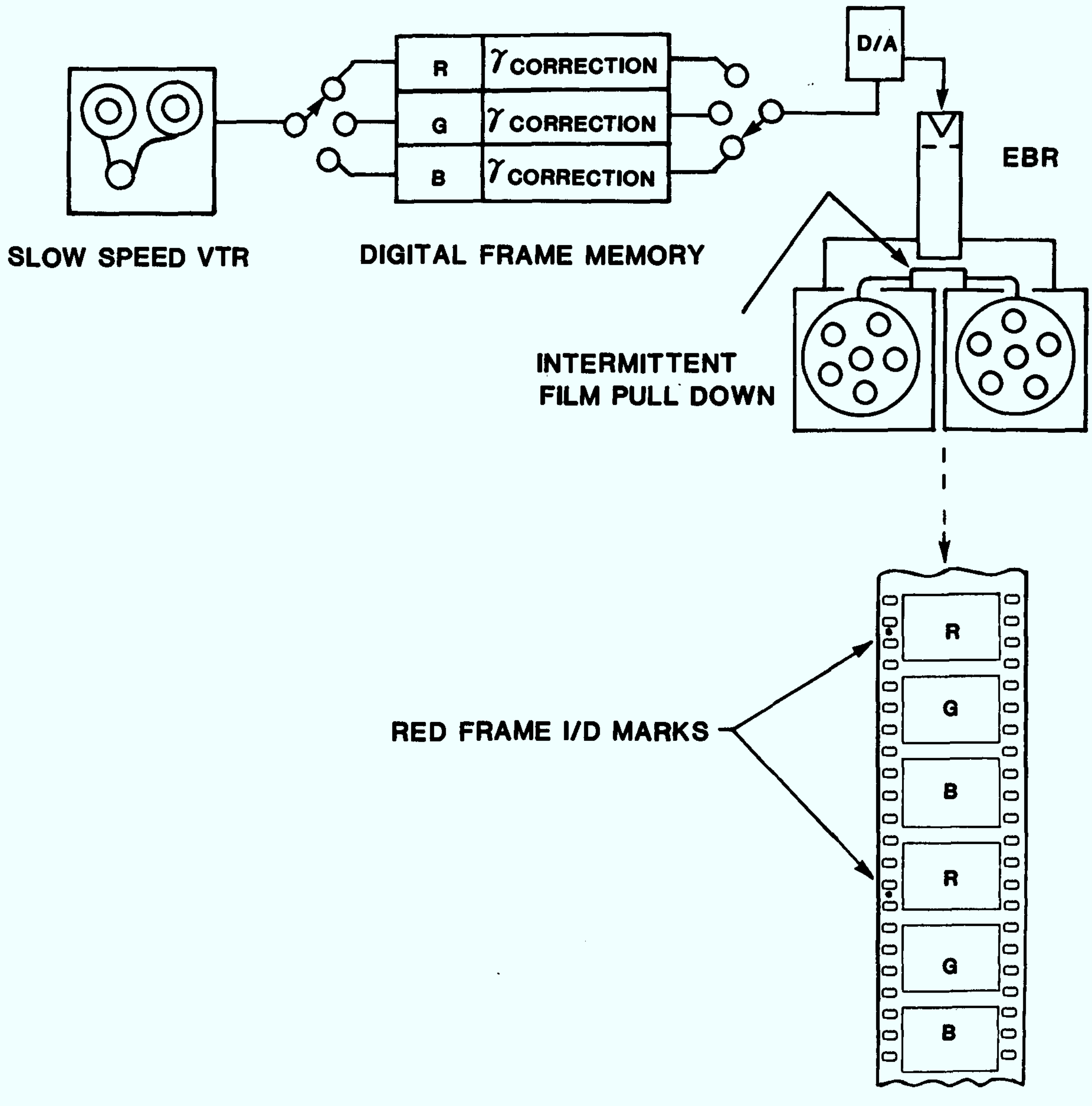


FIGURE 6

EBR TO COLOR NEGATIVE FILM PRINTER

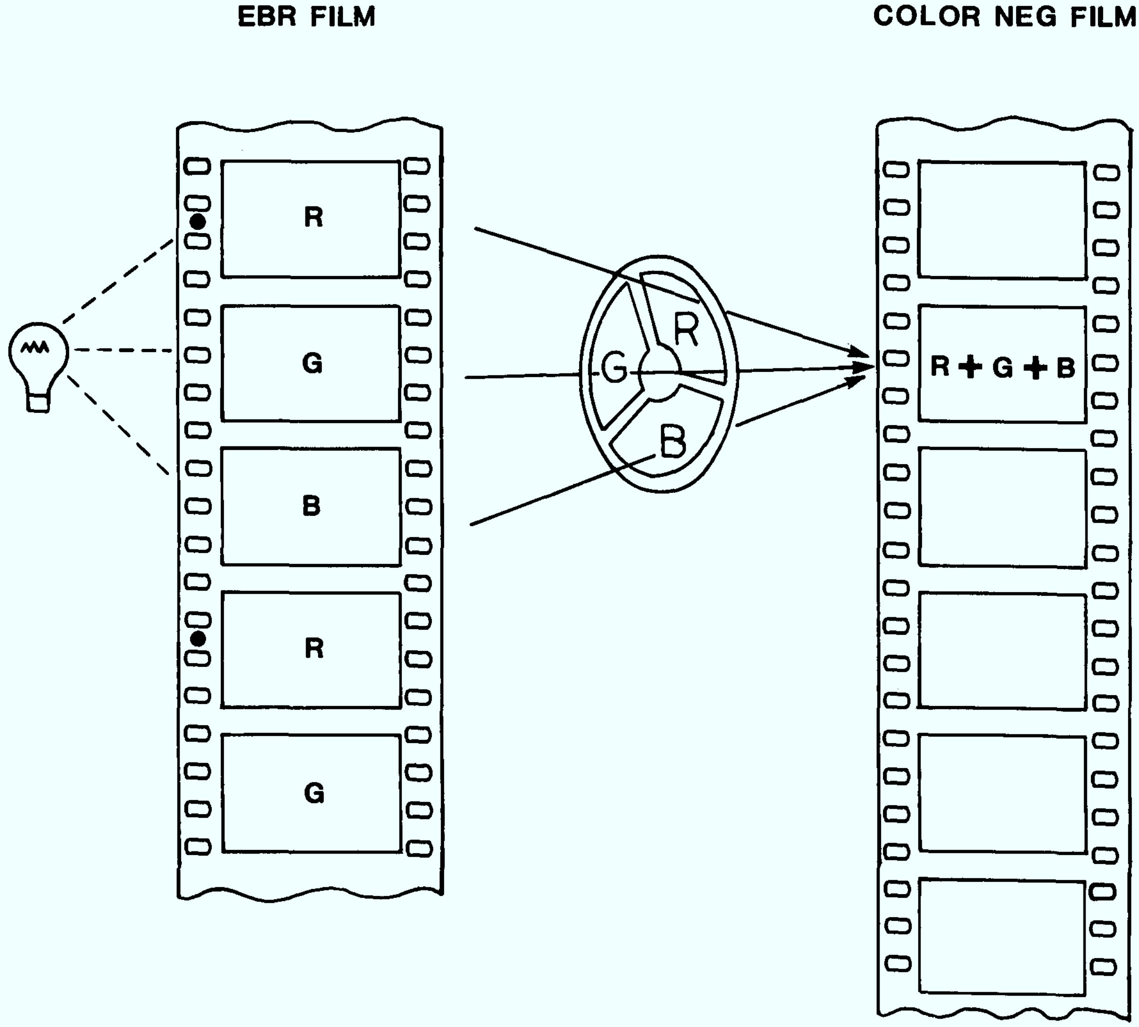


FIGURE 7

SOUND AND IMAGE TRANSFER TO COLOR POSITIVE

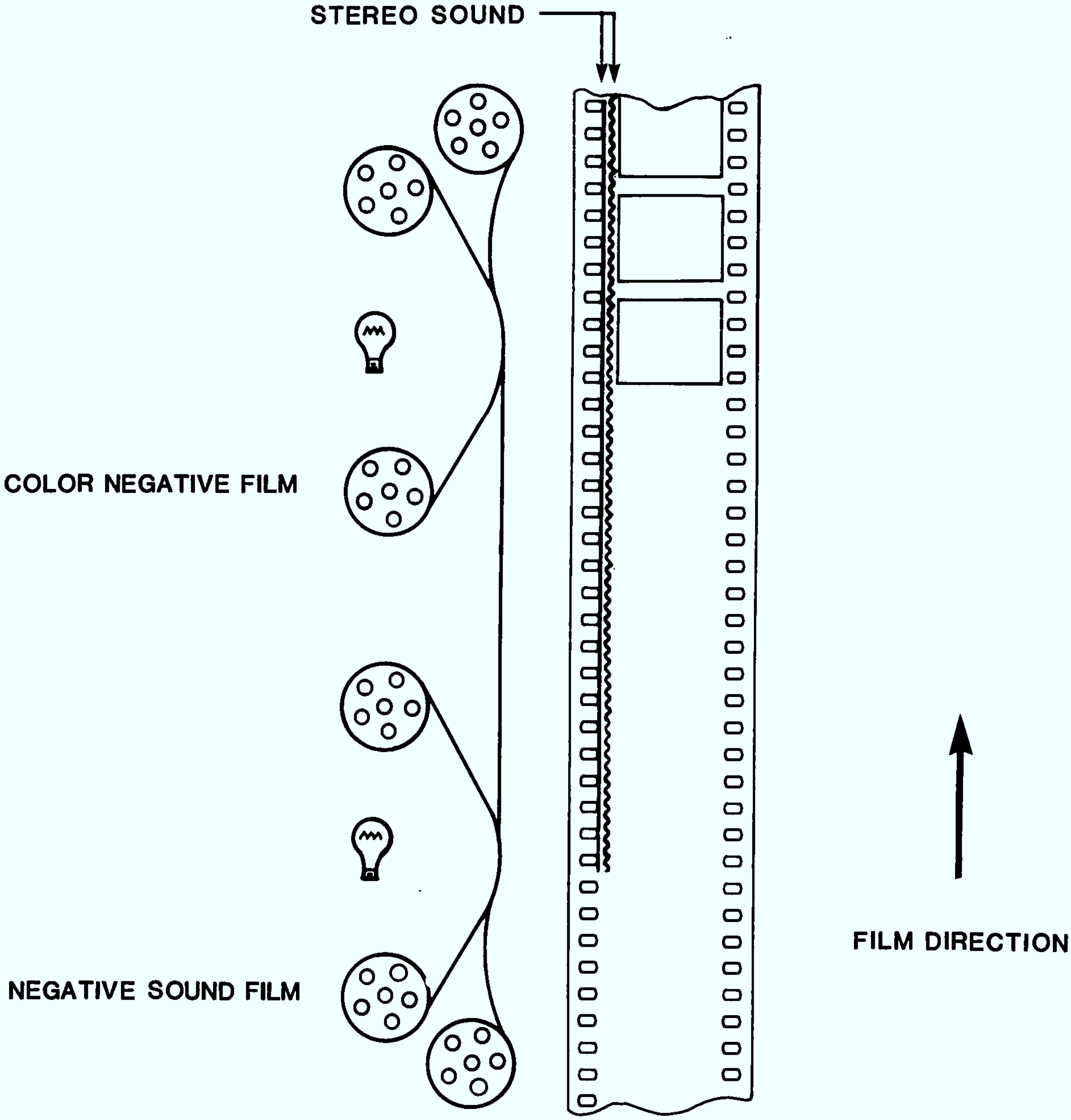


FIGURE 8

The signals are stored, sequentially, in digital form for noise reduction and gamma modification to complement the film recording process.

The 3:2 frame relationship for tape-to-film is accommodated in the frame memories. The EBR film output is sequentially R, G and B frames. Special red frame identifier marks are provided. For the second part of the process, see figure 7.

The EBR film must be stepped 3 times in sync with a color wheel to completely expose each frame of color negative. The transfer speed in this process is 120 frames per minute of EBR film to provide 40 frames of color negative (per minute). This is about 1.67 seconds of real time film per minute.

The final color positive release print runs somewhat faster. See figure 8. This process speed is at 240 feet per minute or about 2.6 times real time.

Notice also that the sound is exposed in the same pass. It, too, is transferred from an EBR negative.

NEAR TERM (5 TO 7 YEARS)

The digital VTR is a technology that has been under development for nearly a decade. The projected "transparency of performance" as well as reduced maintenance costs have been features of strong need for some time.

It is, therefore, natural to assume that since High Definition is a new technology, it would embrace the latest in VTR development.

To consider digitizing HDTV we should look at some numbers relative to the existing DVTR. See figure 9.

As one can see, an increase in recorded data by about a factor of 4 is required. To accomplish this increase by adding 3 more complete channels would reduce a one hour tape reel to 15 minutes! Also, we would experience substantial increase in the cost of scanner and heads.

Both of these proposed schemes make use of 0.9 µm recorded wavelength, which is about the minimum practical today due to tape roughness contributing so significantly to separation loss.

Several approaches are possible that may be used separately or in combination in the future. See figure 10.

Broad use of metal tape is imminent. Indeed, the new 8MM home VCR's use this media. The minimum wavelength is in the order of 0.7 µm. However this by itself would only provide just over 20% improvement in recorded density.

Vertically polarized recording also shows some promise for more flux reversals per unit length. However, this technology is at least as susceptible to separation losses as parallel flux recording. Obviously much work remains before this can be considered a breakthrough.

DIGITAL VTR COMPARISON
NTSC/PAL TO HDTV

(WITH PRESENTLY ACCEPTED 4:2:2 SAMPLING)

		BANDWIDTH (MHZ)	SAMPLING FREQ (MHZ)	DATA RATE (M BITS)	TOTAL DATA RATE (W/O AUDIO)
NTSC/ PAL	Y	5.4	13.5	108	216 −19% BLANKING +25% OVERHEAD * 219 MBIT/SEC
	C_1	2.7	6.75	54	
	C_2	2.7	6.75	54	
HDTV 1125/60	G	20	50	400	800 −19% BLANKING +25% OVERHEAD * 610 MBIT/SEC
	R	10	25	200	
	B	10	25	200	

* INCLUDING ERROR CORRECTION DATA

FIGURE 9

SONY.
SONY TECHNOLOGY CENTER 1985 ©

"OPPORTUNITIES" FOR HIGHER DATA RATE

1) METAL TAPE, SHORTER WAVELENGTHS

2) VERTICALLY POLARIZED RECORDING

3) DATA COMPRESSION

FIGURE 10

In conclusion, the DVTR for HDTV is feasible, even today. However, the approaches necessary would be largely "brute force". Thus for a truly practical, cost effective machine to emerge, we shall require some breakthroughs in compression encoding, and/or significant wavelength reduction through media or head design. There is little doubt these problems will, eventually, be overcome.

LONGER TERM (7 to 10 YEARS)

A very promising future record method for HDTV is the optical disc. However, even though it has significant access time benefits, I do not see it as a total replacement for tape. See figure 11.

Reviewing the basic types of disc under development we encounter, first, **Optical Read Only Memory**. This disc is "recorded" in much the same manner as stamping of phonograph discs. It cannot be re-recorded or modified in any way and is of limited use in video pre or post production.

The next most popular approach is **"DRAW"** or Direct Read After Write. While it can be selectively recorded at random times, no one track can be erased and/or re-recorded. That is, the media is "WRITE ONCE".

Finally, we come to the erasable type; **"M.O."** for **Magneto-Optic**. It can be selectively recorded, erased and re-recorded. In some media types under development, however, the number of re-writes may be as few as 10, others in the tens of thousands.

This latter type, M.O., is the "Holy Grail" product where so many companies are trying to be first. Because of media cost and editability, it is the only method that will be fully acceptable for all applications.

While all the discs employ an optical read and/or write laser, a number of different disc materials, substrates and overcoats are being tried. In many cases the amorphous to crystaline state "switch" is not permanent. In some cases, the the transition is not stable at room temperature. The point is, a lot of development work is underway with no clear timetable identified thus far.

Finally, for today's video disc, the bandwidth is quite limited and as a consequence, the chroma encoding system is "color under" or heterodyne. Video DRAW discs shown to date (and not yet available in a cost effective configuration) have signal-to-noise and bandwidth barely equal to good industrial quality tape recorders using 1/2" and 3/4" tape.

It is true the nearly instant access to up to 54,000 frames is a very important feature. However, the performance will have to improve substantially above that required for NTSC and PAL before these discs can be used for HDTV.

Even if sacrifices in storage capacity are made by individual tracks for R, G and B recording, the quality achieved would not yet challenge the existing VTR for HDTV.

OPTICAL DISC TYPES

READ ONLY (PLAYER) DISC	O.R.O.M.
DIRECT READ AFTER AFTER WRITE	D.R.A.W.
ERASABLE DISC	M.O.

FIGURE 11

Here again, it is just a matter of time until knowledge of the read/write process and the media increases to allow acceptable performance. By the way, when the HDTV disc comes along, some very interesting editing system design will be possible.

CONCLUSION

The need for HDTV is immediate. The fact is that we do have a complete system today. The advent of DVTR and Optical Disc are desirable but non-pacing capabilities that will come later.

The analog VTR as it existed just 10 years ago, could not have met the needs of HDTV. However, with the continued advances in head design, tape, and of great significance, modern MSI and LSI semiconductors, a very practical, reproducible machine for HDTV can be realized today.

Further, the EBR film recorder permits HDTV to coexist with the distribution end of film usage.

Thus it would seem that future improvements and refinements in HDTV (e. g. large screen electronic projection, Magneto Optic Disc Recorders and DVTR's will complement rather than replace elements in the existing, highly practical system.

LES ANALYSEURS DE DIAPOSITIVES COULEURS A HAUTE DÉFINITION

2.10

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RESUMÉ

La télévision haute définition fait l'objet de nombreuses recherches dans le monde actuellement. Bien que les problèmes de diffusion de la TVHD semblent encore assez loin d'être résolus, on note un intérêt grandissant pour l'élaboration d'un standard mondial de production à haute définition.

De nouvelles sources d'images sont à l'étude utilisés pour ce type d'équipement: l'analyse par Flying Spot et l'analyse par barette de CCD. Après avoid discuté des mérites respectifs de ces deux systèmes, les auteurs décrivent deux réalisations récentes utilisant ces principes.

Le premier a bénéficié directement de l'expérience acquise avec les analyseurs classiques à Flying Spot équipant déjà nombreux centres de Télévision. Il s'en distingue par:

- l'utilisation d'un nouveau tube analyseur spécialement conçu pour la haute définition
- un système optique nouveau
- des amplificateurs et des circuits de traitement à large bande.

Les amplificateurs de balayage ont été spécialement conçus pour une adaptation aisés à différents standards d'analyse et plus particulièrement pour les standards 1125-60 ou 1249-50 dans l'attente d'un accord international en ce domaine.

Dans le second appareil, l'analyse est effectuée avec une barette de CCD balayée par l'image de la diapositive à transmettre à l'aide d'un dispositif optique approprié et d'un miroir pivotant à cadence lente. L'image est restituée au standard de Télévision normal à l'aide d'une mémoire Tampon. Grâce à une interface numérique couplée directement à cette mémoire, il est possible de transférer l'image a différentes cadences sur divers supports tels que: banque d'image à disques magnétiques ou optiques; ligne de transmission à faible débit etc. Les 2048 éléments de la barette donnent une résolution compatible avec les futures standards à haute définition.

Ces équipements constituent chacun avec leurs caractéristiques particulières un outil idéal pour les organismes de Télévision (recherche ou exploitation) qui souhaitent disposer d'une source d'image stable et de haute qualité.

ANALYSEURS DE DIAPOSITIVES POUR LA TELEVISION HAUTE DEFINITION

2.10

par Francis DELMAS
Jean CHAMBAUT
Max ARTIGALAS
et Michel FAVREAU

THOMSON VIDEO EQUIPEMENT FRANCE

L'évolution rapide de la Technologie et le développement de nouveaux moyens de diffusion de grande capacité (Satellite, Câble, Vidéodisques etc...) ont suscité dans le monde entier une réflexion sur l'amélioration de la qualité de la Télévision allant même jusqu'à une certaine remise en cause des standards existants.

Des études sont entreprises dans les principaux centres de recherche sur:

- De nouveaux principes de codage (compression temporelle, ''Improved PAL'' etc...)
- Des traitements d'image sophistiqués à la réception et à la prise de vue.
- La Télévision Haute Définition (TVHD), avec, dans un premier temps: recherche d'un standard mondial de production en haute définition devant servir de base à un futur standard de diffusion à plus long terme.

Dans tous les cas, des sources d'image de plus haute qualité deviennent nécessaires.

C'est dans ce but que nous avons étudié la possibilité de réaliser un analyseur de diapositives aux performances poussées compatible avec les futures normes de la TVHD.

.../...

1 - DIVERS PRINCIPES D'ANALYSES SONT A CONSIDERER

1) Tubes analyseurs classiques équipants les caméras de prise de vue directe.

Cette solution n'a jamais pu être utilisée pour l'analyse des images fixes à cause des problèmes de marquage ou simplement de retention d'images apparaissant inévitablement après une exposition prolongée.

2) Senseurs solides surfaciques (CCD)

Ces dispositifs sont très robustes et ne se marquent pas sur expositions prolongées mais ne comportent pas encore suffisamment d'éléments sensibles pour la TVHD.

3) CCD linéaires

Il existe aujourd'hui des barrettes de CCD, comportant 1000 à 2000 éléments sensibles, qui associés à un balayage vertical mécanique ou optique peuvent constituer éventuellement un candidat sérieux pour l'analyse des images fixés en haute définition.

Une réalisation sur ce principe, délivrant actuellement un signal aux normes 625 lignes/50 Hz et 525 lignes/60 Hz a été récemment développée dans nos laboratoires: le TTV 2710:

Ses caractéristiques essentielles sont les suivantes:

- Senseur solide CCD linéaire comportant 2048 éléments sensibles (1440 utilisés pour le format normal).
- Analyse lente et séquentielle des trois couleurs R V et B par miroir oscillant et commutation de filtres colorés en synchronisme (3 passages).
- Restitution du signal entrelacé et à cadence normale (625 L ou 525 L) par mémoire tampon (signal numérique, conforme à la recommandation 601 du CCIR).
- Traitement numérique du signal pour la plupart des fonctions principales:
  . correction de contour
  . inversion de polarité (films négatifs)
  . changement de format (avec filtrage numérique associé).
- Contrôle de sensibilité par variation du temps d'exposition (320 uε à 1220 uε pour 1 ligne).

.../...

- Possibilité de commutation rapide ou de fondu enchaîné entre deux images du même chargeur.

- Lecture de la mémoire à cadence variable permettant de transférer l'image sur divers supports tels que Banques d'images à disques magnétiques ou optiques, lignes de transmissions à faible débit etc...

Aussi séduisant que le principe d'nalyse par barrette de CCD puisse paraître, il reste toujours aujourd'hui un certain nombre de limitations qui repoussent pour quelques temps encore son application à la TVHD.

- Si l'on souhaite effectuer une analyse en temps réel (cas du Télécinéma): la rapidité d'écoulement des charges est encore insuffisante: il faudrait pouvoir utiliser une fréquence d'horloge supérieure à 50 MHz.

- Dans le cas d'une analyse lente comme celle que nous venons de décrire pour l'analyseur TTV 2710, l'utilisation des barrettes CCD ne présente pas de difficulté particulière, mais l'augmentation de capacité de la mémoire (facteur 5) et son temps d'accès posent encore quelques problèmes de technologie et de coût.

On peut toutefois considérer cette solution comme l'une des plus prometteuses à moyen terme.

4) Analyse par faisceau laser

Un Télécinéma fonctionnant sur ce principe a été étudié au Japon par la NHK.

Il comporte un défileur de film à enchaînement d'image pour la conversion 24 - 60 (miroir tournant à 48 facettes) complété par un balayage mécanique. La source de lumière est constituée par 3 faisceaux laser parallèles R V et B ramenés sur un axe optique unique par un jeu de miroirs dichoïques pour faciliter la déflexion.

Une telle solution est évidemment possible pour les images fixes, mais elle reste encore relativement complexe et onéreuse.

5) Analyse classique par tube Flying Spot

C'est le procédé le plus simple et l'un des plus anciens. Il présente encore par rapport à ses concurrents un certain nombres d'avantages:

. Spot d'analyse unique pour les 3 couleurs (pas de problème de registration).
. Système optique simples.

.../...

- Séparation trichrome à miroir ne nécessitant pas de performance particulière (pas d'imagerie: séparation de flux colorés non focalisés.)
- Conversion opto-électronique par photo multiplicateurs présentant des caractéristiques particulièrement intéressantes pour l'amplification des signaux à grande dynamique

  (Bruit de fond proportionnel à la racine carrée du du signal, donc faible dans les zones sombres).

Pour ces diverses raisons, il nous a paru intéressant d'étudier la possibilité de pousser les performances de ce type d'analyseur pour lesquels les limitations semblaients moins évidentes qu'avec les autres systèmes.

Ces études ont conduit à la réalisation de l'analyseur de Diapositive TTV 2707 que nous présentons aujourd'hui.

2 - DESCRIPTION DE L'ANALYSEUR DE DIAPOSITIVE TTV 2707

Cet appareil a bénéficié directement de l'expérience acquise avec les analyseurs classiques à tube Flying Spot équipant déjà de nombreux centres de Télévision, il s'en distingue principalement par:

- l'utilisation d'un nouveau tube Flying Spot spécialement conçu pour la haute définition.
- un système optique nouveau.
- des amplificateurs et circuits de traitement de signal à large bande.

1) Tube analyseur et circuits associés

Caractéristiques principales du Tube 219 Q13 GU RTC

- Diamètre: 130mm (5''), faible angle de déviation: 40°
- Résolution 2000 lignes au centre.
- Courant faisceau nominal: 100 μA
- Persistance ultra courte: 0,2 μS
- Couleur blanche

.../...

- Amplificateurs de balayage

  . Ces amplificateurs ont été spécialement conçus pour une adaptation aisée à différents standards d'analyse et plus particulièrement pour les standards suivants:

  . 1125 lignes 60 trames entrelacées/sec.
  . 1249 lignes 50 trames entrelacées/sec.
  . 625 lignes 100 trames entrelacées/sec.
  . 525 lignes 60 trames non entrelacées sec.
  . 625 lignes 50 trames non entrelacées sec.

Ceci dans l'attente d'un accord international en ce domaine.

Dans ces conditions, la fréquence ligne est voisine de 30 KHz et le temps de retour inférieur à 4 µS.

Les formats d'analyse sont ajustables depuis le format 4/3 jusqu'au format 2/1.

Les performances ont été optimisées pour le format 5.33/3 qui semble aujourd'hui le meilleur candidat pour la future norme mondiale de production mais restent excellentes pour les autres formats. (distorsion inférieure à 1 %).

2) Système optique

L'objectif spécialement calculé pour cet appareil comporte 5 lentilles traitées par un traitement anti-reflet spécial à haute efficacité et présente une fonction de transfert de modulation tout à fait adaptée a l'utilisation en TVHD: taux de modulation supérieur à 80% en zone I et II et à 70% en zone III, pour une fréquence spatiale de 20 mm -1 équivalente à 25 MHz pour un balayage à 30 KHz, format 5/3, sur une diapositive 24 X 36.

3) Amplification et traitement de Signal

L'élargissement de la bande passante des amplificateurs et plus spécialement des correcteurs de gamma et de contour a posé quelques problèmes.

Pour résoudre ces problèmes, il a été nécessaire de recourir à la technologie dite à caissons d'isolation permettant de réaliser des amplificateurs opérationnels monolithiques de hautes performances présentant un produit gain bande de l'ordre de 500 MHz.

.../...

Afin de parfaire la qualité du Signal l'appareil est équipé d'un correcteur de taches (shading) numérique permettant de ramener à quelques pourcents les variations d'uniformité résiduelles pouvant provenir soit de l'inhomogénéité éventuelle de la surface de l'écran du tube analyseur soit du séparateur trichrome.

4) Facilités opérationnelles

Elles sont les mêmes que celles de son aîné le TTV 2705 à savoir:

- Tambour amovible à 80 vues
- Télécommande de vues à accès aléatoire
- Zoom électronique rapport 3 avec possibilité de décadrage.
- Dispositif d'enchaînement sur deux appareils par fondu au noir ou enchaîné télécommandable.

5) Caractéristiques techniques importantes

- Bande passante à $\pm$ 0,5 dB: 20 MHz sur chaque voie.
- Taux de modulation avec correction d'ouverture réglée à 100% au centre de l'image pour la fréquence de 20 MHz
  . supérieur à 95% dans la zone I (cercle de diamètre: 2/3 de la hauteur de l'image)
  . supérieur à 70% dans la zone II (cercle tangent aux bords verticaux de l'image)
- Rapport signal à bruit:
  . supérieur à 40 dB dans les trois voies (mesure effectuée sur densité 1 dans une bande de 100 KHz à 20 MHz.)
- Correction de gamma variable de 0,3 à 0,5 (gain dynamique maximum dans les ombres: 7).

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3 - CONCLUSIONS

Bien que la TVHD ne soit encore qu'au stade expérimental, il nous a semblé important de proposer dès aujourd'hui, sur le marché, un analyseur d'images fixes haute définition non seulement pour offrir aux différents laboratoires ou organismes d'exploitation intéressés une source d'image leur permettant d'étudier plus concrètement la Télévision haute définition et d'envisager ainsi une participation active dans les discussions internationales, mais également pour être exploités dès maintenant comme source de haute qualité par:

- des banques d'images à haute définition pour applications civiles ou militaires comportant par exemple des enregistreurs-lecteurs à vidéodisques.
- des circuits fermés de Télévision pour Palais des Congrès équipés de projecteurs T.V. à grands écrans.
- la Télétransmission d'images fixes haute définition accompagnant des Téléconférences.
- les réalisateurs de dessins animés ou d'images synthétiques pour l'incrustation de décors naturels dans leurs productions destinées aussi bien à la Télévision qu'au cinéma.

COLOR SLIDE SCANNERS FOR HIGH DEFINITION TV

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ABSTRACT

Today, high definition television is the object of much research in the world. Although the HDTV broadcasting problems still seem far from being resolved, an increasing interest in elaborating a world-wide high definition production standard is apparent.

Various manufacturers are studying new image sources. For a long time now, the top quality slide scanner has been of important interest to THOMSON-CSF. Two analysis principles can be used for this type of apparatus: Flying Spot scanning or CCD array analysis. After discussing the respective merits of these two systems, the authors describe two recent realizations using these principles.

The first one benefitted directly from the experience obtained with the classis Flying Spot Scanner, which already equips several television centres. It makes itself distinguishable by:

- using a new scanning tube, especially conceived for high definition
- a new optics system
- wide bandwidth amplifiers and processing circuits.

Sweeping amplifiers have been specially designed for an easy adjustment to different analysis standards and more specifically, for the 1125-60 or 1249-50 standard waiting for an international agreement in this domain.

With the second one, the analysis is carried out with a CCD array scanned by the slide image projected with the help of a special optical device and a pivoting mirror. The image is displayed back to the normal television standard using a "buffer" memory. A digital interface connected straight into this memory makes it possible to transfer the image to different cadences on various supports, such as magnetic or optical disc stillstore, low capacity transmission line etc. The high resolution array (2048 elements) offers a suitable solution for the future high definition standards.

These two new slide scanners, each with their own particular characteristics, constitute an ideal tool for television organizations, (research laboratory or studio operation) who need to have stable and top quality image source at their disposal.

HIGH DEFINITION TELEVISION SLIDE SCANNER

by Francis DELMAS, Jean CHAMBAUT, Max ARTIGALAS
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The rapid evolution of technology and the development of new high capacity means of transmission (satellite, cable, video-disc, etc...) gave rise to a worldwide reflection on the television quality improvement, which even lead to reconsider the existing standards.

Researches are being carried out in the main laboratories on the following subjects:

. new principles of encoding (time compression, improved PAL...)

. sophisticated image processing at source and reception

. high definition television with, at first, an attempt or agreement on a world wide high definition production standard to serve as a basis for a future transmission standard.

In all the cases, it is necessary to improve the image sources quality. This is the purpose of our research aimed at realizing a new high performance slide scanner providing high quality video signals compatible with future high definition television specifications.

1 - VARIOUS SCANNING PRINCIPLES ARE TO BE CONSIDERED

1- The live camera pick-up tubes have never been used in this application because of the after image or burning phenomenon occuring after a long duration exposure.

2- The CCD area imaging devices are very resistant and do not show any burning effect after a long duration exposure, but still lack a number of sensor elements for high definition use.

3- The CCD linear imaging devices available today with 1,000 to 2,000 sensor elements could be, in association with a mechanical (or optical) vertical scanning system, a possible relevant alternative for high definition slide scanning.

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The TTV 2710 slide scanner recently developed in our laboratories makes use of this scanning principle and provides a video signal compatible both with the 625 lines/50 Hz and 525 lines/60 Hz television standards. Its main features are:

. Use of one CCD linear imaging device comprising 2,048 sensor elements (only 1,440 are utilized for the normal scanning format),

. Slow sequential vertical scanning of the RGB colors using an oscillating mirror and the synchronous switching of colour filters.

. Interlace and signal restitution at normal rate (625 or 525 lines) making use of a buffer memory (digital signal in accordance with the 601 CCIR recommendation).

. Sensivity control by exposure time variation over the range 320 μs to 1,220 μs for one line,

. Digital signal processing for most of the main functions:

- contour enhancement,
- polarity in version (negative films),
- scanning format variation (with associated digital filtering),
- possible rapid mixed change-over between two slides of a tray,
- variable rate of memory read allowing the image transfer to various supports such as magnetic or optical disk storing, low capacity transmission line, etc...

However attractive the CCD linear imaging device scanning principle may seem, a number of limits still remains which delay for a while its application to high definition television.

If a real time scanning is needed (as in the telecine application), the charge transport is still not fast enough, as a clock frequency higher than 50 MHz should be used.

In case of a slow scanning (as the above described principle of the TTV 2710), the use of CCD linear imaging devices does not set particular problems but the increase of memory capacity (5 times) and the necessary ultra fast access time still set technology and cost problems.

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This solution can, however, be considered as one of the most relevant in the near future.

4) The laser beam scanning principle is used in a telecine which was studied on an experimental Basis in Japan by NHK.

   It includes a continuous film transport system with an image lap-dissolve optical device for the 24 - 60 conversion (using a rotating 40 facet mirror), associated with a mechanical H and V scanning system. The light source consists of three R, G, B parallel laser beams fused on a single optical axis by a set of dichroic mirrors for easier deflection.

   Such a technique can be applied to slide scanning but still remains relatively complex and expensive.

5) The conventional flying spot scanning is the simplest and one of the oldest scanning principles. It still presents a number of advantages with respect to the other alternatives:

   - same raster for the three colours (no registration problem),
   - simple optical system,
   - mirror color beam splitting which does not require special performance (no imaging: splitting of non focused color beams).
   - optoelectronic conversion using photomultipliers of very interesting characteristics for extremely small and large signals amplification (noise proportional to signal square root and consequently almost unnoticeable in dark areas).

For these reasons we thought interesting to study the possibility of improving the flying spot scanners' performance, as their limits seemed of less importance than for the other scanning systems.

These researches led to the realization of the TTV 2707 high definition slide scanner which we present today.

2 - DESCRIPTION OF THE TTV 2707 SLIDE SCANNER

This equipment has been developped on the benefit of classical flying spot slide scanners operated in many television centers at the present time and differs from them on the main following points:

- new pick-up tube especially developped for high definition television,
- new optical system,
- wide band amplifiers and processing circuits.

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1) Pick-up tube and associated circuits

. Main characteristics of the pick-up tube (219 Q 1 3 GU-RTC)

- 130 mm (5'') diameter, small deflection angle (40°)
- Definition: 2,000 TV lines at raster center
- Nominal beam current: 100 μA
- Very short afterglow: 0.2 μS
- White color.

. Scanning amplifiers

These amplifiers have been especially developped for easy matching to various scanning standards among which:

. 1125 lines, 60 interlaced fields per sec.,
. 1249 lines, 50 interlaced fields per sec.,
. 625 lines, 100 interlaced fields per sec.,
. 525 lines, 60 non interlaced fields per sec.,
. 625 lines, 50 non interlaced fields per sec.,

This, as long as an international agreement has not been reached.

In these conditions, the line frequency is 30 KHz approx. and the flyback duration does not exceed 4 μsec.

The scanning amplitudes can be adjusted for providing an aspect ratio over the range 4/3 to 2/1. The performance was optimized for 5.33/3 which, at the present time, seems the most suitable alternative for the future world production standard (distorsion $< 1\%$).

2) Optical system

The lens assembly was especially calculated for this equipment and comprises 5 lenses whose high efficiency coating reduces the flare to a minimum. Its modulation transfer function is highly adapted to high definition television requirements. Measurements made on first samples give a modulation depth $> 80\%$ in zone I and II and $> 70\%$ in zone III for 20 mm^{-1} spatial frequency (i.e. 25 MHz approx.) with 30 KHz scanning of a 24 x 36 mm slide using a 5/3 aspect ratio.

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3) Amplification and processing

The amplifiers video bandwidth was widened, which set several problems especially for what concerns the gamma correction and contour enhancement circuits. The so-called ''dielectric isolation'' technology was used which allows high performance monolithic operational amplifiers of more than 500 MHz gain/bandwidth product to be realized.

The signal quality is improved by a digital shading correction which reduces to a few per cent the residual nonuniformity due to the possible lack of homogeneity of the pick-up tube screen or beam splitter.

4) Operational facilities

The operational facilities are the same as for the TTV 2705 slide scanner, i.e.:

- 80 slide removal tray,
- random access slide remote control,
- electronic zooming 3: 1 with possible shift,
- possible dual scanner configuration with remotly controlled fade to black or mixer change-over.

5) Main technical characteristics

- Bandwidth at $\pm$ 0,5 dB: 20 MHz for each channel
- Modulation depth when contour enhancement at center of picture is setted at 100% for 20 MHz frequency:
  - more than 95% in zone I (diameter = 2/3 of image height),
  - more than 70% in zone II(diameter = image width)
- Signal to noise ratio $>$ 40 dB for the three channels (measurements made on density 1 to 100 KHz to 20 MHz frequency range).
- Adjustable gamma correction from 0,3 to 0.5 (maximum dynamic gain in dark areas: 7).

3 - CONCLUSION

Through high definition television is still in the experimental stage, we thought important to offer, from now, a high definition slide scanner not only to give the laboratories and broadcast companies interested the opportunity of studying high definition television more concretely and consequently participating more actively in international discussions, but also to already serve as high quality source in the following fields:

- high definition image storing in civil or military applications including videodisc recording units, for example.

- close circuit television for congress houses equipped with large screen television projectors.

- high definition still picture transmission for teleconferencing.

- cartoons or synthetic picture realization with insertion of natural scenery for television or cinema productions.

La TVHD : une révolution lente

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RÉSUMÉ

Bien installés dans leurs systèmes de télévision classiques, même s'ils sont allés jusqu'à les numériser, les ingénieurs, de la production TV à la recherche, ont vu leurs habitudes bousculées par les démonstrations du système de TVHD 1125/60/2 proposé par la NHK, marquant un progrès notable de qualité. Cependant, compte-tenu des grandes marges d'amélioration disponibles, notamment dans les systèmes 625/50/2, il est apparu important d'analyser les points fondamentaux d'amélioration de l'image et de déterminer aussi ceux qui étaient applicables immédiatement de façon compatible avec les systèmes d'émission actuels (composites ou composantes).

A cette fin, des études psychovisuelles ont été entreprises au CCETT, notamment quant à la visibilité du papillotement et du lignage.

Parallèlement, après une évaluation des technologies disponibles permettant un changement de norme aisé, le CCETT a entrepris, en relation avec l'industrie, la mise en place d'une chaîne expérimentale de TVHD pouvant servir aussi de source et de restitution de haute qualité pour les systèmes de télévision dit "améliorés".

Afin de ne pas traiter globalement le jugement de la chaîne, certains équipements de mesure expérimentaux ont été construits au CCETT et la mise en oeuvre de nouvelles métrologies pour les sources et les dispositifs de restitution est en cours.

Enfin, la voie de la production étant maintenant largement engagée, les problèmes de distribution de programmes sont abordés : le câble, la fibre optique, le satellite.

La mise en place d'un système de télévision dit à haute définition ne pourra pas se faire en prenant des raccourcis ignorant l'état actuel : 2 voies seront suivies, l'une tendant à améliorer encore l'image délivrée au téléspectateur selon des normes classiques, l'autre préparant l'introduction d'un nouveau type d'image ne se caractérisant pas uniquement par une plus haute définition.

HDTV: A SLOW REVOLUTION

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ABSTRACT

Engineers who were involved in all aspects of TV from research to production and who felt comfortable with their conventional television systems, having even gone so far as to digitalize them, have had their normal practices upset by demonstrations of the 1125/60/2 HDTV system proposed by NHK, which marks a significant step forward in terms of quality. However, in view of the considerable room for improvement, particularly in 625/50/2 systems, it was obviously important to analyse the basic elements of image enhancement and to determine which of these elements were compatible with, and could be applied to, the present composite and component broadcasting systems.

For this purpose, psychophysical studies were conducted at CCETT, and special attention was paid to flicker and line-structure visibility.

At the same time, after evaluating the technologies available to enable easy conversion to conventional TV standards, CCETT, in consultation with the industry, set about establishing an experimental HDTV system that could also be used as a source of picture material and as a means of recording signals for enhanced television systems.

In order to avoid making too general an assessment of the system, experimental measuring equipment was constructed at CCETT and new measuring techniques are now being used for the sources and recording mechanisms.

Now that the considerations relating to production is well in hand, progam distribution problems are being tackled: cable, fibre optics and satellites are being considered.

A high definition television system cannot be established by means of short cuts that do not take account of the present situation: two courses of action will be pursued, one aimed at further improving the image delivered to the television viewer and the other preparing for the introduction of a new type of image that will incorporate features other than simply higher definition.

LA TVHD : UNE REVOLUTION LENTE

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Quand, à l'aube des années 80, la NHK a présenté au niveau international les résultats d'études entreprises au Japon dès 1968, le monde de la télévision a vu ses habitudes passablement bousculées.

En Europe tout ou moins, la course à la haute définition, datant de la fin des années 40, était bien loin. Au moment où le NTSC décidait d'une norme de télévision en couleur, s'implantaient 2 nouvelles normes en noir et blanc à 625 et 819 lignes, après quelques essais jusqu'à 1029 lignes. Le passage à la couleur s'effectuait en 1967 avec les systèmes PAL et SECAM, et depuis, le potentiel de recherche européen semble avoir été principalement employé à améliorer le service consistant à offrir chez le téléspectateur l'image la plus semblable possible à l'image RVB disponible à la source, ceci sans remettre en cause les données de base de la norme d'analyse à 625 lignes/50 trames entrelacées (625/50/2).

1 - POSITION DU PROBLEME

L'écart notable de qualité entre ces systèmes et le système HDTV de la NHK a suscité des réactions diverses, dont on peut retenir ici celles qui semblent gouverner les 2 axes majeurs de la réflexion actuelle :

- La haute définition et un format plus large sont-ils les caractéristiques les plus importantes à améliorer ?

- Quelles améliorations est-il possible d'apporter quasiment immédiatement à l'image que l'on peut reproduire à partir d'un signal conforme à la norme d'analyse 625/50/2 multiplexant des informations de luminance et de chrominance ?

S'il est souvent difficile de distinguer la spécificité des études menées sur ces 2 thèmes, on a cependant l'habitude d'utiliser les 2 appellations de Télévision à Haute Définition (TVHD) et Télévision Améliorée (TVA).

Dans le premier cas, il est intéressant de noter que les radiodiffuseurs ne sont pas les seuls moteurs de décision, car d'autres demandeurs sinon d'autres marchés se manifestent et l'on peut citer, en plus de la production cinématographique, bien connue mais pas vraiment demanderesse, l'imagerie médicale ou militaire, les simulateurs, le contrôle de fabrication et surtout la vidéoconférence ou la vidéotransmission qui se satisfont difficilement des normes actuelles.

C'est dans ce double cadre TVA-TVHD qu'un département du CCETT a entrepris plusieurs études complémentaires consistant à reprendre des études psychovisuelles qui méritaient d'être complétées, élaborer une chaîne expérimentale afin d'étudier les problèmes et perspectives technologiques, ceci en abordant les difficultés de la métrologie. Avec ces éléments, il a été possible de participer activement aux groupes internationaux chargés de définir une norme de production et de réfléchir aux systèmes de distribution sur des bases théoriques et concrètes.

2 - BASES PSYCHOVISUELLES D'UNE NORME TV

Il n'était pas question dans l'étude de ces bases de refaire toutes les expériences fondamentales, mais, avec l'aide des études disponibles, d'établir tout d'abord une liste des données psychovisuelles nécessaires à l'établissement ou la modification de normes ; puis, quand des données paraissaient incomplètes ou insuffisantes, de faire les expériences correspondantes.

La liste des principales caractéristiques à connaître, compte-tenu aussi de l'acquis d'un passé conséquent en matière de télévision, semble se ramener à la suivante :

Taille de l'image.
Format (largeur/hauteur).
Distance d'observation.
Champ visuel occupé.
Définition.
Continuité.
Granularité.

Brillance.
Contraste.
Couleur.

Fréquence d'échantillonnage du mouvement pour un bon rendu.
Fréquence de papillottement sur les grandes plages.
Fréquence de scintillement interligne dans le cas d'un balayage entrelacé.

Ces paramètres ne sont malheureusement pas indépendants et un certain groupement de ces caractéristiques a permis de dégager une priorité dans les incertitudes à lever, compte-tenu de ses conséquences technologiques ou irréversibles après normalisation : la fréquence de perceptibilité du papillotement sur les grandes plages en fonction de la brillance.

Avec un système d'obturation périodique, dont le facteur de forme est paramétré, d'un faisceau lumineux continu projeté suivant un rectangle paramétré, de brillance uniforme, elle aussi paramétrée, on a ainsi remesuré cette fréquence critique (figure 1).

Les résultats confirment que pour une image de format 4/3 vue à une distance de 6H, le papillotement est imperceptible à une fréquence de 60Hz pour les facteurs de forme 50/50 et 30/70 (d'autres facteurs sont à l'étude) jusqu'aux brillances moyennes maximales des téléviseurs actuels, soit 200 à 400cd/m^2, mais que cela n'est presque jamais le cas à une fréquence de 50Hz (figure 2).

Par contre, pour une image de format de 5/3 vue à une distance de 2,5H, le papillotement à 60Hz est perçu à partir de 40-50cd/m^2 et ne l'est plus au-dessus de 80Hz à 200cd/m^2.

Le mérite et l'inconvénient de ces expériences est de ne pas utiliser le tube à rayon cathodique.

Si l'on peut estimer que ces 3 fréquences sont acceptables pour l'échantillonnage correct du mouvement, on est par contre gêné pour le choix quant à l'acceptabilité du papillotement, acceptabilité qui n'a justement pu être vérifiée par la NHK à 60Hz que jusqu'à une brillance insuffisante pour une visualisation en ambiance lumineuse de salon.

Ce résultat montre à la fois l'utilité de la multiplicité des expériences fondamentales mais aussi celle de l'expérimentation sur une chaîne TV prototype.

3 - CHAINE EXPERIMENTALE DE PRODUCTION EN TVHD

La base de cette chaîne expérimentale est un générateur de synchronisation programmable de conception simple, mais permettant de piloter à la fois des générateurs de mires, des sources et des visualisations à plusieurs fréquences trames, entrelacées ou non (figure 3).

Côté sources, le constructeur français THOMSON-CSF a réalisé, sur cahier des charges du CCETT, il y a 2 ans déjà, une caméra monochrome ayant les facilités d'un banc de mesure pour tubes analyseurs, ce qui a permis de tester les limites de certains tubes utilisables dans des caméras couleur tels que des Saticon Hitachi et des Primicon Thomson. La solution magnétique-magnétique semble par exemple manquer de souplesse pour des tubes ayant par ailleurs des caractéristiques intéressantes.

Une autre source de référence développée à l'initiative du CCETT est l'Analyseur de diapositives (AIF) Couleur THOMSON TTV 2707 décrit dans une autre conférence. Ici, la souplesse de l'analyse à spot mobile permet en particulier le changement facile de norme, ce qui est plus délicat avec un analyseur à barrette CCD tant qu'une norme n'est pas suffisamment figée.

Autre qualité notable pour les études, les fonctions "zoom" et "cadrage" permettent des mouvements fidèlement reproductibles sur des images qui le sont de même. Avantages et inconvénients à la fois, le temps d'intégration et le filtrage vertical par le spot sont très faibles.

La quasi-absence de moniteurs noir et blanc de mesure ou de contrôle de source nous a conduit à développer au CCETT un moniteur de 15" format 4/3.

Côté visualisation couleur, une série de moniteurs à haute définition utilisant un tube autoconvergent de 20" format 4/3 a été développée en collaboration avec la Société ODIL. Ont été ainsi abordés les problèmes du balayage ligne à fréquence double ou quadruple des fréquences actuelles, ainsi que la complexité accrue des alimentations nécessitée lors de l'usage d'une fréquence trame différente de celle du secteur.

Une caractéristique commune des équipements spécialement développés est leur possibilité de fonctionner suivant les normes 625/50/1 ou 625/100/2, nous permettant aussi d'expérimenter des propositions de TVA compatibles.

Les difficultés liées à l'usage de lampes à décharge pour l'éclairage à la prise de vues ont été de la même façon détectées sur cette chaîne expérimentale avec des fréquences trame différentes de la fréquence secteur.

Enfin, la modification récente d'un vidéoprojecteur General Electric PJ5050 en TALARIA HD devrait nous permettre d'aborder l'aspect grand écran à forte luminosité de nos expérimentations.

4 - METROLOGIE

La métrologie appliquée aux systèmes de TVHD est une nécessité pour caractériser les éléments et la chaîne TV.

Elle revêt le double aspect des outils de test et de la méthodologie.

Pour ce qui est des outils de test, il est difficile de demander aux industriels d'élaborer avant la normalisation des générateurs complexes multifonction ou des séries de mires.

Dans ce cas, bâti autour du générateur de synchronisation programmable, nous avons élaboré un équipement constitué de sous-ensembles ajustés à la demande ou bien facilement programmables. C'est le cas pour les fonctions tests essentielles telles que contrôle de la bande passante par vobulation, transitions noir-blanc à fronts calibrés, signaux carrés, échelle de linéarité. Les classiques mires de géométrie ou convergence sont elles aussi élaborées à la demande, compte-tenu notamment des changements possibles de format d'image.

Une caractéristique dont on pouvait penser qu'elle avait un effet secondaire en télévision classique est à surveiller de plus près : c'est l'adaptation d'impédance des quadripôles, compte-tenu des échos perturbateurs pour de très courtes longueurs de câble (5ns/m) dans les bandes vidéo considérées (30-50MHz).

La mesure de bruit pose elle aussi un problème complexe compte-tenu des bandes. Il semble ici que l'analyse de spectre ou la méthode de la "double trace" soient les seules disponibles facilement aujourd'hui (figure 4).

Ce domaine de la métrologie, même s'il est vaste ne doit pas être négligé, car il demande un développement aussi complexe, sinon plus, que celui d'une chaîne vidéo et à ce jour seule l'oscilloscopie semble avoir suivi.

5 - NORMALISATION

Ces 3 actions parallèles complémentaires ont permis de disposer des bases nécessaires à une contribution adéquate aux groupes de travail de l'UER (V1/HDTV) et du CCIR (GTI 11/6).

Ainsi, le concept de **représentation spatio-temporelle échantillonnée de l'image utile,** tout en gardant la relation nécessaire avec l'Avis 601 est une structure permettant de faire des propositions concrètes et multiples de normes numériques de TVHD, le choix final étant lié aux limites technologiques que l'on peut espérer. Ainsi, la révision de la définition photocolorimétrique du signal d'image est en cours.

La première notion, qui fait son chemin, est **la suppression de la correction de gamma** actuellement **à la source** afin de ne la situer que comme élément normal de la commande d'un tube à rayon cathodique ; et elle laisse toute liberté pour d'autres systèmes futurs de visualisation. Dans la séparation en luminance et chrominance qui doit se faire en respectant l'espace colorimétrique de restitution, le principe de luminance constante peut être respecté et les transmodulations de bruit par non-linéarité évitées.

Un avantage complémentaire provient de la non-diminution de résolution chromatique.

La deuxième notion qui est introduite est **la balance automatique** du blanc du système de restitution **sur le blanc adapté à la scène de** restitution d'une manière identique à la commutation de température de couleur d'une caméra. Ce système simple augmenterait le réalisme de l'image restituée.

Ces travaux, engagés depuis plusieurs années sur la normalisation, conduiront à plusieurs étapes : production, émission, distribution.

6 - DISTRIBUTION DES PROGRAMMES

Certains peuvent penser qu'une norme unique de production est en cours d'établissement, d'autres qu'une nouvelle famille se constitue, d'autres enfin seraient pessimistes. Quoiqu'il en soit, il est temps d'amorcer les 2 bouts de la pompe :

- Quels programmes et pour qui ?
  et je ne me sens pas compétent pour répondre.

- Quels modes de distribution, quels supports ?
  Sans être spécialement qualifié sur le sujet, je dois dire que les réflexions au CCETT sur 2 modes de distribution cheminent en suivant les évolutions de la normalisation : un système de va-et-vient fructueux s'amorce compte-tenu du contexte MAC et télévision améliorée, et la prospective en distribution par câble ou par fibre optique apporte des choix.

Si l'on considère les réductions de débit demandées, il devient difficile de quantifier la marge de qualité qui séparera la télévision améliorée transmise suivant les normes MAC paquets et la télévision à haute définition à débit réduit sur un récepteur de coût raisonnable.

7 - CONCLUSION

Si la réponse à la question "quels programmes et pour qui ?" trouve des éléments de réponse suffisants, nul doute que la technique conclura rapidement. Mais en étant un peu dubitatif sur cet aspect, je suis amené à penser que si la Télévision Améliorée est pour demain, la Télévision à Haute Définition est pour après-demain. Alors, si les images de TVHD sont révolutionnaires, il faut prendre les précautions raisonnables qui permettront d'établir des normes de production, d'émission ou de distribution faites pour durer : cette révolution sera lente.

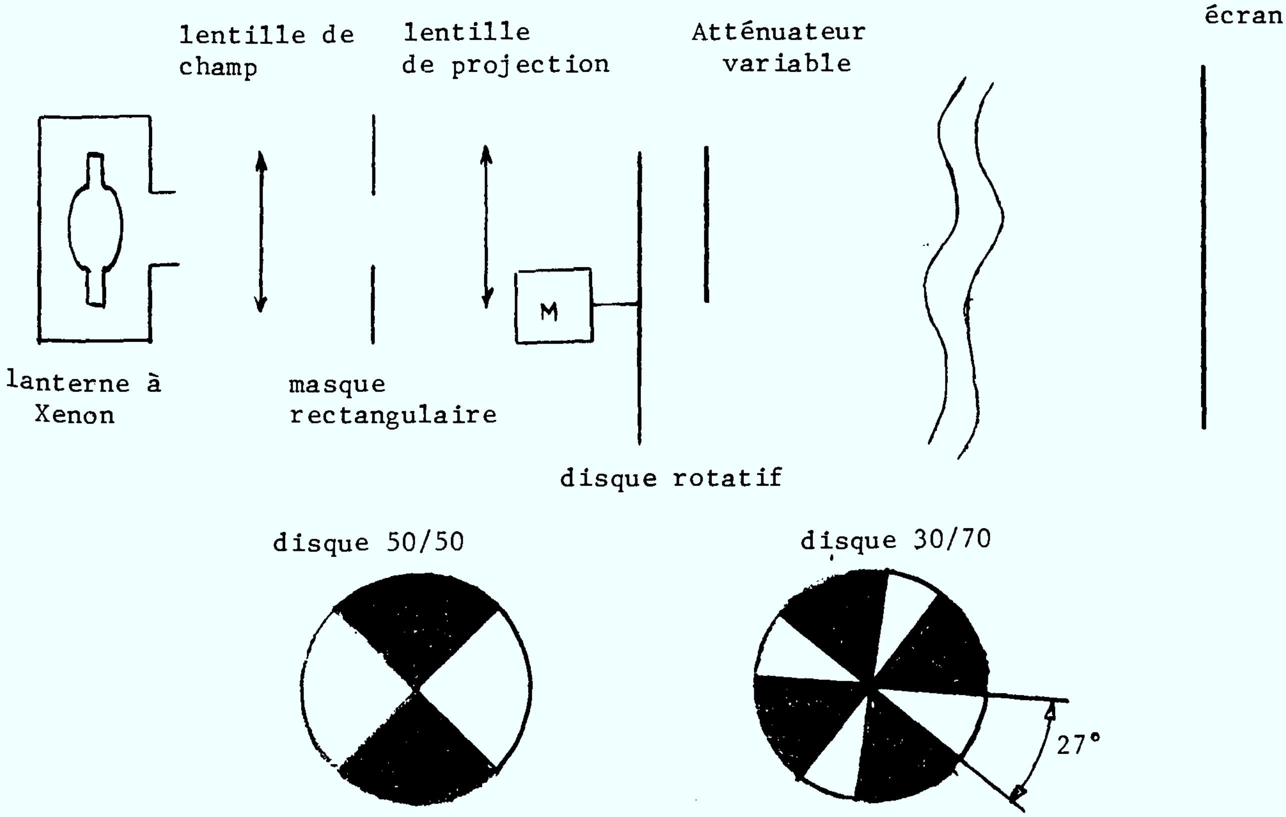
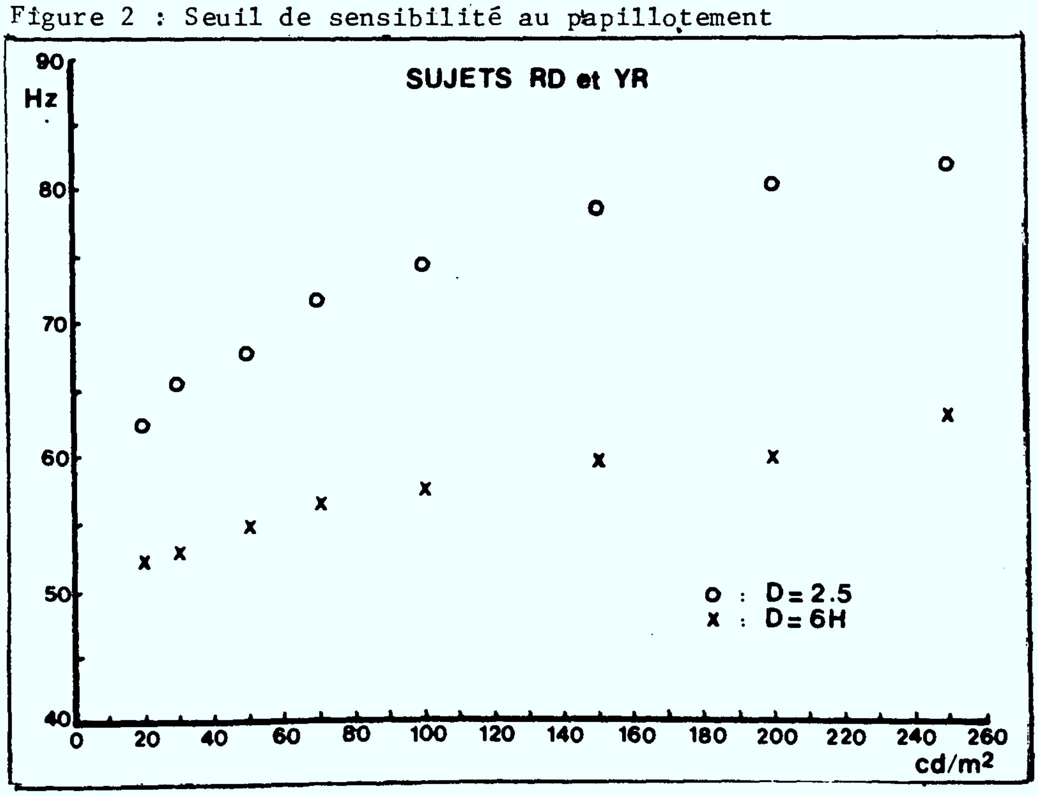


Figure 1 : Dispositif expérimental de mesure du seuil de sensibilité au papillotement

Figure 2 : Seuil de sensibilité au papillotement



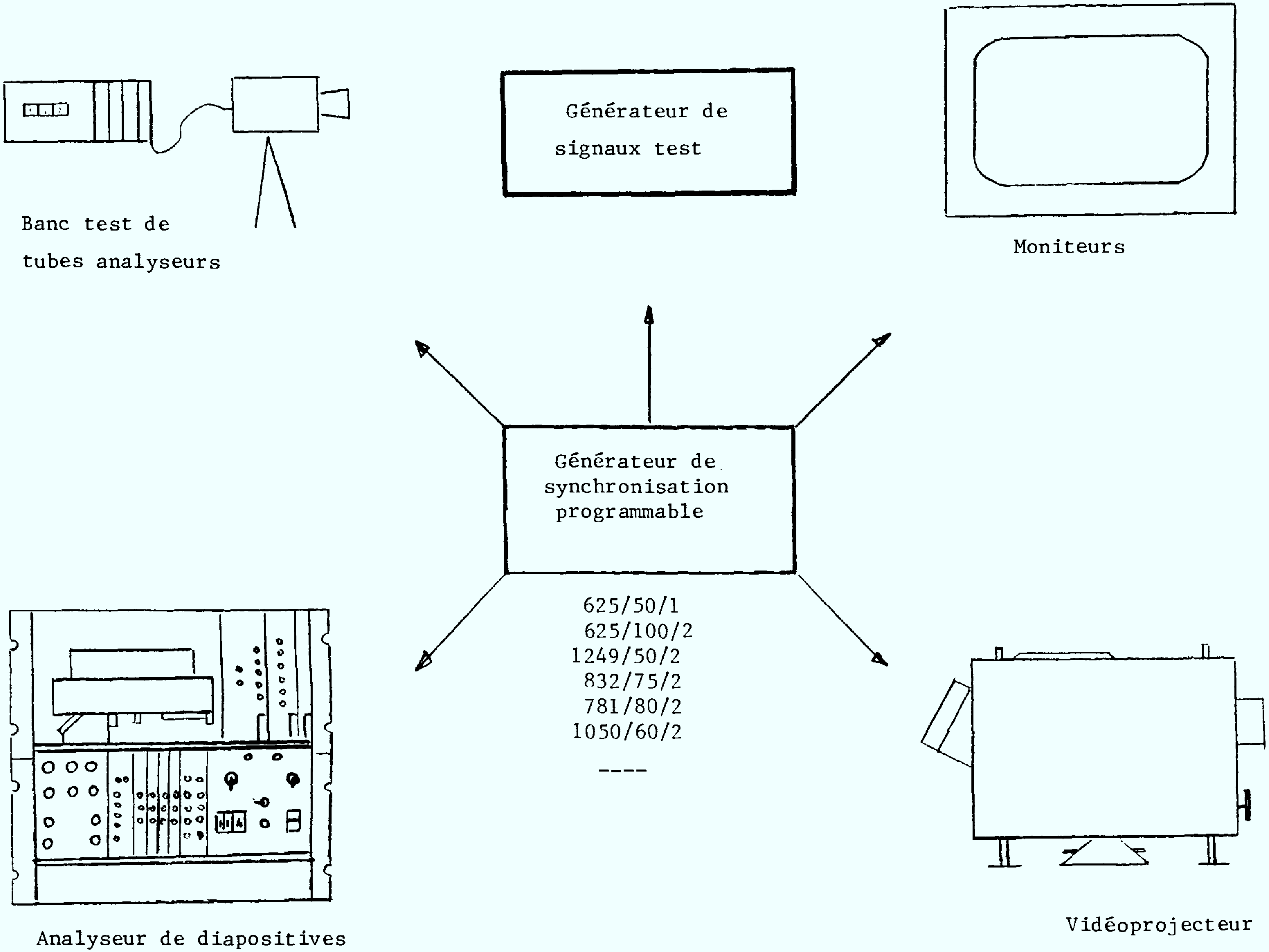
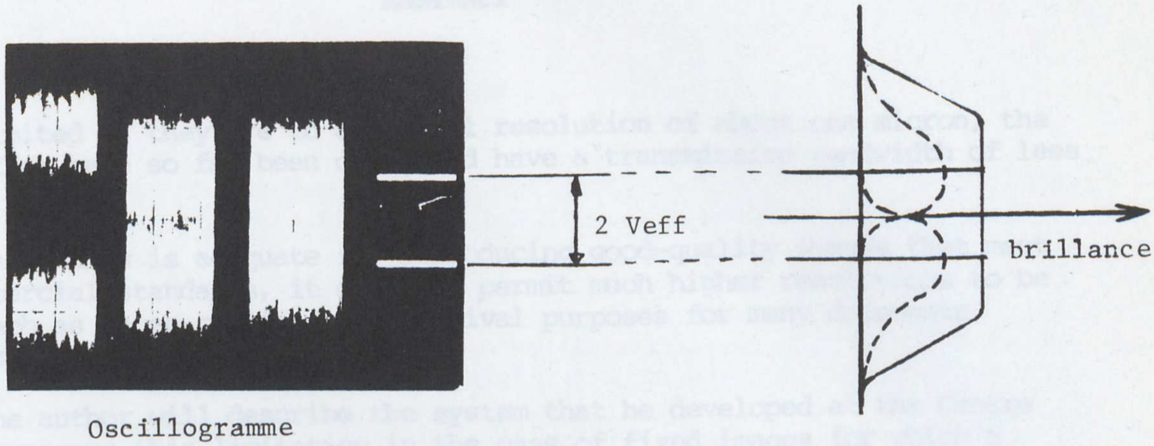


Figure 3 : Matériel expérimental de TVHD



$$\frac{S}{B}\ \mathrm{dB} = 20\ \mathrm{Log}\ \frac{L}{\mathrm{Veff}}$$

Figure 4 : Mesure du rapport signal à bruit
par la méthode de la double trace (ORTF-UTE)
NFC 92 - 200

USING A VIDEODISC AS A MEDIUM FOR HIGH-RESOLUTION FIXED IMAGES

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2.12

ABSTRACT

Limited as they are to a spatial resolution of about one micron, the videodiscs that have so far been developed have a transmission bandwidth of less than 5 MHz.

While this is adequate for reproducing good-quality images that meet present commercial standards, it does not permit much higher resolutions to be achieved, such as those required for archival purposes for many documents (manuscripts, lithographs, prints...).

The author will describe the system that he developed at the Centre Mondial to overcome this limitation in the case of fixed images for which a number of tracks of a videodisc can be used to store information relating to a single document.

To achieve this, the initial image is broken down into elemental blocks of 170 kilobytes, each corresponding to the capacity of a low-resolution image.

These blocks are then reconverted into analog form and recorded on a tape, which is the medium capable of transferring them, as they are, onto a videodisc.

To restore the image to its original state, the process is reversed: selection of partial images, digitalization, memorization, reconstruction and analog reconversion.

At each stage, the information stored in the memory is limited to the useful part of the image, excluding synchronization signals.

The model that will be described pertains to a 1,125 line monochrome image that uses six tracks of a LASERVISION videodisc. The same principle could be applied to colour images and to much higher resolutions.

UTILISATION D'UN VIDÉODISQUE COMME SUPPORT D'IMAGES FIXES DE HAUTE RÉSOLUTION

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ABSTRACT

Limités qu'ils sont à une résolution spatiale voisine du micron, les vidéodisques développés à ce jour ont une bande passante inférieure à 5 MHz.

Cette performance, suffisante pour la restitution d'images de bonne qualité aux standards commerciaux actuels, ne permet pas d'atteindre des résolutions nettement supérieures, comme celles qui sont réclamées par l'archivage de nombreux documents (manuscripts, lithographies, gravures...).

L'auteur décrira le dispositif qu'il a réalisé au CENTRE MONDIAL pour dépasser cette limitation dans le cas d'images fixes pour lesquelles plusieurs spires d'un vidéodisque peuvent être utilisées pour le stockage des informations relatives à un même document.

A cette fin, l'image initiale est d'abord digitalisée pour être décomposée en blocs élémentaires de 170 koctets, compatibles chacuns avec la capacité d'une image de basse définition.

Ces blocs sont reconvertis ensuite sous forme analogique puis enregistrés sur une bande magnétique qui est le véhicule capable de les transférer tels quels sur un vidéodisque.

La restitution est effectuée par le processus inverse: sélection des images partielles, digitalisation, mémorisation, reconstruction et re-conversion analogique.

A chaque stade, les informations stockées en mémoire sont limitées aux seuls parties significatives de l'image, à l'exclusion des signaux de synchronisation.

La maquette qui sera décrite est relative à une image monochrome de 1.125 lignes, occupant 6 spires d'un vidéodisque LASERVISION. Son principe vaut aussi pour des images couleurs et des résolutions beaucoup plus élevées.

INTERLACE SCAN ARTIFACTS

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2.13

ABSTRACT

What happens to picture quality when high resolution, 525 line, 60 Hz progressive scan RGB video is down converted to NTSC? This paper articulates the problems encountered when such conversions are applied to computer graphics displays. The inherent differences between the outputs of cameras and digital graphics generators are discussed. Graphics generators, lacking the intrinsic natural filtration found in analog optical systems, considerably enhance interlace scan artifcats and cross color effects when their outputs are encoded. The NTSC encoding process is accomplished in 2 stages; the first interlaces the raster and the second converts RGB to NTSC. The artifacts produced by interlacing interfere with the color subcarrier encoding in the second stage resulting in a highly deteriorated picture.

Some of the techniques used to reduce interlace scan artifacts are discussed including the use of long persistence phosphors in the CRT display.

A videotape demonstration of a progressively scanned display and the artifacts produced by interlacing and subcarrier encoding is included in the presentation.

DÉFAUTS ASSOCIÉS AU BALAYAGE ENTRELACÉ

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2.13

RÉSUMÉ

Qu'advient-il de la qualité de l'image lorsqu'un signal vidéo RVB de haute résolution 525 lignes et balayage progressif est converti en signal NTSC? Le présent document expose les problèmes que posent ces conversions dans le cas des affichages infographiques. On y discute des différences inhérentes entre les signaux de sortie des caméras et ceux des systèmes numériques de production graphique. Les sytèmes numériques de production graphique ne possédant pas les filtres naturels intrinsèques que l'on retrouve dans les systèmes optiques analogiques, ils accentuent les défauts du balayage entrelacé et la diaphotie de chrominance lorsqu'il y a codage des signaux de sortie. Le codage en NTSC se fait en deux étapes. D'abord, il y a entrelacement de la trame puis conversion du signal RVB en signal NTSC. Les défauts produits par l'entrelacement nuisent au codage de la sous-porteuse couleur dans la seconde étape et causent une grande détérioration de l'image.

Certaines des techniques employées pour réduire les défauts causés par le balayage entrelacé sont discutées dans le document, dont l'emploi de luminophores de longue persistance dans les écrans cathodiques.

La présentation comporte une démonstration magnétoscopique d'une image à balayage progressif et des défauts causés par l'entrelacement et le codage de la sous-porteuse.

INTERLACE SCAN ARTIFACTS

BY

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2.13

The use of computer generated graphics has risen dramatically in the last few years, but nowhere has the impact been on such a broad scale then in the aerospace industry. Simulation systems, CAD/CAM, guidance and control, management information displays and computer generated animation systems for videotape productions, are all included.

Without going into the details of these applications, let me merely point out that as soon as someone creates something on a graphics system, invariably they want to put it onto videotape for demonstrations -- to management, to customers, to whoever cannot physically be present at the computer terminal itself. The range of the types of display is awsome -- some are vector displays and some are raster scan. Of the raster scan versions, which have become the dominant species in recent years, some are monochrome, some color, some progressively scanned and some interlaced scanned. About the only thing the denizens of this zoo have in common is a 4 by 3 aspect ratio that has been imposed on the commercial computer graphics industry by the economical and readily available television CRT.

So, how do you get these computerized images onto a distributable media? The simplest approach is to shoot the graphics screen with a video camera and recorder. This approach is intellectually unsatisfying since it involves both an electronic to optical and an optical to electronic transduction with all attendant degredations. A much more satisfying solution would be to convert the RGB outputs of the graphics display to NTSC and record directly onto videotape.

Let's take a look at both approaches. With the simple video camera loss of resolution is excessive. First the computer graphic display's individual color phosphors are spatially separated by the color mask of the CRT itself and this, coupled with any convergence errors in the RGB electron beams, results in a broadening of individual line structures -- especially those that are not pure red, green, or blue. In addition the optics of the video camera and the electronic/electromagnetic properties of scanning electron beam imaging devices, including registration errors, all conspire to give a fuzzy rendition of the original computer graphic display. On top of all this, CRT displays operate at a relatively high black body radiation temperature that distorts color rendition in garden variety color cameras, even when high temperature filters are used. The bottom line is that the CRT display must be magnified by the shooting camera's optics in order to capture details on videotape. This, of course, means that only a fraction of the screen can be recorded at any given time since the camera must be "zoomed in" on the area of interest.

Until recently most RGB outputs or psuedo NTSC outputs on computer graphic systems were provided for external display capabilities only -- not for video processing or recording. RGB outputs might not conform to RS 170 specifications.

Composite or NTSC type outputs are usually horizontally, and vertically, off frequency since sync pulses are derived from the computer's clock pulse, which is in turn derived from a crystal oscillator using inexpensive, readily available crystals. 20 megahertz crystals are commonly used for 5 megahertz microprocessors. Try as you may, there is no way using simple frequency dividers that you can achieve the NTSC Horizontal Line rate of 15,734 Hz from a 20 megahertz crystal. In addition, the vertical rate may be line locked to 60 Hertz and have nothing to do with the oscillator derived horizontal rate. Needless to say these problems are nothing less than a nightmare to anyone seriously considering deriving an "in-spec" NTSC signal fully synchronized to other studio sources.

So what happens if we do succeed in achieving a stable, synchronous NTSC encoded signal, suitable for studio manipulation and recording? We enter a realm that NTSC was never meant to deal with -- color computer outputs bring out the absolute worst in the NTSC system. NTSC is a camera oriented system that relies upon the natural filtration inherent in optical assemblies, and camera tubes that provide a depth of modulation roll off a higher frequencies. This is <u>not</u> a characteristic of raw computer graphic outputs -- they contain all of <u>the</u> high frequency components during abrupt level transitions (see Figure 1). The graphic system used in this demonstration has RGB output bandwidths that are flat to 10 megahertz according to the manufacturer. In addition this system utilizes a limited state pixel oriented display. By that I mean that each pixel has three components, red, green and blue, and each component is either on or off. This gives eight possible states: black, white, red, green, blue, cyan, magenta and yellow. Patterned clusters of these limited state pixels are used for coloration effects when creating a picture. What this means in terms of the RGB outputs is that <u>every</u> transition is necessarily an abrupt transition that jumps from on to off (<u>or visa</u> versa) in one or more of the outputs. Also, one row of computer pixels equals one horizontal scan line and this results in the pronounced aliasing associated with unfiltered or uninterpolated computer displays. The net result is that computers can drive the NTSC system to it's limits.

A few years ago we set out to convert a 525 line, 60 Hertz progressive scan, RGB output signal to a studio synchronous NTSC signal. We were expecting to do quite a bit of videotape work for the project that was using this particular graphics system. The project ended up on the scrap heap -- but we continued our efforts to achieve synchronous NTSC from the graphics system since we had inherited it from the defunct project.

Without going into the details of how we finally did it -- let's look at what was involved, and what we found when we finally got there. The down conversion to NTSC from a 60 Hertz progressive scan format first requires translation to 30 Hertz interlaced scan (see Figure 2). This means that every <u>other</u> line of the progressive scan raster ends up on the first field, and the <u>lines</u> in between, end up on the second. This process introduces 2 degredations -- interline twitter and zingers. Zingers, as you will see in the demonstration, are the product of aliasing, interline twitter and eye movement. They appear as an assembly line of colored spots, that move along diagonal lines in a graphic display, and are really just a stroboscopic optical illusion -- but that doesn't make them any less real perceptually. Incidentally the term "zinger" was not conceived to compete with such noble terms as "twitter" and "judder" -- it actually developed operationally. While carefully looking at a down converted interlaced graphic, anything that would cause the operator to rapidly move his head to the side, would simultaneously treat him to a glimpse of the high speed "zingers" that can actually produce global effects on the picture. At first I actually thought there had been a hardware glitch in the display and would patiently wait for it to happen again. Of course that would never happen since I was staring intensly at the screen with no eye movement. As the phenomena became recognized for what it was, we began calling the apparent glitch a "zinger".

The next step in the down conversion is encoding to NTSC. Here subcarrier crawl is introduced, and luminance/chrominance interference occurs due to the high bandwidths involved. These four artifacts combine and interfere with each other to produce a sort of unintended animation of an otherwise stable graphic.

Let's briefly look at the conversion system (see Figure 3). Monitor 1 displays a 60 Hertz, 1:1 progressively scanned RGB raster with 512 by 512 pixels per frame. This is then interlaced 2:1 -- 2 consecutive progressive frames become the 2 fields of an interlaced frame and is displayed on a standard RGB monitor (monitor #2). The RGB is then encoded to a sort of psuedo NTSC -- not only is the subcarrier not locked to horizontal sync but horizontal sync is not locked to the 60 Hertz vertical sync. The horizontal rate is derived from a 19.888109 Mhz clock crystal in the graphics generator that we exchanged for the normal 20 Mhz crystal. This new frequency divided by 1264 gives a horizontal frequency of 15,734.263 Hz that is precisely the NTSC specification of 3.579545 Mhz divided by 455 and multiplied by 2. The graphics generator derives it's 60 Hertz field rate from the power line and uses a "zero point crossing/initiate clock out" arrangement to eliminate the phasing problem between the independent horizontal and vertical frequencies. The 3.58 Mhz subcarrier is generated by an independent crystal in the encoder.

This disjointed NTSC appears on monitor #3 and is fed to a pair of cascaded synchronizers. The first is a component synchronizer that is capable of handling the unlocked signal and the second is a highly transparent composite synchronizer that minimizes differences between the output signals of the two units. By freezing a "cel" in the second synchronizer, a new "cel" can be routed through the first synchronizer allowing dissolve animation or other special effects. The switcher is controlled by the editing system for precise timing.

A videocassette of the first 3 monitors was made by shooting the displays "close up" with an NTSC camera. By magnifying portions of a display, the artifacts produced on that display are effectively decoupled from the NTSC capture medium. Magnifications of 1.5 and 3.0 are used to show details and monitors 2 and 3 are really the same monitor -- switch selectable between the interlaced RGB and the NTSC output of the encoder. The first videocassette also shows an example of the direct switcher output. In order to minimize interline twitter all line structures are generated with double thickness; this effectively cuts down resolution by a factor of 2 but is much more desirable from an artifact standpoint.

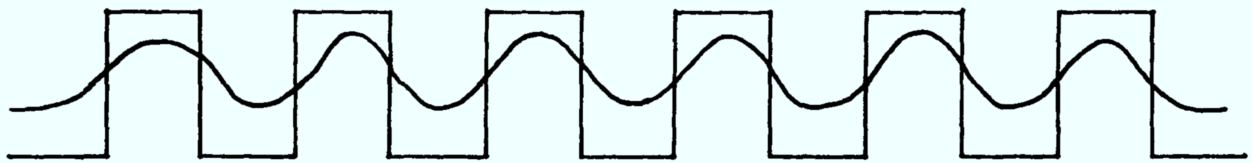
The second videocassette shows some of the same pictures from the first cassette that have been run through a slow motion videodisc to allow field by field analysis. In addition some shots from a 1024 line interlaced scan color graphics screen are included. To reduce interline twitter this display uses high persistence phosphors (see Figure 4). The red and green phosphors are classified as long persistence and the blue is classified as very short; a long persistence blue phosphor (50 msec) has been developed but apparently is not yet widely available. The decay times listed are the times for the phosphor to drop to 10 percent of it's initial (brightest) luminance. Assuming exponential decay for a first order approximation to the actual decay profile allows a plot (see Figure 5)of the three phosphors and their values at 33 msec -- the interlace scan refresh rate (the 50 msec blue phosphor is shown here since the actual 1 μsec phosphor is too short to show on the graph). Further assuming that relative contributions to luminance are 59% green, 30% red and 11% blue, a horizontal white line will fluctuate 50% in brightness every 33 msec. Thus perceivable flicker is only reduced and not eliminated by the use of high persistence phosphors. It is interesting to note that there is also a color change due to the differing phosphor decay rates but this variation is not perceivable at a refresh rate of 33 msec. In fact when we analyzed line structures from this display on the slow motion videodisc we found that while luminance variation was quite perceivable at 33 msec, color variation did not become apparent until the refresh rate was 66 msec (1/15 sec) or slower. This is in accordance with the findings of W. E. Glenn of the New York Institute of Technology Research Center.

In conclusion, the computer graphics industry has made tremendous strides recently in image quality. For example the color slides used in this presentation were computer generated on a 2,048 line scan system. Much of the graphics developed on these systems will be used for electronic cinematography purposes and already far exceed the display capabilities of present television systems. It is highly desirable that the development of a High Definition Television Standard proceed with consideration of computer generated images as well as camera images.

DIRECT COMPUTER OUTPUT CHARACTERISTICS

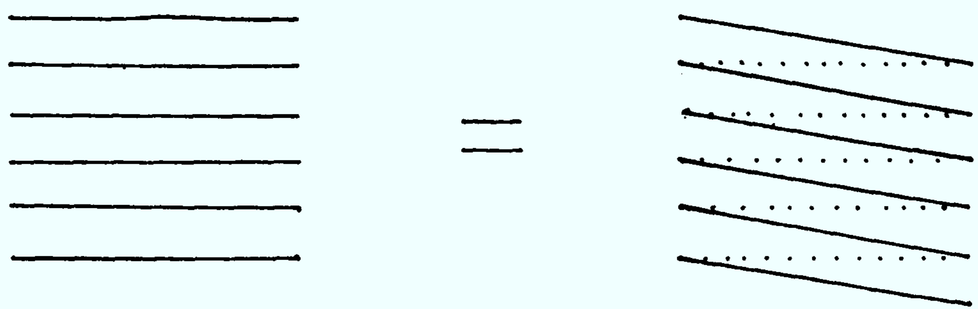
o NO DEPTH OF MODULATION ROLL-OFF AT HIGH FREQUENCIES

CAMERA
COMPUTER



o ONE ROW OF COMPUTER PIXELS EQUALS ONE CRT SCAN LINE

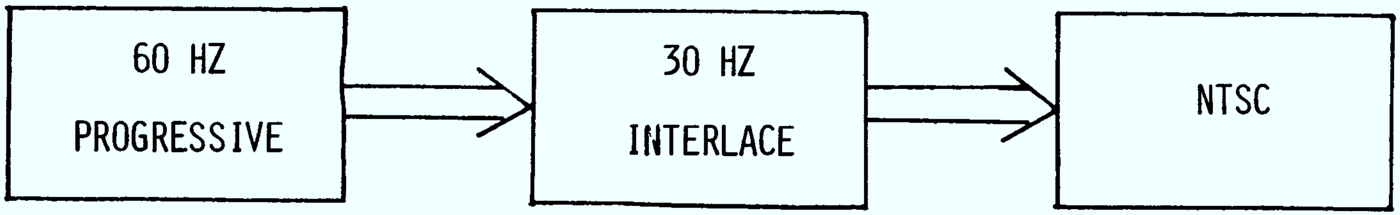
COMPUTER
PIXEL
ROWS



CRT
SCAN
LINES

FIGURE 1

60 HZ PROGRESSIVE SCAN TO NTSC ENCODING PROCESS



ARTIFACTS PRODUCED (30 HZ INTERLACE)

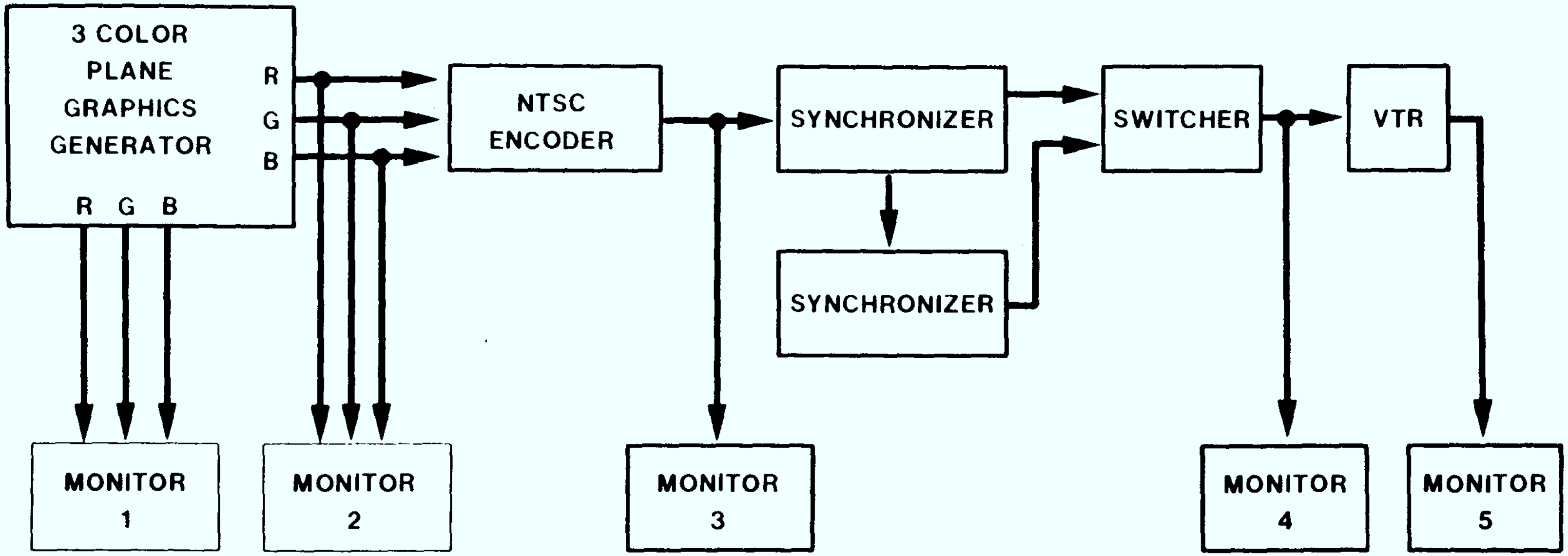
- o INTERLINE TWITTER
- o "ZINGERS" (ALIASING + TWITTER + EYE MOVEMENT)

ARTIFACTS PRODUCED (NTSC)

- o SUBCARRIER CRAWL
- o LUMINANCE/CHROMINANCE INTERFERENCE

FIGURE 2

FIGURE 3



MONITORS

1. 60 HZ PROGRESSIVE SCAN RGB, 512 X 512 PIXELS PER FRAME
2. 30 HZ INTERLACE SCAN RGB
3. PSUEDO-NTSC (COLOR SUBCARRIER NOT LOCKED TO SYNC)
4. NTSC
5. PSUEDO-NTSC (HETERODYNE COLOR)

LUMINANCE DECAY TIMES

- o TIME TO DROP TO 10% OF MAXIMUM LUMINANCE

RED:	100 MSEC	(LONG)
GREEN:	150 MSEC	(LONG)
BLUE:	1 uSEC	(VERY SHORT)

- o ASSUMING EXPONENTIAL DECAY

$$A/A_o = e^{-t/T}$$

$$= .1 \ @ \ t/T = 2.3$$

FIGURE 4

PHOSPHOR DECAY RATES

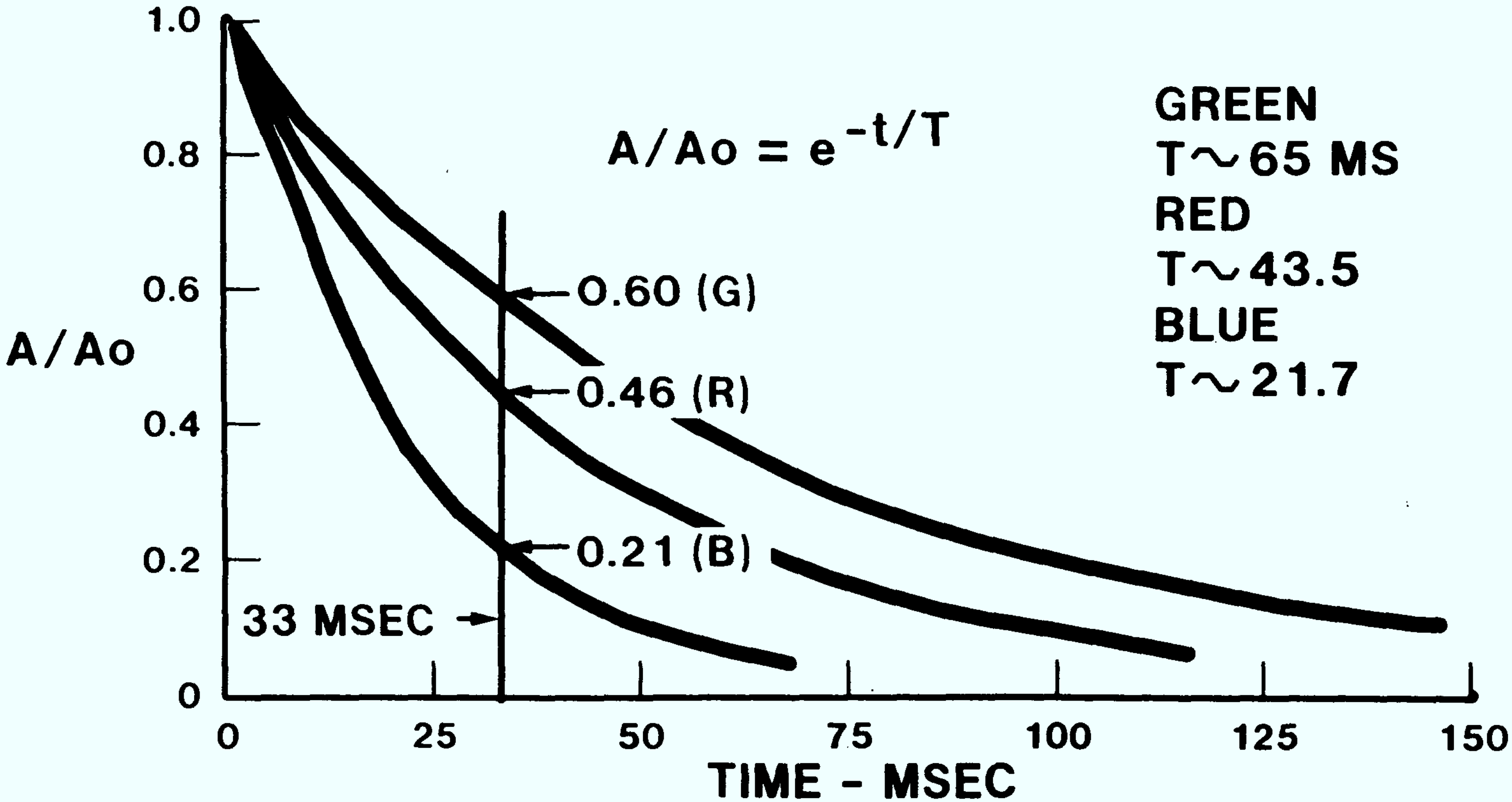


FIGURE 5

COMPATIBILITY CONSIDERATIONS FOR HDTV SOURCES AND DISPLAYS

N.E. Tanton, I. Childs and C.P. Sandbank

British Broadcasting Corporation
London, England

3.1

ABSTRACT

The choice of parameters for an HDTV production standard has a direct effect not only on the basic quality of the HDTV picture but also on the compatibility of the HDTV signal with other media. These include the use of HDTV converted to present-day scanning standards as programme contributions to the terrestrial networks, the transfer of HDTV to film distribution and the transfer of film to HDTV for subsequent broadcast.

If the viewer of HDTV is also to be able to receive conventional standards of television, there will be a conspicuous disparity in the displayed image quality between the HDTV and conventional pictures. Some display artefacts may also intrude even in the HDTV picture. Display up-conversion can therefore assist both to mask some of the difference in picture quality between the two standards and to improve the HDTV picture still further.

It is important that the potential quality of any future HDTV production standard be assessed on the basis of the likely technological advances that will occur during the lifetime of that standard. These advances may be due to natural evolution or they may be responses to the technical challenges set by the choice of standard. HDTV sources will evolve towards being able to do full justice to the production standard. The choice of parameters for that standard must take into account this evolution and the need for compatibility with present television standards and with other media for programme exchange.

CONSIDÉRATIONS LIÉES A LA COMPATIBILITÉ DES SOURCES ET DES SUPPORTS DE PRÉSENTATION

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RÉSUMÉ

Le choix des paramètres retenus pour une norme de production TVHD a une influence directe, non seulement sur la qualité fondamentale de l'image de télévision, mais aussi sur la comptabilité du signal TVHD avec les autres procédés. Ces derniers comprennent la conversion de la TVHD aux normes de balayage actuelles pour acccroître l'éventail des émissions offertes par les réseaux terrestres, le transfert de TVHD à film pour distributin cinématographique et le transfert de films à TVHD pour diffusion ultérieure.

Si l'on prévoit que le consommateur de TVHD doit aussi pouvoir capter les signaux de la télévision conventionnelle, il y aura une nette différence entre la qualité de l'image TVHD et de l'image de télévision conventionnelle. Il pourrait même arriver que certains défauts apparaissent dans l'image de TVHD. La conversion vers le haut des supports de présentation peut aider à masquer en partie l'écart de qualité de l'image entre les deux normes et à améliorer encore l'image de TVHD.

Il importe que la qualité attendue de toute norme future de production TVHD soit évaluée dans le contexte des progrès techniques qui seront vraisemblablement accomplis pendant la "vie utile" de la norme. Ces perfectionnements pourront être le fruit de l'évolution naturelle ou des défis techniques découlant de la norme choisie. A force de raffinements, les sources de TVHD se rapprocheront de plus en plus de la norme de production. C'est pourquoi les divers paramètres retenus pour la norme doivent tenir compte de cette évolution et de la nécessité d'assurer la compatibilité de la TVHD avec les normes de télévision actuelles et avec les autres médias pour permettre la médiatisation intégrale de toutes les émissions.

COMPATIBILITY CONSIDERATIONS FOR HDTV SOURCES AND DISPLAYS

N.E. Tanton, I. Childs and C.P. Sandbank 3.1

British Broadcasting Corporation

London, England

INTRODUCTION

It is important that the potential quality of any future HDTV production standard be assessed on the basis of the likely technological advances that will occur during the lifetime of that standard. These advances may be due to natural evolution or they may be responses to the technical challenges set by the choice of standard. There are examples in present-day systems : PAL cross-colour was not a particular problem in broadcasting until such time as picture sources were developed with the resolution to cause it.

There will be a considerable need, particularly in the early years of HDTV broadcasting, for the HDTV signals to be converted into the present-day 625/50 and 525/60 scanning systems. As a result, any worldwide HDTV studio standard must have a field rate chosen so that not only is the motion portrayal of the HDTV standard good in its own right, but also the conversion to 625/50 and 525/60 should have adequate quality. The correct choice of HDTV standard will minimise any impairments in the standard conversion process and could equally result in a picture with improved resolution compared with existing signal sources.

Similarly it will frequently be necessary to convert between film and HDTV, both because film will provide considerable programme material for HDTV broadcasts and because HDTV will be used for electronic cinematography. The choice of standard will influence the quality of transfer between the two media.

BASIC QUALITY OF HDTV

SPATIAL RESOLUTION

One of the main reasons for increasing the resolution of a television picture is to enable it to be displayed on a larger screen which occupies more of the observer's field of view than contemporary domestic displays. In general the size of screen envisaged is about 1 metre across the diagonal and the viewing distance about three times picture height. In practice these figures are unlikely to be exceeded in the average home due to the very real limitations of living space and the usual need for several people to view the screen at once.

To accomodate this increase in screen size, the suggested intention for HDTV [1] is an approximate doubling of both the horizontal and the vertical resolution of present-day scanning standards; this 'guideline' has been adopted by the CCIR.

In addition there is a general agreement that an increase in aspect ratio is desirable both on aesthetic grounds and to harmonise with the aspect ratios prevalent in the motion-picture industry.

It should be noted that with conventional camera tubes sequential (progressive) scanning gives inherently better vertical resolution than interlace. This is because unless an interlace scan reads all the photocharge on a camera tube each field, the tube image will be integrated for an entire picture period resulting in blurring on movement. Thus the interlace scanning spot must sacrifice resolution for movement portrayal.

In addition, adjacent picture lines sequentially scanned are from proximate time instants unlike adjacent interlaced lines. Vertical aperture correction may therefore be applied to the higher in-band vertical spatial frequencies without adversely affecting motion portrayal. In an interlaced signal vertical aperture correction is restricted to processing lines within the same field and thus to boosting the mid-band vertical spatial frequency components.

MOTION PORTRAYAL

If the projected increase in static resolution provided by the HDTV production standard is to be matched by a relative dynamic resolution (the portrayal of moving picture detail) comparable with present scanning standards, it will be necessary to reduce the effects of camera integration on motion portrayal. This can be done either by increasing the field-rate or by shuttering the camera.

(a) INCREASING THE FIELD-RATE

Increasing the field-rate for HDTV results in an improved fundamental quality of motion portrayal both because the camera integration time is reduced and because the temporal sampling frequency is increased. The disadvantages of increasing the field-rate are again that signal bandwidth is increased and there is a consequent decrease in signal-to-noise ratio. The subjective effect of increasing the noise by increasing the field-rate will be mitigated to some extent by the temporal low-pass characteristic of the human eye/brain combination; the additional noise components will be at frequencies which are less visible to the human observer.

Any loss of moving detail caused by camera integration will be most marked when the camera (lens and scanning aperture) are doing full justice to the potential static resolution afforded by HDTV. Judgements on the adequacy of motion portrayal based on present camera technology may therefore be rather optimistic.

In a sequence of subjective tests, the BBC have assessed the effect of field-rate on motion portrayal in unshuttered camera pictures. A broadcast television camera was modified to enable the field-scan waveform to be generated externally using a microprocessor-controlled DAC. A picture monitor was similarly modified so that camera and display could be driven together over a range of field frequencies with both sequential and interlaced scanning.

To obviate registration problems and to simplify the necessary electronics, the green channel signal was displayed as a monochrome signal on the monitor. Line frequency was kept constant: reduced-height pictures were therefore available at field-rates greater than 50 Hz and for sequential scanning. Sequential scanning was used for these tests to maintain near constant static vertical resolution at the different field-rates assessed. Previous experience has shown that the integration-time for present-day cameras is approximately the same whether the scan be interlaced or sequential. Scan-line pitch was kept constant and the picture blanked appropriately to maintain a constant displayed picture-height regardless of field-rate. Thus in practice the displayed picture comprised a window of about 1/4 picture height.

Field frequencies of 50, 60, 70 and 80 Hz were investigated. With picture material moving at near constant horizontal velocity, a clear and progressive preference was show for pictures generated and displayed at higher field-rates. Measured on the CCIR 5-point quality scale, pictures generated and displayed at 80 Hz were preferred by more than 1 grade to 60 Hz at moderate and fast motion speeds and by between 1.8 and 2.4 grades to 50 Hz for the same speeds.

(b) CAMERA SHUTTERING

Shuttering the camera, on the other hand, serves to reduce the integration time whilst maintaining the same temporal sampling frequency. As a result, moving detail is less blurred but the level of motion aliassing (manifest as judder) is increased. This increase will adversely affect the quality and difficulty of post-production operations including standards conversion to present terrestrial scanning standards (see below).

There is also a loss of sensitivity due to shuttering as less of the available light contributes to photocharge; signal-to-noise is consequently degraded. In the longer term this problem may diminish because CCD image sensors have a read-out noise much less than the noise from camera tubes (typically -20dB).

If the present progress in the development of charge-coupled image sensors is maintained, CCD devices suitable for HDTV cameras are likely to become available within the next ten years. Such devices may allow the direct use of signal processing in each sensor element. One such use of this could be to reduce the level of temporal aliassing present in the output television signal. To make the best advantage of this possibility it will be desirable both to use a field-rate higher than 50 Hz and to use sequential scanning, in the sensor.

CONVERSION TO PRESENT SCANNING STANDARDS

As has been discussed, future HDTV studios will be required to provide an input to existing television standards.

Present-day standards converters converting between the conventional scanning standards of 625/50 and 525/60 operate by resampling the input standard signal on the output standard sampling sites. Because the input and output scanning lines do not correspond in spatial position and the input and output fields bear no fixed relationship to one another (either in frequency or phase) the process of conversion involves interpolating the output picture signal from line and field contributions from the input picture [2]. The process can also be envisaged as representing sampling, low-pass filtering and resampling; in practice the filtering and resampling are combined in one operation.

In most applications of sampling it is normal to precede the sampling process by a low-pass filter to ensure that no components beyond half the sampling frequency are present to cause aliassing. The particular problems which are associated with standards conversion (and are evident in the quality of converted output picture) stem from the close proximity of the sampling frequencies (represented by the similar line pitches and field-rates), the relatively low temporal sampling frequency of the television field-rate and the inadequate pre-filtering of the input image signal prior to scanning which results in the inclusion of alias components within the scanned signal itself.

Thus the converter must attempt to filter the input standard to allow resampling with the minimum of passband loss (manifest as loss of static and moving detail) but with the minimum of aliassing due to the resampling. Thus aliassing may be manifest as some or all of static vertical aliassing, flicker on fine vertical detail, vertical modulation on moving detail and judder on movement. In practice most of these conversion artefacts can be substantially reduced by careful design of the converter and choice of interpolation aperture; line related artefacts are easier to deal with than field related ones. On the other hand it is hard to remove the judder on moving picture detail which occurs with temporal frequency components equal to the differences between harmonics of the input and output field-frequencies. With conversion between 625/50 and 525/60 the prime component of judder is at 10 Hz and so falls right in the temporal passband; it can only be removed with unacceptable loss of moving detail and under certain conditions can even contribute to the perceived dynamic resolution. Thus interpolating converters operating between 625/50 and 525/60 must compromise between judder and blurring on motion.

One proposed HDTV standard is based on a field frequency of 60 Hz [4]. While this will give a good quality of conversion to 525/60 terrestrial systems, some doubt has been expressed about the potential quality of conversion to 625/50 if the majority of terrestrial transmissions are to be derived from HDTV sources.

If the input field-rate were chosen to maximise the frequency of this judder component a better compromise would be possible, judder would be subjectively less objectionable and the blurring due to passband losses in the temporal characteristic minimised.

In a series of subjective tests, the BBC have investigated the potential quality of conversion using interpolating conversion between signals originated at field rates of 80 Hz, 60 Hz and 50 Hz and display field rates of 60 Hz and 50 Hz.

As with the tests on motion portrayal described äbove, a camera was modified to enable the field-scan waveform to be generated externally using a microprocessor-controlled DAC. The microprocessor also controlled field-stores and an interpolator, enabling various field interpolation apertures to be investigated for each conversion. The interpolator used contributions from four input fields; to avoid the intrusion of interlace artefacts in the conversion process the camera was scanned sequentially.

With picture material moving at near constant horizontal velocity, for different representative motion speeds the pictures originated on 80 Hz were judged to give a significantly better quality than those originated at 60 Hz when converted to 50 Hz. Similarly when converted to 60 Hz, an origination at 80 Hz was preferred to that at 50 Hz. A preference was also shown for interpolation apertures which preserved moving detail at the expense of judder.

In general, the choice of interpolating aperture in such a converter is simplified, and the quality of conversion marginally improved, if the input picture signal is sequentially scanned.

An alternative to interpolating converters has recently been demonstrated by NHK converting from 1125/60/2:1 to 625/50/2:1. In this particular converter, motion within the scene is measured from the picture signal itself and frame-store addresses are adjusted according on the basis of whether the local picture information is judged to be moving or not. When the motion has been correctly identified and quantified, a sharp image results, free from the sort of judder which besets interpolating converters. Failure to follow this motion however causes a sudden shift in local picture information which appears as a relatively low-level incoherent judder. The difficulty faced by such an adaptive system is the correct identification and measurement of motion within a scene in the presence of contrary motion, temporal aliassing and noise. Nevertheless the method shows great promise and represents a considerable feat of engineering.

The subjective effect of judder in an interpolating converter is dependant on motion speed, slow motion producing little judder whilst faster motion generates more. In recent tests conducted by the BBC as part of the EBU subjective tests on the quality of conversion of HDTV to 625/50, slowly moving detail was usually judged better when converted by interpolation than by movement following, whereas faster motion was better served by the movement following converter.

It may be possible to combine the advantages of motion following with that of interpolation in order to produce an acceptable quality of converted picture. It is appropriate to note that the detection of motion in a television scene is made easier if the scanning is sequential.

INTERFACING WITH FILM

The choice of parameters for an HDTV production standard has a considerable effect on the likely quality of transfer between film and HDTV.

It is expected that 35 mm film will be a major source of programme material especially in the early days of an HDTV broadcasting service. Conversely, telerecording is of interest because one of the key areas for the use of HDTV is in electronic cinematography in which HDTV will be the medium of production and 35 mm print film the medium of distribution. There may also be times when combinations of these transfers can be envisaged, for example electronic productions incorporating film inserts being themselves transferred to film.

For transfers between film and HDTV the principal problems lie in the presence of temporal aliassing in the form of judder at the beat frequency between the television field-rate and the nearest harmonic of the film frame-rate. In addition, the whole film image is exposed at the same instant whereas in a television camera the exposure instant for a scan line at the top of a given field is not the same as for the bottom of the field. In principle therefore the interpolation aperture for conversion between film and television should vary down the television field. In practice this latter effect is usually ignored and the transfer process considered simply as conversion between a sequential standard at one field frequency and an interlaced standard at another frequency.

As a result, the choice of field-frequency for an HDTV standard is likely to have a significant effect on the quality of motion portrayal in film-to-HDTV and HDTV-to-film transfers.

For example, a field frequency of 60 Hz bears a relatively simple relationship (5:2) to the 24 Hz frame-rate used for motion picture film. In this case, an HDTV telecine could have a simple 5-field cycle wherein one film frame is repeated for two successive fields and the next frame for three fields. Conventional telecines working on the 525/60 standard are operated in the same manner.

Such a telecine is known to exhibit a visible judder on moving objects; the judder frequency of 12 Hz is at the beat frequency between the second and the third harmonics of the film frame-rate and the television field frequency. In the past this judder has been partly suppressed by the use of telecines employing vidicon camera tubes whose storage characteristics help to integrate the judder.

Another technique is to use movement interpolation; again this reduces judder at the expense of movement blurring. Previous work on telecines [3] has shown that movement interpolation can produce an acceptable compromise between these impairments in which 24 Hz judder, caused by the undersampling of basic film frame rate itself, helps to mask the residual 12 Hz judder.

A similar degree of 12 Hz judder has been reported when HDTV signals, originated at a 60 Hz field rate, are recorded onto film; in this case the subjective appearance of the judder appeared to be worse than that produced by a telecine. Some improvement may be possible with the use of simple movement interpolation though the greater subjective visibility of the judder might make a suitable compromise between judder and blurring more difficult to achieve. Sophisticated motion adaptive techniques, similar to those demonstrated by NHK for standards conversion, are also applicable to film transfer; a comparable quality of conversion should be possible.

It would be preferable to be able to eliminate the beat-frequency judder completely. This could be achieved by running the film at a non-standard rate chosen to be an exact sub-multiple of the HDTV field-frequency. One suitable rate would be 30 Hz; such a rate could easily be used in the film camera where the film is destined for HDTV distribution. It is however less likely that cinema film projectors could be so easily modified to cope with the 25% increase in speed if this film frame-rate were used for HDTV-to-film transfer. An additional complication in television-to-film conversion at this frame rate is that each film frame will always be composed of a pair of input television fields having a fixed phase relationship. The edges of moving picture detail will thus exhibit a combing structure at the television field-line pitch, whose effect is to make the object appear blurred. At a viewing distance beyond that at which the combing structure can be resolved, the subjective impression is similar to that of a camera with a 1/30th second integration time.

DISPLAY CONVERSION

If the viewer of HDTV is also to be able to receive conventional standards of televison, there will be a conspicuous disparity in the displayed image quality between the HDTV and conventional pictures. Furthermore some display artefacts may intrude even in the HDTV picture. Display up-conversion can assist both to mask some of the difference in picture quality between the two standards and to improve the HDTV picture still further.

The television display, in conjunction with the human eye and brain, attempts to reconstruct a spatially and temporally continuous brightness signal (representing the scene viewed by the camera) from the discontinuous samples of the scanned image in the form of lines and fields. The resulting picture suffers from a number of defects because the display is an imperfect reconstructing low-pass filter. These defects are manifest as:

(1) large-area flicker at the field frequency in plain areas of high brightness,

(2) interline twitter at the picture frequency on fine vertical detail,

(3) line crawl (in which the eye is able to follow the interlace structure especially around coarse detail and perceives the field lines)

and

(4) a visible picture - line structure.

These defects become particularly evident when the picture is displayed on a large screen. They can be substantially reduced by the use of storage and processing in the receiver to up-convert the image by interpolating additional lines and increasing the field-rate. In display up-conversion there is naturally no real increase in resolution in the displayed picture but some subjective improvement in display quality may result.

Experiments using these techniques have been carried out by the BBC and others using conventional scanning standards [5].

Good portrayal of stationary picture detail is possible but there is a fundamental problem with interlaced scanning on moving scene detail. To interpolate extra television lines for the display, information is used from spatially adjacent lines; in an interlaced scan these are derived from substantially different time instants (approximately 1 field period apart). If interpolation includes information from different fields, moving detail will be temporally filtered and thus blurred. To perform display conversion on an interlaced signal it is therefore necessary to make use of some motion adaptive techniques whereby static detail is processed in one way and moving detail in another.

The results of the BBC experiments were encouraging but on more critical picture material it was found that transitions between detail processed with a stationary algorithm and that processed with a movement algorithm were rather visible. Sophisticated methods which make use of more complex interpolation, motion measurement and adaption techniques will further improve display up-conversion. However, as with standards conversion, it is necessary correctly to detect and measure motion within the scanned scene in the presence of contrary motion, aliases and noise.

Whilst a sequential standard for the transmission path would make interpolation of line and fields for display up-conversion much simpler, it would require a greater transmission bandwidth for a given static resolution, one of the most important factors in HDTV.

CONCLUSIONS

HDTV sources will evolve towards being able to do full justice to the production standard. The choice of parameters for that standard must take into account this evolution and the need for compatibility with present television standards and with other media for programme exchange.

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HDTV - ALTERNATIVES IN FIELDRATES AND CONVERSION TO 50 Hz

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3.2

ABSTRACT

In the current process of standardisation of a worldwide HDTV studio standard, different field rates and scanning systems are discussed. For example, 60 Hz and 80 Hz with 2:1 interlace, 30 Hz and 40 Hz progressively scanned and a system proposed by Powers with 40 frames per second, vertically scanned and with a 15:1 interlace have been proposed. In order to achieve compatibility with existing 50 Hz, 60 Hz TV systems and with film, the final HDTV standard should allow conversion to the existing 625/50 and 525/60 standards with a quality as least as good as that available from signals generated directly in the existing standards.

In order to find out what proposal could be a basis for comming as close as possible to this ideal goal formulated in the CCIR Report 801-1 (Mod I), we are carrying out a comparative study of standard conversion to 50 Hz, starting from 60 Hz, 80 Hz and from the system described by Powers.

The study is based on computer simulations using a sequence with panning and tilting a camera in a harbour environment (Kiel harbour). The sequences are generated in a way that camera lag is avoided; by this an ideal camera and a worst case condition for signal processing is simulated.

The standard conversion algorithms are based on linear interpolation. They are not optimum in a strict sense but show the relative improvement possible with a field rate higher than 60 Hz. Concerning Powers' system, the typical distortions in the 50 Hz down converted sequence are shown and filters to improve the picture quality are proposed. The original and the processed sequences are recorded in black and white and in 50 Hz on a VTR BCN 50 (Bosch).

TVHD - NOUVELLES FRÉQUENCES DE TRAME ET CONVERSION À 50 Hz

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RÉSUMÉ

Un standard de studio, différentes fréquences de trame et des systèmes de balayage sont analysés dans le cadre du processus courant de normalisation internationale de la TVHD. Il a été proposé, par exemple des fréquences de trame de 60 Hz et 80 Hz à rapport d'entrelacement de 2/1, des fréquences de 30 Hz et 40 Hz avec balayage progressif et un système conçu par Powers à vitesse de 40 images/secondes, balayage vertical et rapport d'entrelacement de 15/1. La compatibilité avec les systèmes existants de télévision 50 Hz/60 Hz et de cinématographie peut être obtenue si le standard final de télévision haute définition autorise la conversion des standards courants 625/50 et 525/60, tout en assurant une qualité au moins égale à celle offerte par les signaux directement produits dans les standards précités.

Une étude comparative traite de la conversion à 50 Hz des systèmes à fréquences de trame de 60 et 80 Hz et du système décrit par Powers.

L'étude se fonde sur des simulations par ordinateur à partir d'une séquence filmée dans un port (Kiel) avec panoramique et travelling d'une caméra. Les séquences simulées sont produites de manière à éviter le retard de temps de la caméra (lag) et à fixer les conditions les plus défavorables pour le traitement des signaux.

Les algorithmes de conversion de standard sont basés sur une interpolation linéaire. Même s'ils ne sont pas potimums au sens strict, ils démontrent qu'une amélioraton relative est possible à des fréquences de trame supérieures à 60 Hz. L'étude comparative fait état des distorsions typiques obtenues dans les séquences converties à 50 Hz pour le système Powers et décrit les filtres à employer dans ce cas pour améliorer la qualité de l'image. Les séquences originales et simulées sont enregistrées en blanc et noir à une fréquence de trame de 50 Hz sur un magnétoscope BCN 50 de Bosch.

HDTV - Alternatives in fieldrates and conversion to 50 Hz

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3.2

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1. Introduction

A central problem in the current discussions on a worldwide HDTV studio standard is the selection of the fieldrate. Various suggestions are being discussed, e.g. 50 Hz, 60 Hz, 80 Hz. Systems based on progressive scanning with framerates of 30 Hz, 40 Hz, and 60 Hz are being discussed as well. On the basis of the justified requirement for convertibility without detectable loss of quality from HDTV to existing TV standards with 60 Hz and 50 Hz fieldrates, the problems with respect to a worldwide HDTV studio standard are increased.

A TV system based on the lowest common multiple of 50 Hz, 60 Hz and 24 Hz was presented by Powers /1/. This is based on a fieldrate of 600 Hz, an interlacing factor of 15:1, and vertical scanning. As will be shown later, however, problems exist in conversion due to the low number of columns in a field.

The EBU has, amongst other parameters, suggested a fieldrate of 80 Hz for a worldwide HDTV studio standard. Due to the larger frequency difference, lower quality losses can be expected in conversion of this fieldrate to a current TV standard than from 60 Hz to 50 Hz. Due to the fact that the difference between the mains frequency and the fieldrate is also larger, fewer problems with respect to illumination are to be expected. A disadvantage of an 80 Hz fieldrate is, however, the unfavorable relationship to film with 24 frames per second.

As the selection of a suitable fieldrate for a worldwide HDTV studio standard is very closely connected with its convertibility into an existing TV standard, this paper will first deal shortly with the principle problems of fieldrate conversion with linear interpolation. This is followed by a comparison between the quality losses caused by conversion from 80 Hz to 50 Hz and from 60 Hz to 50 Hz. Finally, the conversion problems in the TV system presented by Powers will be dealt with.

2. Computer generated sequences

In order to permit closer consideration of the problems in fieldrate conversion, artificial sequences with defined motion speeds - currently only in the horizontal direction - were generated in a computer. These were based on an "ideal" camera suitable for instantaneous shots. This camera does not have any lag and therefore does not cause any loss of focusing even in the case of rapid motion. As measures for a reduction of the integration time are already being considered today in order to improve the resolution of moving scenes - for example by the use of a synchronous shutter - the above assumption is justified as a worst case for signal processing.

The artificial sequences are based on the HDTV picture Kiel-Harbor with 1440 pel/line and 1200 lines. The pictures themselves have, on the basis of the digital TV standard, 720 pel/line and 576 lines. Each field or frame of the artificial sequence represents a section of the HDTV picture. The position of the various sections determines the type and speed of movement. Depending on the application, artificial sequences with progressive scanning or with interlacing can be implemented.

Table 1 provides a list of the various sequences with horizontal motion (panning) and with different speeds. As these are sequences with interlacing, the shift from one field to the next is

SEQ	SPEED PEL/FIELD	MOTION TIME SEC 50 HZ	FIELDRATE 60 HZ	80 HZ
1	3	4.8	4.0	3.0
2	4	3.6	3.0	2.25
3	6	2.4	2.0	1.5
4	8	1.8	1.5	1.125
5	9	1.6	1.33	1.0
6	12	1.2	1.0	0.75

Table 1: Computer generated sequences with horizontal motion and different motion speeds in pel/field. The motion time as a function of the fieldrate in colummn 3, 4 and 5 specifies the time which is required to pan from left to right edge of the screen.

specified in pel/field. The time which is required to pan from the left to the right edge of the screen is specified in columns 3, 4 and 5. Here this time is called motion time and is based on 720 pel/line. In order to permit better indication of conversion errors, sequences with low motion speeds have been omitted. As will be discussed later, the sampling theorem has been violated with respect to the fieldrate of the sequences listed in the Table 1.

Observation of the artificial sequences, which were displayed with a fieldrate of 50 Hz, showed that the human eye is capable of following the moving object in spite of the higher motion speeds so that no judder is visible. If the eye is oriented to a fixed point, it is a well-known fact that judder starts already at low speeds. The eye and the brain together can thus, in spite of violation of the sampling theorem, be considered under certain assumptions as an "ideal interpolator". As will be shown later, this advantage is lost completely in fieldrate conversion.

3. Fieldrate and sampling theorem

When a scene is taken by a camera, the sequential fields correspond to a time-sampling of the object (see, for example /2/). If an "ideal" camera is assumed, as in the previous section, then it can be determined that alias as the result of insufficient fieldrate sampling is not only dependent on the speed of motion of the individual objects, but also on the spatial frequency spectrum of the subject. This can be shown with a simple example.

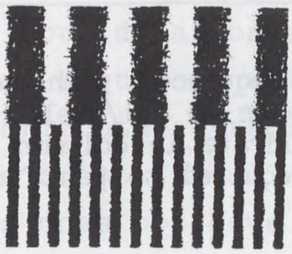

Fig. 1: Bar pattern with two different spatial frequencies.

Fig. 1 shows part of a periodic, sinusoidal pattern. The period duration of the upper pattern is three times as large as that of the lower. The whole bar pattern is moved horizontally with an increasing motion speed and sampled by a camera. In this case in the lower part of the picture the well-known alias occurs earlier, than in the upper part. Depending on the motion speed it seems, that the lower bar pattern can appear to be stationary or even move in opposite direction while the upper bar pattern moves with the actual motion speed. In this example the motion speed of the whole picture without alias in the upper bar pattern can be three times as high as the motion speed without alias in the lower bar pattern. The results of this experiment makes it clear that alias as a result of fieldrate depends not only on the speed of motion but also on the spatial frequency spectrum of the subject.

With Eq. (1), the processes in the above experiment can be generally defined :

$$I(x,t) = I_0 \, (1 + \sin\, (2\pi f_x \, (x + v_x t)). \qquad (1)$$

$I(x,t)$ is the intensity of the subject as a function of the position x and the time t. I_0 is the mean intensity, f_x the spatial frequency of the periodic oscillation, and v_x the horizontal speed. If the time-curve of the intensity of a moving object is now considered at a location x_0, then the following applies:

$$I(x_0,t) = I_0 \, (1 + \sin\, (2\pi f_x \, (x_0 + v_x t). \qquad (2)$$

In this case, the intensity is only a function of the time t and has a period duration T.

$$T = 1 \,/\, (v_x f_x). \qquad (3)$$

If the function $I(x_0,t)$ in Eq. (2) is to be sampled, then the sampling theorem results in the following relationship for the sampling frequency f_T:

$$f_T = 2 \, v_x f_x. \qquad (4)$$

If this result is referred to the experiment described initially, then f_T is the fieldrate, i.e. with a given fieldrate f_T and horizontal speed v_x, a maximum spatial frequency must not be exceeded if the sampling theorem is not to be violated. If one nevertheless increases the spatial frequency, either the horizontal speed must be reduced or the fieldrate must be increased. For simplification, vertical structures and motion in other directions were deliberately omitted from this experiment.

From the above results the following conclusion can be drawn for HDTV. In order to obtain the same conditions with respect to alias in an HDTV standard, compared with present TV standards, the field-rate must be doubled or - something which will probably be impossible - the speed of movement must be reduced to one half. This is surely a hard requirement for future HDTV standards. If, however, one considers natural, generally not periodic subjects, instead of the periodic bar pattern - for example the sequences shown in Table 1 - , then the observer doesn't recognize sampling errors.

If the spatial frequency spectra of the various pictures in Table 1 are calculated, and the necessary fieldrates estimated in the same manner as shown in Eq. (1-4), then the sampling theorem is already violated in the first sequence, which shows the lowest speed of motion in the table. However, as various experiments with these sequences have shown, the alias is hardly visible in the sequences with slower movement. The eye and the brain together can therefore generally be regarded as an "ideal interpolator". Because the human eyes are able to follow the moving objects, the sampling errors become visible to the observer only at higher motion speeds.

These results agree with experience gained with present TV systems. The sampling errors caused by subsampling of a moving scene are generally hardly visible. If, however, the fieldrate is converted, considerable problems occur in subsampled moving picture scenes. This will be shown in the following section.

4. Fieldrate conversion

On the basis of the artificial sequences shown in Table 1, a comparison is made between fieldrate conversions with linear interpolation from 80 Hz to 50 Hz and from 60 Hz to 50 Hz. In addition, the fieldrate conversion between the TV system suggested by Powers /1/ and today's 50 Hz TV standard is examined.

4.1 Fieldrate conversion with linear interpolation

In the case of fieldrate conversion where there is no integral relationship between the two fieldrates, it is necessary to construct pictures for intermediate times. Linear interpolation is one possibility of achieving this aim. The simplest form of linear interpolation, a weighted addition of two fields, is shown in Fig. 2a. The values of the coefficients A, B and C depend on the position X of the desired intermediate field. Fig. 2b shows the interpolation algorithm for progressiv scanning.

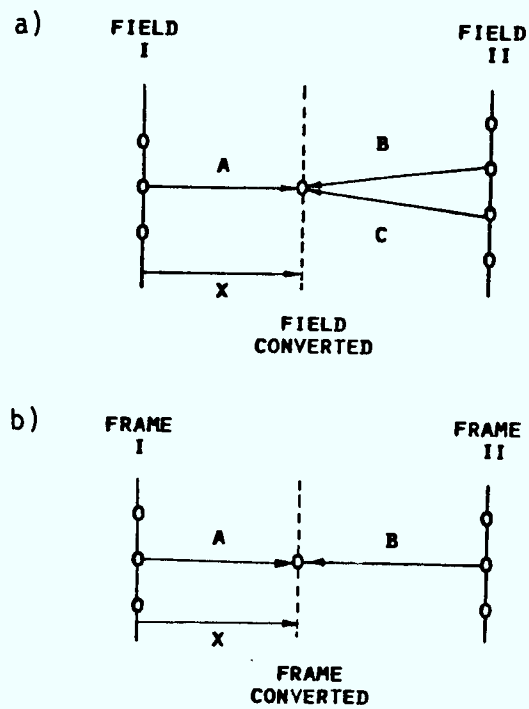

Fig. 2: Simplest linear interpolation:
a) interlaced scanned sequences
b) progressiv scanned sequences

In order to permit better recognition of the limits of linear interpolation in fieldrate conversion, Fig. 3a shows a part of a black/white transition which moves from left to right and requires, for example, 4.8 seconds for this movement. If this speed is related to the fieldrate of 50 Hz and to 720 pel/line, this corresponds to a motion speed of 3 pel/field. It is easily shown that in this case the sampling theorem is violated with respect to the field-rate. If the horizontal spatial frequency spectrum of the object

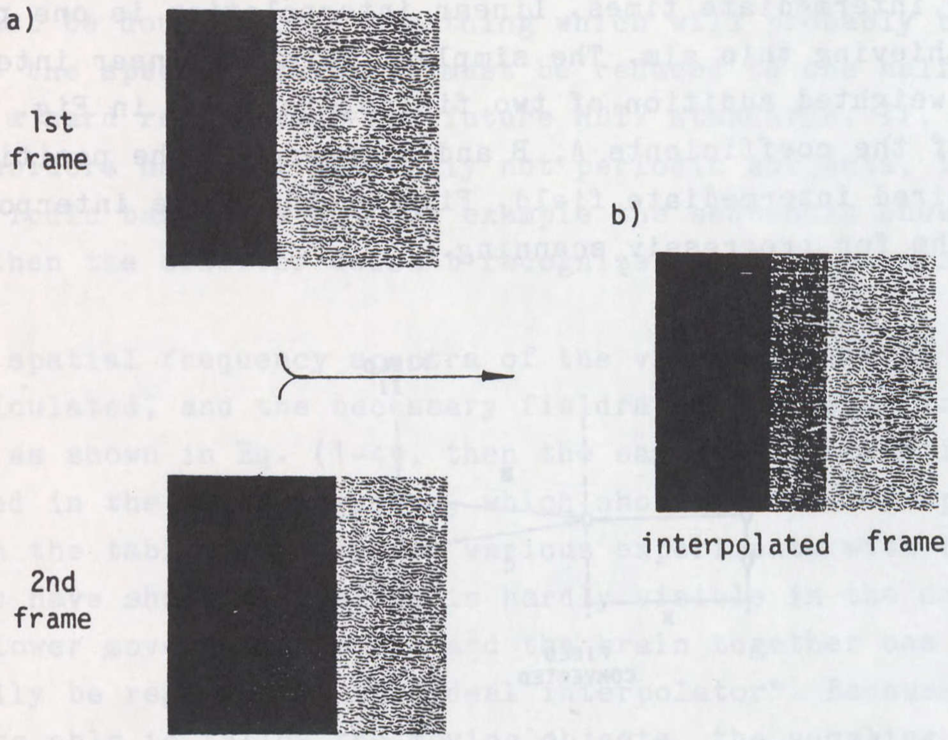

Fig. 3: Black/white transition with horizontal motion:
a) two adjacent frames.
b) interpolated frame with algorithm presented in Fig. 2.

is calculated and compared with the maximum permissible spatial frequency f_x in Eq. (4), it can be seen that the motion sequence is subsampled. As various experiments have shown, this subsamling is generally not visible to the human eye. If, however, in respect to fieldrate conversion, an intermediate picture is generated by the interpolation method (Fig. 2 a,b) a staircase intensity distribution occurs in the vicinity of the black/white transition (Fig. 3 b). This disturbance is also obtained if the interpolation is extended over several fields, even up to the limit case of an infinite number of fields.

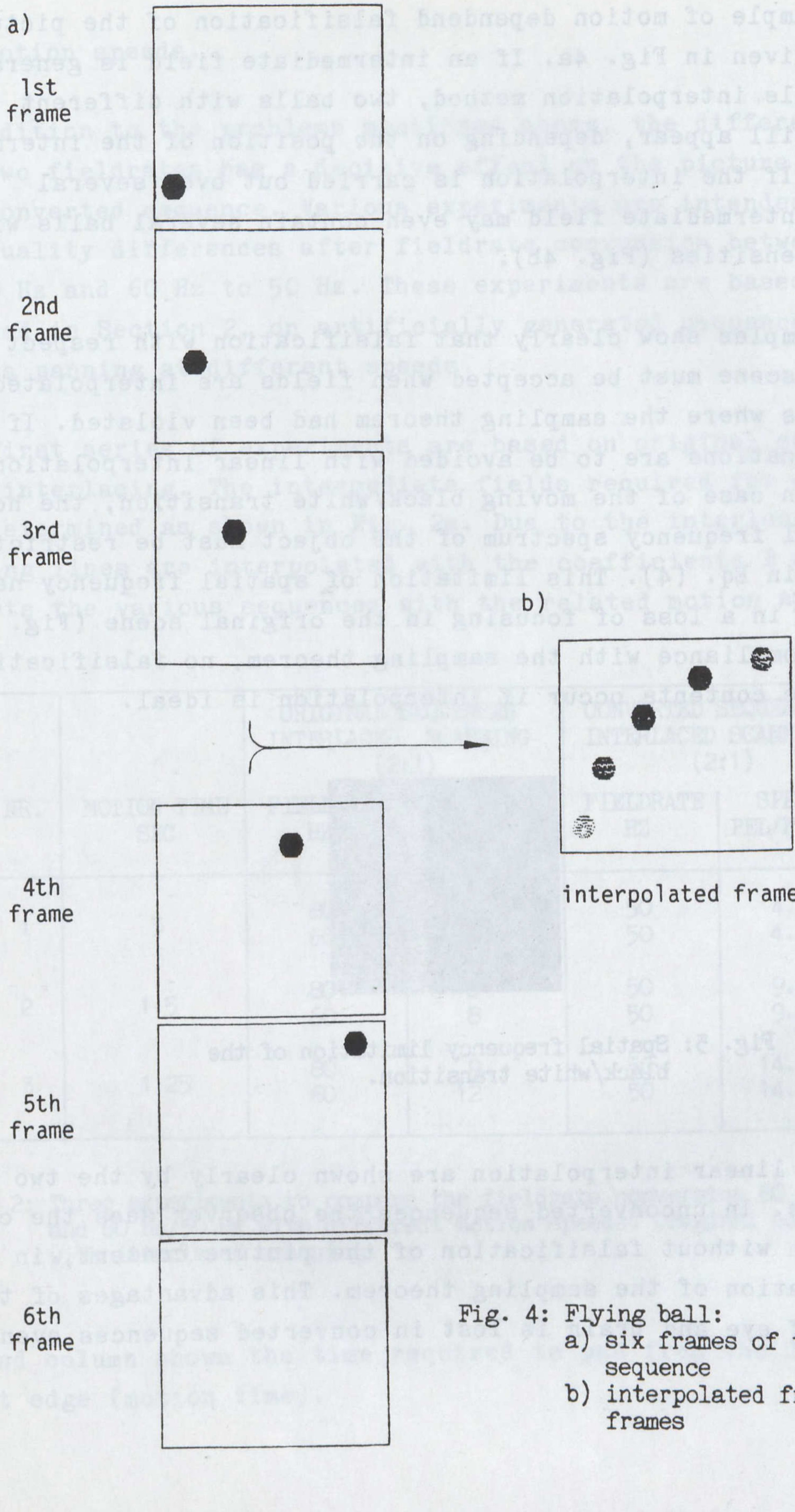

Fig. 4: Flying ball:
a) six frames of the original sequence
b) interpolated frame using six frames

A further example of motion dependend falsification of the picture contents is given in Fig. 4a. If an intermediate field is generated with the simple interpolation method, two balls with different intensities will appear, depending on the position of the intermediate field. If the interpolation is carried out over several fields, the intermediate field may even contain several balls with different intensities (Fig. 4b).

These two examples show clearly that falsification with respect to the original scene must be accepted when fields are interpolated from sequences where the sampling theorem had been violated. If these falsifications are to be avoided with linear interpolation, for example in case of the moving black/white transition, the horizontal spatial frequency spectrum of the object must be restricted as specified in Eq. (4). This limitation of spatial frequency naturally results in a loss of focusing in the original scene (Fig. 5) but, due to compliance with the sampling theorem, no falsification of the picture contents occur if interpolation is ideal.

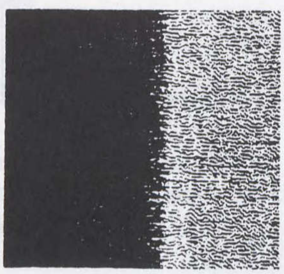

Fig. 5: Spatial frequency limitation of the black/white transition.

The limits of linear interpolation are shown clearly by the two examples above. In unconverted sequences the observer sees the continuous motion without falsification of the picture content, in spite of violation of the sampling theorem. This advantages of the combination of eye and brain is lost in converted sequences even at low motion speeds.

In addition to the problems mentioned above, the difference between the two fieldrates has a decisive effect on the picture quality of the converted sequence. Various experiments are intended to show the quality differences after fieldrate conversion between 80 Hz to 50 Hz and 60 Hz to 50 Hz. These experiments are based, as described in Section 2, on artificially generated sequences with camera panning at different speeds.

The first series of experiments are based on original sequences with interlacing. The intermediate fields required for conversion are determined as shown in Fig. 2a. Due to the interlacing, the missing lines are interpolated with the coefficients B and C. Table 2 lists the various sequences with the related motion speeds. The

NR.	MOTION TIME SEC	ORIGINAL SEQUENCES INTERLACED SCANNING (2:1)		CONVERTED SEQUENCES INTERLACED SCANNING (2:1)	
		FIELDRATE HZ	SPEED PEL/FIELD	FIELDRATE HZ	SPEED PEL/FIELD
1	3	80 60	3 4	50 50	4.8 4.8
2	1.5	80 60	6 8	50 50	9.6 9.6
3	1.25	80 60	9 12	50 50	14.4 14.4

Table 2: Three experiments to compare the fieldrate conversion 80 Hz/50 Hz and 60 Hz/50 Hz with different motion speeds. Original sequences with interlaced scanning.

second column shows the time required to pan from the left to the right edge (motion time).

In the second series of experiments, progressively sampled sequences are used (Table 3), as frames are basically available in a conversion from HDTV to TV systems with 625 or 525 lines. Fig. 2b shows the procedure required for interpolation. As the original sequences are sampled progressively, interpolation of the missing lines is not necessary.

NR.	MOTION TIME SEC	ORIGINAL SEQUENCES PROGRESSIVE SCANNING (1:1) FRAME HZ	SPEED PEL/FRAME	CONVERTED SEQUENCES INTERLACED SCANNING (2:1) FIELDRATE HZ	SPEED PEL/FIELD
1	3	80 60	3 4	50 50	4.8 4.8
2	1.5	80 60	6 8	50 50	9.6 9.6
3	1.25	80 60	9 12	50 50	14.4 14.4

Table 3: Three experiments to compare the fieldrate conversion 80 Hz/50 Hz and 60 Hz/50 Hz with different motion speeds. Original sequences with progressive scanning.

Finally, the same sequences (progressive scanning) as above are used again (Table 3), but, discribed in /3/, four pictures are used for linear interpolation of the intermediate fields. The set of coefficients is in each case matched to the framerates of the sequences in accordance with the suggestion by I. Childs /4/. If the three experiments are compared with each other, then the loss of quality after conversion from 60 Hz to 50 Hz, compared with conversion from 80 Hz to 50 Hz, is clearly visible. As expected, the qualtity losses increase with motion speed. These results support the experiments made by BBC.

As the experiments are based on relatively high motion speeds and artificially generated sequences, the overall picture quality of the converted sequences is not satisfactory. The aim of these experiments was not the absolute, but the relative picture quality - the quality differences between fieldrate conversion 80 Hz/50 Hz and 60 Hz/50 Hz. Furthermore, the systematic weaknesses of fieldrate conversion with linear interpolation which were discussed at the start of this paper became very obvious during these experiments.

If the first and second series of experiments are compared with each other, then it can be seen that a further quality reduction must be accepted due to the additional line interpolation in the case of the original sequences with interlacing.

The above experiments clearly show the problems of fieldrate conversion with linear interpolation and the reduction in picture quality related to motion speed. The picture quality can certainly be improved by suitable measures such as motion compensation and displacement estimation. However, it is questionable whether a suitable method can be found to permit conversion between HDTV standards with interlacing and different fieldrates without reducing the picture quality in the case of complex motion. Due to this question, which is extremely difficult to answer, a worldwide HDTV fieldrate would be desirable. In order to permit conversion into TV standards with a fieldrate of 50 Hz or 60 Hz with only slight quality losses, HDTV should have a higher fieldrate than these standards.

4.2 Fieldrate conversion starting from a superinterlaced TV-system

We have seen before, that usual fieldrate conversion methods work well only when the Nyquist theorem is not violated. Therefore systems with fieldrates higher than 50 Hz, 60 Hz or even 80 Hz are of interest.

A proposal in this direction was made by Powers /1/. The aim of this work was to get a HDTV system from wich other existing standards like film and different normal TV standards could be derived easily. This means, that not only fieldrate but also line number and aspect ratio have to be converted.

Our main interest was the possibility of converting the fieldrate. Therefore we simplified this proposal in some details, that did not concern our investigations. Standardized fieldrates are 24 Hz for film and 50 Hz or 60 Hz for TV systems. For achieving compatibility with all these systems a fieldrate of 600 Hz was proposed, which is 25x24 Hz or 12x50 Hz or 10x60 Hz. Technical realisation of such a high fieldrate is possible only in combination with a high interlace factor. 15:1 is proposed in /1/ with an interlace sequence of (1+4(n-1))mod15 to make the high interlace factor less visible; n is the fieldnumber.

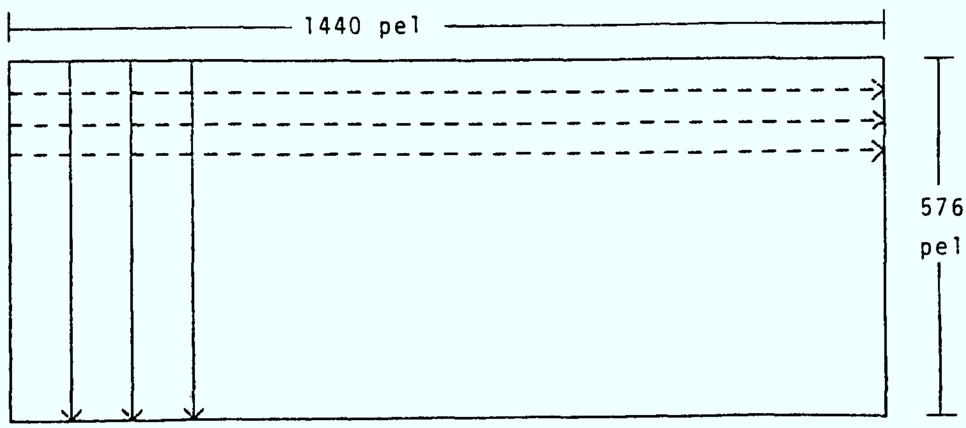

Fig. 6: Schematic picture of the framestore: The picture information is vertically written into the store with 600 fields per second, 15:1 interlaced with the interlace sequence (1+4(n-1))mod15; n is the fieldnumber. Reading is done in horizontal direction with 50 fields per second, 2:1 interlaced. Thereby each line is filtered down from 1440 pel to 720 pel.

In order to simplify line conversion and for some technical reasons the scanning of the picture is done in vertical direction. The information is written into a framestore and read out in horizontal direction with the desired fieldrate and line number (Fig. 6).

As we want to get a sequence with a fieldrate of 50 Hz, 2:1 interlaced, 576 lines/frame and 720 pel/line, one converted field with 288 lines has to be read out in the same time as 12 fields with 96 columns each are written. So after each four columns written into the framestore one line is read out and filtered down from 1440 pel to 720 pel. This algorithm has been applied to artificial sequences. Similar to the method described in section 2 these were generated by moving a window from left to right over a large still picture of 576 lines and 2880 pel/line. So the objects in the scene move from right to left over the screen.

By taking a very simple testpattern it is best seen how the algorithm works. A bar pattern is chosen with an inclination of 45 degrees, each line has a width of 24 pel in horizontal direction, that means 12 pel in the converted 50 Hz sequence. For different motion velocities Fig. 7 shows a magnified part of the content of the framestore, which is equivalent to a 600 fields per second monitor. The corresponding part of one field of the converted 50 Hz sequence is shown in Fig. 8. In the 50 Hz sequence the motion is 6 times the velocity of the 600 Hz sequence.

Because of the 15:1 interlace the content of the framestore is composed of the 15 most recent fields. This performs a kind of automatic temporal filtering or an interpolation over the last 1/40 second, the time of one frame. Of course this picture is highly structured, but the structures are quickly varying due to the high fieldrate. This fact is changed by the conversion to a 50 Hz fieldrate. Now the structures are frozen and simulate a wrong information in each field. The brain cannot reconstruct the correct picture and so the artifacts of the spatial subsampling become visible.

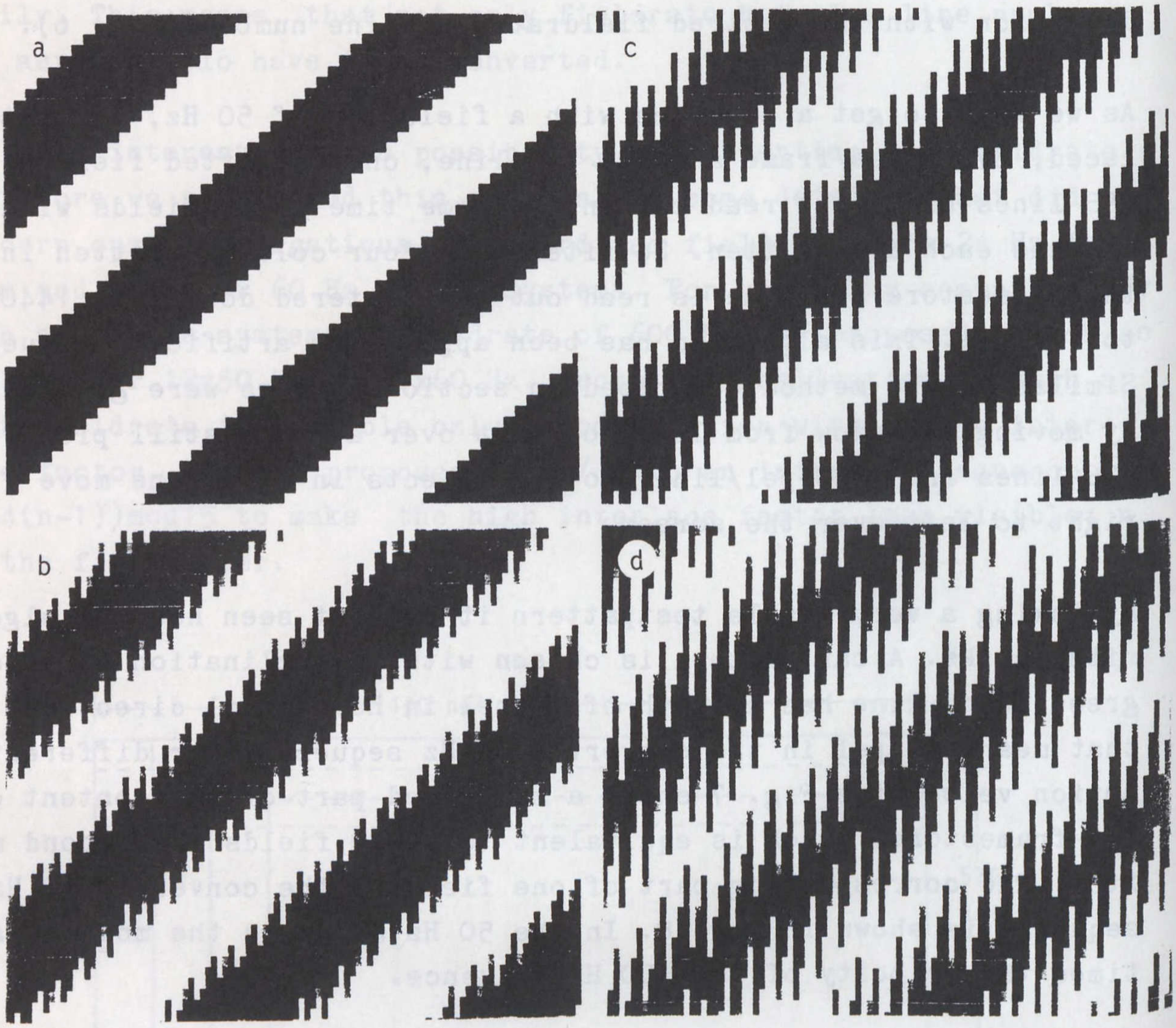

Fig. 7: Parts of the framestore content for different velocities: (a) v = 0 pel/field, standing picture, (b) v = 1/2 pel/field, (c) v = 1 pel/field, (d) v = 3/2 pel/field in the 600 fields/second sequence.

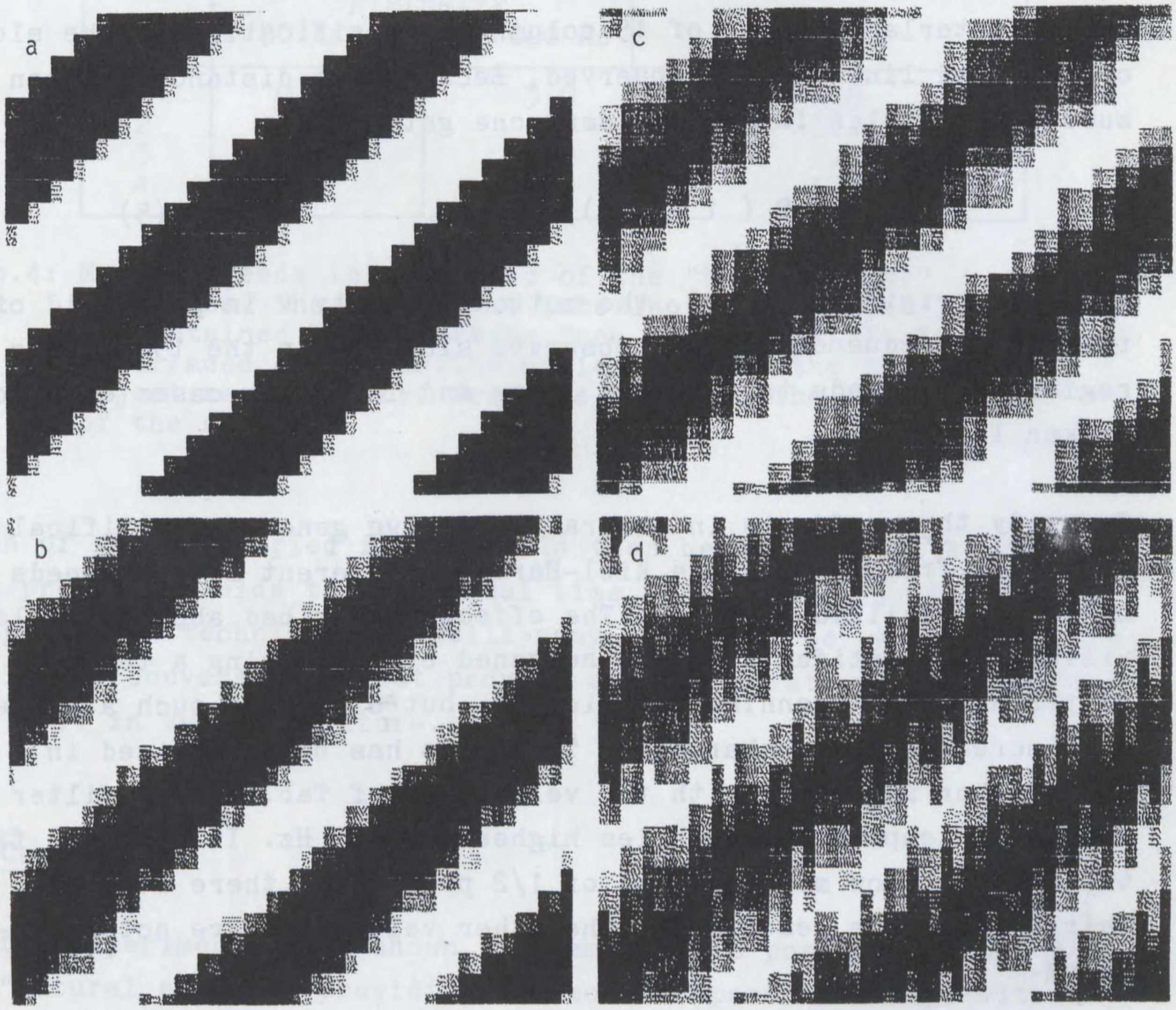

Fig. 8: Parts of one field of the converted 50 Hz sequence for different velocities: (a) v = 0 pel/field, standing picture, (b) v = 3 pel/field, (c) v = 6 pel/field, (d) v = 9 pel/field. The velocities for the 50Hz sequences correspond to those of Fig. 7.

Those artifacts depend strongly on the motion velocity. Of course, still pictures don't have any visible falsifications. With increasing motion unsharpness and ghosts on edges occur. Within the so called interlace period of 15 columns a falsification of the slope of inclined lines can be observed. Because the distance between two successive fields is four columns one gets

$$S' = S\ (\ 1 + v/4), \qquad (5)$$

with the original slope S, the motion velocity v in pel/field of the 600 Hz sequence and the observed slope S' in the 15 columns region. This leads to indented lines and in extrem cases even to broken lines.

To study these effects in natural scenes we generated artifical sequences from the picture Kiel-Harbor. Different motion speeds have been realized (Tab. 4). The effects described above are clearly visible. The artifacts can be softened by performing a temporal filtering while scanning the picture, but of course such a filtering increases the unsharpness. This also has been realized in Kiel-Harbor sequences with the velocities of Tab. 4. The filter used cuts temporal frequencies higher than 60 Hz. It has been fitted for the slow motion speed of 1/2 pel/field, there it works fairly well. The results for the other velocities are not satisfying.

With our artificial sequences we simulated an "ideal" camera without any lag. With a real camera the described artifacts should be less visible, because a continuous filtering in time is automatically performed by the tube. Nevertheless it is important to know the boundaries of a method, which can be experienced only under extreme conditions.

Like in the other methods for fieldrate conversion only a very good motion compensation could solve the problems. A spatial interpola-

SEQ.	SPEED (PEL/FIELD) FIELDRATE 50 Hz	600 Hz	MOTION TIME (SEC)
1	0.5	3.0	4.8
2	0.75	4.5	3.2
3	1.0	6.0	2.4
4	1.5	9.0	1.6

Tab.4: Motion speeds in pel/field of the "Kiel-Harbour" sequences. The 50 Hz, 2:1 interlaced sequences are obtained by conversion from the 600 Hz, 15:1 interlaced sequences.The motion time is the time an object needs to move from the right to the left side of the screen.

tion of the subsampled fields could then be done by extrapolating the previous fields to the actual time. Unfortunately the motion compensation technique has still many problems, so we believe, that fieldrate conversion cannot provide an appropriate picture quality for HDTV in the near future.

5. Conclusion

As the experiments have shown, subsampling is possible in the case of "natural scenes", providing the motion speeds are kept within certain limits. The observer is, under these assumptions, capable of seeing smooth motion without falsification of the original picture contents. If, however, fieldrate conversion with linear interpolation is used for subsampled moving scenes, then quality reductions must be expected.

Furthermore, it became apparent that higher quality losses occurred with fieldrate conversion from 60 Hz to 50 Hz, compared with 80 Hz to 50 Hz conversion. From the point of view of convertibility of HDTV into existing TV standards, a higher fieldrate, such as 80 Hz, would be more suitable with respect to a worldwide HDTV studio standard.

The TV system presented by Powers, with a fieldrate of 600 Hz and a column interlacing factor of 15:1, leads to resolution problems in the converted scenes due to the small number of columns per field. Vertical edges and lines may be busy, inclined lines even broken at higher horizontal speeds. This interference can be reduced by inclusion of suitable filters. However, a loss of resolution is the result.

As suitable algorithms will hardly be available in the near future to permit fieldrate conversion between various HDTV standards (with interlacing) without loss of quality, a worldwide HDTV studio standard is desirable. However, the convertibility of the HDTV standard into existing TV standards must not be ignored; this means that neither 60 Hz nor 50 Hz appear suitable for a worldwide HDTV fieldrate.

6. Acknowledgment

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A SCANNING SCHEME FOR A NEW HDTV STANDARD

3.3

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ABSTRACT

The progress of VLSI-techniques and digital signal processing makes feasible television systems with pre- and postprocessing, by this obtaining higher picture quality. Therefore, there are good reasons to think about a new HDTV standard taking into account the progress of signal processing for EDTV systems.

Results have been published on several proposals to improve picture quality such as

- progressive scan reproduction,
- vertical pre- and postfiltering,
- diagonal pre- and postfiltering.

By these methods impressive improvements of picture qualities can be achieved, which have been assessed by subjective tests comparing with the standard TV-system as well as with a high line number system.

As a main result it comes out that progressive scan reproduction is a powerful method to improve picture quality. Line flicker is overcome and the impression of resolution and sharpness is improved. This can be achieved by motion-adaptive progressive scan reproduction at the receiver end. But then there still remain heavy aliasing effects in moving picture parts due to the coarse line pattern of the field scanning. This can only be avoided by a progressive scan in the camera. Therefore, for a new HDTV standard field aliasing and the implementation cost for a motion controlled HDTV frame store can be avoided by a progressive scan production standard.

Another result out of the subjective tests is, that there is no Kell-factor for progressively scanned (natural) pictures. Therefore, to get a harmonic distribution of resolution, there is a demand for a higher horizontal resolution as it is in standard television systems. That means we need a bandwidth e.g. equal to the checkerboard frequency. This is a very important fact for a new HDTV standard.

Finally it was shown, that diagonal pre- and postfiltering is the best processing for a given video bandwidth or channel capacity. This is due to the fact, that diagonal processing is better matched to human eye and the distribution of contours in natural pictures.

From these results we can conclude that a new HDTV-standard could have the following properties

- progressively scanned signals
- harmonic resolution in horizontal and vertical directions,
- offset sampling and diagonal signal processing

This proposal will be presented at the conference.

SYSTEME DE BALAYAGE POUR UNE NOUVELLE NORME TVHD

3.3

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RÉSUMÉ

Les progrès des techniques VLSI et des méthodes de traitement des signaux numériques rendent possibles des systèmes de télévision comportant le pré-traitement et le post-traitement, permettant ainsi une qualité d'image supérieure. Par conséquent, il est tout naturel de penser à une nouvelle norme TVHD qui tiendra compte des progrès du traitement des signaux pour les systèmes EDTV.

Des résultats ont déjà été publiés concernant plusieurs propositions pour améliorer la qualité de l'image, par exemple:

- balayage progressif de l'écran,

- pré-filtrage vertical et post-filtrage vertical,

- pré-filtrage diagonal et post-filtrage diagonal.

Ces méthodes permettent des améliorations appréciables de la qualité de l'image, d'après les évaluation qui ont suivi à l'aide de tests subjectifs comparant ces méthodes avec le système de télévision conventionel et un système de télévision comportant un grand nombre de lignes. Le principal résultat de ces tests confirme que la reproduction du balayage par lignes contigues (balayage progressif) constitue une puissante méthode d'amélioration de la qualité de l'image. Le scintillement des lignes est éliminé et l'impression de définition et de netteté est améliorée. Le résultat voulu s'obtient par reproduction du balayage par lignes contigues avec compensation de mouvement au récepteur. Mail il reste encore des effets de repliement importants dans les zones en mouvement en raison de la configuration grossière des lignes de balayage de trame. Cela ne peut s'éviter que par le balayage par lignes contigues à la caméra. Par conséquent, dans le contexte d'une nouvelle norme HDTV, il est possible d'éviter le repliement et les coûts d'implantation d'une mémoire de trame TVHD avec compensation de mouvement, en ayant recours à une norme de production de balayage par lignes contigues.

Les tests subjectifs ont également montré qu'il n'y a pas de coefficient Kell dans le cas des images (naturelles) balayées par lignes contigues. Par conséquent, pour obtenir une distribution harmonique de la résolution, une meilleure résolution horizontale est nécessaire comme dans le cas des systèmes de télévision conventionels. Cela signifie que nous avons besoin d'une largeur de bande égale à celle de la mire en forme d'échiquier. Il s'agit là d'un fait très important dont if faut tenir compte pour établir une nouvelle norme TVHD.

Finalement, il a été montré que le pré-filtrage diagonal et le post-filtrage diagonal constituent le meilleur traitement possible pour une largeur de bande vidéo donnée ou une capacité de canaux donnée. Cela est dû au fait que le traitement diagonal est mieux adapté à l'oeil humain et à la distribution des contours des images naturelles.

A partir de ces résultats, nous pouvons conclure qu'une nouvelle norme TVHD pourrait comporter les caractéristiques suivantes:

- signaux balayés par lignes contigues;
- résolution harmonique dans les sens horizontal et vertical;
- échantillonnage avec compensation de mouvement et traitement diagonal des signaux.

Cette proposition sera présentée à la conférence.

INVESTIGATIONS ON RASTER CONVERSION FOR HDTV DISPLAY

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3.4

ABSTRACT

A second generation, experimental, real-time, motion adaptive raster conversion system is described. This produces simultaneous 625 line sequential and 1249 line interlaced outputs from a wideband 625 line interlaced input. Some subjective test results obtained both on monitors and large screen projectors will be presented.

The motion adaptive algorithm being used is explained, its limitations are analysed and the consequential effects on the displayed picture are discussed. Some suggestions for improved algorithms and some preliminary simulation results are also presented.

RECHERCHES SUR LA CONVERSION DE TRAME POUR PRÉSENTATION SUR ÉCRAN DE TÉLÉVISION À HAUTE DÉFINITION (TVHD)

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3.4

RÉSUMÉ

Ce rapport décrit un système expérimental de deuxième génération pour la conversion de trame en temps réel avec adaptation au mouvement. Ce système produit simultanément des signaux de sortie séquentiels de 625 lignes et des signaux de sortie entrelacés de 1 249 lignes, à partir d'un signal d'entrée à large bande de 625 lignes entrelacées. On y expose divers résultats obtenus dans des tests subjectifs qui ont été faits au moyen de moniteurs et de systèmes de projection sur grand écran.

On y explique aussi l'algorithme d'adaptation au mouvement qui est employé, on en analyse les limites et on en discute les effets sur l'image. Enfin, on y propose des améliorations des algorithmes et l'on y donne quelques résultats préliminaires des simulations.

INVESTIGATIONS ON RASTER CONVERSION FOR HDTV DISPLAY

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3.4

Introduction

Consumer acceptance of a broadcast HDTV service depends on it offering something significantly better than conventional TV. This will be done by widening the angle of view (i.e. by having larger displays with an increased aspect ratio) and by trying to remove all the artefacts and impairments due to the coding and scanning processes. There is virtually no possibility of there being broadcast channels that are able to carry the HDTV information in a form ready for direct display. Therefore there will be a need for substantial signal processing in the receiver.

In this paper we are primarily concerned with transmission systems that are 'raster compatible' with current standards but have an increased horizontal bandwidth e.g. extended MAC systems(1,2). The transmitted signal is in a wideband, component, interlaced format with 625 or 525 lines per picture. If displayed directly all the well-known defects of interlaced scanning displays would impair the picture.

Mitsuhashi(3) has shown, using a 60Hz field rate system, that a sequentially scanned picture with about 0.6n lines is of equivalent quality to a 2:1 interlaced picture of n lines.

Stollenwerk(4) has confirmed that this figure is also about right for 50Hz systems, but points out that the determining factor is the basic raster visibility. If the scene contains vertical detail of sufficiently high spatial frequency for the interlaced picture to exhibit interline flicker, then the sequential picture has an even greater advantage over the interlaced one. In these circumstances there is clearly a large potential improvement in picture quality to be gained by converting to a sequentially scanned display format. It must be noted however that the results referred to above were all obtained either with no standards conversion, or using non-moving scenes when error-free conversion is possible.

This paper addresses the problem of performing interlace to sequential conversion for sequences of moving images in such a way that the artefacts introduced by the conversion process do not detract from the improved quality of the sequential picture. A series of investigations has been undertaken using both real time hardware and computer simulations to try to evaluate the performance of various interlace to sequential conversion algorithms.

If a conversion has been performed so that there are (say) 625 lines available every 1/50 second then the question can still be asked whether it is better to display that information as a 625 line sequential picture or as a 1249 line interlaced picture. The interlaced picture with the larger number of lines will be better from the point of view of raster visibility, but depending on the characteristics of the display and the programme content, some interline flicker will be reintroduced. A second object of our investigations is to compare these two raster formats subjectively. The conversion from 625 line sequential to 1249 line interlaced is performed according to the scheme illustrated in Fig.1. This facility enables comparison to be made between the two scanning formats using sequences of realistic programme material and we hope to be able to present the latest subjective testing results at the Colloquium.

Since one of the key elements of HDTV is larger pictures we feel it is important to evaluate our results both on monitors and on high quality large-screen displays. We have developed such a projection display in our laboratory(5). This projector will produce a 5:3 aspect ratio picture with a diagonal of 1.5m. It is capable of displaying various raster formats including 625 lines sequential and 1249 lines interlaced with a video bandwidth exceeding 20MHz.

Basic method

Fig.2 illustrates the basic algorithm used for interlace to sequential conversion(6). To produce the extra line, 'E', in the sequential signal, a choice of two simple interpolations is available. These are temporal averaging of the adjacent fields, (A+B)/2, or vertical averaging of the adjacent lines, (C+D)/2. Temporal averaging removes line crawl and interline flicker and recovers the full vertical resolution. However, it involves the combination of samples from different points in time. In moving scenes this leads to the well-known serration effect from line to line which is subjectively very noticeable. Temporal averaging can therefore only be used for still parts of the scene. Vertical averaging only removes the line crawl, but gives no problems with movement.

Thus there is a need for movement adaption between the two averaging processes. In our original experimental equipment(6), movement adaptive processing was performed by comparing the picture difference signal, $|A-B|$, with a fixed threshold. If the picture difference was less than the threshold then temporal averaging was used, otherwise vertical averaging was used.

Problems with the basic method

Although movement adaption as described above produces a considerable improvement over non-adaptive systems it is still imperfect. Some of the main problems that occur when using this simple approach are:

1. Movement detection

Even with a noise-free signal, the movement detection can give incorrect results. The algorithm is not really detecting motion as such; it is detecting change from one picture to another. In some circumstances there will be no change detected on this basis, i.e. the signal at points A and B (Fig.1) will be the same, even though motion is present. A simple example is a horizontally moving vertical bar on a plain background. This is illustrated in Fig.3a. Field 0 represents the current field. The picture difference signal is the difference between the picture signals in fields 1 and -1 and will be zero during the period that the bar is being processed in field 0. Thus no movement will be detected and temporal interpolation will be incorrectly used with the result as shown in Fig.3b. Fig.3a is taken from Ref.7 where the fundamental problems with this type of movement detection are more fully discussed. In general, it is impossible on a local basis to unambiguously reconstruct a sequentially scanned picture from an original interlaced signal because a 25Hz temporal component in the interlaced signal can arise either from vertical detail in a still scene or from part of a moving scene.

2. Noise

In any real situation the picture signal will contain a certain amount of random noise. Thus even for a still scene the actual signal will vary from picture to picture by an amount depending on the signal to noise ratio. In our situation this means that the movement detector could incorrectly decide there was movement in a scene because of the presence of noise. The consequence of this is that vertical interpolation would be used instead of temporal. This false movement detection is not so subjectively damaging as failure to detect motion in the previous case but it means we are not getting the full benefit from the conversion process. One way of improving the situation is to make the value of the threshold vary with the measured signal to noise ratio. The problem then is that at higher noise levels the threshold will be increased and the amount of 'real movement' that is permitted before vertical averaging is applied will increase. Thus there is more chance of the field serration effect being produced.

3. Switching between interpolations

The basic method involves a binary decision on each pixel to determine which interpolation method to use. This means there will be sharp transitions between parts of the picture using different interpolations which in some circumstances can cause visible artefacts. There is also the possibility of frequently switching back and forth from one interpolation method to the other on a pixel to pixel basis. This can be caused by the picture difference signal going rapidly above and below threshold due to added noise. This leads to an undesirable 'business' particularly around the edges of moving objects.

Approaches to an improved algorithm

We will describe three approaches to improving the performance of the sequential converter described above. These are based on processing of the picture difference signal, on improved movement detection methods and on 'soft' switching between interpolation methods. Of course these approaches may be combined but, for clarity, we will start by separately describing some possible options.

1. Processing the picture difference signal

As stated above it is impossible on a local, pixel by pixel, basis to always reconstruct the correct sequential signal. However in 'real-life' scenes it is unlikely that there will be sequences of pixel to pixel changes between stationarity and movement. Any such sequences that are produced by our basic movement detector are therefore likely to be spurious. One way of using this knowledge is to low-pass filter the picture difference signal before applying thresholding. We have investigated two implementations by simulation:

a) Spatial low-pass filtering

The picture difference signal is spatially low-pass filtered before thresholding. The smoothing operation of the filter reduces the influence of noise on the movement detector signal and prevents the rapid fluctuation in interpolation referred to above. The smoothing operation will spatially 'spread' the picture difference signal, the amount of spreading being related to the impulse response of the filter.

We have experimented with a simplified version of this approach which just applies horizontal low-pass filtering. Fig.4 shows a portion of a single field of a sequentially scanned image sequence. It has been converted from an interlaced original using the basic method described earlier. The original scene was moving horizontally at a speed of approximately 6 secs/picture width. Conversion artefacts can be seen as the white 'blobs' in the vertical black beams of the building. Fig.5 shows the same scene converted to sequential scan with a 5-element low-pass horizontal filter applied to the picture difference signal before thresholding. The improvement can be clearly seen. In each case the switching threshold had a value of 20 (the range of the video signal was from 7 to 221).

b) Temporal low-pass filtering

Time smoothing can also increase the reliability of the movement estimation measure by preventing rapid fluctuations in interpolation method. This can be achieved by applying a temporal low-pass filter to the picture difference signal. Transversal filters could be used although this would require a large number of field stores for delays. However, a similar amount of smoothing can be achieved with a recursive filter where the number of field delays required will be minimal.

A first order recursive filter has the form shown in Fig.6, and its response is given by:

$$y(t) = m.x(t) + (1-m).y(t-T)$$

where $x(t)$ is the input - in our case the magnitude of the picture difference signal - and $y(t)$ is the output; m is the parameter that determines the effective length of the filter impulse response. T is the time delay used and in our application could be either a field or picture delay. The result of applying this process to the same scene as before is shown in Fig.7. For this experiment the time delay was one input picture period, i.e. 40 msecs, the factor 'm' was 0.4 and the threshold was again 20. An improvement can be seen over the basic method used in Fig.4 but there are still some visible artefacts present. It should be mentioned that the parameters used both here and in the previous example are not optimised, they are given merely as examples. Comparing Figs.5 and 7, the horizontal filter appears to give the better results, but this particular scene is a rather special case where only horizontal motion is present.

To reduce the storage requirements for the temporal low-pass filter it is possible to group together the picture difference information for a block of pixels. This reduces both the storage capacity and the data rate in the field delays of the recursive filter. Such an approach has been tried with reported good results in[8].

2. Improved movement detection

So far, we have only looked at picture difference signals for movement detection. There are inherent problems in confining ourselves to this measure as exemplified in Fig.3a. Here the velocity of the moving bar is such that there is no change detected when comparing signals one picture period apart. Obviously, if the signals one field period apart were compared, then the 'motion' would be detected. The difficulty with doing this is that, in the interlaced signal, information at identical spatial positions one field period apart is not available. One way to overcome the problem is to vertically low-pass filter the field information before making the comparison. This gives a useful extra measure of the amount of movement in the scene which can then be combined with the picture period based movement information to give an overall measure of the movement in the scene.

The movement detection methods mentioned so far have all been based on pixel to pixel comparisons. Another approach would be to peform some form of correlation between groups of pixels separated in time. Many such methods have been described in the image processing literature (e.g. [9]). All of them tend to require considerable amounts of signal processing and it is open to question when (or if) such techniques will find application in consumer oriented equipment.

3. Soft switching

Instead of changing abruptly from one interpolation to another depending on whether the movement detector signal is above or below a threshold, it is possible to 'soft switch' gradually depending on the magnitude of the picture difference signal. In the simplest case, referring again to Fig.1, we now have:

$$E = K.(C+D)/2 + (1-K).(A+B)/2$$

where $K = f(|A-B|) \quad 0 < K < 1.$

The function f() relates the magnitude of the picture difference signal to the value of K. In general, the form of the function would have to be chosen on the basis of subjective evaluation of the converted picture, though the form of the function will probably be as shown in Fig.8. K is biased towards temporal averaging in the case of little movement and towards vertical averaging in the case of greater movement. Now the interpolated pixel value depends on the four surrounding pixels in the vertical and temporal directions.

Soft switching can be applied in conjunction with any of the foregoing methods of movement detection and filtering of the movement signal.

Experimental Work

Currently we are using a second generation converter which has several extra facilities compared to our earlier machine. Firstly, it converts from a wideband 625 line interlaced signal to both a 625 line sequential and a 1249 line interlaced signal. Secondly, the movement adaption is capable of 'soft' switching between vertical and temporal averaging. This means that the interpolated line in the sequential output is composed of a linear combination of vertically averaged signal and temporally averaged signal as described above. In this particular equipment the factor 'K' depends on both the frame difference (A-B) and vertical difference (C-D) signals. Whichever of these is the smaller is used to address a PROM which contains the mapping function relating the difference signal to the value of K. In practice there are a finite number of values for K. In our current hardware implementation these consist of 9 steps of 1/8 from zero to unity.

This equipment enables subjective comparisons of the conversion process to be carried out using different mapping functions for the soft switching. Whereas simulation methods are invaluable in initially testing a variety of algorithms, we believe that it is also necessary to use real time hardware in the evaluation process. In particular this allows the performance of a conversion algorithm to be judged on many lengthy sequences of programme material.

Conclusion

The measures described above give noticeable improvements to the interlace to sequential conversion process. However there will still be some situations where the picture content is such that the process 'fails' and produces annoying artefacts. To go further, it is probably necessary to change the conceptual level of the conversion process.

We have said above that in the interlaced signal it is impossible to distinguish on a local basis between stationary vertical detail and movement. However, the viewer watching a conventional television receiver has no such difficulty! This is, of course, because he has a wealth of contextual information and usually recognises features or objects within the image on the screen. He knows, for instance, that the edge of a familiar object does not suddenly serrate when it starts to move.

To take advantage of such concepts in our situation is not easy. It represents a considerable image processing problem to recognise and to track features or objects even in a simplified and controlled environment. In broadcast television, where (almost) anything can appear on our screens, it is even more formidable. If however, image recognition and tracking is possible, then it opens the door to movement compensated processing with potentially improved results for such processes as interlace to sequential conversion. Such ideas are starting to attract attention in the broadcast TV world as can be seen from the NHK work on MUSE and field rate conversion. How far this can go and how realistic it is to consider such processing in the TV receiver are questions for the future.

Acknowledgements

We would like to acknowledge the contribution to this work of our colleague Mr M.G. Hulyer.

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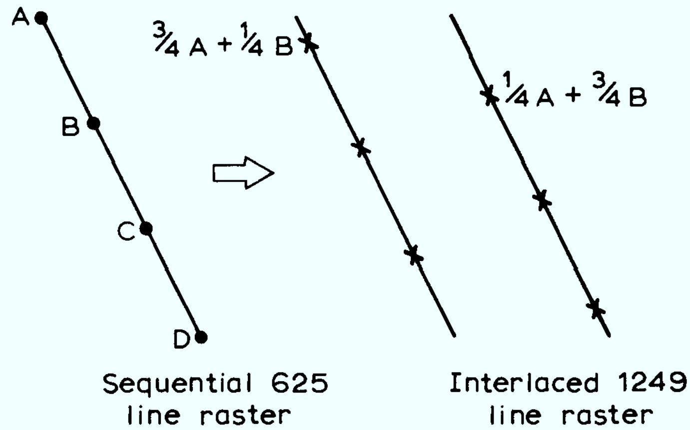
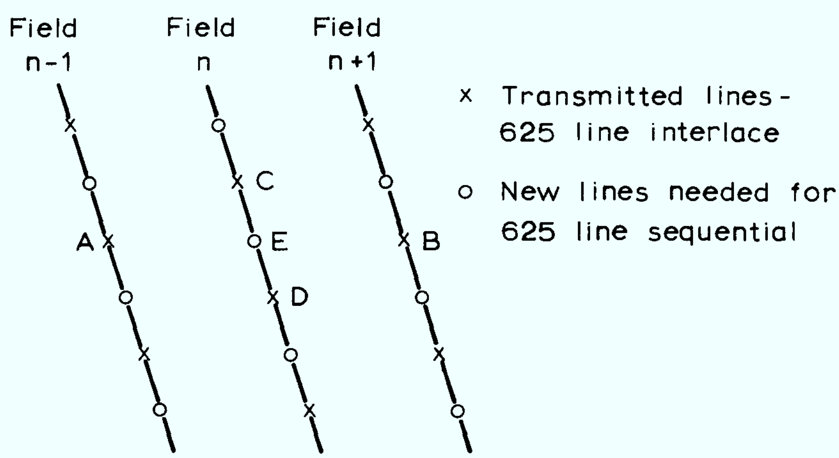


Fig. 1. Conversion from a 625 line sequential to a 1249 line interlaced raster.



For still pictures (field averaging): $E = \frac{1}{2}(A+B)$

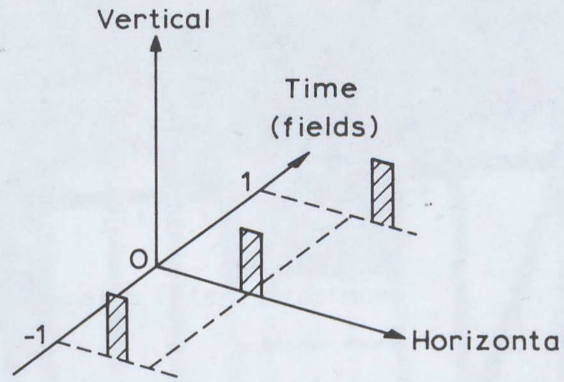
For moving pictures (line averaging): $E = \frac{1}{2}(C+D)$

Simple movement detector

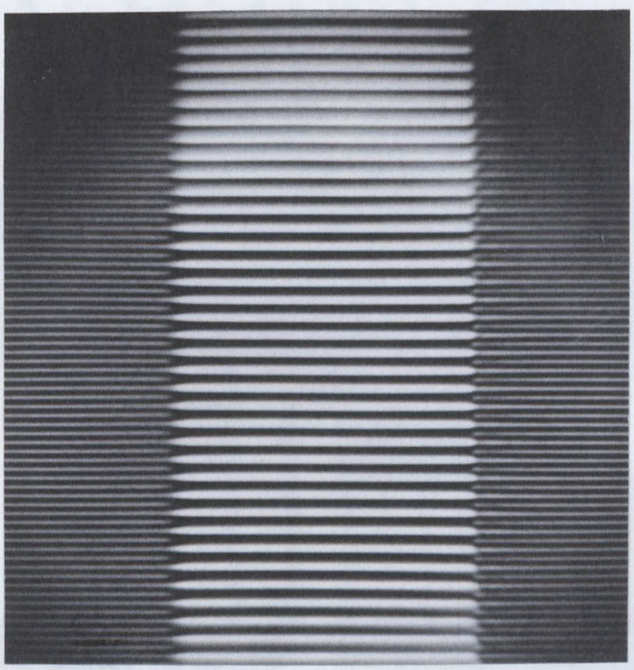
still : if $|A-B| < \text{threshold}$

moving : if $|A-B| > \text{threshold}$

Fig. 2. Interlace to sequential conversion.



(a) A horizontally moving bar over three television fields.



(b) Sequentially scanned TV picture of a horizontally moving vertical bar. One frame exposure.

Fig. 3.

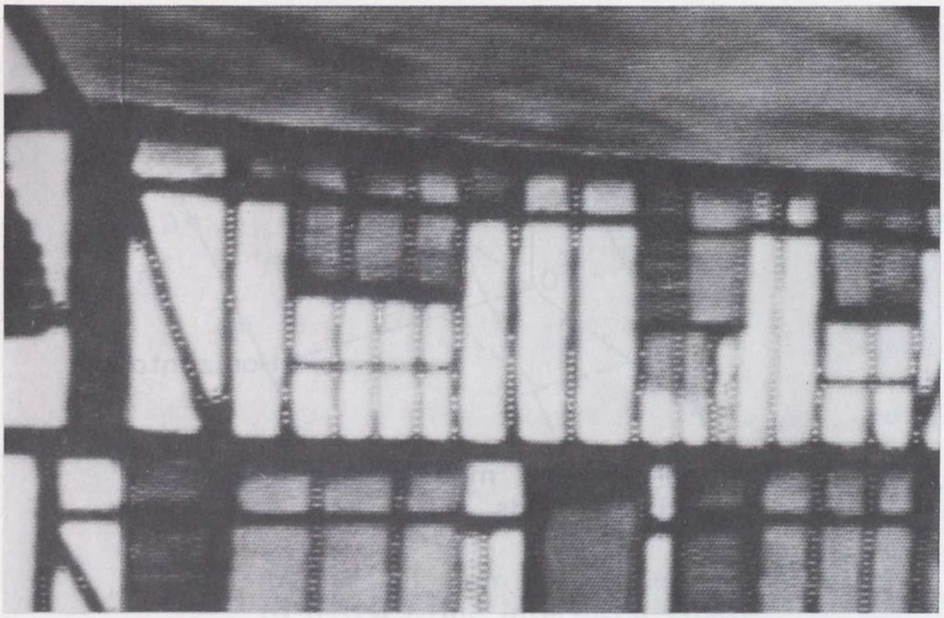


Fig. 4. Basic movement adaptive method.
Sequential scan, single frame exposure.

Fig. 5. Movement adaption with horizontal filtering
of the picture difference signal.
Sequential scan, single frame exposure.

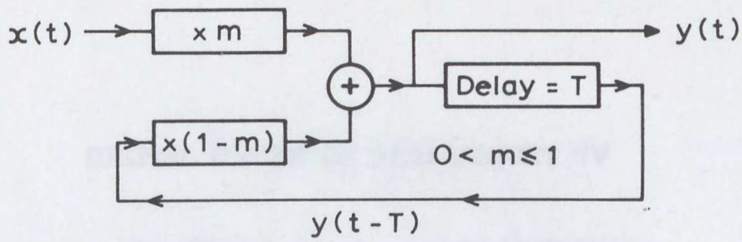


Fig.6. Recursive filter structure.

Fig. 7. Movement adaption with temporal filtering of the picture difference signal.
Sequential scan, single frame exposure.

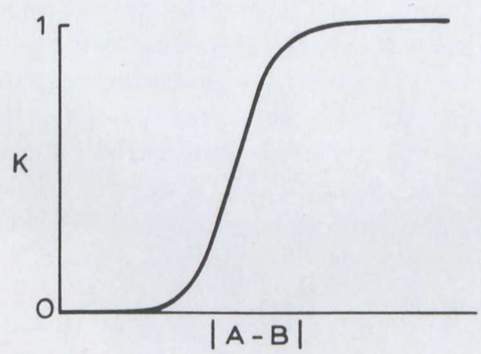


Fig. 8. Relation between soft switch parameter, K, and picture difference signal.

DIGITAL CODING OF HIGH QUALITY TV

3.5

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ABSTRACT

The digital coding of high quality television signals at different sampling densities is considered. A theoretical analysis of image coding performance using rate distortion theory based on an isotropic image model is carried out. These results are used to determine bounds on the performance of practical coders as a function of the sampling density. The analysis quantifies the widely known fact the coding efficiency increases with the sampling density.

Experiments have been carried out to verify these results with a particular coding algorithm under conditins approximating those of high definition television (HDTV) and enhanced quality television (EQTV) with-up conversion at the receiver. The coding algorithm used is transform coding with the discrete cosine transform. This method has been chosen because it is capable of operating over a wide range of bit rates. The theoretical analysis and preliminary coding experiments indicate that the rate required to code the HDTV signal near the threshold of visibility of impairments is about 1.8 times the rate required for the EQTV system.

CODAGE NUMÉRIQUE DES SIGNAUX DE TÉLÉVISION DE HAUTE QUALITÉ

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RÉSUMÉ

Le codage numérique des signaux de télévision de haute qualité est étudié pour différentes densités d'échantillonnage. Une analyse théorique de la performance des codeurs pratiques en fonction de la densité d'échantillonnage.

Des expériences ont été effectuées afin de vérifier ces résultats avec un algorithme de codage particulier, sous des conditions approchant celles de la télévision à qualité améliorée (EQTV) utilisant l'interpolation au récepteur. Le codage par transformée en cosinus a été utilisé. L'analyse théorique et des expériences préliminaires de codage indiquent que le débit requis pour coder des signaux de HDTV près du seuil de visibilité de distorsion est environ 1.8 fois le débit requis pour le système EQTV.

Digital Coding of High Quality TV

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3.5

1. Introduction

The study and development of systems for higher quality television has seen tremendous growth in recent years. This has been motivated by the fact that existing television systems give inadequate picture quality, especially for viewing on large screen displays. The main impairments which have been identified are scanning artifacts (line stucture visibility and flicker), limited resolution, and luminance/chrominance cross effects. The approaches which have been proposed to reduce these impairments are high-definition television (HDTV) and various enhanced quality television (EQTV) schemes. HDTV involves scanning the original scene with an increased number of lines per frame (usually more than 1000), and with correspondingly greater horizontal bandwidth. This signal is directly transmitted and displayed on a HDTV monitor. EQTV systems have been proposed as a possible alternative to — or as an intermediate step towards — HDTV. In EQTV the transmission is compatible with the NTSC (PAL or SECAM) standard, at least in scan format, but the quality is improved by signal processing in the transmitter and receiver to reduce the visibility of scanning artifacts and luminance/chrominance cross effects. In this paper, we are concerned with techniques to reduce the visibilty of scanning artifacts. In this form of EQTV system, HDTV cameras and monitors are used. The signal is down-converted to the NTSC scanning standard in the transmitter, and up-converted in the receiver for the HDTV display. EQTV offers a picture quality that is somewhat inferior to HDTV; however, it gives a dramatic improvement on standard NTSC while maintaining full transmission compatibility.

Television signals can be distributed in either analog or digital form. Of course analog transmission is predominant at this time, and the existence of large numbers of NTSC channels and receivers is the main motivation behind EQTV. If analog transmission of HDTV is foreseen, the analog bandwidth will be at least four times that of the NTSC channel, and generally more depending on the aspect ratio and color coding format used. Digital transmission facilities are becoming increasingly available and will largely replace analog transmission (except perhaps in over-the-air broadcasting). Digital transmission allows for the use of sophisticated digital source coding techniques to make efficient use of the available channel. With such coding, the HDTV signal does not require the large increase in digital transmission capacity that is indicated by the analog bandwidth [1]. This is due to several factors:

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- The HDTV signal has higher correlation between adjacent samples due to the finer sampling grid; hence, it contains more statistical redundancy which can be removed by digital coding.

- The quantization noise in the HDTV signal is distributed over a larger spatial bandwidth. Due to the characteristics of the human visual system, the distortion is significantly less visible in an HDTV system than in an EQTV system at the same signal to distortion ratio.

- The up-converter in the EQTV receiver generally amplifies high spatial frequencies to improve the contrast; however, the coding error is also amplified. Hence, the visibility of quantization errors is further increased, imposing more stringent requirements for coding of EQTV signals.

The goal of this paper is to study digital image coding performance as a function of sampling density. It should be noted that the theoretically optimum coding scheme that uses a higher sampling frequency can always give at least as good quality as an optimum coder operating at a lower sampling frequency with the same rate in bits per second — at the higher sampling frequency there is more freedom to make a trade-off between resolution and quantization noise.[1] Another important question addressed is the required bit rate for transparent transmission at different resolutions. In this case, we want to transmit a picture at a given sampling frequency in such a way that there is no visible degradation compared to the *sampled* original.

Section 2 of this paper presents an analysis of theoretical coding performance for different sampling densities. The tool used for this analysis is rate distortion theory. Both distortion with respect to an unsampled continuous picture, and with respect to the sampled original, are derived. The distortion measure takes into account the response of the visual system by using a frequency weighted mean square error criterion.

In section 3 we present the coder structure used for our studies. A theoretically optimum coding scheme makes a trade-off between resolution (i.e., bandwidth) and in-band noise (quantization). This trade-off can also be achieved in a transform coder to some extent; this is the reason that a transform coding scheme can generally operate at lower bit rates (per pel) than a predictive coder. At high rates they should theoretically be equivalent; both coders are transmitting the full available bandwidth, and no trade-off can be made between resolution and quantization noise. Our coding experiments were performed using transform coding. Since we want to compare results at different sampling densities, it is important to have a coding scheme capable of working over a wide range of rates in bits per pel. Intraframe adaptive transform coding was used. Higher compression ratios can be achieved with interframe coding; however, we believe that it is necessary to use adaptive techniques such as motion compensation [2] to get a significant gain over intraframe coding, especially on critical broadcast scenes such as panning.

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[1] Nevertheless, in a digital image transmission system the choice of sampling frequency is not primarily governed by the available bit rate, since the image quality can be expected to depend on the number of bits *per unit area* rather than the number of bits per pel. Instead, the reason for not choosing an excessively high sampling frequency is to limit the processing requirements, usually a linear function of the sampling frequency.

Section 4 outlines the simulation methods we used to compare digital coding for HDTV and EQTV and presents some preliminary results. Conclusions are given in section 5.

2. Rate Distortion Analysis of Coding at Different Resolutions

In this section we give an estimate of the required bit rate to code an image at different resolutions. The rate *per pel* for a given distortion will be lower at higher resolution due to increased correlation between adjacent pels and decreased visibility of quantization noise. In the analysis, we will determine the rate distortion function [3] for a simple image model. This is a lower bound for the performance of any coding scheme. Several simplifications are made in order to get a tractable problem; the most restrictive is the assumption that the source signal can be modelled as a stationary Gaussian source. Neither the stationarity nor the Gaussian assumption are valid for typical images; however, it is interesting to see whether bit rate predictions based on a simple model can be extrapolated to the practical case.

We start by determining the rate distortion function for a continuous image source; the rate is expressed in bits per unit area. Then, the effects of sampling are analyzed. A weighted square error criterion is incorporated to account for the properties of the human visual system (HVS).

2.1 R(D) for a spatially continuous image source

The MSE (mean square error) rate distortion function of a time-continuous stationary Gaussian source with power spectrum $\Phi(f)$ has the parametric representation

$$\begin{aligned} D_\theta &= \int_{-\infty}^{\infty} \min[\theta, \Phi(f)] df \\ R(D_\theta) &= \frac{1}{2}\int_{-\infty}^{\infty} \max\left[0, \log\frac{\Phi(f)}{\theta}\right] df \end{aligned} \tag{1}$$

where D_θ is the MSE for a certain choice of the distortion parameter θ, and $R(D_\theta)$ is the corresponding rate. $R(D)$ represents the lowest rate which can be obtained by any coding method with distortion less than or equal to D. Fig. 1 illustrates the situation. The regions of the spectrum where $\Phi(f) \leq \theta$ will never be transmitted, while the other parts are quantized with Shannon quantizers that give the distortion θ, requiring the rate $\frac{1}{2}\log(\Phi(f)/\theta)$. Hence, we get an error spectrum $\Phi_N(f) = \min[\theta, \Phi(f)]$. The generalization of (1) to multi-dimensional signals is straightforward.

When the MSE is computed, it is assumed that the error generated by deleting regions of the spectrum (filtering error) is equivalent to quantization error; however, it is straightforward to modify the procedure for a distortion criterion giving a higher weight to quantization error than to filtering error.

A frequency-weighted MSE,

$$D = \int |W(f)|^2 \Phi_N(f)\, df \tag{2}$$

is easily incorporated by filtering the source signal with a filter having a frequency response equal to $|W(f)|$. Then, the rate distortion function is computed for the filtered signal with

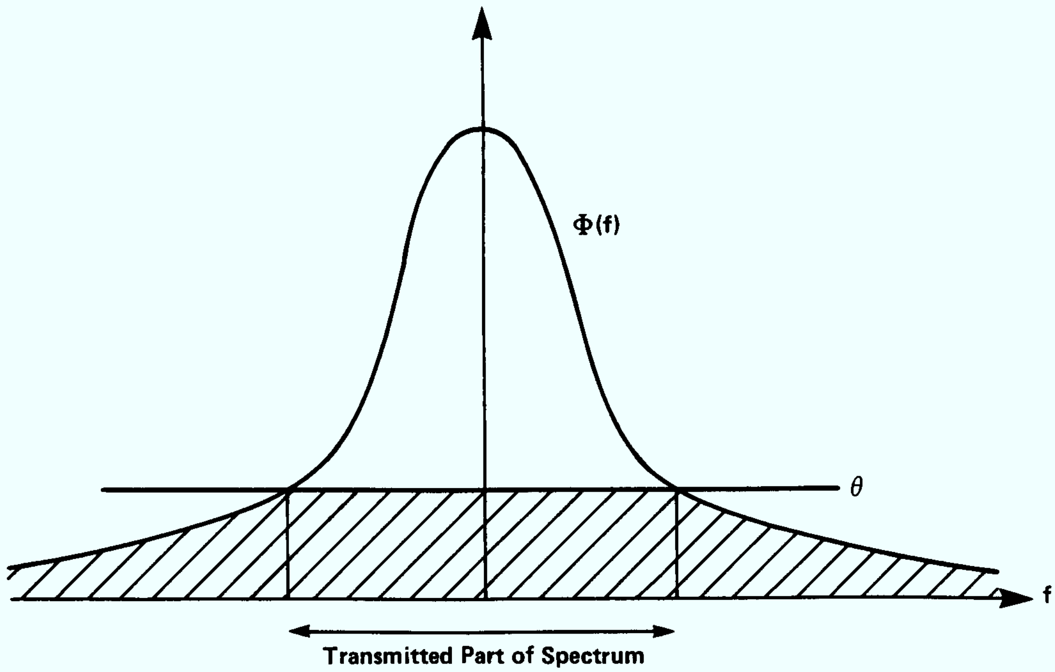

Fig. 1 Power spectrum of stationary Gaussian source and error under optimal source coding.

spectrum $\Phi(f)|W(f)|^2$. In the receiver, an inverse filtering is performed, and we obtain the error spectrum

$$\Phi_N(f) = \min\left[\frac{\theta}{|W(f)|^2}, \Phi(f)\right]. \tag{3}$$

Two commonly used models for still image statistics are a separable and an elliptic covariance model. A separable two-dimensional autocorrelation function (acf) that is exponential in both dimensions is given by

$$\phi_{sep}(x_1, x_2) = \sigma^2 \exp(-\alpha_1|x_1| - \alpha_2|x_2|). \tag{4}$$

The elliptic acf is defined as

$$\phi_{ell}(x_1, x_2) = \sigma^2 \exp(-\sqrt{(\alpha_1 x_1)^2 + (\alpha_2 x_2)^2}). \tag{5}$$

For $\alpha_1 = \alpha_2$ the elliptic model gives an isotropic acf. The separable acf is preferable if the images are dominated by horizontal and vertical edges. If there is a significant content of diagonal structures, the elliptic model is better.

Our analysis will be concentrated on the elliptic model. The power spectrum is given by

$$\begin{aligned}\Phi_{ell}(f_1, f_2) &= \frac{2\pi\sigma^2/(\alpha_1\alpha_2)}{(1 + (2\pi f_1/\alpha_1)^2 + (2\pi f_2/\alpha_2)^2)^{3/2}} \\ &= \Phi_{iso}(\omega_r) = \frac{2\pi\sigma^2/(\alpha_1\alpha_2)}{(1+\omega_r^2)^{3/2}}, \qquad \omega_r = 2\pi\sqrt{(f_1/\alpha_1)^2 + (f_2/\alpha_2)^2}.\end{aligned} \tag{6}$$

The rate distortion function for the elliptic model can be shown to have the parametric representation [4]

$$\begin{aligned}D_{\omega_{cut}} &= \sigma^2 \frac{1 + \frac{3}{2}\omega_{cut}^2}{(1+\omega_{cut}^2)^{3/2}} \\ R(D_{\omega_{cut}}) &= \frac{3\alpha_1\alpha_2}{16\pi}(\omega_{cut}^2 - \log(1+\omega_{cut}^2)).\end{aligned} \tag{7}$$

The parameter ω_{cut} is the normalized cut-off frequency; the region outside the ellipse

$$\left(\frac{2\pi f_1}{\alpha_1}\right)^2 + \left(\frac{2\pi f_2}{\alpha_2}\right)^2 = \omega_{cut}^2 \tag{8}$$

is not transmitted. The region inside the ellipse is transmitted with an error $\theta = \Phi_{iso}(\omega_{cut})$. The rate distortion function is plotted in Fig. 2.

2.2 R(D) for a sampled image source

To study the effects of sampling we will assume that an ideal low-pass filtering is performed before sampling to avoid aliasing. After low-pass filtering, sampling and reconstruction is a transparent process. Hence, the effects of sampling are equivalent to the effects of low-pass filtering.

Denote the passband by B_p,

$$B_p = \{(f_1, f_2) : \ -f_{p1} < f_1 < f_{p1} \ \wedge \ -f_{p2} < f_2 < f_{p2}\}. \tag{9}$$

This passband applies for rectangular sampling. For different sampling structures, other passbands are more appropriate [5]. Ideal low-pass filtering gives the spectrum Φ_{LP}:

$$\Phi_{LP}(f_1, f_2) = \begin{cases}\Phi(f_1, f_2), & (f_1, f_2) \in B_p \\ 0, & (f_1, f_2) \in \overline{B}_p\end{cases} \tag{10}$$

The rate distortion function is denoted $R'(D')$, where the distortion D' is the MSE compared to the *unfiltered* original. The rate distortion function for the low-pass filtered process is denoted $R_{LP}(D_{LP})$, where D_{LP} is the MSE relative to the low-pass filtered process. For a given value of the parameter θ the relation is

$$\begin{aligned}D'_\theta &= D_{filt} + D_{LP\theta} \\ R'_\theta &= R_{LP\theta}\end{aligned} \tag{11}$$

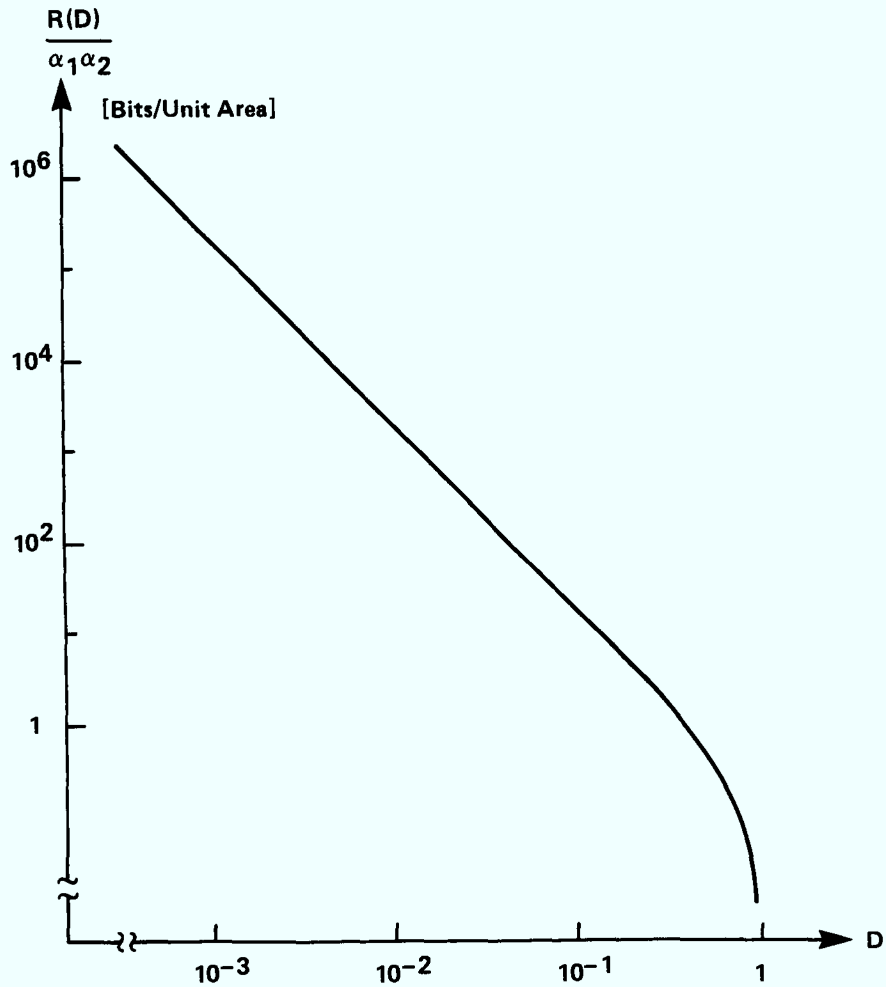

Fig. 2 Rate distortion function for elliptic covariance model under an unweighted MSE distortion criterion expressed in bits per unit area. The rate is plotted on a logarithmic scale.

where the error due to low-pass filtering is

$$D_{filt} \triangleq \int \int_{\overline{B}_p} \Phi(f_1, f_2) df_1 df_2. \tag{12}$$

For distortion levels above $D_{\theta crit}$, no frequencies outside B_p are transmitted even for the unfiltered signal. Hence, $R'(D')$ is equal to the unfiltered case:

$$D'_\theta = D_\theta, \qquad R'_\theta = R_\theta \tag{13}$$

if

$$\theta \geq \theta_1 \triangleq \max_{(f_1, f_2) \in \overline{B_p}} \Phi(f_1, f_2) \tag{14}$$

For the elliptic model the critical threshold is $\theta_1 = \Phi_{iso}(\omega_{crit})$, where

$$\omega_{crit} = 2\pi \min_{i=1,2} \frac{f_{pi}}{\alpha_i}. \tag{15}$$

Assuming a passband tailored to the signal statistics,

$$\frac{f_{p1}}{\alpha_1} = \frac{f_{p2}}{\alpha_2} = \frac{\omega_{crit}}{2\pi} \tag{16}$$

the rate distortion function $R'(D')$ is given by eq. (7) for rates lower than R_1.

$$\begin{aligned} R_1 &= \frac{3\alpha_1\alpha_2}{16\pi}(\omega_{crit}^2 - \log(1+\omega_{crit}^2)) \\ &\approx \frac{3\pi}{4} f_{p1} f_{p2} \quad \text{nats/unit area}, \qquad \omega_{crit} \gg 1. \end{aligned} \tag{17}$$

Sampling at the Nyquist limit,

$$f_{si} = 2 f_{pi}, \qquad i = 1, 2 \tag{18}$$

we get the rate

$$R_1 \approx \frac{3\pi}{16} \ \text{nats/sample} \approx 0.85 \ \text{bits/sample}, \qquad \omega_{crit} \gg 1. \tag{19}$$

For $\omega_{cut} \in (\omega_{crit}, \sqrt{2}\omega_{crit})$ the region of transmitted frequencies is as indicated in Fig. 3. If $\omega_{cut} \geq \sqrt{2}\omega_{crit}$, then the whole region B_p will be transmitted.

For an arbitrary power spectrum, all frequencies within the passband are transmitted when

$$\theta \leq \theta_2 \stackrel{\triangle}{=} \min_{(f_1, f_2) \in B_p} \Phi(f_1, f_2). \tag{20}$$

In that case

$$\begin{aligned} D'_\theta &= D_{filt} + D_{LP\theta} = D_{filt} + 4\theta f_{p1} f_{p2} \\ R'_\theta &= R_{LP\theta} = \frac{1}{2}\int\int_{B_p} \log \frac{\Phi(f_1, f_2)}{\theta} df_1 df_2 \\ &= R_2 + 2 f_{p1} f_{p2} \log \frac{\theta_2}{\theta} \end{aligned} \tag{21}$$

where

$$R_2 \stackrel{\triangle}{=} \frac{1}{2}\int\int_{B_p} \log \frac{\Phi(f_1, f_2)}{\theta_2} df_1 df_2. \tag{22}$$

For the elliptic model, sampled at the Nyquist limit

$$R_2 \approx \frac{3}{4}\left(3 - \frac{\pi}{2}\right) \ \text{nats/sample} \approx 1.55 \ \text{bits/sample}, \qquad \omega_{crit} \gg 1. \tag{23}$$

The function $R'(D')$ is plotted in bits/sample in Fig. 4 for the sampling frequency $f_{si} = 25\alpha_i$. The rate distortion function for the lowpass filtered process is also indicated.

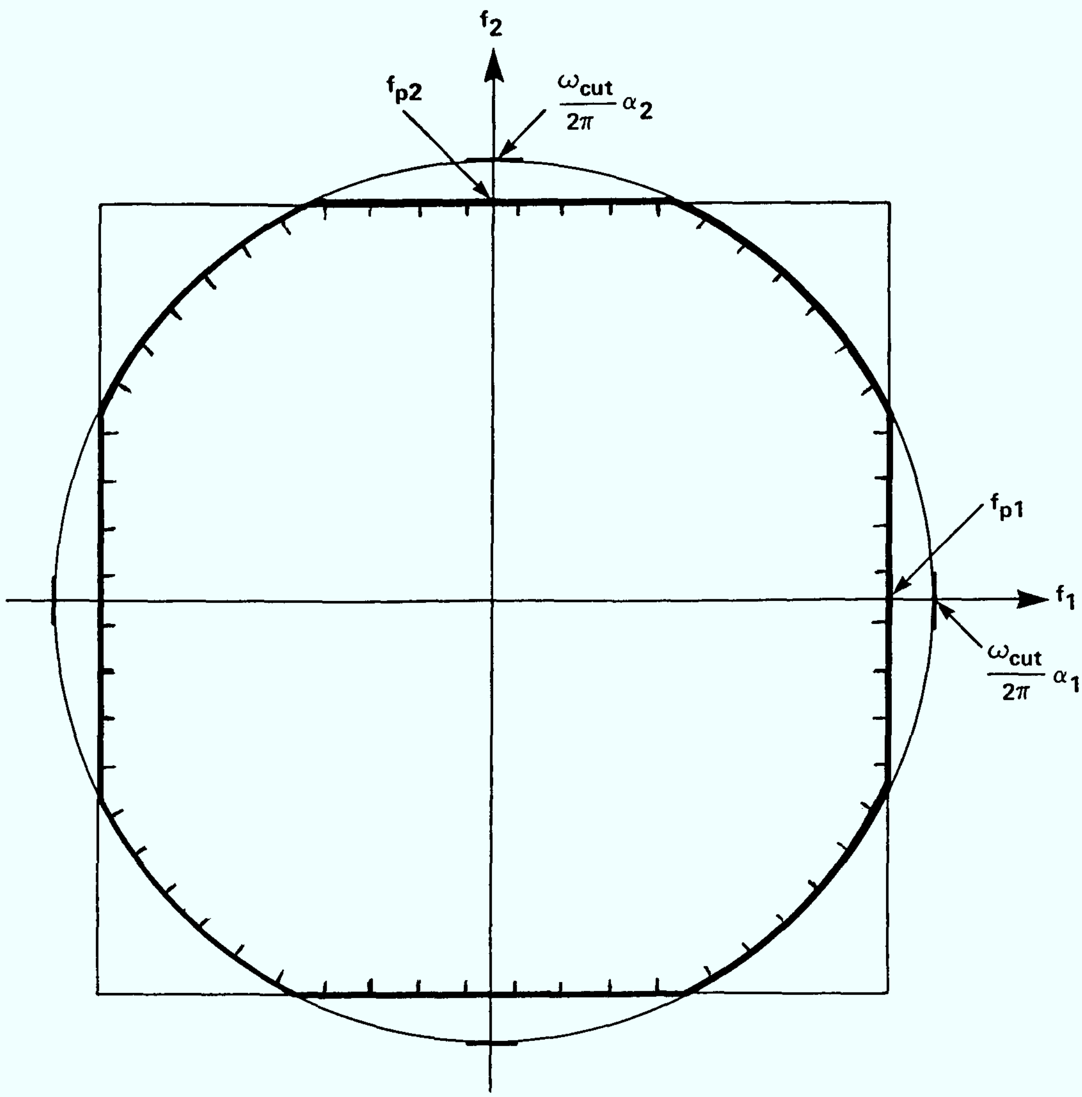

Fig. 3 Transmitted region of spectrum for rates $R_1 < R < R_2$.

2.3 Frequency weighted MSE

It is well known that the contrast sensitivity of the HVS has a bandpass characteristic. In the low spatial frequency range, the HVS acts as a differentiator due to lateral inhibition; at high spatial frequencies the response is limited by the optics of the eye and the density of the receptors and neural network of the retina. If we assume that the high-frequency cut-off is due to diffraction, we obtain a simple model for the contrast sensitivity,

$$C_{nb}(f_r) = e\frac{f_r}{f_0}e^{-f_r/f_0}C_{nbmax} \tag{24}$$

where f_r is radial frequency; the function obtains its maximum at $f_r = f_0$. The index nb

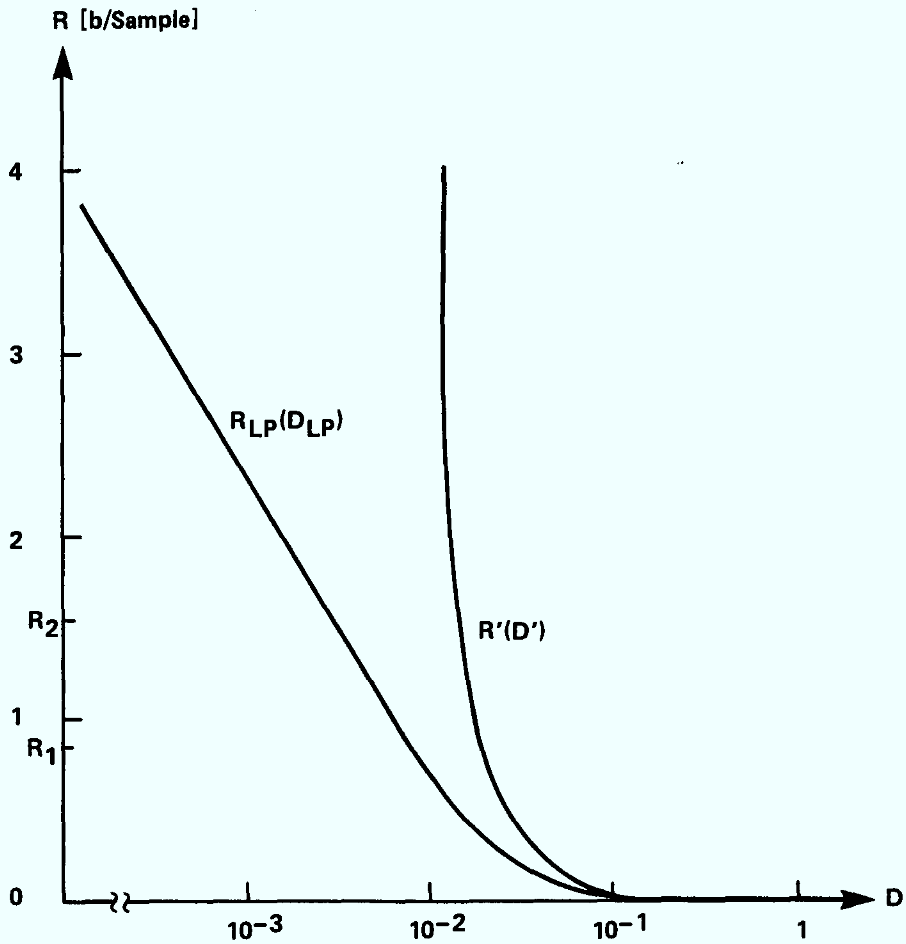

Fig. 4 Rate distortion function in bits per sample for elliptic covariance sampled at $f_{si} = 25\alpha_i$.

indicates that narrowband stimuli are considered.

Most measurements of the spatial frequency characteristics have utilized sinusoidal gratings. Narrow-band noise was used by Sakrison [6]; the contrast sensitivity curve had about the same shape as for sinusoidal gratings. A reasonable fit to most published curves is obtained by eq. (24) with $f_0 \approx 4$ cycles/degree, although the high-frequency roll-off is somewhat less abrupt than $\exp(-f_r/f_0)$. The anisotropy of the HVS has not been incorporated, although it is known that the sensitivity to diagonal gratings is about 3 dB less than to horizontally or vertically oriented gratings [7].

A weighted squared error has the form

$$D = \int\int \Phi_N(f_1, f_2)|W(f_1, f_2)|^2 df_1 df_2 \tag{25}$$

where $\Phi_N(f_1, f_2)$ is the noise power spectrum, and $W(f_1, f_2)$ the weighting function. Now, would the contrast sensitivity function give a useful weighted MSE? The answer depends on the kind of distortion that is being considered. It should be appropriate to predict the visibility threshold for narrowband stimuli, but it is probably less useful for suprathreshold distortion levels or broadband noise, e.g., quantization noise.

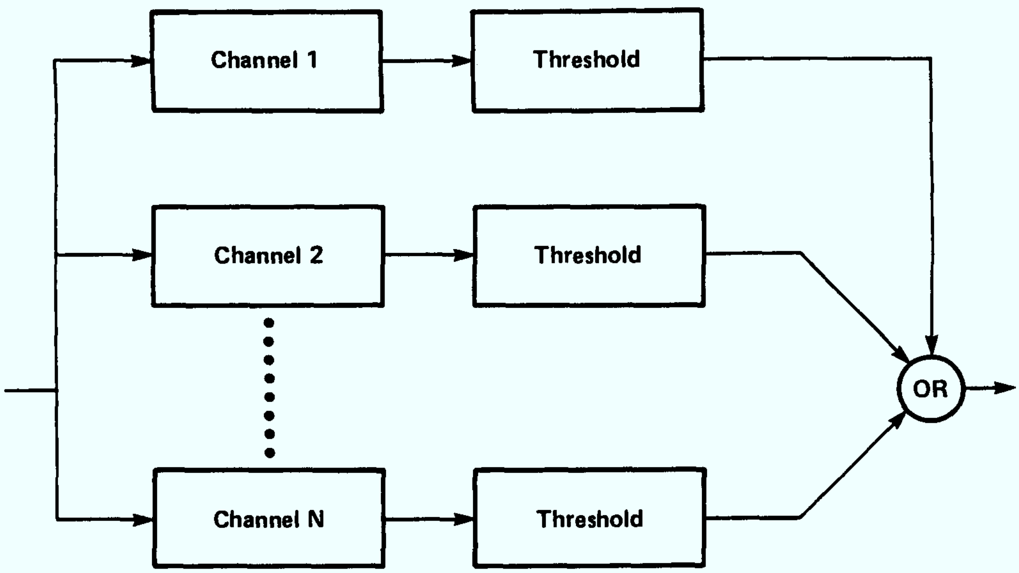

Fig. 5 Detection model for the human visual system with frequency-selective channels.

Experiments with detection of compound gratings consisting of two frequency components have led to a model with parallel processors, the independent channels model, shown in Fig. 5. The processors are assumed to be spatial-frequency selective and a stimulus is detected when the activity in any of the frequency channels exceeds a threshold. The structure of a single channel has been studied by Mostafavi and Sakrison [8] (the results are reviewed in [6]). Experiments indicate that the relative bandwidth of each channel should be approximately constant [9]; Sakrison's work indicates a radial bandwidth of about one octave, and angular bandwidth of $\pm 10°$. To account for the different absolute bandwidths in high and low frequency channels, we multiply $C_{nb}(f_r)$ by f_r. Hence, a simple model for the sensitivity to wide-band stimuli gives the sensitivity function

$$C_{wb}(f_r) = \frac{e^2}{4}\left(\frac{f_r}{f_0}\right)^2 e^{-f_r/f_0} C_{wbmax} \tag{26}$$

which attains its maximum value at $f_r = 2f_0$.

The weighted MSE does not accurately model the OR operation of the channel model; however, considering the large radial bandwidth of the channels we can expect a reasonably good prediction of the detection threshold for isotropic noise. In particular, a noise spectrum inversely proportional to the weighting,

$$\Phi_N(f_r) = \frac{a}{|C_{wb}(f_r)|^2} \tag{27}$$

should give simultaneous detection in all channels for a certain value of a. Hence, for optimum encoding according to rate distortion theory a weighting function proportional to $C_{wb}(f_r)$ should be used.

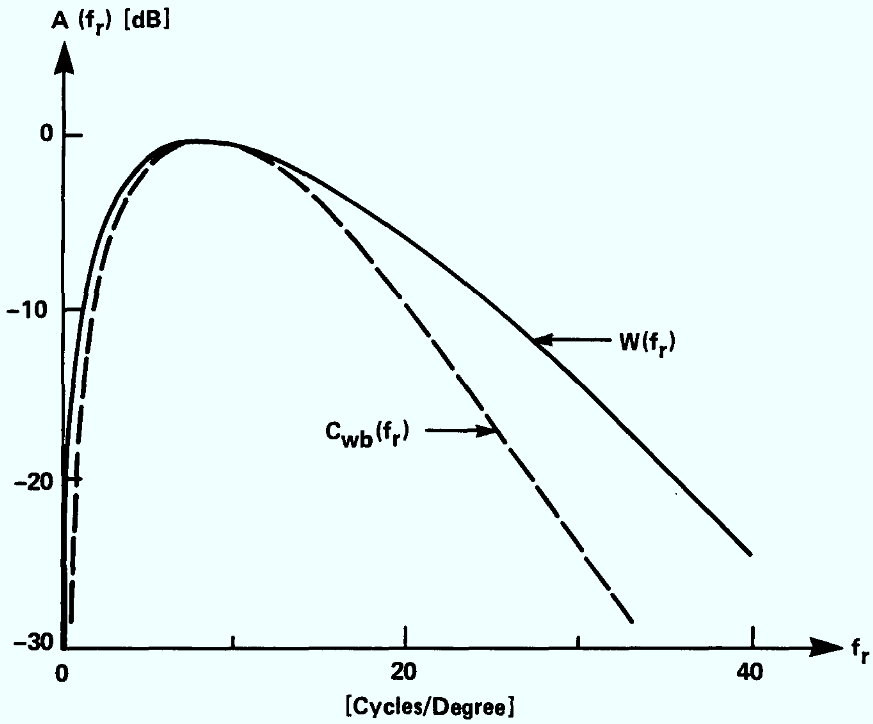

Fig. 6 Experimentally obtained weighting function [10] compared to a weighting function derived from a simple model of the HVS.

Mannos and Sakrison simulated optimum encoding of still pictures using different frequency weighting functions [10]. The best subjective quality was obtained with

$$W(f_r) \approx 2.6(0.0192 + 0.114 f_r) \exp\left[-(0.114 f_r)^{1.1}\right] \tag{28}$$

where f_r is the radial frequency in cycles/degree. The function is outlined in Fig. 6 together with our theoretically derived function $C_{wb}(f_r)$. As seen, $W(f_r)$ also obtains its maximum at 8 cycles/degree, one octave above the maximum for narrow-band stimuli. The high-frequency roll-off is slower—the same tendency as when comparing measured contrast sensitivity functions to $C_{nb}(f_r)$. The low-frequency attenuation is significant: 26 dB at $f_r = 0$.

The rate distortion function was computed numerically for the weighted MSE distortion measure defined in eq. (25) and the weighting function (28). An isotropic source is assumed;

the spectrum is given by eq. (6) with $\alpha_1 = \alpha_2 = \alpha$. The rate distortion function for the continuous image source is shown in Fig. 7. The effect of low-pass filtering is also shown for cut-off frequencies $f_{p1} = f_{p2} = 12.5$ and 25 cycles/degree.

The rate in bits per sample is shown in Fig. 8. We have also indicated the weighted MSE for a coder optimized under a non-weighted MSE criterion. The distance between the two curves is the improvement that can be expected by taking the HVS spatial frequency characteristics into account in the coding process. Fig. 8 can be used to estimate the difference in bit rates for coding EQTV and HDTV at the same weighted MSE. We assume that $f_s = 25$ corresponds to EQTV and $f_s = 50$ corresponds to HDTV. Suppose that the HDTV signal achieves the desired distortion level at 1 bit/pel. The same weighted MSE is obtained at about 2.2 bits/pel for the EQTV signal. Assuming a 4:1 ratio of sampling frequencies, the HDTV bit rate is only 1.8 times higher than the EQTV rate.

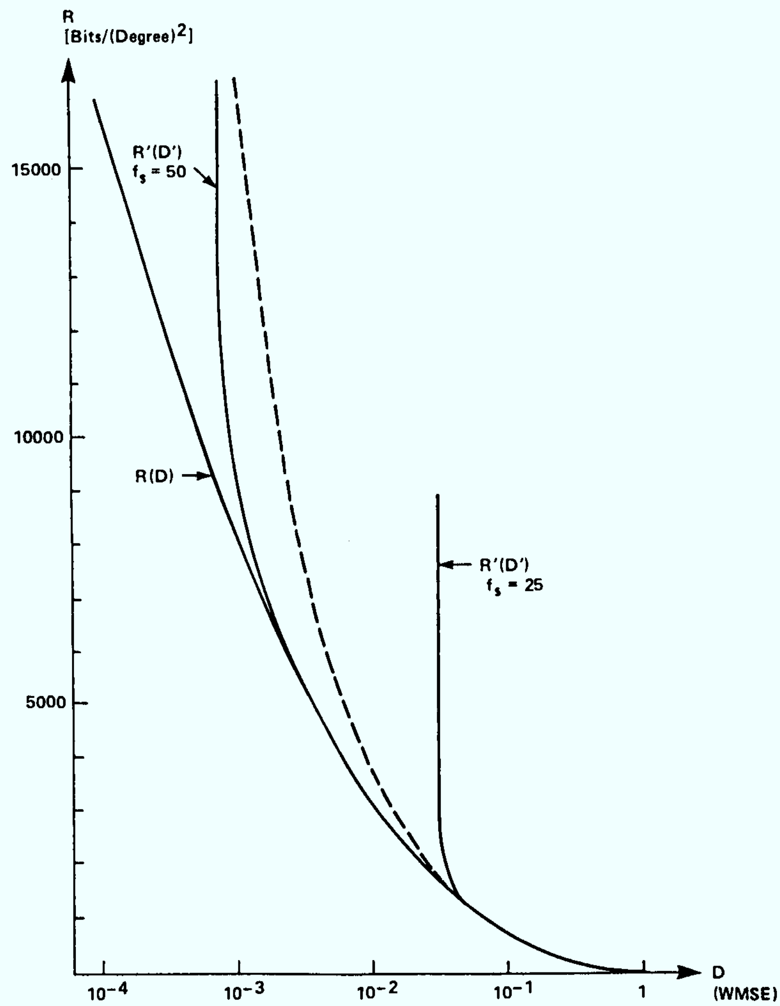

Fig. 7 Rate distortion function for isotropic model under a weighted MSE criterion; $\alpha_1 = \alpha_2 = 2$ cycles/degree. The dashed curve indicates the weighted MSE for a coder that is optimum under a non-weighted MSE criterion.

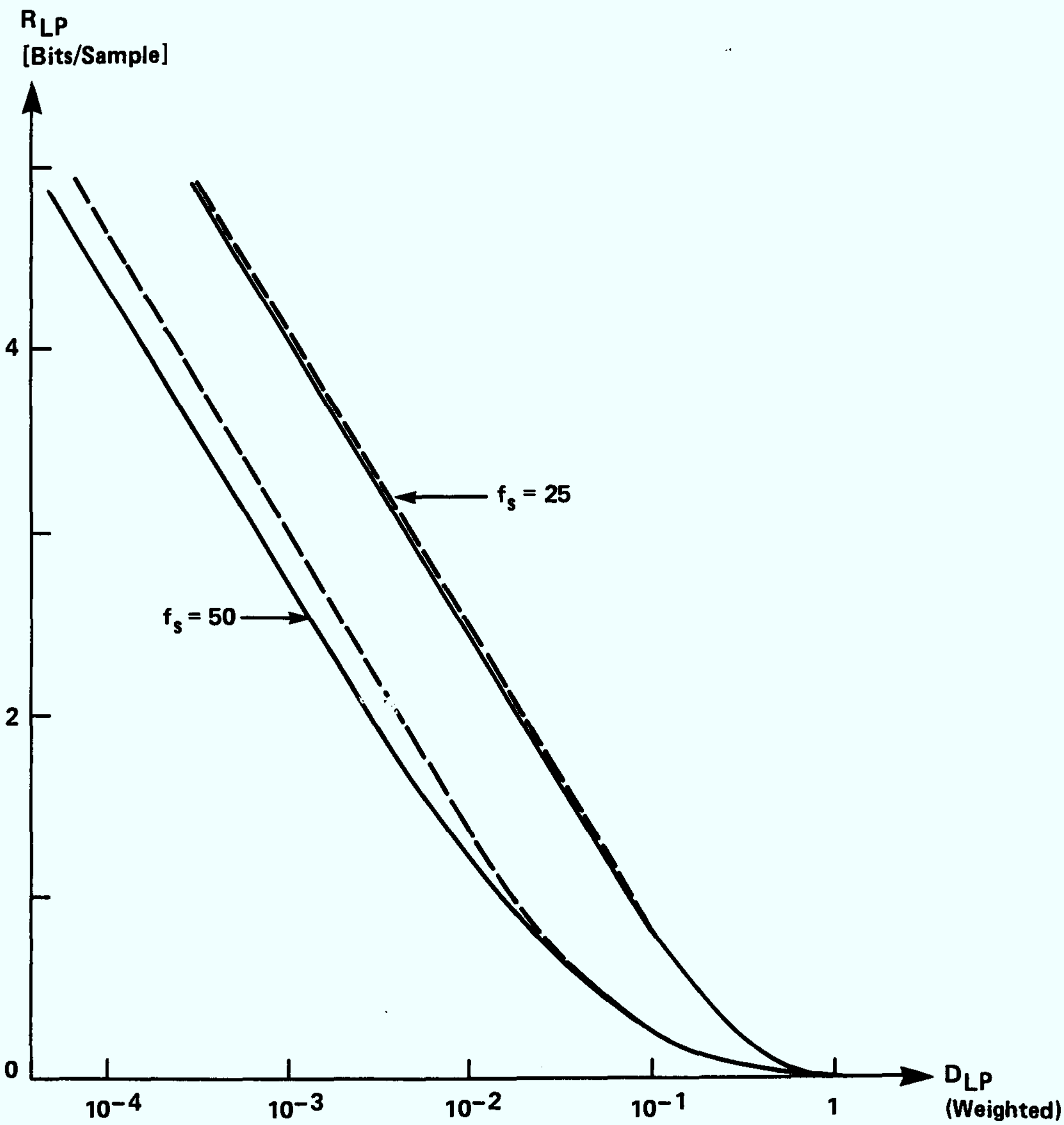

Fig. 8 Rate distortion function in bits per sample for a medium-detailed picture ($\alpha = 2$) and sampling frequencies $f_{s1} = f_{s2} = 25$ and 50 samples/degree. The dashed curves indicate the weighted MSE for a coder that is optimum under a non-weighted MSE criterion.

3. Frequency Weighted Transform Coding

In our coding experiments, an adaptive transform coder has been used. As illustrated in Fig. 9, transform coding consists of three steps: transformation, quantization, and variable length coding. In the receiver, the quantized values are reconstructed from the received data stream, and the inverse transform is performed.

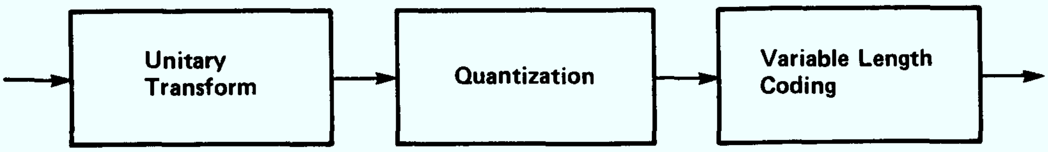

Fig. 9 Transform coder.

The coding scheme employed here has many characteristics in common with the Scene Adaptive Coder described by Chen and Pratt [11]. The main addition is that frequency weighting is employed to account for the different sensitivity of the HVS to the different transform coefficients. The weighting function (28) was determined for full frame Fourier transform; however, important modifications must be made for a block-wise transform. The frequency-weighted transform coding scheme presented here has also been used for interframe coding with good results [12].

Transform

The Discrete Cosine Tranform (DCT) is used, since its energy compaction performance is close to the theoretically optimal Karhunen-Loève transform for Markov sources (exponential covariance function) with correlation in the range 0.5 to 1 [13]. For a two-dimensional source with separable covariance, the performance will also be close to optimum if the correlation is exponential in both dimensions. In the previous section we focused our attention on an isotropic covariance function. Natarajan and Ahmed have shown that the energy compaction is close to optimum for the isotropic case also [14].

The two-dimensional DCT is defined as

$$X(u,v) = \frac{C(u)C(v)}{N^2} \sum_{i=1}^{N} \sum_{j=1}^{N} x(i,j) \cos \frac{(i-\frac{1}{2})(u-1)\pi}{N} \cos \frac{(j-\frac{1}{2})(v-1)\pi}{N}$$
$$C(u) = \begin{cases} 1 & \text{for } u = 1 \\ \sqrt{2} & \text{for } u = 2,3,\ldots,N \end{cases} \tag{29}$$

for $u, v = 1, 2, \ldots, N$.

A large blocksize is more efficient for decorrelation of a stationary source; however, when the statistics are non-stationary a smaller blocksize can adapt better to the local statistics.

Generally, a smaller blocksize gives better image quality at high bit rates (high quality), while a larger blocksize is superior at low rates [15]. Based on previous experience, a blocksize of 8×8 was chosen for the current experiments.

Quantization

Zonal coding and threshold coding are the two most commonly used quantization strategies. In a *zonal coder* a bit assignment is decided for each transform coefficient. More bits are usually assigned to low sequency (frequency) coefficients. Adaptivity can be achieved by choosing one out of several bit assignments. Each transform block is classified into one of M classes, and then quantized using the corresponding bit assignment.

Threshold coding is a procedure where all transform coefficients with a magnitude exceeding a certain threshold are quantized and transmitted. It is inherently adaptive; different coefficients are transmitted from block to block. A uniform quantizer has been used in several studies, e.g., by Tescher [16]. In his scheme, the transformed coefficients are scanned according to Fig. 10. Long runs of zeros are coded with a run-length code and a separate Huffman table.

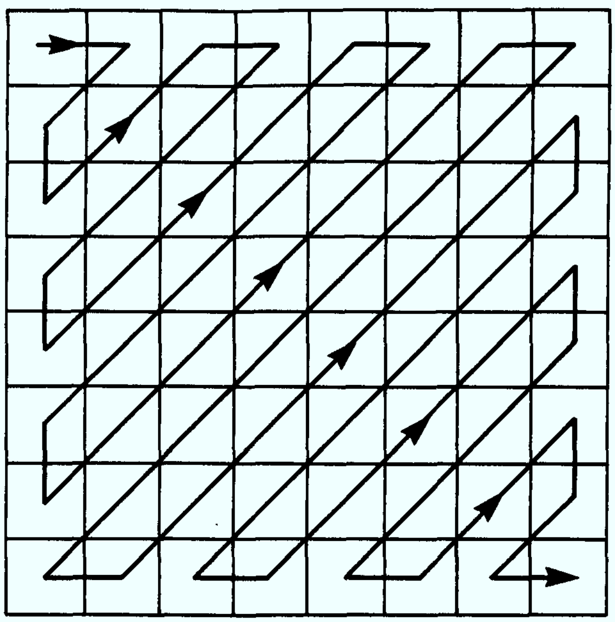

Fig. 10 Zig-zag scanning of transform coefficients (from [17]).

Chen and Pratt [11] designed an adaptive transform coder with many characteristics similar to Tescher's coder: zig-zag scanning of each block and run-length coding of zeros; however, the uniform quantizer characteristic has been modified, as outlined in Fig. 11. The zero level has been extended to increase the probability of a zero. Two Huffman codes are used, one for amplitudes and one to code runs of zeros.

The different sensitivity to quantization noise in different transform coefficients can be accounted for by weighting them. Then, the weighted coefficients are quantized such that

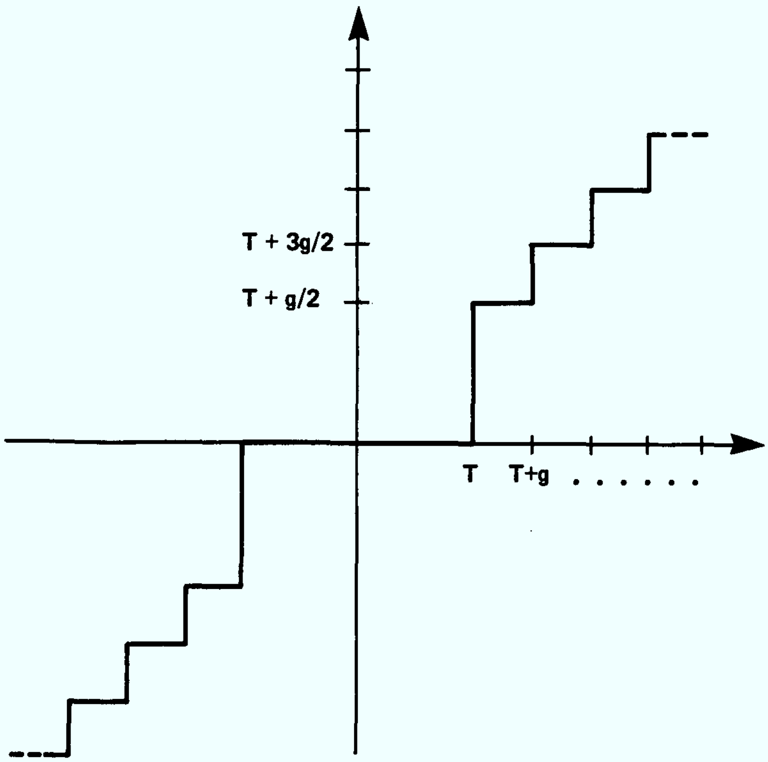

Fig. 11 Threshold coder quantization characteristic.

they get the same mean square error. An inverse weighting is performed in the receiver. Thus, the error in each coefficient depends on the weight.

Most work on frequency weighted transform image coding has been done using a full frame Fourier transform, e.g., Yan and Sakrison [18]. They applied the weighting function (28) to the transform coding in a two-component coding scheme. When smaller transform blocks are used, it is not possible to use the same weighting function due to edge effects. Because of the finite window, the spectra of the transform basis functions are not located at discrete frequencies, as illustrated in Fig. 12. In [12] it was shown that a modified low frequency portion of the weighting function (28) was necessary for small blocksizes. Thus, the weighting function $W'(f_r)$ was defined, where

$$W'(f_r) = \begin{cases} 1, & |f_r| < 8 \text{ cycles/degree} \\ W(f_r) & \text{otherwise} \end{cases} \tag{30}$$

Furthermore, the weights

$$\begin{aligned} w_{i_1 i_2} &= W'(f_r) \\ f_r^2 &= f_1^2 + f_2^2 \\ f_j &= \begin{cases} \frac{i_j - 1}{2N_j} f_{sj}, & i_j = 1, 2, \ldots, N_j - 1 \\ f_{sj}/2, & i_j = N_j \end{cases} \qquad j = 1, 2 \end{aligned} \tag{31}$$

were suggested for an $N_1 \times N_2$ DCT, where $N_1, N_2 \geq 8$. If the weighted transform coefficients are quantized with the same mean square error, the error spectrum will give a good fit to the desired spectrum (given in eq. (3)) for radial frequencies above 8 cycles per degree.

In the experiments, the transform coefficients were weighted according to eq. (31), and then quantized by the same quantizer. The weighting is equivalent to a scaling of the quantizer characteristic. The weighted transform coefficients were quantized by the quantizer outlined in Fig. 11, which is defined by a threshold T and a quantization step g. The ratio $T/g = 1.5$ was used in the experiments.

Quantizer overload is avoided by using many levels. Hence, infrequent large errors should not occur in the picture. The strategy is supported by our knowledge of subjective image quality; the subjective quality is based on the local error in a few critical areas rather than on a global average [19,20].

Variable Length Coding and Rate Control

The variable length coding was performed as described in [11]. The DC coefficient was coded with a fixed number of bits. The AC coefficients were scanned according to a zig-zag pattern as outlined in Fig. 10, and Huffman coded. The code table contains codewords for amplitudes, runs of zeros, and an End-of-Block word indicating that the remaining coefficients were quantized to zero.

In most applications, a fixed output bit rate is required. This was achieved by scaling the quantizer characteristic. The scaling factor was found for each frame by an iterative search algorithm. Although inefficient for real-time implementation, this method facilitates comparison of different coding parameters without going into the details of rate buffer control.

4. Experiments

The transform coding experiments were performed on a VAX-11/780, and the results were displayed on the HDVS (High resolution Digital Video sequence Store) of Bell-Northern Research/INRS Computer Laboratory. This system allows real-time acquisition and display of 525-line component video.

The experiments were performed on a sequence recorded by a broadcast quality TV camera. Only the luminance component, sampled at 13.5 MHz, was processed in the experiments described here. The active window consists of 256×212 pels per frame, which is approximately 15 % of the full screen area.

To be able to perform experiments without access to a high-definition video signal we consider the active window to be an even smaller part (3.7 %) of a system with twice the number of lines compared to NTSC, i.e., 1050 lines per frame, 2:1 line interlacing, and 30 frames/60 fields

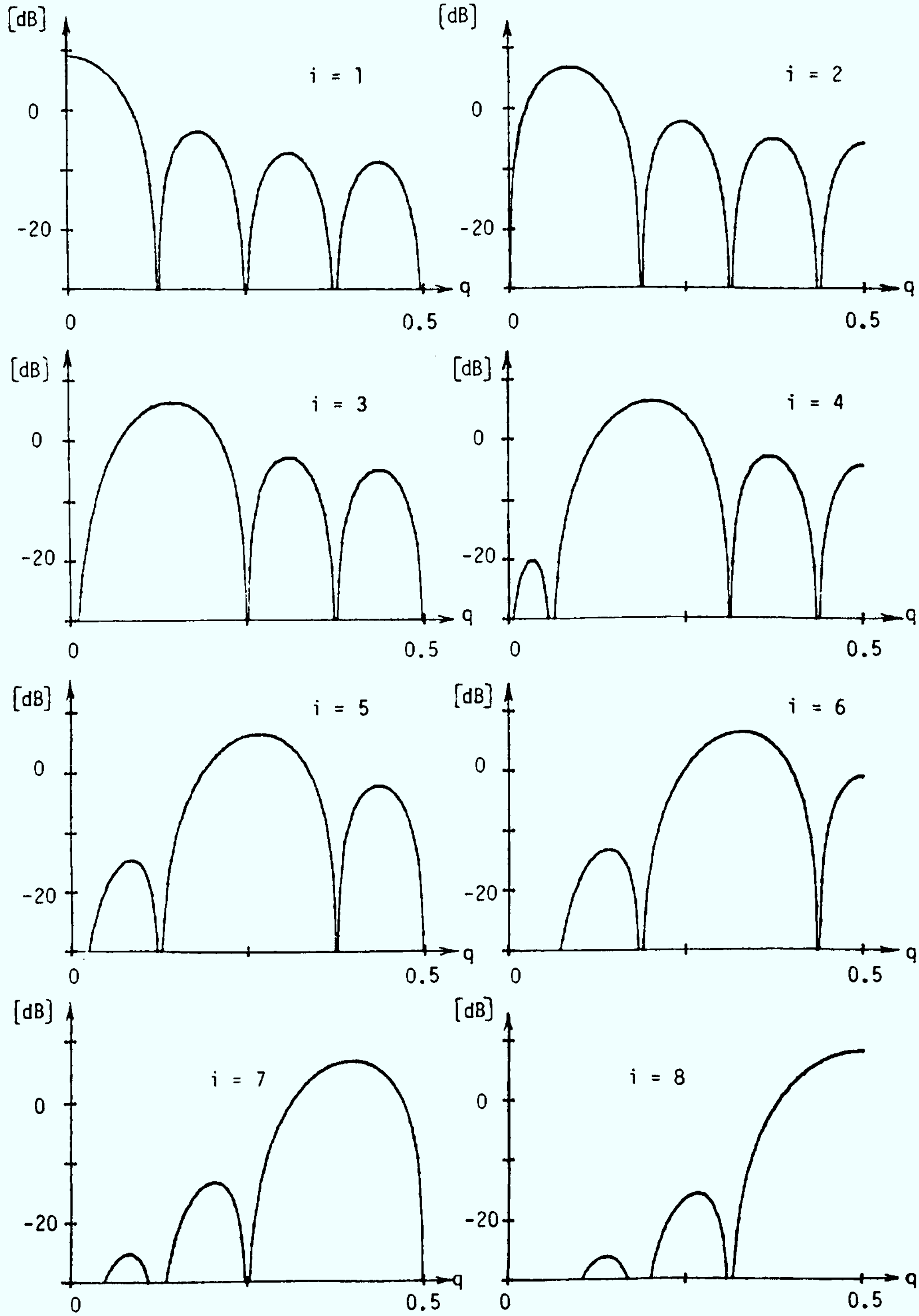

Fig. 12 Spectra of the 8-point DCT basis functions.

per second. The aspect ratio is 4:3 to be compatible with NTSC, and the Kell factor (defined here as the ratio of horizontal to vertical resolution) is chosen to be 0.5, the same value as in the NHK 1125-line system [21]. This corresponds to a bandwidth of 12 MHz, assuming the same ratio between active line period and horizontal blanking interval as in NTSC. All frequencies would be 4 times higher in such a system, e.g., the sampling frequency used by the DVS corresponds to 54 MHz in the 1050-line system.

Two cases have been studied: coding of a (supposed) "1050-line" HDTV signal, and coding of a 525-line signal in an NTSC-compatible enhanced TV (EQTV) system. The EQTV case will illustrate the stricter requirements that are posed on the 525-line standard when the receiver employs up-conversion and a high-definition monitor.

In the first case, an "HDTV original" was obtained by bandlimiting the luminance to $12/4 = 3$ MHz. The lowpass filter was an equi-ripple symmetric FIR filter of length 35. The "HDTV" signal was transform coded with different parameters and displayed for subjective evaluation.

The second case included down- and up-conversion. The HDTV original was down-converted to 128×53 pels per field by intrafield processing of every 256×106 input field. The spatial relationships between an HDTV frame and a down-converted frame are shown in Fig. 13. The output lines are obtained by linear interpolation in the vertical direction with the weighting factors 3/4 and 1/4. In the horizontal direction, a 2:1 subsampling is performed; no prefiltering is necessary.

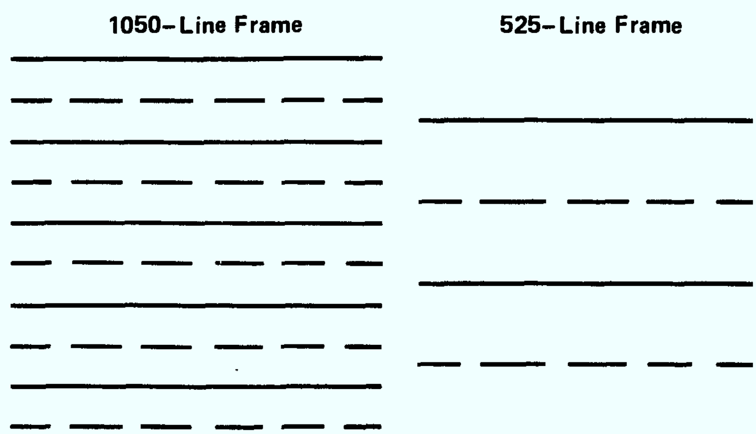

Fig. 13 Spatial location of lines in 1050-line frame and the down-converted 525-line frame. Solid lines indicate even field, hatched lines indicate odd field.

The bandlimitation introduced by the NTSC channel was simulated by applying a lowpass filter to the down-converted signal. A 25-point symmetric FIR filter was used. It is an equi-ripple design with 0.16 dB ripple below 3.75 MHz, and 34 dB attenuation above 4.75 MHz.

Then, the "NTSC" luminance window of 128×53 pels was transform coded, up-converted to 256×106 pels, and displayed on the HDVS. Following Tonge [22], the up-conversion process is divided into two stages:

I. Conversion from 525-line/60Hz/2:1 interlaced to 525/60/1:1 non-interlaced format.

II. Conversion from 525-line non-interlaced to the desired 1050-line/60Hz/2:1 interlaced signal.

Stage I involves motion-adaptive processing, while Stage II is a straightforward digital interpolation.

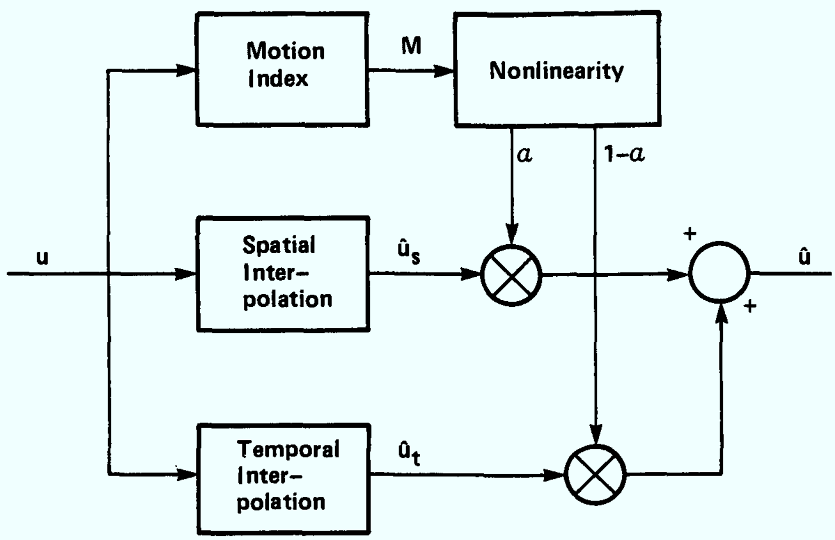

Fig. 14 Motion-adaptive interpolation system (from [5]).

A motion-adaptive interpolator is shown in Fig. 14. It weighs the outputs of a temporal and a vertical interpolator depending on a motion index α. The interpolators are implemented as the average in temporal and vertical direction respectively:

$$\begin{aligned} \hat{u}_t(n,m,k) &= (u(n,m,k-1) + u(n,m,k+1))/2 \\ \hat{u}_s(n,m,k) &= (u(n,m-1,k) + u(n,m+1,k))/2 \end{aligned} \tag{32}$$

The indices n, m, k indicate horizontal, vertical, and temporal direction, respectively.

The control parameter α can only take on two different values, i.e., either vertical or temporal interpolation is used. The decision is based on the temporal and vertical differences in a 3×3 window:

$$\begin{aligned} D_{temp} &= \sum_{i=-1}^{1} \sum_{j=-1}^{1} |u(n+j, m+i, k+1) - u(n+j, m+i, k-1)| \\ D_{vert} &= \sum_{i=-1}^{1} \sum_{j=-1}^{1} |u(n+j, m+1+i, k) - u(n+j, m-1+i, k)| \end{aligned} \tag{33}$$

Vertical interpolation ($\alpha = 1$) is used if the temporal difference is larger than the vertical difference.

$$\alpha = \begin{cases} 0 & \text{if } D_{temp} \leq D_{vert} \\ 1 & \text{if } D_{temp} > D_{vert} \end{cases} \tag{34}$$

By comparing two differences we avoid the problem of choosing a motion detector threshold, which would be dependent on the noise level. Hence, it should not be necessary to know the input SNR with the above criterion.

Stage II consists of two linear filters: a horizontal 1:2 interpolator and a vertical quarter-pel shifter. The horizontal interpolation filter is shown in Fig. 15 for different values of the HF boost parameter β_h. The value $\beta_h = 0.25$ was used in the experiments. The filter performing the fractional pel shift (1/4 pel) is shown in Fig. 16. This filter is used to shift the odd field downwards, while its mirrored version $h_{shift}(-n)$ is applied to the even field to shift it 1/4 pel upwards. The cascade of the down-converter and the quarter-pel shifter gives the transfer function outlined in Fig. 17. The vertical HF boost parameter was chosen to be $\beta_v = 0.75$.

Twelve frames of the test sequence were coded and displayed on the HDVS. The viewing distance corresponded to three times picture height for a 960-line display. For the HDTV original the visibility threshold was at an approximate bit rate of 1.2 bit per pel. The inclusion of frequency weighting gave a very marginal improvement.

The down-converted picture needed a bit rate of 2.8 b/pel to give a coding error at the visibility threshold after up-conversion. Thus, assuming a 4:1 ratio of sampling frequencies, the HDTV bit rate is 1.7 times higher than the EQTV rate. This is quite comparable to the theoretical result obtained in Section 2. Furthermore, the HDTV picture at the same bit rate per unit area as the EQTV picture, i.e., 0.7 b/pel, looked significantly better than the uncoded sequence that had passed the down- and up-converter.

5. Conclusion

A theoretical study of optimal coding performance as a function of resolution has been carried out using rate distortion theory. This predicts, as expected, that coding efficiency increases as the sampling density increases. Although this result has been known qualitatively for some time, few quantitative results have been available.

A transform coder operating at different sampling densities was used to determine how these theoretical results compare with actual coder performance for conditions approximating those of HDTV and EQTV. Results quite comparable to the theoretical predictions were obtained: the coded HDTV signal requires a bit rate only about 1.7 times greater than the EQTV signal, assuming the same aspect ratio, when both are coded near the threshold of visibility of coding distortion. This is much smaller than the 4:1 ratio of analog bandwidths or PCM bit rates. Furthermore, at the same bit rate, the coded HDTV signal gives a significantly better picture quality than the upconverted EQTV signal. These results should be considered in the planning of digital transmission systems for future television services.

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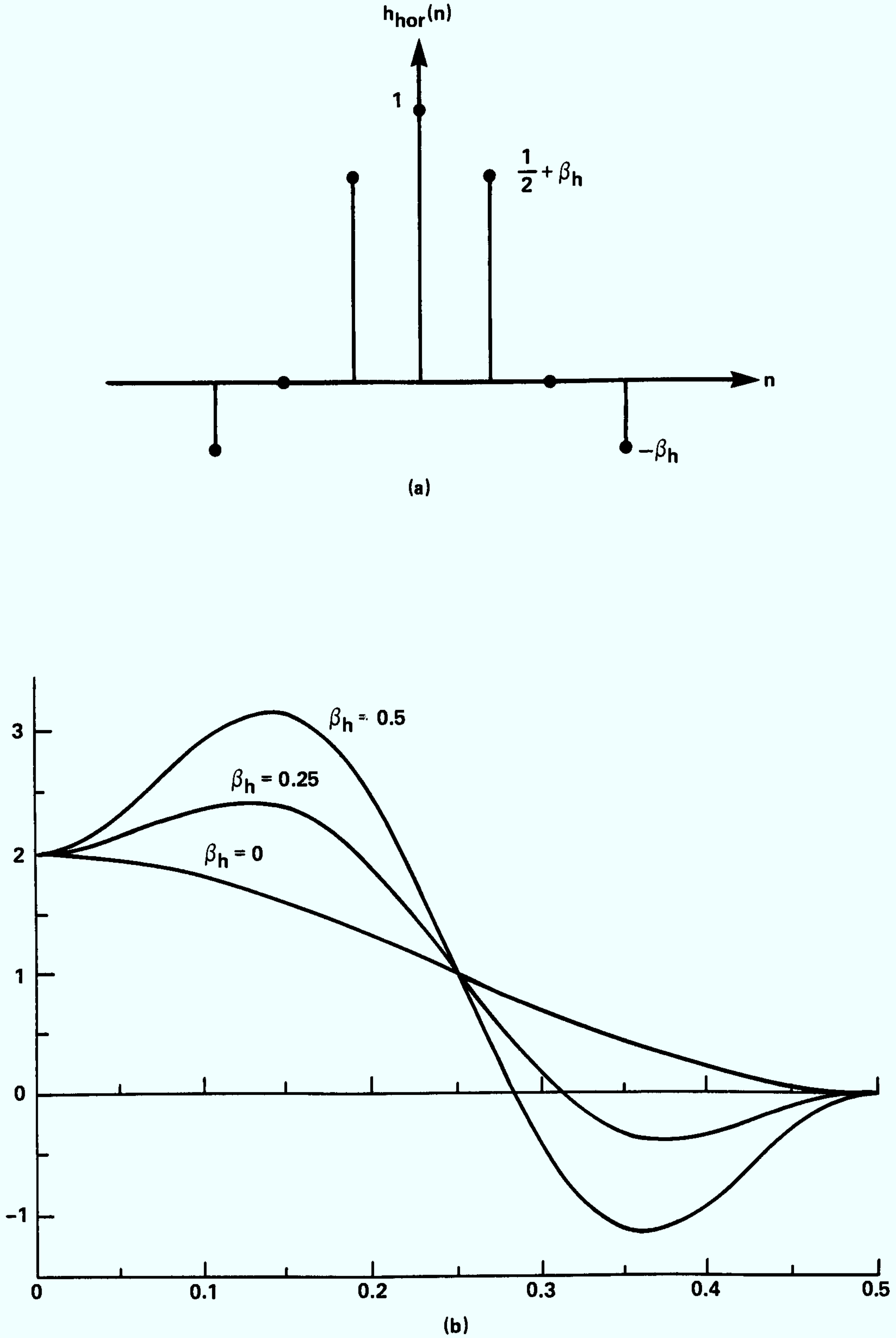
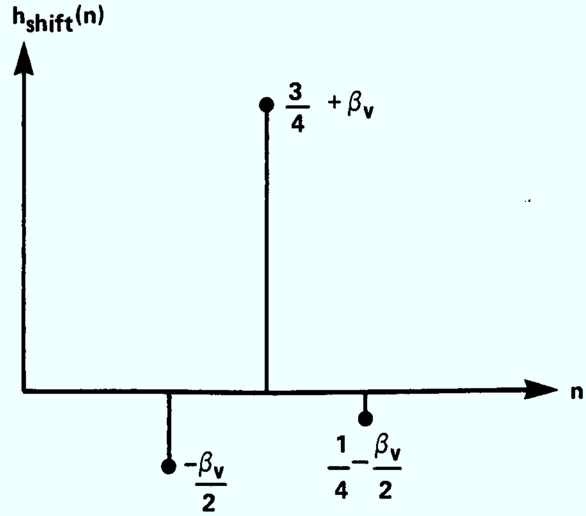
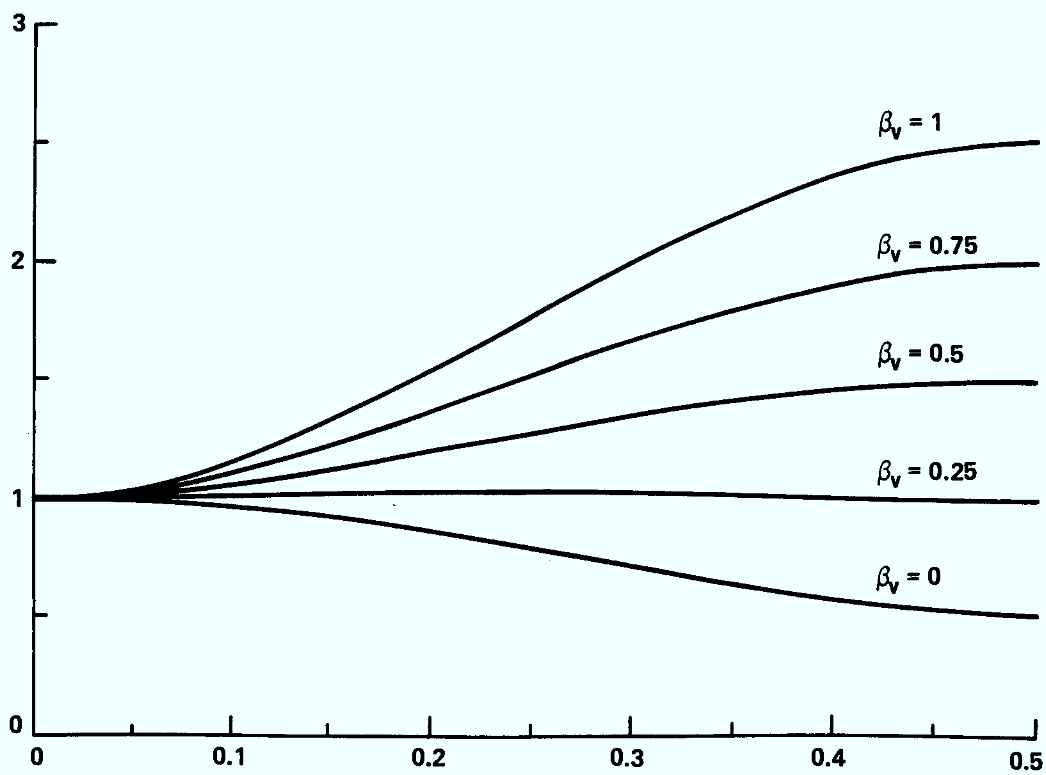


Fig. 15 Horizontal interpolation filter. (a) Impulse response. (b) Frequency response for different values of β_h.



(a)



(b)

Fig. 16 Quarter-pel shifter. (a) Impulse response.
(b) Amplitude response for different values of β_v; $f_s = 480$ c/ph.

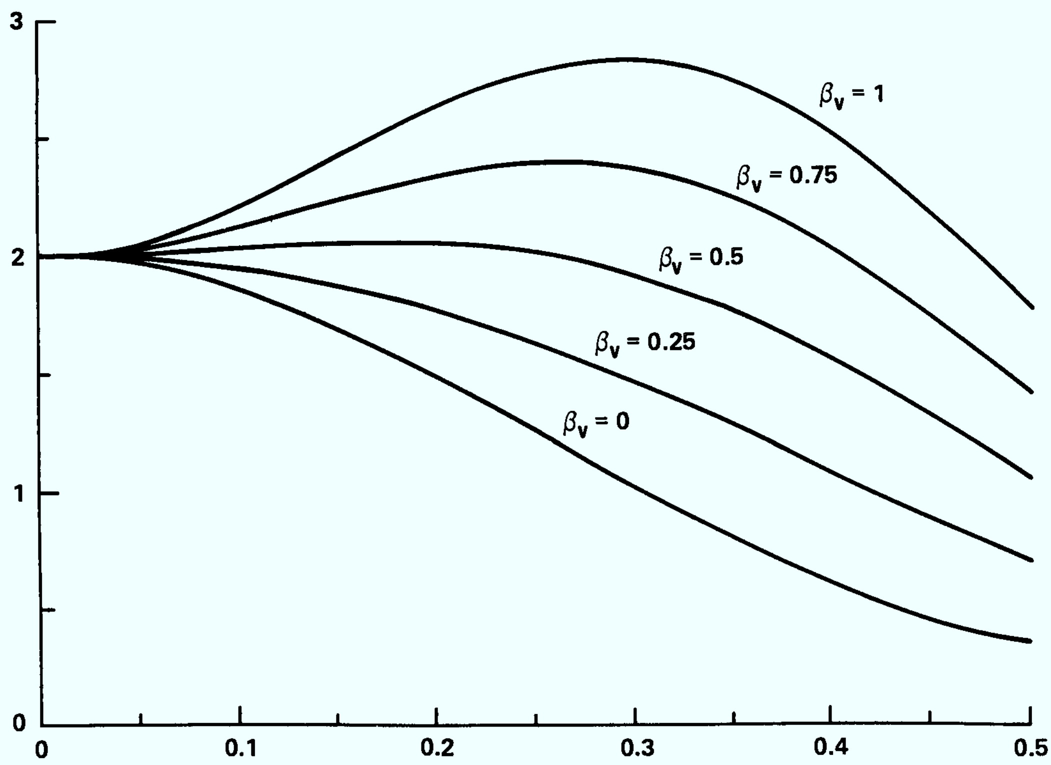


Fig. 17 Vertical amplitude response of down-converter cascaded with up-converter for different values of β_v; $f_s = 480$ c/ph.

LES VOIES EUROPEENNES VERS LA TELEVISION DE MEILLEURE QUALITE

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3.6

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RÉSUMÉ

Dans de nombreux cas, la qualité des images et du son de la télévision est maintenant limitée par les systèmes actuellement exploités et non plus par la technologie. La prochaine mise en oeuvre de la radiodiffusion directe par satellite fournit une occasion idéale pour l'introduction des systèmes nouveaux dont les objectifs essentiels sont la flexibilité et la qualité.

Les études techniques de l'UER ont tout d'abord porté sur le point jugé le plus faible des systèmes actuels à savoir le son pour lequel la numérisation permet d'accroître à la fois la qualité et le nombre de voies diffusées. On s'est ensuite préoccupé d'améliorer la qualité de l'image pour laquelle on propose le codage en MAC (multiplexage analogique des composantes).

L'article décrit la famille de systèmes compatibles recommandés par l'UER : C-MAC/paquets pour la radiodiffusion par satellite, D-MAC/paquets pour la distribution par câble de toute l'information contenue dans le système précédent et D2-MAC/paquets pour la distribution par câble dans des canaux à bande étroite ou pour d'autres applications. On examine ensuite les possibilités d'évolution de ces systèmes vers une qualité d'image encore accrue et l'on indique les voies d'approche ultérieure pour la diffusion de télévision à haute définition.

Le paragraphe de conclusion résume la situation actuelle en Europe où les décisions ne sont pas toutes prises au niveau des gouvernements.

1. INTRODUCTION

Tout comme c'est le cas en Amérique du Nord, les normes de télévision en couleur actuellement exploitées en Europe (PAL et SECAM avec balayage à 625 lignes/50 Hz) ont été developpées il y a près de trente ans, selon les technologies de l'époque.

Pour de nombreux types d'image, la qualité est maintenant limitée par les systèmes eux-mêmes et non plus par les performances potentielles des équipements. On connaît bien les dégradations inhérentes au principe du codage composite (diaphotie de luminance et de chrominance) ainsi que celle dues à la nature du balayage : limitation des résolutions verticale et horizontale, papillotement des grandes surfaces, visibilité de la structure de ligne, scintillement interligne etc.. En outre, le son n'est jamais de très haute qualité et, dans le meilleur des cas, les systèmes actuels de télévision ne permettent que la diffusion de deux voies son (ou d'une voie stéréophonique) ainsi que de quelques centaines de pages de télétexte.

Avec l'explosion des techniques numériques et la disponibilité de circuits intégrés permettant de réaliser des fonctions complexes à bas prix (si la taille du marché est suffisante), l'étude de nouveaux systèmes s'imposait d'évidence. Une occasion unique pour l'introduction d'une norme améliorée est fournie par l'imminence des premiers services de radiodiffusion par satellite pour lesquels le récepteur individuel comportera de toute manière certains équipements nouveaux, même si l'on diffuse des signaux aux normes actuelles. Mais il est impératif de permettre également la réception communautaire et la distribution par câble avec un système sinon identique, du moins compatible - normes de modulation mises à part - vis-à-vis des dispositifs de traitement du signal prévus dans le récepteur individuel de radiodiffusion directe.

Ces considérations ont amené l'UER à recommander, à la fin de 1984, une famille dite MAC/paquets de systèmes compatibles. Les membres de cette famille comprennent les systèmes C-MAC/paquets (pour la radiodiffusion par satellite), D-MAC/paquets (pour la distribution par câble, dans des canaux d'au moins 10,5 MHz, de toute l'information contenue dans le système précédent) et D2-MAC/paquets (pour la distribution par câble dans des canaux de 7 ou 8 MHz mais avec une capacité réduite). Le système D2-MAC/paquets est également recommandé par l'industrie européenne pour la radiodiffusion par satellite avec la même largeur de bande vidéo que le système C-MAC/paquets et il pourrait être un candidat pour une norme future de diffusion par émetteurs de Terre ainsi que pour de nouveaux magnétoscopes domestiques.

Le présent article contient une description succincte de cette famille de systèmes développés en Europe. On examinera plus particulièrement les aspects liés à la qualité de l'image et les potentialités d'évolution vers une définition améliorée, avec des proportions d'image de 5/3, qui pourraient, dans le cas des applications domestiques, être compétitives vis-à-vis de la télévision à haute définition.

2. HISTORIQUE DES ETUDES DE L'UER

Les premières études sur une norme nouvelle pour la radiodiffusion par satellite ont porté, au début des années 1980, sur le point jugé le plus faible des systèmes actuels de télévision, à savoir le son. Dans ce domaine, la maîtrise des techniques numériques offre la possibilité d'accroître considérablement la qualité et d'augmenter le nombre de voies son, facteur jugé capital vu la multiplicité des langues parlées en Europe. En outre, moyennant un système de multiplexage adéquat, la capacité d'un canal numérique est librement échangeable entre des services sonores et des services de radiodiffusion de données dont on prédit un important développement. La nomenclature des systèmes examinés par l'UER est bien connue et est utilisée dans le monde entier :

- systèmes A : multiplexage en fréquence avec l'image par sous-porteuse à modulation numérique

- systèmes B : multiplexage temporel avec l'image, en bande de base et codage numérique à réponse entière

- systèmes C : multiplexage temporel avec l'image en radiofréquence. Ce sont ces systèmes qui possèdent la plus forte capacité pour un canal RF donné.

Plus récemment, lors des études sur la distribution par câble, sont apparus les systèmes D qui sont des multiplex temporels en bande de base avec codage à réponse partielle (plus spécifiquement duobinaire).

Par la suite, et toujours en vue de la radiodiffusion par satellite, l'UER s'est préoccupée de l'amélioration de l'image et elle a examiné des systèmes composites qui sont des multiplex FDM complexes entre la luminance et la chrominance. L'unanimité s'est cependant faite en faveur du système à composantes analogiques MAC avec multiplexage TDM et compression dans le temps.

Après avoir recommandé, en 1983, le système C-MAC/paquets pour la radiodiffusion par satellite (modulation de type C, codage de l'image en MAC, multiplexage par paquets des services numériques), l'UER a concentré ses efforts sur la distribution par câble et elle a proposé, à la fin de 1984, le système D-MAC/paquets qui est une "copie conforme" du C-MAC/paquets, à cela près que le multiplexage est en bande de base et le codage numérique en duobinaire. Face aux exigences des télédistributeurs qui n'entendaient pas modifier l'espacement des canaux de 7 ou 8 MHz utilisé sur le câble, ainsi que des milieux industriels favorables à un système exploitable sur tous les supports (satellite, câble, émetteurs de Terre, etc.), l'UER a également spécifié le système D2-MAC/paquets, identique au D-MAC/paquets, sauf que le débit binaire de la salve numérique est réduit de moitié, avec une perte correspondante de capacité.

Dans les trois systèmes que l'on appellera pour simplifier C, D et D2, l'image est codée en MAC exactement de la même manière et a donc en principe la même qualité et les mêmes possibilités d'extension. Toutefois le filtrage, introduit au niveau de la modulation AM/VSB pour faire tenir le système D2 dans un canal de 7 ou 8 MHz, introduit une perte significative de résolution horizontale. Pour le reste la discussion des mérites respectifs des systèmes concerne la partie numérique; on a déjà indiqué que le système C a la capacité la plus élevée et utilise au mieux le canal de radiodiffusion par satellite.

Au moment de la rédaction de cet article, les spécifications des systèmes C, D et D2 publiées par l'UER (1), (2) font l'objet d'un large débat avec les industriels. Il importe de rappeler qu'en Europe ni les radiodiffuseurs ni l'industrie, quelle que soit leur influence, n'ont le pouvoir de décision sur les normes; ce pouvoir appartient en effet, au plan national, à chaque gouvernement. Les auteurs ne sont dès lors pas à même de déclarer dans quelle mesure les systèmes seront utilisés.

3. OBJECTIFS DES NOUVEAUX SYSTEMES : FLEXIBILITE ET QUALITE

En dehors de l'impératif fondamental de la meilleure utilisation du spectre, la famille de systèmes proposée par l'UER se caractérise par la recherche de la flexibilité maximale au niveau des services, par une amélioration immédiate de la qualité et par des possibilités d'évolution ultérieure.

Le multiplex temporel conserve une structure de balayage à 625 lignes et 25 trames complètes (ou images) par seconde. Dans cette trame, il est cependant loisible d'insérer à la demande tout élément analogique ou numérique dont la position est signalée par des données dites de "contrôle du multiplex temporel" que l'on insère dans la ligne 625. Il en résulte, en terme de services, la possibilité d'émettre, dans un canal donné, une association variable et évolutive d'images mobiles, d'images fixes, de graphismes, de sons de qualité diverse et de données quelconques. Pour les services numériques, le multiplexage par paquets a lui-même été retenu pour sa flexibilité, car il autorise la coexistence de plusieurs voies numériques, sans contraintes sur le débit binaire, la régularité ou le synchronisme.

L'amélioration de la qualité du son est obtenue par le codage numérique. La fréquence d'échantillonnage spécifiée est de 32 kHz (ou de 16 kHz pour des sons tels que des commentaires qui ne demandent qu'une largeur de bande réduite). La résolution correspond à 14 bits par échantillon en codage linéaire; on a cependant également prévu une réduction du débit binaire par compression quasi intantanée de 14 à 10 bits par échantillon (système connu en particulier sous le nom de NICAM). Deux options sont spécifiées en ce qui concerne la protection contre les erreurs (en plus de la protection fournie par la transmission du facteur d'échelle) : soit un bit de parité par échantillon, soit un code de Hamming couvrant les bits de poids fort des échantillons. Malgré la complexité accrue du décodeur, ces différentes configurations ont été définies pour permettre aux radiodiffuseurs de choisir, cas par cas, dans les limites de la capacité totale disponible, le meilleur compromis entre le nombre de voies son diffusées, leur qualité finale et leur résistance aux erreurs, c'est-à-dire l'étendue de la zone de couverture.

L'amélioration de la qualité de l'image est fournie par l'emploi du codage en MAC décrit plus en détail au paragraphe suivant. Quant aux possibilités d'évolution, y compris la diffusion d'images de proportions accrues, elles découlent, comme on le montrera plus loin, de la flexibilité du multiplex temporel.

4. CODAGE DE L'IMAGE EN MAC

Le principe du codage des composantes analogiques multiplexées de luminance et de différence de couleur est maintenant bien connu : ces composantes sont codées séparément et transmises successivement dans la période d'une ligne de balayage (52 µs pour les normes 625/50). Pour y faire tenir l'information, il est nécessaire de faire subir aux composantes une compression temporelle ainsi que, naturellement, la décompression inverse à la réception; ces opérations se font aisément de nos jours par conversion en numérique suivie du chargement et de la lecture d'une mémoire de ligne aux vitesses appropriées.

De longues études ont conduit les spécialistes de l'UER à optimaliser les paramètres du système MAC pour les conditions de diffusion d'une image au format normal 4/3, accompagnée d'une salve numérique.

La Fig. 1 donne la forme d'onde recommandée pour une ligne de l'image. Sans revenir en détail sur la justification des caractéristiques choisies, nous rappellerons brièvement les points suivants qui soulignent l'objectif fondamental de transparence vis-à-vis de la norme numérique mondiale de production dite 4:2:2 qui est spécifiée dans l'Avis 601 du CCIR :

- la fréquence d'horloge fondamentale est de 20,25 MHz soit exactement 3/2 fois la fréquence d'échantillonnage de luminance dans la norme de studio 4:2:2; il y a donc 1296 périodes d'horloge par ligne;

- le rapport de compression de la luminance est égal au même facteur 3/2, ce qui assure une largeur de bande de luminance non comprimée équivalente à celle de la norme de studio, avec une largeur de bande de canal de 8 à 9 MHz;

- le rapport de compression de la différence de couleur est égal à 3, soit le double de celui de la luminance, ce qui donne également la même largeur de bande qu'avec la norme de studio, avec une largeur de bande de canal de 8 à 9 MHz;

- compte tenu du nombre de périodes d'horloge nécessaires dans le multiplex complet pour les données et les sons numériques, la synchronisation, le clampage et les transitions, une ligne sur laquelle on insère des informations d'image comporte 697 échantillons de luminance et 349 échantillons de différence de couleur;

- le système est séquentiel en ligne, c'est-à-dire que les signaux U et V de différence de couleur sont transmis successivement une ligne sur deux; ici le parallélisme avec la norme de studio n'est plus respecté, mais la transmission des deux signaux U et V à chaque ligne aurait exigé des rapports de compression incompatibles avec une robustesse suffisante vis-à-vis du bruit en radiodiffusion par satellite;

- le recouvrement des spectres verticaux est largement atténué par l'emploi d'un préfiltrage vertical relativement complexe à l'émission et d'un post-filtrage plus simple à la réception.

Afin d'éviter les dégradations dues à un recodage composite (en PAL ou SECAM), il est recommandé de traiter directement à la réception les composantes de luminance et de différence de couleur et d'en déduire par matriçage les signaux R, V, B que l'on appliquera au téléviseur. Cette opération est possible grâce au connecteur "Péritélévision" qui se généralise peu à peu sur les récepteurs domestiques en Europe.

Avec les caractéristiques précédentes, la bande de luminance comprimée est idéalement de 8,4 à 9 MHz. Après décompression la bande est réduite par un facteur 2/3 (inverse du rapport de compression) et est donc de 5,5 à 6 MHz. De même, après décompression, la bande de chrominance peut atteindre 3 MHz, bien que, pour atténuer la visibilité du bruit, il puisse être utile de la réduire à 2 MHz à la réception. Ces valeurs de bande passante - et donc de résolution horizontale - atteintes avec le MAC sont à comparer aux bandes de luminance et de différence de couleur obtenues en pratique dans un récepteur PAL domestique et qui sont respectivement d'environ 3 et 1 MHz.

Des essais subjectifs sur des images codées en C-MAC ont montré qu'après passage dans un simulateur de satellite avec un rapport C/N élevé (environ 20 dB), mais en présence de brouillages aux limites tolérées par la CAMR-RS-1977, la qualité moyenne (sur l'échelle de qualité à 5 notes) est à peine à 0,1 ou 0,2 note en dessous de la valeur atteinte par la norme numérique de studio 4:2:2; l'objectif de transparence vis-à-vis de cette norme est donc bien respecté. En outre, les images en MAC sont très robustes vis-à-vis du bruit, comme le montrent les chiffres suivants: les premiers effets de seuil sont perçus à un C/N de 10 dB avec un démodulateur normal et de 8 dB avec un démodulateur à extension de seuil. Le point de défaillance complet correspondant à la note de qualité 1,5 est atteint à un C/N de 2 à 3 dB (on estime que c'est à ce niveau de qualité qu'un téléspectateur cessera de regarder les images, quel que soit l'intérêt propre du programme).

5. STRUCTURE ET CAPACITE DES TRAMES NUMERIQUES DES SYSTEMES C, D ET D2

Dans les trois systèmes de la famille proposée par l'UER, le signal vidéo est précédé par une période de clampage, d'une durée de 15 périodes d'horloge, et par une salve numérique principalement destinée aux voies son et aux données. La capacité exigée pour celle-ci dans certains projets européens de radiodiffusion par satellite est équivalente à 8 voies son échantillonnées à 32 kHz avec compression quasi instantanée et protection par bit de parité*. Le débit binaire d'une voie de ce type est d'environ 377 kbit/s. Il était donc nécessaire d'avoir, dans la configuration normale du multiplex TDM, un débit moyen supérieur à 3 Mbit/s et, compte tenu d'une horloge de base à 20,25 MHz, d'insérer plus de 192 bits d'information utile dans chaque ligne de balayage.

Une autre condition était de rendre compatibles les systèmes C et D d'une part, qui fontionnent à plein débit, et le système D2 d'autre part qui, pour pouvoir être transmis dans des canaux de câble de 7 MHz, ne pouvait accepter qu'un débit instantané de l'ordre de 10 Mbit/s. Plus exactement l'objectif recherché par l'UER a été de faire en sorte que le système D2 devienne un sous-ensemble des systèmes C et D. C'est pourquoi la trame numérique des systèmes C et D a été divisée en deux sous-trames identiques dont l'une devient la trame complète lors du transcodage vers le système D2, l'autre sous-trame étant inévitablement perdue avec les services qu'elle diffuse.

La structure finalement retenue est donnée à la Fig. 2 pour les systèmes C et D, où l'on voit que l'information proprement dite est répartie sur les lignes 1 à 623, les lignes 624 et 625 étant réservées à d'autres fins. Dans chacune des 623 premières lignes le bit n° 1 est un bit de départ destiné à la démodulation différentielle pour le système C; il est suivi d'un mot de synchronisation de ligne de 6 bits puis de deux séries de 99 bits d'information constituant les deux sous-trames, le dernier bit de la salve (bit 206) étant inutilisé.

La Fig. 3 donne la structure correspondante pour le système D2. La synchronisation de ligne est identique, mais l'information proprement dite se réduit à 99 bits par ligne.

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* Cette capacité est indispensable notamment pour répondre aux besoins des pays nordiques qui, en, plus des sons liés à l'image, ont l'intention de diffuser dans le même canal de satellite, des programmes de radio indépendants de la télévision.

La structure des paquets est identique dans les trois systèmes et est donnée à la Fig. 4. Chaque paquet contient une adresse de 10 bits dont la reconnaissance permet au récepteur d'aiguiller les données vers le décodeur approprié (son, télétexte, etc.); la longueur de l'adresse permet de définir jusqu'à 1024 voies numériques indépendantes dont la coexistence est possible dans le multiplex. Les deux bits suivants forment un indice de continuité qui permet de détecter et donc de dissimuler une éventuelle perte de paquet due à une mauvaise reconnaissance de l'adresse à la suite d'erreurs de transmission. Un suffixe de 11 bits assure ensuite une forte protection de l'adresse par emploi du code de Golay (23,12). Un octet dit PT (Packet Type) permet de savoir si les données qui suivent contiennent des échantillons d'une voie son ou des blocs dits d'"interprétation", lesquels indiquent, sous forme codée la nature du son (mono, stéréo, loi de codage, méthode de protection, embrouillage pour accès conditionnel, etc.). Finalement, pour une longueur totale de 751 bits par paquets, les données utiles occupent 720 bits, soit 90 octets.

Si l'on reporte les chiffres de la Fig. 4 dans les Figs. 2 et 3 qui décrivent les trames numériques, on voit que la capacité totale est de 2 fois 82 paquets par trame pour les systèmes C et D, soit un total de 4100 paquets/s. Avec le système D2, la capacité est de 82 paquets par trame, soit 2050 paquets/s.

Il importe de souligner que, pour conserver la flexibilité maximale des systèmes C et D, les règles de multiplexage définies n'obligent pas à transmettre un service donné dans une seule sous-trame, mais permettent aux paquets correspondants d'être répartis dans les deux sous-trames (par exemple pour un son stéréophonique, la voie "gauche" dans la sous-trame n°1 et la voie "droite" dans la sous-trame n° 2). Un service de ce type ne pourra généralement pas être récupéré lors d'un transcodage vers le système D2.

Les Tableaux I et II illustrent la capacité numérique finale des systèmes pour quelques exemples de charge du multiplex par des sons monophoniques de haute qualité. On y indique, en paquets par seconde, le débit exigé par les voies son (en supposant que chaque son demande une moyenne de 3 paquets d'interprétation par seconde) et le débit résiduel disponible pour des données auxiliaires. Pour interpréter ces tableaux, on se souviendra du fait que de nombreuses configurations différentes sont possibles et que notamment la suppression d'une voie son libère la capacité correspondante pour des services de données.

Tableau I (Systèmes C et D)

Exemples de charge du multiplex numérique par des voies son monophoniques de haute qualité

CHARGE DU MULTIPLEX	CAPACITE EN PAQUET/S	
	VOIES SON	DONNEES AUXILIAIRES
8 voies comprimées avec bit de parité	4024	88
4 voies linéaires avec protection de Hamming	3567 5/9	538 4/9
6 voies linéaires avec bit de parité	4018	91
6 voies comprimées avec protection de Hamming	4018	91

Tableau II (système D2)

Exemples de charge du multiplex numérique par des voies son monophoniques de haute qualité

CHARGE DU MULTIPLEX	CAPACITE EN PAQUETS/S	
	VOIES SON	DONNEES AUXILIAIRES
4 voies comprimées avec bit de parité	2012	38
2 voies linéaires avec protection de Hamming	1783 7/9	266 2/9
3 voies linéaires avec bit de parité	2009	41
3 voies comprimées avec protection de Hamming	2009	41

6. SIGNAUX DE REFERENCE ET D'IDENTIFICATION DES SERVICES

La description détaillée des fonctions auxiliaires réalisées dans les systèmes C, D et D2 sort du cadre de cet article. On se bornera à indiquer (voir Fig. 2 et Fig. 3) que la ligne 624 est réservée à des signaux de référence de niveau (blanc, noir, etc), à des signaux permettant la correction adaptative pour l'image et les données en présence d'échos ainsi qu'à un mot spécial qui repère la position de la période de clampage, celle-ci pouvant être modifiée à l'avenir si l'on raccourcit la salve de données pour permettre la diffusion d'images avec un format élargi. La ligne 625 contient notamment un mot de synchronisation de trame ainsi que les données signalant la position de tous les éléments du multiplex TDM et qui en assurent donc la flexibilité.

D'autres données d'identification des services sont transmises dans une voie spécialisée du multiplex par paquets (paquets d'adresse "0"); elles donnent la liste de tous les services disponibles dans le canal et les informations nécessaires à la configuration automatique du récepteur et des décodeurs en fonction du choix de l'usager. Le multiplex par paquets achemine également les données relatives à l'accès conditionnel (voir le § 8 ci-après).

7. METHODES DE CODAGE ET DE MODULATION

Dans le cas du système C, destiné uniquement à la radiodiffusion par satellite, la modulation de fréquence est naturellement recommandée pour la partie analogique du signal, avec les caractéristiques prévues lors de la CAMR-RS-1977. Une courbe spéciale de préaccentuation a cependant été taillée sur mesure pour le MAC. Pour la partie numérique, on a retenu la modulation 2-4 PSK, qui est une approximation de la modulation MSK et en possède dès lors la plupart des avantages, mais qui en outre permet la réalisation d'un démodulateur différentiel très simple dont la performance, en termes de C/N, n'est dégradée que de 1 dB par rapport à la démodulation cohérente. Expérimentalement on a obtenu, en démodulation différentielle, un taux d'erreur sur les bits de 10^{-3} à un C/N de 7,6 dB. Par ailleurs, il faut insister sur le fait que, pour simplifier le récepteur, il est tout à fait possible de n'employer qu'un seul démodulateur FM pour l'ensemble du signal, mais au prix d'une perte de performance sur la partie numérique (soit le même taux d'erreur sur les bits à un C/N de 2 dB plus élevé).

Contrairement au cas des émissions par satellite où la limitation principale de performance est due au bruit, ce sont les échos à retard court (de l'ordre de 100ns) qui constituent la difficulté majeure pour des signaux numériques sur les réseaux de câble. Le codage en bande de base devait donc offrir le meilleur compromis entre la largeur de bande occupée et la résistance aux échos. Pour un débit instantané de 20 Mbit/s et une modulation AM/VSB, le codage binaire simple exige un canal d'au moins 14 MHz; le codage duobinaire ne demande plus qu'un minimum de 10,5 MHz et le codage quaternaire permet de descendre à 7 MHz, mais la fragilité de cette dernière méthode vis-à-vis des échos rend douteuse son exploitation courante sur les réseaux de câble existant en Europe. Le choix s'est donc porté sur le codage duobinaire pour les systèmes D et D2, en notant d'ailleurs que les caractéristiques de certains réseaux anciens devront être améliorées (cette amélioration étant de toute façon nécessaire pour la distribution du télétexte avec les débits binaires instantanés actuellement utilisés en Europe).

Signalons encore au passage qu'en spécifiant le détail des systèmes D et D2 l'UER s'est efforcée d'unifier certaines normes terrestres actuelles en Europe, notamment en recommandant la modulation positive et des formes semblables pour les filtres AM/VSB.

Le système D exigera une replanification des canaux de certains réseaux de câble ainsi que le développement de nouveaux tuners et démodulateurs, mais son avantage est d'être transparent vis-à-vis du système C et donc de fournir les mêmes services avec la même qualité à tous les usagers, qu'ils soient abonnés au câble ou qu'ils reçoivent les émissions des satellites avec une antenne individuelle*. Avec le système D2, certains tuners modernes aux normes L/SECAM sont utilisables directement; le signal en bande de base sort du téléviseur par la prise "Péritélévision" pour être traité dans une "boîte noire" et rentrer par la même prise sous forme de signaux R, V, B d'une part et de signaux audio d'autre part. Dans les autres cas et notamment celui des normes B ou G/PAL et I/PAL, le système D2 demandera lui aussi de nouveaux tuners ou des modifications aux tuners existants.

Quel que soit finalement le système (C, D ou D2) ou le mode de réception (satellite ou câble), le récepteur d'usager aura la configuration illustrée à la Fig. 5 où l'on voit que les étages RF pourraient différer d'un cas à l'autre, mais que le traitement des signaux démodulés se fera de manière identique. Au moment de la rédaction de cet article, des industriels ont déjà confirmé qu'ils pourraient produire un type unique de récepteur pour les systèmes C et D2 en radiodiffusion par satellite ainsi que D et D2 en distribution par câble avec un faible supplément de coût par rapport à un récepteur destiné à un seul système. C'est dans ce sens que la proposition de l'UER porte sur une famille de systèmes mutuellement compatibles au niveau du récepteur, même si la qualité et la quantité des services ne sont pas les mêmes pour tous les membres de la famille.

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* Dans le cas des petites installations collectives, à l'échelle d'un immeuble, le signal C-MAC/paquets peut être distribué directement à la première fréquence intermédiaire (950-1750 MHz).

8. ACCES CONDITIONNEL

Un système très élaboré d'accès conditionnel a été développé pour application à la famille des systèmes C, D et D2-MAC/paquets. Le schéma général en est donné à la Fig. 6. On voit que les différents éléments (image, son, données) sont d'abord embrouillés par une séquence binaire pseudo-aléatoire. La position dans le cycle du générateur pseudo-aléatoire est définie par un mot dit "mot de contrôle". Le mot de contrôle "local" est fixe et connu lorsque l'émission est à accès libre et le récepteur peut alors désembrouiller le signal sans disposer d'autres données. En cas d'accès contrôlé (c'est-à-dire non libre), le mot de contrôle est chiffré par une "clé d'autorisation", elle-même chiffrée par une "clé de distribution". Pour déchiffrer la clé d'autorisation, l'usager utilise d'une part sa clé personnelle de distribution et d'autre part un signal de validation qui peut être transmis sur antenne ou par d'autres supports physiques. Pour obtenir le mot de contrôle, on a besoin de la clé d'autorisation ainsi que la version chiffrée du mot de contrôle. Le signal peut alors être désembrouillé par une séquence binaire pseudo-aléatoire identique à celle utilisée pour l'embrouillage. Ce système offre un haut degré de sécurité et le désembrouillage n'est possible que par un usager qui possède un titre d'accès valide, c'est-à-dire en pratique qui est en règle de paiement.

Les messages de contrôle d'accès (version chiffrée du mot de contrôle ainsi que le signal de validation dans le cas de la distribution sur antenne) sont transmis dans le multiplex par paquets.

L'embrouillage du signal MAC est réalisé par coupure et rotation de segments de ligne active. On peut définir, par la séquence pseudo-aléatoire soit un point de coupure dans la luminance et un autre dans la différence de couleur (procédé à double coupure et rotation des composantes), soit un point unique dans la différence de couleur (procédé à simple coupure et à rotation de ligne). Le premier procédé offre une sécurité plus élevée mais est plus sensible à la distorsion d'inclinaison de ligne et à la distorsion de la réponse amplitude/fréquence qui sont susceptibles de se produire dans les réseaux de câble et les étages RF des récepteurs. La tolérance globale pour l'inclinaison de ligne est d'environ de 0,5%.

Il est à remarquer qu'un signal à composantes comme le MAC est beaucoup plus facile à embrouiller et à désembrouiller de façon sûre qu'un signal composite comme le PAL. Selon des sources industrielles, et toute considération de qualité mise à part, le gain de prix sur l'embrouillage en utilisant le MAC au lieu du PAL dépasse le supplément de prix exigé par le MAC vis-à-vis du PAL pour un système sans embrouillage.

9. EXTENSIONS POSSIBLES DU SYSTEME MAC

La diffusion d'images MAC de qualité améliorée, mais sans doute non encore à haute définition, peut être envisagée au départ comme par exemple des futures sources vidéo à haute définition ou du film de 35 mm. Cet objectif semble réaliste à moyen terme mais il demande l'adjonction au système MAC d'une série de traitements du signal, à l'émission comme à la réception, en vue d'améliorer la résolution et de permettre un format élargi. On envisage la diffusion d'images de proportions d'environ 5/3 tout en conservant une compatibilité avec le format 4/3 classique. On a déjà indiqué qu'une réorganisation, en principe quelconque, du multiplex temporel est permise dans les spécifications de l'UER concernant les systèmes C, D et D2 grâce aux données de contrôle du multiplex (TDMCTL) transmises dans la ligne 625, ainsi que, si nécessaire, par le paramètre "configuration vidéo" (VCONF) qui fait partie de la voie spécialisée d'identification des services transmise dans le multiplex par paquets.

Il est à remarquer que les systèmes C et D2 en particulier ont théoriquement les mêmes possibilités d'amélioration de l'image s'ils sont utilisés dans un canal à bande large, comme le canal de radiodiffusion par satellite. Toutefois, si le système D2 est exploité sur câble dans des canaux de 7 MHz, le filtrage introduit lors de la modulation AM/VSB fixe une limite inéluctable à la résolution horizontale.

Plusieurs propositions ont été formulées à ce jour pour la réorganisation du multiplex temporel MAC en vue de la transmission d'images de proportions approximativement égales à 5/3 ou davantage.

La première est schématiquement décrite par la structure de trame donnée à la Fig. 7a. La partie de l'image au format 4/3 occupe la même place qu'auparavant dans le multiplex et la compatibilité est dès lors assurée vis-à-vis des décodeurs de première génération. L'information d'image supplémentaire pour le format 5/3 est transmise d'une part dans la suppression de ligne, en raccourcissant la salve de données, et d'autre part dans la suppression de trame, en diminuant le nombre de lignes à présent disponibles pour d'autres applications (comme le télétexte aux normes actuelles).

Une seconde proposition est décrite à la Fig. 7b. L'image est uniquement transmise au format 5/3 avec des rapports de compression inchangés; la suppression de ligne ne comporte plus que les indispensables fonctions de synchronisation et de clampage, les services sonores et de données étant alors transmis dans la suppression de trame. Dans ce cas, le décodeur au format 4/3 doit être à même d'interpréter correctement les "fenêtres" des signaux de luminance et de différence de couleur correspondantes.

D'autres organisations du multiplex ont été suggérées mais elles impliquent un changement des rapports de compression actuellement proposés soit pour l'image à format élargi soit pour la "sous-image" de format 4/3. On a par exemple suggéré de transmettre sur toutes les lignes actives uniquement le signal de luminance non comprimé : il en résulte un gain immédiat et appréciable de définition horizontale puisque la largeur de bande (non comprimée) dépasse d'emblée 8 MHz. En revanche, les signaux de différence de couleur doivent être transmis dans la suppression de trame avec des rapports de compression plus élevés et ils deviennent donc plus sensibles au bruit. On espère qu'à plus ou moins court terme, un accord se fera sur un petit nombre de nouvelles configurations du multiplex temporel adaptées à telle ou telle application.

Quelle que soit la configuration retenue, l'amélioration de la qualité de l'image au format élargi - qui est normalement destinée à la visualisation sur grand écran - exigera des traitements supplémentaires dont nous allons donner quelques exemples.

La résolution horizontale atteinte avec le système MAC dépend essentiellement de la fréquence d'horloge utilisée pour le traitement de l'image. Avec la fréquence normale de 20,25 MHz, la largeur de bande vidéo est limitée à une valeur de 8,5 à 9 MHz environ. Il n'y a cependant pas de raison fondamentale de limiter la bande vidéo à ce chiffre. Dans un canal de satellite, on pourrait sans difficulté étendre la bande jusqu'à 12 MHz sans rencontrer de problèmes de brouillage avec les canaux adjacents et, avec une fréquence d'horloge de 27 MHz, la bande de luminance non comprimée serait alors de 8 MHz, si l'on conserve le rapport de compression de 3/2.

En ce qui concerne la résolution verticale, on devra envisager d'introduire à la réception un balayage non entrelacé. Un exemple possible est de calculer à partir du signal reçu à 625 lignes/50 Hz 2:1 un nouveau signal à 625 lignes/50 Hz 1:1, doublant ainsi le nombre de lignes et de trames, sans qu'il y ait adjonction d'informations. Des études récentes montrent qu'avec des traitements de ce type il serait possible d'atteindre la résolution verticale théorique des systèmes à 625 lignes qui, avec 575 lignes actives, est de 287,5 cycles par hauteur d'image; ce chiffre correspond à une résolution horizontale de 7,37 MHz avec le format habituel 4/3.

Si l'on met en oeuvre l'ensemble des possibilités précédentes - reconfiguration du multiplex, élargissement de la bande passante et traitements spatio-temporels - il semble que l'on puisse atteindre une qualité d'image pratiquement indiscernable de la vraie haute définition, pour des applications domestiques où la surface de l'écran ne dépasserait pas 1 m^2 environ, mais ceci doit encore être démontré.

10. TELEVISION A HAUTE DEFINITION

Les extensions du MAC décrites au paragraphe précédent mènent sans aucun doute à une télévision de qualité améliorée, mais non encore à la télévision à haute définition dans l'acception proposée par le CCIR. Nous ne mentionnerons pas ici la norme mondiale de production à haute définition que toutes les Unions de radiodiffusion du monde - y compris l'UER - ainsi que le CCIR, s'efforcent d'élaborer en ce moment, et nous nous bornerons à citer deux types de voies d'approche vers un futur système de diffusion à haute définition qui, on le remarquera, sont tous deux basés sur le codage des composantes analogiques et peuvent donc être considérés comme appartenant, au sens large, à la famille MAC.

La première voie est celle choisie par le NHK au Japon avec le développement du système MUSE. Elle consiste à utiliser des techniques de sous-échantillonnage et d'interpolation adaptative entre plusieurs trames. La bande de base du système MUSE à 1125 lignes et 60 trames par seconde est à peine de 8 MHz, de sorte que le signal peut être diffusé dans un seul canal de radiodiffusion par satellite à 12 GHz. Ce système n'est pas compatible avec les normes actuelles de balayage.

La deuxième voie peut être illustrée par la proposition de CBS aux Etats-Unis où l'on utilise deux canaux de radiodiffusion par satellite qui diffusent respectivement un signal "compatible" et l'information complémentaire pour la haute définition. En Allemagne, un système similaire est étudié sur la base du système C-MAC/paquets. Cette approche exige le double de spectre radioélectrique et, de l'avis des auteurs, on voit mal comment l'utiliser en Europe dans la bande des 12 GHz qui sera probablement saturée à court terme, au moins pour certains pays.

La question du spectre utilisable pour la haute définition est plus critique en Europe qu'ailleurs où - comme dans l'ensemble de la Région 1 - la bande 22,5-23 GHz n'a pas été allouée à la radiodiffusion par satellite, contrairement à la Région 2 (Amériques) et à la Région 3 (Asie-Pacifique). S'il était possible à une prochaine Conférence de l'UIT d'étendre cette allocation à la Région 1, il serait intéressant d'étudier l'opportunité d'une norme mondiale de diffusion à haute définition à 23 GHz.

11. CONCLUSIONS

On a montré que la proposition de l'UER concernant une famille de systèmes (C, D et D2) utilisant les principes du multiplexage temporel, du codage de l'image en MAC et du multiplexage numérique par paquets, constitue une base solide pour l'amélioration à très court terme de la qualité de la télévision (image et son) et la diversification des services audiovisuels. Il serait regrettable de ne pas profiter de l'occasion offerte par la radiodiffusion par satellite pour introduire ces nouveaux systèmes, aussi bien en réception individuelle qu'en réception par l'intermédiaire des réseaux de câble. La flexibilité du multiplex temporel fournit en outre la clé d'extensions futures, y compris la diffusion d'images avec un format élargi et une définition voisine des limites théoriques du système à 625 lignes. Malgré l'intérêt des voies d'approche existantes, la diffusion d'une télévision à haute définition fait encore l'objet d'incertitudes et n'est souvent perçue en Europe que comme un objectif lointain.

S'il existe une réelle unanimité parmi les ingénieurs et techniciens pour reconnaître les mérites des propositions de l'UER, les positions politiques ne sont pas figées au moment de la rédaction de cet article. Le gouvernement britannique et ceux des pays nordiques se sont prononcés en faveur du C-MAC/paquets pour la radiodiffusion par satellite. De puissants groupes industriels et certaines sphères politiques (notamment en France) sont favorables à l'exploitation du D2-MAC/paquets sur tous les supports. Parmi les facteurs susceptibles d'intervenir lors de la prise de décision, il convient de citer le délai très court dont on dispose pour le développement et la fabrication en série des circuits intégrés nécessaires pour les nouveaux systèmes, puisque l'échéance des premiers services opérationnels par satellite se situe à la fin de 1986 ou en 1987. Ce facteur est à ce point critique que certains pourraient proposer de s'en tenir aux normes conventionnelles, PAL et SECAM, jusqu'à l'époque de la disponibilité commerciale d'un système à haute définition.

L'UER espère cependant que l'occasion ne sera pas perdue d'unifier les normes européennes et de mettre en oeuvre des systèmes de télévision de qualité significativement meilleure possédant en outre un potentiel non négligeable d'évolution future.

12. REFERENCES BIBLIOGRAPHIQUES

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(2) Methods of conveying C-MAC/packet signals in small and large community antenna and cable networks installations. Specification of the D-MAC/packet and of the D2-MAC/packet systems. Document de l'UER SPB 352, décembre 1984.

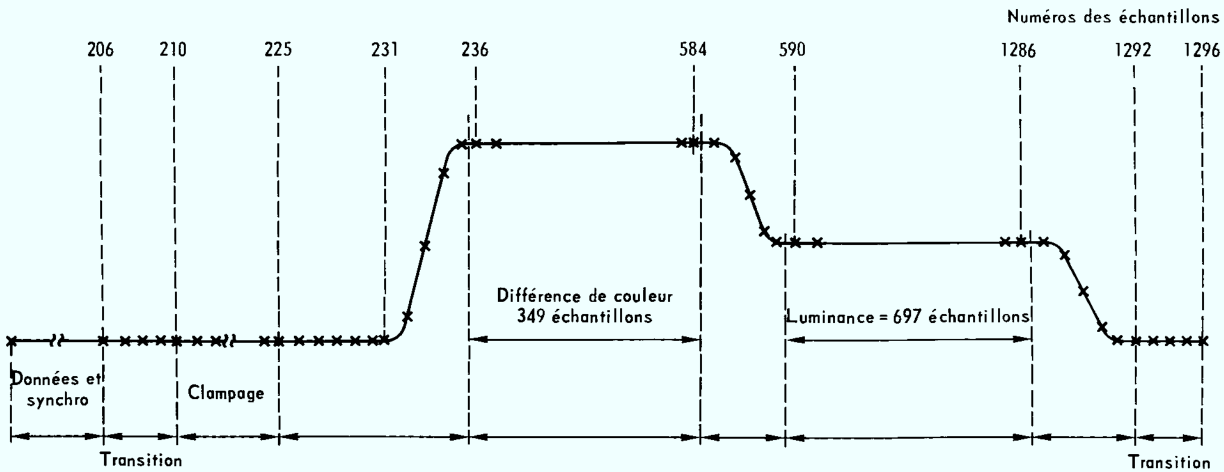


*Fig. 1 Forme d'onde du signal C-MAC/paquets non embrouillé, avant préaccentuation
(Le signal vidéo est identique dans les systèmes D- et D2-MAC/paquets)*

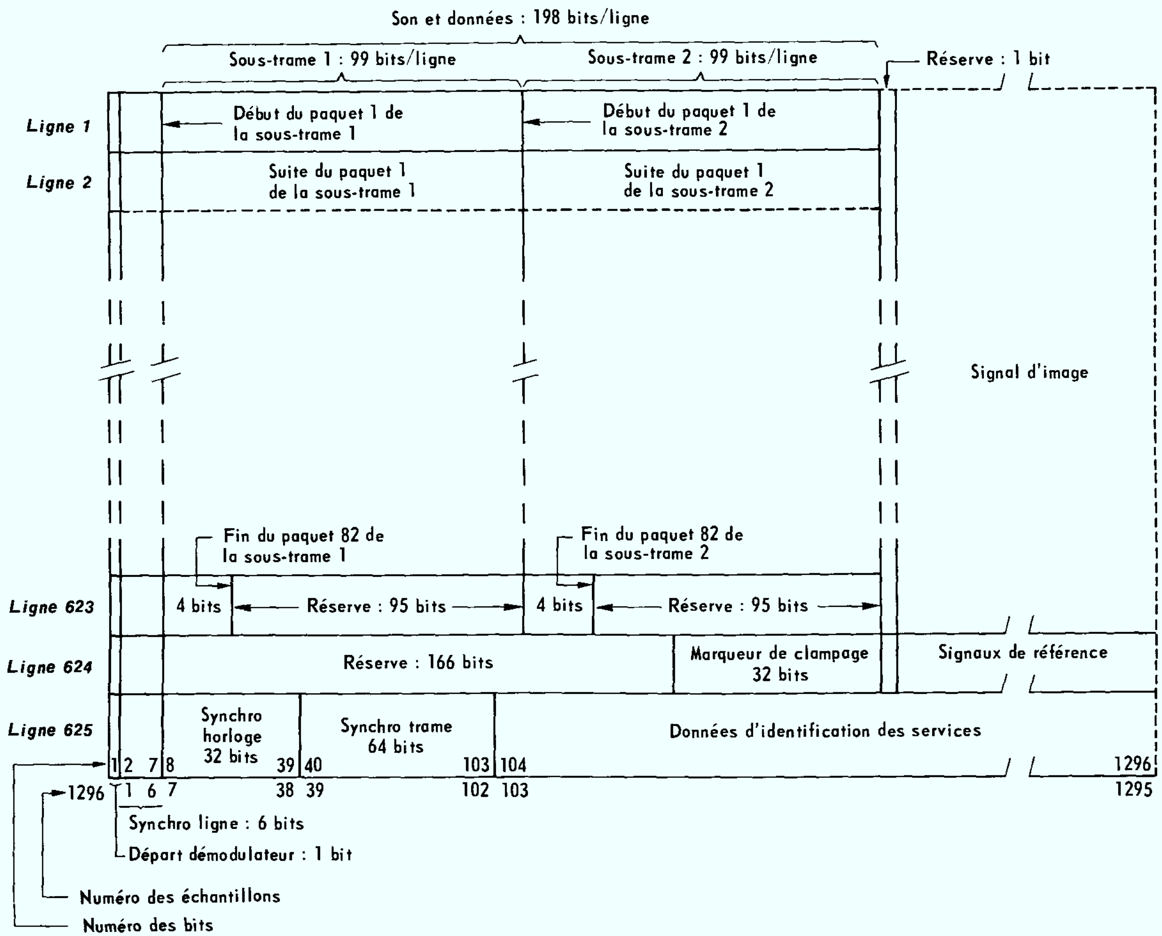


Fig. 2 Structure de la trame des systèmes C- et D-MAC/paquets
(Fréquence d'horloge : 20,25 MHz)

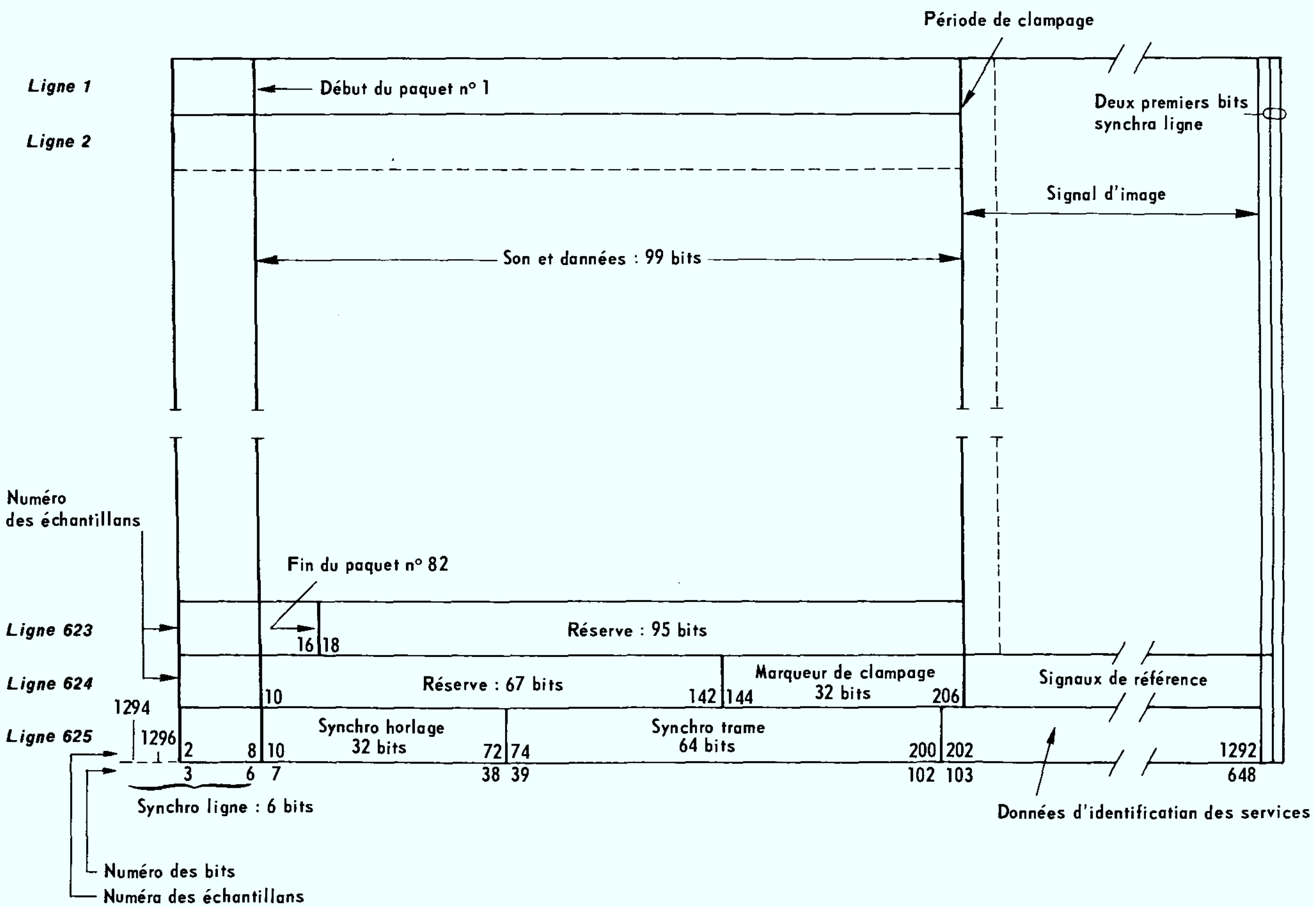


Fig. 3 ***Structure de trame du système D2-MAC/paquets***
(Le multiplex TDM est défini en termes d'échantillons à 20,25 MHz
mais les données sont transmises à 10,125 Mbit/s sur les échantillons pairs)

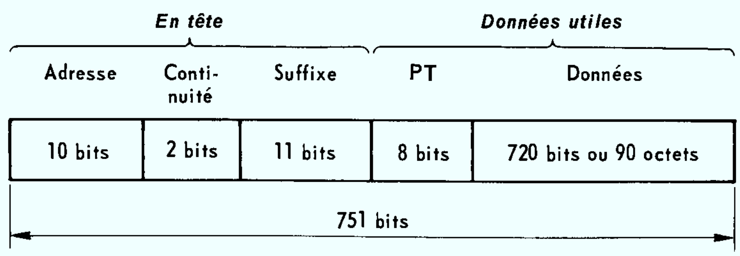


Fig. 4 Structure des paquets

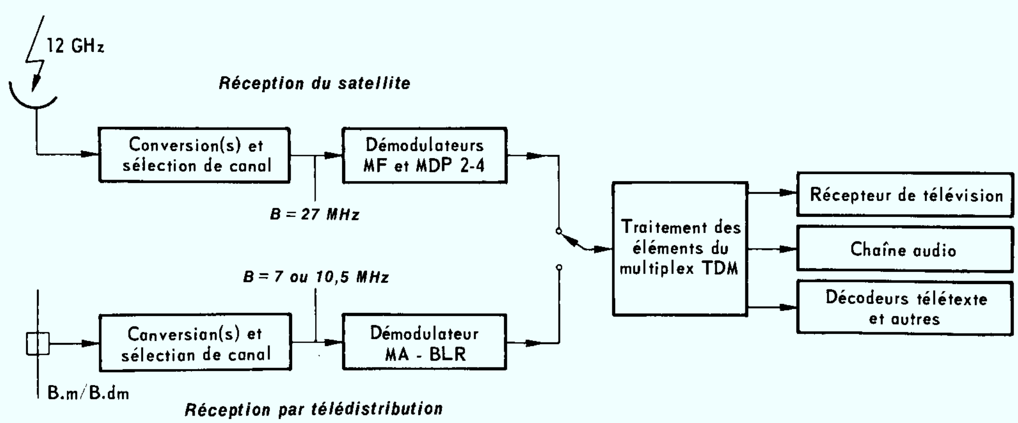


Fig. 5 Schéma simplifié de l'installation de réception pour les systèmes C-, D- et D2-MAC/paquets

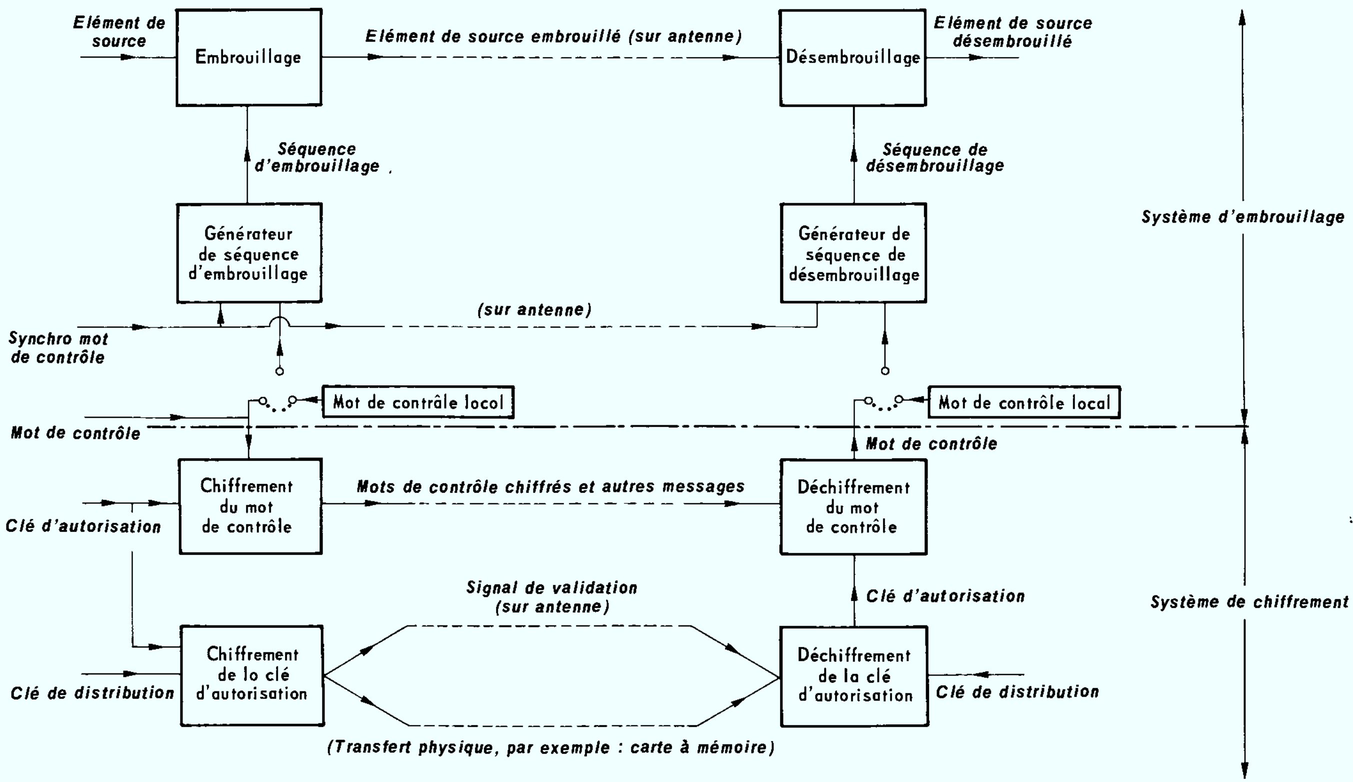
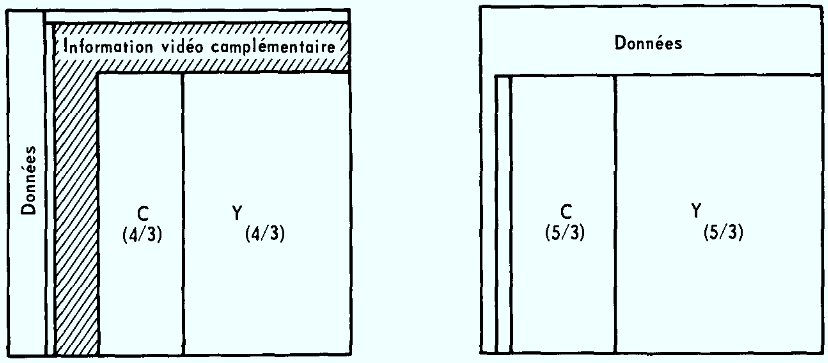


Fig. 6 Schéma simplifié du système d'accès conditionnel



(a) (b)

Fig. 7 Exemples de configurations du multiplex temporel proposées pour permettre la diffusion d'images en format 5/3 avec les systèmes C-, D- et D2-MAC/paquets

THE EUROPEAN APPROACHES TO BETTER QUALITY IN TELEVISION

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ABSTRACT

In many cases, television picture and sound quality is limited by the inherent shortcomings of the systems in use, rather than by technology. Direct broadcasting by satellite will soon be with us and this offers an ideal opportunity to introduce new systems having flexibility and quality as their principal objectives.

The technical studies within the EBU were initially directed at what was then seen as the weakest point in the existing systems, the sound. Here, the adoption of digital techniques allows an increase in both the quality and in the number of channels. The EBU then turned to ways of improving the picture quality and for this the MAC (Multiplexed Analogue Components) system is proposed.

This paper describes the family of compatible systems recommended by the EBU: C-MAC/packet for satellite broadcasting, D-MAC/packet for the cable distribution of all the information contained in the first system, and D2-MAC/packet for narrow-band cable distribution or other applications. This is followed by an examination of the possibilities for developing these systems towards even better picture quality and indications are given of future approaches towards the broadcast transmission of high-definition pictures.

The concluding section summarises the present situation in Europe. Decisions have not yet been taken by all the governments.

1. INTRODUCTION

As in North America, the colour television standards currently in use in Europe (PAL and SECAM, with 625-line/50 Hz scanning) were developed almost thirty years ago on the basis of the technologies available at that time.

For many types of picture the quality is now limited by the systems themselves and not by the potential equipment performance. We are familiar with the inherent defects of the composite coding principle (cross-luminance and cross-colour) and those resulting from the type of scanning: limitation of the vertical and horizontal definition, large-area flicker, visibility of the line structure, inter-line flicker, etc.. In addition, the sound is not of the highest quality and, at best, the present television systems allow the inclusion of only two analogue sound channels (or one stereophonic channel), plus a few hundred pages of teletext.

With the rapid expansion of digital techniques and the availability of integrated circuits able to carry out complex functions at low cost (provided the market is sufficiently large), it was evidently possible to envisage the development of new systems. A unique opportunity presents itself to introduce a new improved standard with the imminent introduction of the first satellite broadcasting services. Individual receivers will in any case have to be equipped with some kind of remodulation system even if conventional sigals are broadcast. It is also imperative to allow for community reception and cable distribution with a system which is identical to - or at least compatible (apart from the modulation) with - the signal processing circuits of the individual direct broadcast receiver.

These considerations led the EBU to propose at the end of 1984 a family of compatible systems known as the MAC/packet family. The members are C-MAC/packet (for satellite broadcasting), D-MAC/packet (for cable distribution, with channels at least 10.5 MHz wide and carrying all the information contained in the first system), and D2-MAC/packet (for cable distribution in channels only 7 or 8 MHz wide but with reduced capacity). The D2-MAC/packet system is also recommended by the European industry for satellite broadcasting with the same vision bandwidth as the C-MAC/packet system and may be a candidate for a future terrestrial broadcast transmission standard and for new forms of domestic VTR.

The present paper gives a brief description of this family of standards developed in Europe. Particular attention will be given to the picture quality and the scope for evolution towards extended definition and an aspect ratio of 5:3 which may, in domestic applications, be competitive with high-definition television.

2. BACKGROUND TO THE EBU STUDIES

The first studies on a new standard for satellite broadcasting were concerned, in the early 1980s, with arguably the weakest point in the present television systems which is the sound. In this domain today's mastery of digital techniques offers the possibility of increasing the quality quite considerably and of increasing the number of sound channels; this, in view of the multiplicity of languages spoken in Europe, is regarded as of major importance. Also, by means of a suitable multiplexing system, the capacity of any given digital channel can be traded between sound and data broadcasting services, and there have been predictions that the latter will expand dramatically. The EBU nomenclature used for the various systems that have been studied is well-known and has been used throughout the world:

- "A" systems: frequency multiplexing, with the picture, of a digitally-modulated subcarrier;
- "B" systems: baseband time multiplexing, with the picture, of a digitally-coded signal with full response;
- "C" systems: radiofrequency time multiplexing with the picture. These systems give the greatest transmission capacity for a given RF channel width.

More recently, during the studies for cable distribution, the type "D" systems appeared which are baseband time multiplexes with partial-response coding (more specifically, duo-binary coding).

Later, still with a view to satellite broadcasting, the EBU turned its attention to improving picture quality and it examined improved composite systems which are more complex frequency multiplexes of the luminance and chrominance information. There is unanimous preference, however, for the multiplexed analogue components (MAC) system which uses time-division multiplexing and temporal compression.

After it had recommended, in 1983, the C-MAC/packet system for satellite broadcasting (type "C" modulation, MAC picture coding and packet multiplexing of the digital services) the EBU concentrated its efforts on cable distribution and, at the end of 1984, it proposed the D-MAC/packet system which is a "carbon copy" of the C-MAC/packet system except that the multiplexing is done in the baseband, and duo-binary coding is used for the digital services. To accommodate the requirements of cable network operators who were not prepared to modify the 7 or 8 MHz channel spacings used on their systems, and faced also with certain manufacturers who favoured a system that could be used on all supports (satellites, cable, terrestrial transmitters, etc.) the EBU also specified the D2-MAC/packet system which is identical to the D-MAC/packet system except that the bit-rate of its digital burst is reduced by one-half with a corresponding decrease in the capacity.

In all three systems, which to simplfy matters we call C, D and D2, the picture is coded using MAC in exactly the same manner. In principle the quality is the same and there is the same scope for future extensions. However the filtering involved in the AM/VSB modulation to restrain the D2 signal within the confines of a 7 or 8 MHz channel results in a significant loss of horizontal definition. Apart from this, all discussion of the relative merits of the three systems is concerned with the digital part; it has already been mentioned that the C system has the greatest capacity and that it makes the most efficient use of the satellite broadcasting channel.

At the time when this paper was being written the specifications of the C, D and D2 systems published by the EBU <1, 2> were the subject of an intensive debate with European industry. It is important to bear in mind that in Europe, regardless of their influence, neither broadcasters nor industry have the power to take a decision on standards; this power resides with each nation's government, and it is therefore beyond the capacity of the authors to state irrefutably the extent to which the systems will be used.

3. OBJECTIVES OF THE NEW SYSTEM: FLEXIBILITY AND QUALITY

Apart from the fundamental requirement to make the best possible use of the spectrum, the family of systems proposed by the EBU are distinctive in that they offer maximum flexibility as regards services, an immediate improvement in quality, and possibilities for future evolution.

The time multiplex retains a 625-line raster with 50 fields (or 25 frames) per second. In these frames, however, we have the option of inserting, as required, any analogue or digital component we wish, with their positions being signalled by what are known as "time multiplex control" data carried in line 625. The result, in terms of services, is the possibility of transmitting in any given channel a variable and evolutionary combination of moving pictures, still pictures, graphics, sound signals of a variety of qualities and any form of data. For the digital services the packet multiplexing system has been chosen for its flexibility; it allows the coexistence of several digital channels without restrictions as regards their individual bit-rates, their repetition rates or their timing.

The improvement in sound quality is achieved through the use of digital coding. The sampling frequency used is 32 kHz (or 16 kHz for sound signals such as commentaries for which a reduced audio bandwidth is acceptable). The resolution is that corresponding to 14 bits per sample in linear coding although bit-rate reduction has been provided in the form of near-instantaneous companding from 14 to 10 bits per sample (the system commonly known as "NICAM"). Two options are provided as regards error-protection (in addition to the protection given by the scale factor transmission): either one parity bit per sample or a Hamming code covering the most-significant bits of the samples. Despite the increased decoder complexity, these different configurations have been defined to allow broadcasters to select, on a case-by-case basis, within the limits of the total capacity available, the best compromise between the number of sound channels broadcast, their final quality and their ruggedness (i.e. in effect the size of the coverage area).

The improvement in picture quality is derived from the use of the MAC coding described in detail in the next section. As regards the scope for future developments, including the transmission of pictures with wider aspect ratios, these are derived, as will be seen later, from the flexibility of the time multiplex.

4. MAC PICTURE CODING

The principle of multiplexed analogue coding for the luminance and colour-difference components is now well-known: these components are coded separately and transmitted in turn within the duration of one scanning line (52 μs for the 625/50 standards). To make the information fit into the available time slot the components have to be compressed in the time domain (and of course there has to be corresponding temporal expansion in the receiver); these operations can easily be achieved today by A/D conversion and then loading and reading a line store at the appropriate speeds.

Long studies have led the EBU specialists to optimise the MAC system parameters to suit the conditions applying to the broadcast transmission of a picture in the normal aspect ratio of 4:3, accompanied by a digital burst.

Fig. 1 shows the recommended waveform of one picture line. Without going into the detailed justification for the chosen characteristics, we will briefly recall the following points which highlight the fundamental objective of transparency with respect to the worldwide digital production standard known as 4:2:2 which is specified in CCIR Recommendation 601:

- the basic clock frequency is 20.25 MHz which is exactly 3/2 times the luminance sampling frequency in the 4:2:2 studio standard; there are therefore 1296 clock periods per line;

- the luminance compression ratio is equal to this same factor of 3/2, thus giving a non-compressed luminance bandwidth which is equivalent to that of the studio standard for a channel bandwidth of 8-9 MHz;

- the compression ratio of the colour-difference components is equal to 3, which is twice that of the luminance, thus giving the same bandwidth as in the studio standard for a channel bandwidth of 8-9 MHz;

- bearing in mind the number of clock periods needed in the complete multiplex for the data and digital sound signals, synchronisation, clamping and transitions, each line of picture information contains 697 luminance sampling periods and 349 colour-difference sampling periods;

- the system is line-sequential; i.e. the U and V colour-difference signals are transmitted in turn on alternate lines; here the parallel with the studio standard has not been respected, but the transmission of both U and V signals on every line would have required the use of compression ratios which would be incompatible with the requirements for system ruggedness in the presence of the noise in satellite broadcasting;

- vertical aliasing is largely attenuated by the use of relatively complex vertical pre-filtering at the transmitter and simpler post-filtering at the receiver.

To avoid the impairments caused by re-coding into composite form (in PAL or SECAM) it is recommended that the luminance and colour-difference components should be processed directly in the receiver, with the RGB signals being derived by matrixing and fed to the display circuitry. This is possible by means of the "peritelevision" connector which is gradually being introduced into domestic receivers in Europe.

With the characteristics outlined above the compressed luminance bandwidth is ideally 8.4-9 MHz. After expansion the bandwidth is reduced by a factor of 2/3 (the reciprocal of the compression ratio) and is therefore about 5.5-6 MHz. Similarly, after expansion the colour-difference bandwidth can be up to 3 MHz, although, to reduce the noise bandwidth, it may be advantageous to reduce this to about 2 MHz in the receiver. These bandwidth figures, and the corresponding horizontal resolutions, should be compared with the luminance and colour-difference bandwidths obtained in practice with a domestic PAL receiver, the figures here being of the order of 3 and 1 MHz respectively.

Subjective tests on pictures coded in C-MAC have shown that after passing through a satellite simulator with a high C/N ratio (about 20 dB), but in the presence of interference at the maximum levels allowed by the WARC-BS-1977, the mean quality (on the 5-grade quality scale) is barely 0.1 or 0.2 grade lower than the value reached by the digital 4:2:2 studio standard; the objective of transparency in respect of this standard has therefore been well respected. Furthermore, pictures in MAC are very rugged in the presence of noise, as shown by the following figures: the first threshold effects are seen at a C/N ratio of 10 dB with a normal demodulator and 8 dB with a threshold-extension demodulator. The total failure point, corresponding to quality grade 1.5 is reached at a C/N ratio of 2 to 3 dB (it is reckoned that at this level of quality a viewer will cease to watch the picture, regardless of the inherent interest of the programme).

5. STRUCTURE AND CAPACITY OF THE DIGITAL FRAMES IN THE C, D, AND D2 SYSTEMS

In all three systems in the family proposed by the EBU, the video signal is preceded by a clamp period which lasts 15 clock periods, and by a digital burst serving principally for the transmission of sound channels and data. The capacity needed in this digital burst for certain European satellite broadcasting projects is equivalent to 8 sound channels sampled at 32 kHz with near-instantaneous companding and parity-bit protection*. The bit-rate of a channel of this type is about 377 kbit/s. It has therefore been necessary to have in the normal configuration of the TDM multiplex, a mean bit-rate of more than 3 Mbit/s and, in view of the basic clock rate of 20.25 MHz, more than 192 information bits have to be inserted in each scanning line.

Another condition was to make the C and D systems, operating at the full bit-rate, compatible with each other and to ensure compatibility with the D2 system which, if it is to fit into 7 MHz cable channels, could have an instantaneous bit-rate of no more than about 10 MHz. More precisely, the EBU objective was to make the D2 system a true sub-set of the C and D systems. It is for this reason that the digital frame of the C and D systems is divided into two identical sub-frames, one of which will become the full frame when transcoding to the D2 system; the other sub-frame will inevitably be lost, together with the services it carries.

The configuration that was finally adopted is shown in Fig. 2 for the C and D systems. It is seen that the information (as distinct from the control data) is carried in lines 1 to 623; lines 624 and 625 are reserved for other purposes. In each of the first 623 lines bit no. 1 is a run-in bit used in differential demodulation for the C system. It is followed by a line synchronisation word of 6 bits and then by two series of 99 information bits constituting the two sub-frames; the last bit of the burst (bit 206) is not used.

Fig. 3 shows the corresponding structure for the D2 system. The line synchronisation is identical but the useful information is reduced to 99 bits per line.

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* This capacity is indispensible in particular to meet the requirements of the Nordic countries where, in addition to sound signals associated with the picture, it is intended to broadcast, in the same satellite channel, a selection of sound radio programmes.

The packet structure is identical in the three systems and is shown in Fig. 4. Each packet contains a 10-bit address which is recognised by the receiver and used to steer the data to the appropriate decoder (sound, teletext, etc.); the address length is sufficient for as many as 1024 independent digital channels to coexist in the multiplex. The next two bits form a continuity index which can be used to detect, and thus to conceal, any packet loss caused by incorrect recognition of the address owing to transmission errors. An 11-bit suffix then provides strong protection for the address through the use of a Golay cyclic code (23,12). A so-called PT (packet type) byte indicates whether the subsequent data are samples of a digital sound channel or what are known as "interpretation blocks" which serve to indicate in coded form the nature of the sound (mono, stereo, etc.). Finally, out of a total of 751 packet bits, the useful data occupy 720 bits or 90 bytes.

Transfering the figures of Fig. 4 across to Figs. 2 and 3 which describe the digital frames, it is seen that the total capacity is 2 times 82 packets per frame in the C and D systems, or a total of 4100 packets/s. With the D2 system, the capacity is 82 packets per frame, or 2050 packets/s.

It is important to stress that, to maintain maximum flexibility in the C and D systems, the defined multiplexing rules do not impose that any given service has to be transmitted in only one sub-frame: the packets of this service can be divided between both the sub-frames (for example, in a stereophonic sound programme the "left" channel may be carried in sub-frame no. 1 and the "right" channel in sub-frame no. 2). A service of this type could generally not be recovered when transcoding to the D2 system.

Tables I and II illustrate the final capacity of the systems for a few examples of multiplex loading with high-quality monophonic sound signals. The tables show, in terms of packets per second, the data-rate needed for the sound channels (assuming that each sound signal requires an average of 3 interpretation packets per second) and the residual data-rate available for auxiliary data. In interpretating these tables is should be borne in mind that many different configurations are possible and in particular that if one sound channel is liberated the corresponding capacity is then available for data services.

Table I (C and D systems)

Examples of digital multiplex loading with
high-quality monophonic sound channels

MULTIPLEX LOADING	CAPACITY IN PACKETS/S	
	SOUND CHANNELS	AUXILIARY DATA
8 companded channels with parity bit	4024	88
4 linear channels with Hamming protection	3567 5/9	538 4/9
6 linear channels with parity bit	4018	91
6 companded channels with Hamming protection	4018	91

Table II (system D2)

Examples of digital multiplex loading with
high-quality monophonic sound channels

MULTIPLEX LOADING	CAPACITY IN PACKETS/S	
	SOUND CHANNELS	AUXILIARY DATA
4 companded channels with parity bit	2012	38
2 linear channels with Hamming protection	1783 7/9	266 2/9
3 linear chanels with parity bit	2009	41
3 linear channels with Hamming protection	2009	41

6. REFERENCE AND SERVICE IDENTIFICATION SIGNALS

It would not be possible for reasons of space to give a detailed description here of the auxiliary functions included in the C, D and D2 systems. We will simply indicate (see Fig. 2 and Fig. 3) that line 624 is to be used for signals such as level reference signals (black, white, etc.), signals allowing adaptive equalisation for the picture and data in the presence of echoes, and a special word which indicates the position of the clamp period, this being necessary because the timing may be changed in the future if the data burst is shortened to accommodate pictures with wider aspect ratio, etc.. Line 625 contains, in particular, a frame synchronising word and data which indicate the positions of all the elements of the TDM multiplex, thus ensuring the flexibility of the entire system.

Other service identification data are transmitted in a specialised channel of the packet multiplex (packets with the address "0"); this gives a list of all the services available in the channel and the information needed for the automatic configuration of the receiver and its decoders to suit the choice made by the user. The packet multiplex also carries data relating to conditional access (see § 8 below).

7. CODING AND MODULATION METHODS

In the case of the C system, intended only for satellite broadcasting applications, frequency modulation is of course recommended for the analogue part of the signal, with the characteristics laid down by the WARC-BS-1977. A special pre-emphasis curve has nonetheless been defined, tailored to the MAC system. For the digital part, the choice was 2-4 PSK which is an approximation to MSK modulation and thus has most of its advantages, but which also allows the construction of a very simple differential demodulator whose performance, in terms of C/N, is only 1 dB worse than that of a coherent demodulator. In experiments with differential demodulation a bit error-rate of 10^{-3} has been obtained with a C/N ratio of 7.6 dB. It should be stressed that, to simplify the receiver, it is fully possible to use a single FM demodulator for the entire signal, although the penalty is a loss of performance (the same error rate at a C/N ratio 2 dB higher) in the digital part.

In contrast to the situation with satellite transmissions where the main performance limit is set by the noise, short-delay echoes (of the order of 100 ns) are the main difficulty when passing digital signals through cable networks. The baseband coding must therefore give the best possible compromise between bandwidth occupied and resistance to echoes. For an instantaneous bit-rate of 20 Mbit/s and with AM/VSB modulation, simple binary coding requires a channel width of at least 14 MHz; duo-binary coding requires a minimum of 10.5 MHz and with quaternary coding this limit can be pushed down to 7 MHz although the lack of ruggedness of this latter method in the presence of echoes makes it doubtful as a contender for every-day use on the cable networks in use in Europe. The choice has therefore fallen on duo-binary coding for the D and D2 systems, although it is to be noted that certain older networks will have to be improved (this improvement is in any event needed if these networks are to distribute teletext at the data rates used currently in Europe).

It may be mentioned in passing that here again, in specifying the details of the D and D2 systems, the EBU has sought to unify with certain European terrestrial standards in particular with recommendations for positive modulation and similar forms of AM/VSB filter.

The D system will make it necessary for certain cable networks to be re-planned and new tuners and demodulators will be needed. It has however the advantage of being transparent to the content of the C system and, hence, of offering the same services, with the same quality, to all users whether they subscribe to a cable network or whether they receive satellite broadcasts with an individual antenna*. With the D2 system certain modern tuners for L/SECAM may be suitable for use directly; the baseband signal leaves the receiver via the "peritelevision" connector, is processed in a "black box" and is fed back to the receiver via the same connector in the form of R, G and B signals accompanied by the audio signals. In other cases, and in particular with B or G/PAL and I/PAL receivers, the D2 system will also need new tuners or modifications to existing tuners.

Regardless of which system is used (C, D or D2) and regardless of whether the programmes are received from satellite or cable, the user's receiver will have the configuration shown in Fig. 5 where it is seen that the RF stages may differ from one case to another but that the processing of the demodulated signals is identical in all cases. At the time when this paper was being written some manufacturers had already confirmed that they could produce a single type of receiver for the C and D2 systems in satellite broadcasting and for the D or the D2 systems in cable distribution with a small additional cost as compared to the cost of a receiver working with only one system. It is in this sense that the EBU proposal covers a family of systems which are compatible within the receiver, even if the quality and quantity of the services are not the same for all members of the family.

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* In small collective antenna systems, serving a building, the C-MAC/packet signal may be distributed directly at the first intermediate frequency (950-1750 MHz).

8. CONDITIONAL ACCESS

A very elaborate conditional access system has been developed for use with the family of C, D and D2-MAC/Packet systems. The principles are outlined in Fig. 6 where it is seen that the different components (picture, sound, data) are first scrambled by a pseudo-random binary sequence. The point in the cycle of the PRBS generator is defined by a so-called "control word". The "local" control word is fixed and can be used when there is free access to the programme. The receiver can descramble the signal without needing other data. Where access is controlled or not free, the control word is encrypted by an "authorisation key" which, in turn, is encrypted by a "distribution key". To decrypt the authorisation key, the user uses his personal distribution key together with a validation signal which may be transmitted with the broadcast signal or sent by some other physical means. To obtain the control word, the user needs the authorisation key and the encrypted version of the control word. The signal can then be descrambled by a pseudo-random binary sequence identical to that used for scrambling. The system offers a high degree of security and descrambling is possible only by users who are entitled to do so, which in practice will usually mean those who have made the necessary payments.

The access control messages (the encrypted version of the control word and the validation signal in the case of over-air transmission) are transmitted in the packet multiplex.

The MAC signal scrambling is done by cutting and rotating active picture line segments. It is possible to define, by the pseudo-random sequence, either a cut point in the luminance and in the colour-difference (the double-cut component rotation process) or a single cut point in the colour-difference (the single-cut line rotation process). The first process offers the greatest security but it is somewhat more sensitive to line-tilt distortion and amplitude/frequency response distortion which can occur in cable networks and in the RF stages of receivers. The overall tolerance required for the line-tilt is about 0.5 %.

It may be noted that a component signal like MAC is much more easily scrambled and descrambled, with high security, than is a composite signal such as PAL. According to industrial sources, leaving aside quality considerations, the saving in costs to scrambling brought about by using MAC rather than PAL is greater than the additional costs of using MAC rather than PAL for a non-scrambled system.

9. POSSIBLE EXTENSIONS OF THE MAC SYSTEM

The broadcast transmission of extended quality MAC pictures, perhaps not yet of high-definition quality, may be envisaged with pictures originated from, for example, high-definition video sources or 35-mm film. This objective seems realistic in the medium term but it requires the addition to the MAC system of a series of signal processes at both the sending and receiving ends of the chain, intended to improve the definition and to provide a wider aspect ratio. Consideration is being given to the transmission of pictures having an aspect ratio of about 5:3, whilst conserving compatibility with the conventional 4:3 format. We have already indicated that a reorganisation, in principle in any form, of the time multiplex is allowed for in the EBU specifications for the C, D and D2 systems by virtue of the mutliplex control (TDMCTL) data transmitted in line 625 and, if necessary, the "video configuration" (VCONF) parameter which is included in the special service-identification channel transmitted in the packet multiplex.

It should be noted that the C and D2 systems, in particular, have the same theoretical scope for picture enhancement if they are transmitted in wideband channels (such as a satellite channel). However, if the D2 system is used on cable networks in 7 MHz channels, the filtering introduced during the AM/VSB modulation sets an unavoidable limit to the horizontal definition.

Several proposals have been put forward so far for the reorganisation of the MAC time multiplex to cater for the transmission of pictures with aspect ratios approximately equal to 5:3 or more.

The first is described in outline by the frame structure shown in Fig. 7a. The part of the picture in 4:3 format occupies the same position in the multiplex as before and so compatibility is thus assured in respect of first-generation decoders. The additional picture information for the 5:3 format is transmitted partly in the line blanking, by reducing the data burst, and partly in the field blanking, by reducing the number of lines currently available for other applications (such as teletext in the present-day standards).

A second proposal is described in Fig. 7b. The picture is transmitted only in 5:3 format, with the compression ratios unchanged. The line blanking contains only the information essential for synchronisation and clamping and the sound and data services are transmitted in the field blanking. In this case, the 4:3 format decoder must be able to correctly interpret the "windows" in the luminance and colour-difference signals.

Other arrangements for the multiplex have been suggested but they imply changes for either the wide aspect ratio picture or the 4:3 sub-picture in the existing compression ratios. For example, it had been suggested that the non-compressed luminance signal should be transmitted throughout every active line: this gives an immediate increase in horizontal definition because the (non-compressed) bandwidth is more than 8 MHz. However the colour-difference signals must then be transmitted in the field blanking with higher compression ratios and they therefore become more susceptible to noise. It is to be hoped that sooner or later agreement will be reached on a small number of new configurations of the time multiplex, each suited to a particular application.

Whichever configuration is selected, the improvement of the quality of pictures in wide aspect ratio format - normally intended for large-screen display - will demand the use of additional processing and a few examples will now be given.

The horizontal definition obtained with the MAC system depends mainly on the clock frequency used for processing the picture. With the normal frequency of 20.25 MHz, the video bandwidth is limited to about 8.5-9 MHz. However there may be no fundamental reason to limit the video bandwidth to this value. In a satellite channel the bandwidth could be extended without difficulty to 12 MHz without creating problems of interference with the adjacent channels and, with a clock frequency of 27 MHz the non-compressed luminance bandwidth would be 8 MHz, assuming the compression ratio is maintained as 3/2.

For vertical definition, consideration can be given to the use of progressive scanning in the receiver. One example involves calculating from the signal received at 625 lines/50 Hz 2:1 a new signal at 625 lines/50 Hz 1:1, thus doubling the number of lines and fields without there being any additional information. Recent studies have shown that with processing of this sort it may be possible to achieve the maximum theoretical vertical definition of 625-line systems which, with 575 active lines, is 287.5 cycles per picture height; this figure corresponds to a horizontal definition of 7.37 MHz with the normal 4:3 aspect ratio.

If all the above-mentioned possibilities are implemented - reconfiguration of the multiplex, expansion of the passband and spatio-temporal processing - it could be that the picture quality will be practically indiscernable from true high-definition, for domestic applications in which the screen area does not exceed about one square metre, although this remains to be proven.

10. HIGH-DEFINITION TELEVISION

There is no doubt that the extensions of MAC outlined in the previous section lead to better quality television but they still fall short of true high-definition in the sense proposed by the CCIR. We will not consider in detail here the worldwide high-definition production standard which all the world's broadcasting unions - including the EBU - together with the CCIR, are attempting to establish at the moment but we will just mention two types of approach to a future high-definition transmission system which, it will be noted, are both based on analogue component coding and which can therefore be regarded in a general sense as belonging to the MAC family.

The first approach is that chosen by the NHK in Japan with the development of the MUSE system. This involves techniques using sub-sampling and adaptive interpolation covering several frames. The MUSE baseband width at 1125 lines and 60 fields per second is barely 8 MHz so the signal can in principle be transmitted in a single satellite broadcasting channel in the 12 GHz band. This system is incompatible with conventional scanning systems.

The second approach may be illustrated by the CBS proposal in the United States where two satellite broadcasting channels are used, one carrying a "compatible" signal and the other the additional information for the high-definition picture. In Germany a similar system has been devised on the basis of the C-MAC/packet system. This approach uses twice as much radioelectric spectrum and the authors believe it is difficult to see how it could be used in Europe in the 12 GHz band which will probably be saturated in the near future at least in certain countries.

The question of the spectrum space available for high-definition is more critical in Europe than elsewhere because, in common with the rest of Region 1, the band 22.5 - 23 GHz has not been allocated to satellite broadcasting, in contrast to the situation in Region 2 (the Americas) and Region 3 (Asia-Pacific). If it were possible at a forthcoming ITU Conference to extend this allocation to Region 1 it would be interesting to examine the benefits of a worldwide high-definition transmission standard for 23 GHz.

11. CONCLUSIONS

It has been shown that the EBU proposal for a family of systems (C, D and D2) using the principles of time multiplexing, MAC picture coding and digital packet multiplexing constitutes a firm basis for an improvement of television quality (both picture and sound) in the very near future and for a diversification of audiovisual services. It would be regrettable if we were not to take advantage of the opportunity presented by the start of satellite broadcasting to introduce these new systems, both for individual reception and for reception via the intermediary of the cable networks. The flexibility of the time multiplex also provides the key to future evolution, including the transmission of pictures in wide aspect ratio and resolution close to the theoretical limits of the 625-line system. Despite interest in the present lines of approach, there is still some uncertainty as regards the broadcast transmission of high-definition television and this is often seen in Europe as a long-term objective.

Although there is real unanimity among engineers and technicians in recognising the merits of the EBU proposals, the political positions have not yet been fixed. The United Kingdom and Nordic governments have declared themselves in favour of the C-MAC/packet system for satellite broadcasting. Powerful industrial groups and certain elements in the political arena (in particular in France) favour the D2-MAC/packet system for all supports. Among the factors that may have an influence when decisions are taken is the very short time-scale available for the development and mass production of the integrated circuits needed for the new systems, bearing in mind that the deadline for the start of the first operational satellite services is the end of 1986 or 1987. This factor is so critical that some may propose retaining the conventional standards, PAL and SECAM, until such time as a high-definition system comes to the market-place.

The EBU nonetheless hopes that we will not waste this opportunity to unify the European standards and implement television systems with significantly better quality, offering quite considerable scope for future evolution.

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(2) Methods of conveying C-MAC/packet signals in small and large community antenna and cable networks installations. Specification of the D-MAC/packet and of the D2-MAC/packet systems. EBU document SPB 352, December 1984.

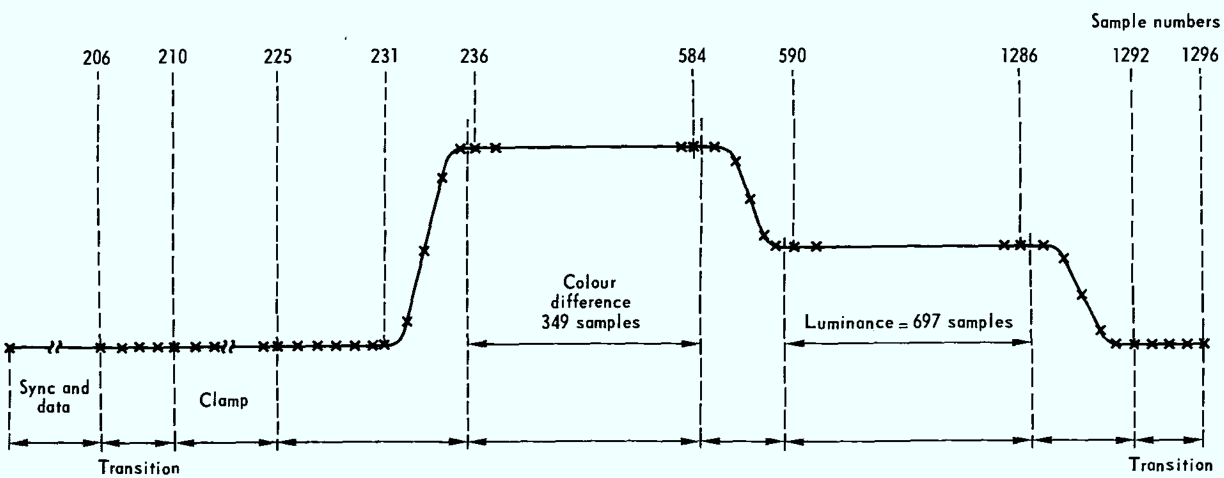

Fig. 1 Waveform of the C-MAC/packet signal, unscrambled and before pre-emphasis
(The vision signal is identical in the D- and D2-MAC/packet systems)

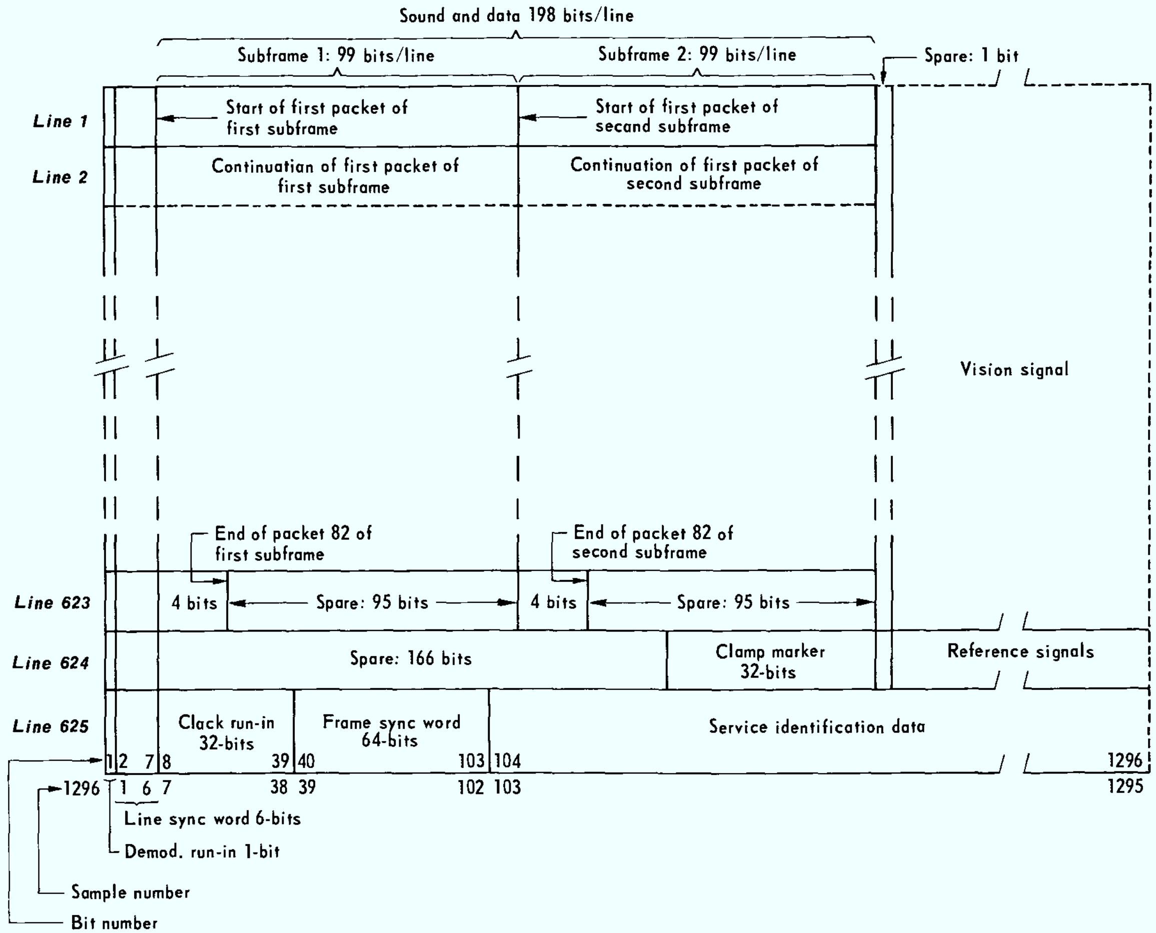

Fig. 2 Frame structure of the C- and D-MAC/packet systems (Clock frequency: 20.25 MHz)

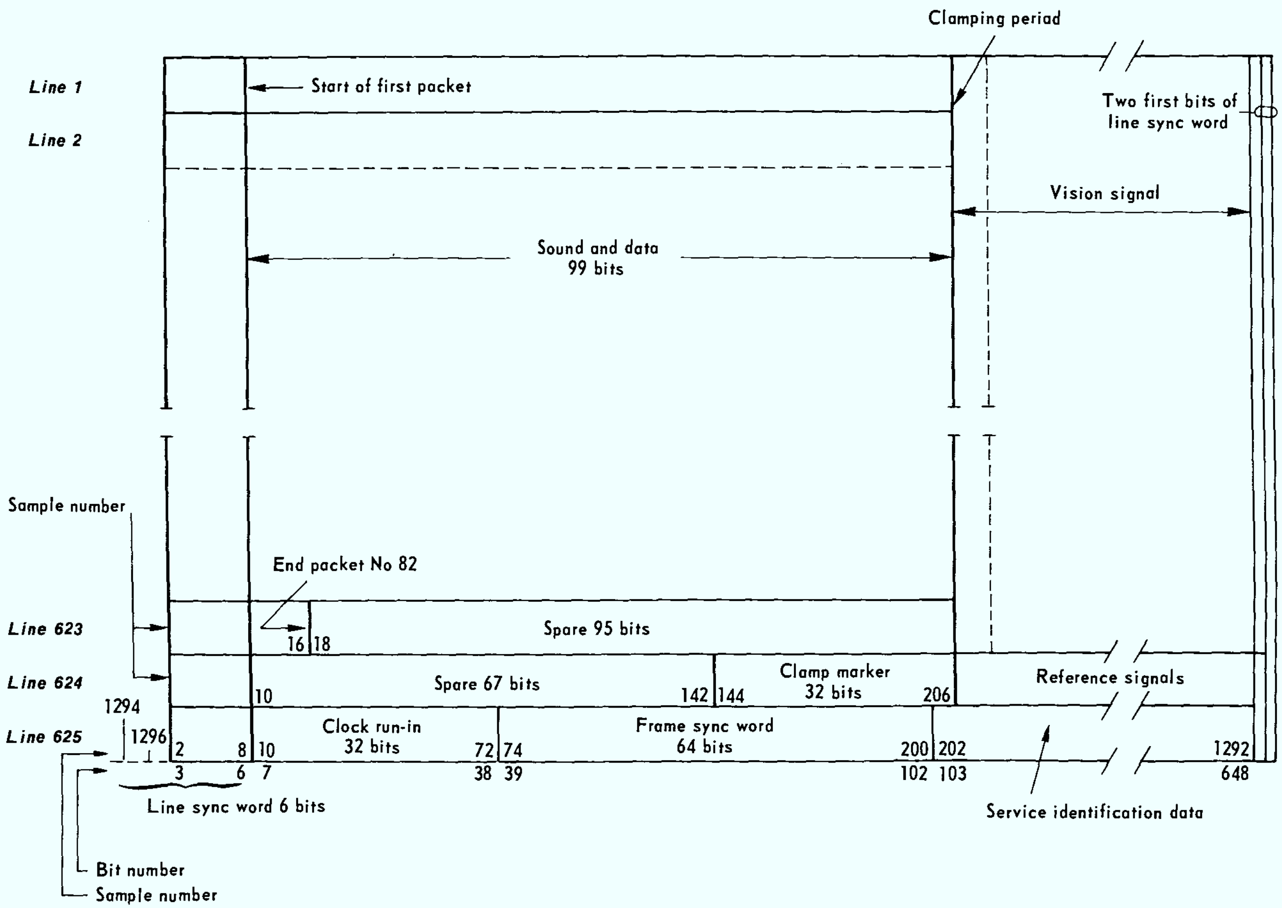

Fig. 3 Frame structure of the D2-MAC/packet system (The TDM multiplex is defined in terms of samples at 20.25 MHz but the data are transmitted at 10.125 Mbit/s and carried in the even samples)

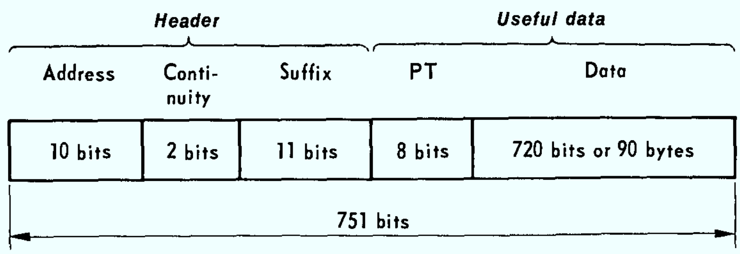

Fig. 4 Packet structure

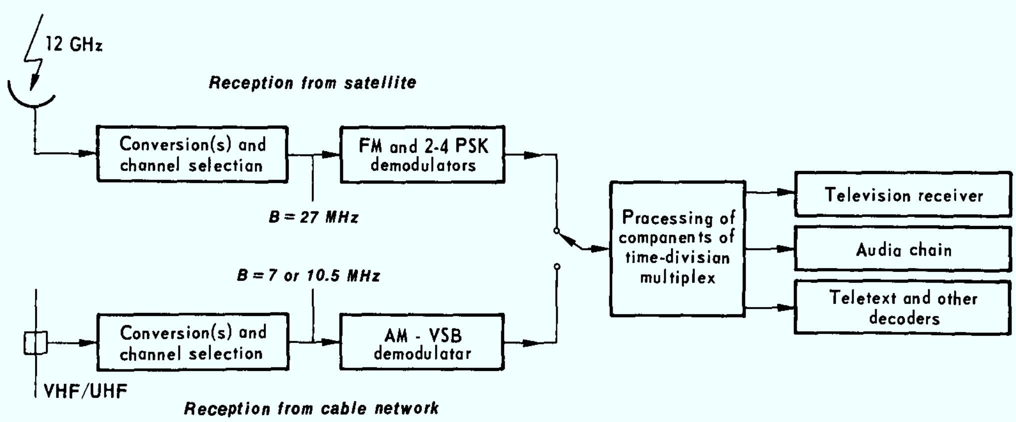

Fig. 5 Simplified block-diagram of the receiving installation for the C-, D- and D2-MAC/packet systems

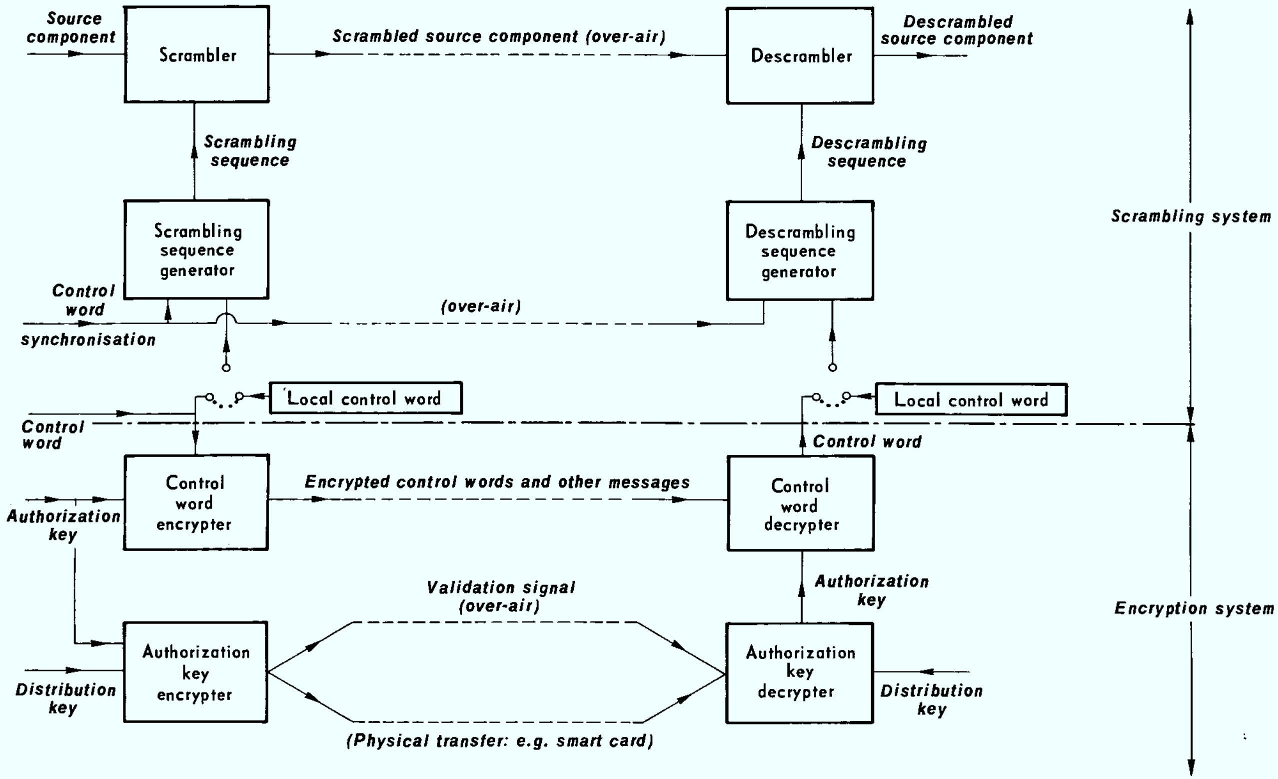

Fig. 6 Simplified block diagram of the conditional access system

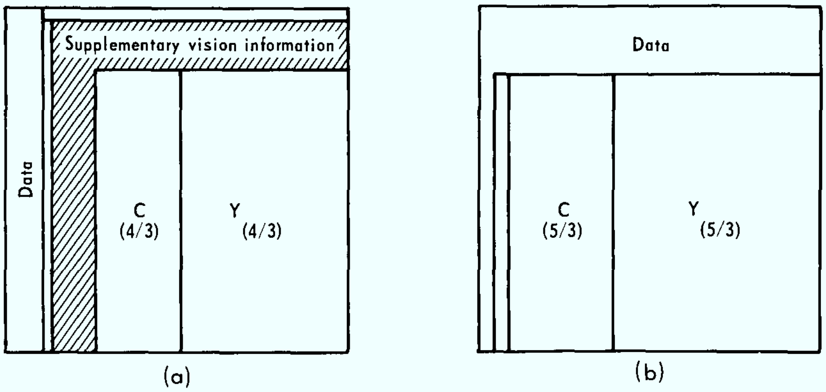

Fig. 7 Examples of proposals of the TDM configuration for transmission of pictures having an aspect ratio of 5/3, with the C-, D- and D2-MAC/packet systems

EUROPEAN MAC: A COMPONENT MAKER'S VIEWPOINT

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ABSTRACT

International standards are an important method of achieving a large market necessary for the development of application specific VSL1 circuits. In setting a standard the system designer is more and more faced with the difficult decision that the system that is recently introduced will be obsolete before the natural life cycle has elapsed. There is a grave tendency for system designers therefore to aim new systems at too high a standard. This has two major dangers:

1. The cost of early equipment bears the cost of future enhancements.

2. Evolution of components and technologies over the life cycle can never be predicted, and the planned enhancements may still be rendered obsolete.

The European family of Mac Systems should be seen as an important step. It ensures that the new DBS services planned to start from mid-1986 onwards will start a system based on modern technologies which should lead to economic receivers in the early stages of the service. The European Mac Systems have the possibility of evolving upward whilst still retaining compatibility with the early decoder.

SYSTÈME MAC EUROPÉEN
POINT DE VUE D'UN FABRICANT DE COMPOSANTS

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3.7

RÉSUMÉ

Les normes internationales constituent une méthode importante permettant d'obtenir le vaste marché nécessaire à la mise au point de circuits à intégration à très grande échelle (VLSI) correspondant à des applications particulières. Lors de l'établissement d'une norme, le concepteur est de plus en plus souvent confronté à l'idée que le système récemment établi sera désuet avant la fin de sa vie utile normale. Les concepteurs ont par conséquent tendance à viser des normes trop élevées pour les nouveaux systèmes, ce qui présente deux dangers:

1. Le coût du matériel mis au point en premier supporte le coût des améliorations futures.

2. L'évolution des composants et des techniques pendant la durée de vie utile ne peut jamais être réellement prévue et les améliorations envisagées peuvent aussi devenir désuettes.

La famille européenne de systèmes MAC doit être considérée comme une étape importante. Elle assure que les nouveaux services de radiodiffusion directe par satellite, dont la mise en oeuvre devrait commencer au milieu de 1986, débuteront avec un système se fondant sur les technologies modernes, ce qui devrait conduire à des récepteurs économiques dans les premières étapes du service. Les systèmes MAC européens ont la possibilité de se perfectionner, tout en gardant leur compatibilité avec les premiers décodeurs.

THE EVOLUTION OF B-MAC INTO A FULLY COMPATIBLE EDTV SYSTEM

3.8

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ABSTRACT

For the past three years, Digital Video Systems in Toronto has been working on the development of a new format for delivery to the home of improved quality television pictures with up to six high fidelity digital sound channels combined with a range of text, data and access control features. The set of custom integrated circuits for implementation of a low cost consumer B-MAC decoder for operation in both 525 and 625 line standards, is now essentially complete.

While designed principally to optimize channel utilization for satellite distribution, the format also applies for terrestrial broadcast, cable TV, master antenna TV, multipoint distribution systems, etc.

The B-MAC format can provide for compatible distribution of 4:3 (1.33/1) and 16:9 (1.78/1) aspect ratios in the same channel, with selection by the viewer of the ratio appropriate to his display equipment. "Pan & Scan" for selection of the 4:3 portion of the total picture area will become a built-in feature of the home decoder, under frame by frame digital control from the broadcast centre.

This paper gives an overview of the B-MAC system, and details various parameters of the format that are related to the compatible wide screen technique.

The following paper by Charles Rhodes, discusses the utilization of a second distribution channel which can be added to this standard broadcast compatible channel for presentation of full high definition wide screen video, sound and data.

ÉVOLUTION DU B-MAC VERS UN SYSTEME DE TVHD TOTALEMENT COMPATIBLE

3.8

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RÉSUMÉ

Depuis trois ans, la Digital Video Systems de Toronto travaille à la mise au point d'un nouveau format pour la transmission à domicile de signaux d'image de télévision de meilleure qualité comportant jusqu'à six canaux audio numériques de haute fidélité et une gamme de fonctions d'affichage de textes, de transmission de données et de contrôle d'accès. La fabrication des circuits intégrés spéciaux que requiert un décodeur B-MAC grand public bon marché fonctionnant dans les standards 525 et 625 lignes est à toutes fins pratiques maîtrisée.

Quoique conçu pour optimiser l'utilisation du canal en distribution par satellite, le format convient aussi à la radiodiffusion de Terre, à la télévision par câble, à la télévision à antenne collective, aux systèmes de distribution multipoint, etc.

Le procédé B-MAC rend compatible la distribution, dans le même canal, de signaux ayant un rapport largeur-hauteur de 4/3 (1,33/1) et de 16/9 (1,78/1). Il appartient au téléspectateur de choisir le rappoirt qui convient à son appareil. Les décodeurs domestiques comporteront une fonction "panoramique et balayage" pour la sélection d'une partie de l'image totale en fonction du rapport 4/3. Cette fonction sera contrôlée par un signal numérique trame par trame, transmis par le centre de diffusion.

Le mémoire donne un aperçu du système B-MAC et décrit divers paramètres du format qui se rattachent à la technique grand écran compatible.

La communication suivante de M. Charles Rhodes examine l'utilisation d'un deuxième canal de distribution, lequel peut être ajouté au canal de diffusion compatible normal, afin de présenter sur grand écran des images de haute définition pour distribution vidéo, son et données.

THE FURTHER EVOLUTION OF B-MAC SIGNAL FORMAT FOR HDTV BROADCASTING

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3.9

ABSTRACT

The fundamental limit for bandwidth of component based transmission systems is the Nyquist Limit, one-half the sampling frequency. In both 525/60 and 625/50 versions of B-MAC, these sampling frequencies are just above 14 MHz. The luminance bandwidth can therefore by 6.4 MHz.

While there would be some advantage gained in using this additional bandwidth just to enhance the horizontal resolution of R/G/B pictures, this bandwidth in the case of FM transmission (DBS) comes at a cost of requiring a higher C/N for the same S/N_W. In terrestrial broadcasting, VSB-AM is used and the present channel widths are inadequate for MAC transmissions, however, two adjacent channels would be adequate for a wideband MAC signal. These costs must be justified by the incremental benefits to the public. The author suggests that a better alternative would be to provide a wide screen enhanced TV picture with a 16:9 aspect ratio as recommended by SMPTE for HDTV Production. The B-MAC time compression ratios make such a system compatible with 4:3 display screens.

The horizontal resolution available with 6.4 MHz bandwidth is equivalent to 4.8 MHz with a 4:3 display. This is a considerable enhancement in resolution with respect to the resolution provided by most receivers. The author believes the public will be able to recognize a 50% increase in horizontal resolution combined with the new look of the wider screen.

This transmission format may be used for terrestrial transmission if and when the governmental regulatory agency would authorize the extension of significant sideband energy into the upper adjacent channel. Extension of the effective channel bandwidth appears to be technically feasible at UHF. This signal format can be carried over CATV systems by allocating two adjacent mid-band or other CATV channels. This signal can be delivered to the CATV "head-end" via satellite, demodulated, descrambled, and re-modulated as VSB-AM. The bandwidth of the upper sideband may extend to 9.6 MHz.

This system can be readily extended into a two channel, compatible HDTV transmission system along the lines described by CBS in 1983. In this case, the augmentation channel can be optimized to transmit the other set of lines, probably using a different compression scheme as that channel would not be used for 4:3 displays and carries no audio or addressability data. In this way, horizontal resolution can be averaged up.

ÉVOLUTION SUPPLÉMENTAIRE DE LA STRUCTURE DES SIGNAUX B-MAC POUR RADIODIFFUSION TVHD

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RÉSUMÉ

La limite fondamentale de la largeur de bande des systèmes de transmission axés sur les composantes est la limite de Nyquist, la moitié de la fréquence d'échantillonnage. Dans les versions 525/60 et 625/50 de la structure B-MAC, ces fréquences d'échantillonnage se trouvent juste au-dessus de 14 MHz. La largeur de bande de luminance peut donc être 6.4 MHz.

Il y aurait certains avantages à utiliser cette largeur de bande suppléentaire juste pour améliorer la résolution horizontale des images R/V/B, mais cette largeur de bande dans le cas de la transmission MF (SRS) impose un rapport porteuse/bruit supérieur pour un même rapport S/N . Dans le cas de la radiodiffusion de Terre, le système BLR-AM est utilisé et les largeurs de voie actuelles ne sont pas adaptées aux transmissions MAC; toutefois, deux voies adjacentes suffiraient à la transmission d'un signal MAC large bande. Les coûts doivent être justifiés par l'amélioration des avantages offerts au public. L'auteur suggère qu'un meilleur choix consisterait à donner une image télévisuelle améliorée sur écran de grandes dimensions avec un rapport de dimensions 16:9, conformément à la recommandation SMPTE pour la production TVHD. Les rapports de compression temporelle B-MAC rendent un tel système compatible avec les écrans d'affichage de rapport 4:3.

La résolution horizontale possible avec une largeur de bande de 6.4 MHz équivaut à une largeur de bande de 4.8 MHz avec un affichage de rapport 4:3. Il s'agit d'une amélioration considérable de la résolution par rapport à la résolution donnée par la plupart des récepteurs. L'auteur croit que le public pourra reconnaître une augmentation de 50% dans la résolution horizontale combinée avec la nouvelle apparence d'un écran plus large.

Cette structure de transmission peut être utilisée pour les transmissions de Terre si les agences de réglementation des gouvernements autorisent l'extension de l'énergie appréciable des bandes latérales dans la voie adjacente supérieure. L'extension de la largeur de bande effective semble techniquement possible aux fréquences UHF. Cette structure de signal peut être adaptée aux systèmes de télévision par câble en attribuant deux voies adjacentes du milieu de la bande ou d'autres voies de télévision par câble. Le signal peut être transmis au système par l'intermédiaire d'un satellite, puis démodulé, désembrouillé et remodulé sous la forme d'un signal BLR-AM. La largeur de bande de la bande latérale supérieure peut être étendue jusqu'à 9.6 MHz.

Ce système peut facilement s'adapter à un système compatible de transmission TVHD à deux voies, selon les lignes directrices décrites par la CBS en 1983. Dans ce cas, la voie d'augmentation peut être optimisée pour transmettre l'autre jeu de lignes, probablement en utilisant une autre structure de compression car cette voie ne serait pas utilisée pour les affichages 4:3 et elle ne transporte aucune donnée audio ni aucune donnée d'adressage. De cette façon, il est possible d'effectuer la moyenne de résolution horizontale.

THE FURTHER EVOLUTION OF THE B-MAC SIGNAL FORMAT FOR HDTV BROADCAST

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The B-MAC transmission signal format was developed in Canada primarily for Direct Broadcast Satellite applications for its inherent advantages over composite signal formats at or below threshold Carrier-to-Noise conditions. The improvement is demonstrated in the first two slides which are of NTSC and B-MAC at 6 dB C/N. The luminance bandwidth for this application is 4 MHz. Aside from the threshold improvement, B-MAC provides pictures free of the usual artifacts of composite systems, cross color and cross luminance, moreover the color edges are notably sharper in MAC due to the considerably increased chroma bandwidth. The luminance bandwidth of B-MAC is set by the choice of sampling frequencies, 14.32 MHz. for luminance and half that for chroma. The Nyquist Limit being one half of the sampling frequency. In practice, the actual bandwidth is somewhat less due to the anti-aliasing filters. For practical filters the luminance bandwidth can be 6.4 MHz. Chroma bandwidth could be 3.2 MHz; however, chroma ringing must be controlled by a Gaussian roll off of, say 12 dB. at this "cutoff frequency" so in practice the chroma bandwidth is 1.6 MHz. at -6 dB. 6.4 MHz of luminance bandwidth in a 525 or 625 line TV system provides 336 cycles per picture width (c.p.w.) of resolution. The 1125 line HDTV system would provide 475 c.p.w. NTSC receivers typically provide 3.2 MHz bandwidth or 168 c.p.w. resolution although some comb filter receivers claim useful response to 4 MHz, (210 c.p.w.). Therefore we see that the B-MAC format can provide a meaningful increase in horizontal resolution.This increase may not be universally useful as it comes at a price of requiring atleast 3 dB higher C/N for the same weighted S/N in DBS systems. This C/N penalty would be less for amplitude modulated systems such as terrestrial TV broadcasting.

A great deal has been said about the desirability of a wide screen aspect ratio for HDTV, and until recently it had been rather generally assumed that only when a HDTV broadcast service could begin, could the public have widescreen TV pictures. Perhaps the greatest attraction of widescreen is that motion pictures could be televised without the need to crop about 1/4 of the picture so that what had been filmed at 1.85:1 can be displayed at 1.333:1. The other attraction is the desire to dramatize the introduction of something new in consumer electronics by making it readily differentiatable by the public from ordinary TV sets in the stores. Simply increasing picture quality would not immediately attract public attention.

In the U.S., the Society of Motion Picture and Television Engineers has recommended an aspect ratio of 16:9 for HDTV production. This aspect ratio comes very close to 1.85:1 which is typical of Hollywood feature film practice. The Advanced Television Systems Committee in the United States has accepted this recommendation and its report to the U.S. National CCIR committee will recommend 16:9 as the aspect ratio of the HDTV Production or Studio standard which is based upon the 1125 line, 60 field 2:1 interlaced proposal by NHK, Japan. This particular aspect ratio was, to the writers knowledge, first proposed by Dr. Joe Nadan of North American Philips at an HDTV seminar in 1983. His aspect ratio was given as 5.333:3 but this is 16:9 and the later way of expressing it is in line with CCIR practice which is exact. 16:9 is precisely the square of the aspect ratio common to all broadcast TV standards.

The author assumes that the CCIR will adopt the HDTV standard proposed with the aspect ratio of 16:9 although this is is not crucial to the scheme being proposed. For example, the 1125 line HDTV Production Standard in its original form provided an aspect ratio of 5:3 and an active line count of 1035 lines per frame. Cropping 60 lines from the top/and or bottom yields 965 active lines which is twice the number of active lines in a 525/60 picture. The resulting picture is 1050 lines (TOTAL) AND WOULD HAVE THE DESIRED 16:9 ASPECT RATIO. Conversion from the 1125 line HDTV Production Standard with 16:9 aspect rati involves digital interpolation in the ratio of 15:14 which converts the image to 1050 lines and from there, a further 2:1 interpolation yields a 525/60 image structure suitable for widescreen broadcasting. Our proposal would permit transmission of the entire 16:9 picture.

A considerable benefit to be obtained by a CCIR decision for the 16:9 aspect ratio for its HDTV Production Standard is that it would stimulate development of CRT designs and tooling for the 16:9 aspect ratio of display devices and projection screens.

To provide a widescreen TV picture itself is not difficult. The central problem is to do so in a way which is compatible with the TV screens now in use which are 4:3 in aspect ratio. We shall now look at the B-MAC format in detail to see how it is uniquely able to meet this requirement.

COMPATIBILITY BETWEEN ASPECT RATIOS

In B-MAC the receiver samples the video signal at a frequency of 1365*Fh (approx 21.5 MHz)and writes it into line stores. The luminance line store is normally clocked out at 910 Fh (2/3 the writing frequency) thereby time de-compressing the luminance component 3:2. Chrominance is clocked out of its line store at one half the luminance read clock rate (455 Fh). These clock frequencies are in the ratio of 12:8:4. In the active line time of 52.5 uS, there will be 752 samples of the luminance component at 910 Fh. and there will be 376 samples of a chroma component at 455 Fh. If we were to read these samples at 3/4* 910 Fh (for luminance samples) and at 3/4* 455 Fh for chroma samples, within 52.5 uS we could only read out 3/4 of the information previously written. The 564 samples which are read from the luminance line store and the 288 samples recovered from the chroma line store comprise 75% of the entire line. These samples can be used with a conventional 4:3 display to form the picture without geometric distortion. All that is required is that the clock frequencies have the relationship of 12:6:3 This is possible by dividing the master clock by 4 whenever a 4:3 display is in use, and by dividing the master clock by 3 whenever a widescreen display is used. The problem remaining is:

"Which part of the picture is the most suitable for display when all of it can't be displayed?"

The answer, is that a film editor should preview the film, scene-by-scene to make this judgement. Once made, this information can be logged and conveyed to the receiver digitally as an eight bit data word inserted into a dedicated time slot within the vertical blanking interval (VBI). As not all broadcasts will be in wide screen format, this data will only be inserted during broadcasts which are in widescreen format. The data is a number within the range of 1-188. It is to be transmitted in negative true logic so that the number 255 is all zero(s). The pan and scan number determines which part of the widescreen picture is to be displayed on 4:3 screens.The pan &

Scan number is added to the number obtained from the decription circuitry. This number controls the effective signal delay. Line translational scrambling is used with B-MAC and for widescreen displays, no additional memory is required in the decoder. Broadcasters will send all zero(s) when they are not transmitting widescreen pictures. The receiver will interpret that number as the flag signalling that 4:3 aspect ratio pictures are being transmitted. In this case, the Pan & Scan delay is set to zero and the aforementioned frequency divider divides by 4, outputting a lum. read clock of 3/4* 910 Fh. if the display aspect ratio is 4:3, If the display aspect ratio is 16:9, the lum. read clock is 910 Fh. The chroma read clock is always derived from the lum. read clock being divided by two from the luminance read clock.

The signal processor is controlled by the pan and scan number and by the setting of a manual switch which is set at time of installation.This manual switch advises the processor whether the display is 4:3 or 16:9 in aspect ratio. The processor may indicate to the viewer when a widescreen picture is being transmitted if the manual switch is in the 4:3 position so the viewer is made aware of broadcasts of which he is presently not réceiving to the fullest advantage. 4:3 Transmissions must be regarded as likely to be around for many years as films made prior to about 1953 were, and are in 4:3. Some films produced later on in wider screen formats may be available only in video taped format,and are already cropped to 4:3. Other such program material may also be of interest from historical archives.

Transmissions in 4:3 aspect ratio can be displayed on widescreen displays by several means. The line stores normally used to time de-compress the B-MAC signal can be used to time compress the luminance, and chroma components of 4:3 signals. 4:3 time compression applied to the 52.5 uS. luminance and chroma components results in their being displayed in 39.375 uS. The picture would of course not fill the screen, it would occupy 75% of the screen width and 100% of its heigth. Blank borders would surround such a picture. An interesting possibility when teletext is to be displayed would be to offset the picture say to the left and use the rightmost part of the screen for information display rather than superimpose the alpha-numerics over the image. Such features are however receiver designer options.

TABLE 1 summarizes the clock frequencies used for the two picture formats and for the two display formats.

RESOLUTION

Table 2 summarizes the resolution provided for each case. 6.4 MHz of bandwidth can support 336 cycles per picture width (c.p.w) where the picture width, expressed in time, is the normal value of 52.5 uS active line time. When only 3/4 of those cycles can be displayed, 252 c.p.w. are resolved which is the case when a widescreen picture is displayed on a 4:3 screen. A picture transmitted in 4:3 will be displayed in 4:3 ratio and it would have the full horizontal resolution of 336 c.p.w. Chroma resolution is always scaled from the actual luminance resolution provided. In the vertical direction, this proposal does not differ from conventional performance of a 525 line B-MAC system. Vertical resolution of existing TV systems can be improved by de-interlacing the picture at the receiver.De-interlaced receivers may be available to those willing to bear their added cost within the next two years, perhaps by the time of launching of the first high power DBS satellites. De-interlaced screens provide a subjective picture improvement said to be equivalent to an increase in the number of lines by about 1.6 The horizontal resolution improvement over typical NTSC receivers is about 50%. Assuming 20 MHz.luminance bandwidth for the 1125 HDTV line system and 5:3 aspect ratio, its equivelant bandwidth is 7.5 MHz. vs 4.8 MHz for B-MAC on a 4:3 screen. With de-interlaced TV sets, vertical resolution is subjectively improved by a similiar ammount. Temporal resolution of the 1125 line HDTV system, and this system are equal, being 2:1 interlaced 60 field TRANSMISSION systems.

Before leaving the matter of improved resolution, several possibilities for further improvements are possible. Sub-Nyquist sampling has been proposed for this purpose by Prof. Wendland of the University of Darmstat, (W. Germany). His technique can improve horizontal and vertical bandwidth within a fixed transmission channel bandwidth. Diagonal resolution is not increased in this scheme which may be called offset sampling with diagonal filtering. Possibly the best application of this technique is to decrease the channel bandwidth and thereby improve Signal/noise ratio rather than to further increase resolution.

CLOCKS AND INTERFERENCE

B-MAC and the two European component systems, C-MAC and D/2 MAC time compress luminance 3:2 and chroma 3:1. The clock frequencies used in the systems are given in Table 3. These clocks are harmonics of the line scan frequency Fh with the actual frequencies given in MHz.
These forms of MAC all employ clocks whose frequency ratio is the same; 12:8:4. The actual sampling frequencies used in B-MAC are slightly higher than those of the C, D/2 systems. The three clock frequencies used in C and D/2 MAC have a set of harmonics which fall directly upon the international distress signalling frequencies 121.500 and 243.000 MHz. These distress transmissions come from small battery operated transmitters carried aboard aircraft, boats and ships. These signals are monitored by aircraft in flight and orbiting satellites. Radiation from C-MAC or D/2 MAC decoders at 121.500 MHz. could jam the distress signal with phase noise, or render such monitoring impracticable due to the prevelance of false alarms reported. It seems unlikely that such a vital program as this will be permitted to suffer such interference when alternative clock frequencies such as are used in B-MAC can shift the unwanted radiation out of the distress signalling channels. The clocks used in C and D/2 MAC and the harmonics which fall at 121.5 or 243 MHz. are shown in Table 3. The clock frequencies used in both 525/60 and 625/50 versions of B-MAC are also given and it can be seen that there are no harmonics at the distress frequencies. The clocks used in B-MAC could also be used in C and D/2 MAC as all employ the same compression factors 3:2 and 3:1.

This proposal for a widescreen, compatible system must also include means to display NTSC pictures on widescreens. Table 4. shows one way to use the same line stores which de-compress MAC components for time compressing NTSC luminance and chrom components so they can be displayed on a widescreen without geometric distortion. We have shown how compatibility between widescreen and 4:3 is possible with B-MAC and how NTSC and widescreen displays can be made compatible.

HDTV SYSTEM BASED ON B-MAC

This system concept could be extended to a 1050 line two transponder system along the lines first proposed by CBS in 1983. (Ref. 3). We have already discussed the first channel except to note that it must carry all signal addressability and audio and synchronization information. The first channel in this proposal provides the wide screen picture. This reduces the video loading of the second channel. The second channel would not be received by 4:3 screens so the B-MAC time compression factors of 3:2 and 3:1 need not be used by this augmentation channel. As more time per line is available for video in the augmentation channel, the luminance time compression factor may be less than 3:2 which permits a higher bandwidth if a higher luminance sampling frequency is also used. Another alternative is to improve the WEIGHTED S/N of the second channel by lowering the compression factor. In most spacecraft designs, the EIRP limit is set by the allowable power dissipation in the TWT amplifier, not by DC power considerations. In this case, the second transponder should be designed for improved bandwidth. As its load consists of video only, one can choose to time compress the lumimance component 6:5 and the chroma component 3:1 which are quite close to the values chosen by CBS. In this case, the luminance component is compressed 6:5 by sampling it at 5*Fsc and clocking it out at 6 Fsc. in 5/6* 52.5 uS (43.75 uS). Chroma would be sampled at 2 Fsc and clocked out at 6 Fsc (in 17.5 uS for a time compression of 3:1. Together the luminance and chroma components occupy the ancilliary channel for 61.25 uS per line. The balance of the line can be used for Line Translational Scrambling as a part of the signal security system.

This system owes a considerable debt to the earlier work by the CBS Technology Center. This proposal provides the wide screen advantage with the first transponder which may facilitate more rapid public acceptance. The specific examples for time compresssion given for the ancilliary transponder above are not the only possibilities and further studies should be carried out. 6:5 luminance compresssion can carried out with a luminance sampling frequency of 5*Fsc and a read clock of 6 Fsc. With a sampling frequency of 5 Fsc, (17.89 MHz) the Nyquist Limit is 8.94 Mhz. so that the ancilliary transponder can provide 8 Mhz bandwidth. This can considerably "average up" the bandwidth available from the first transponder.

CONCLUSION

We have shown how the B-MAC format can be readily extended to provide wide and enhanced screen TV pictures in a way compatible the the existing receivers. B-MAC has been designed for both 525/60 and 625/50 systems so these advantages are available world-wide. The 1125 line 60 field HDTV Production Standard which we expect to be adopted by the CCIR this year has been shown to be compatible with this proposal for a transmission standard and its extension to true HDTV.

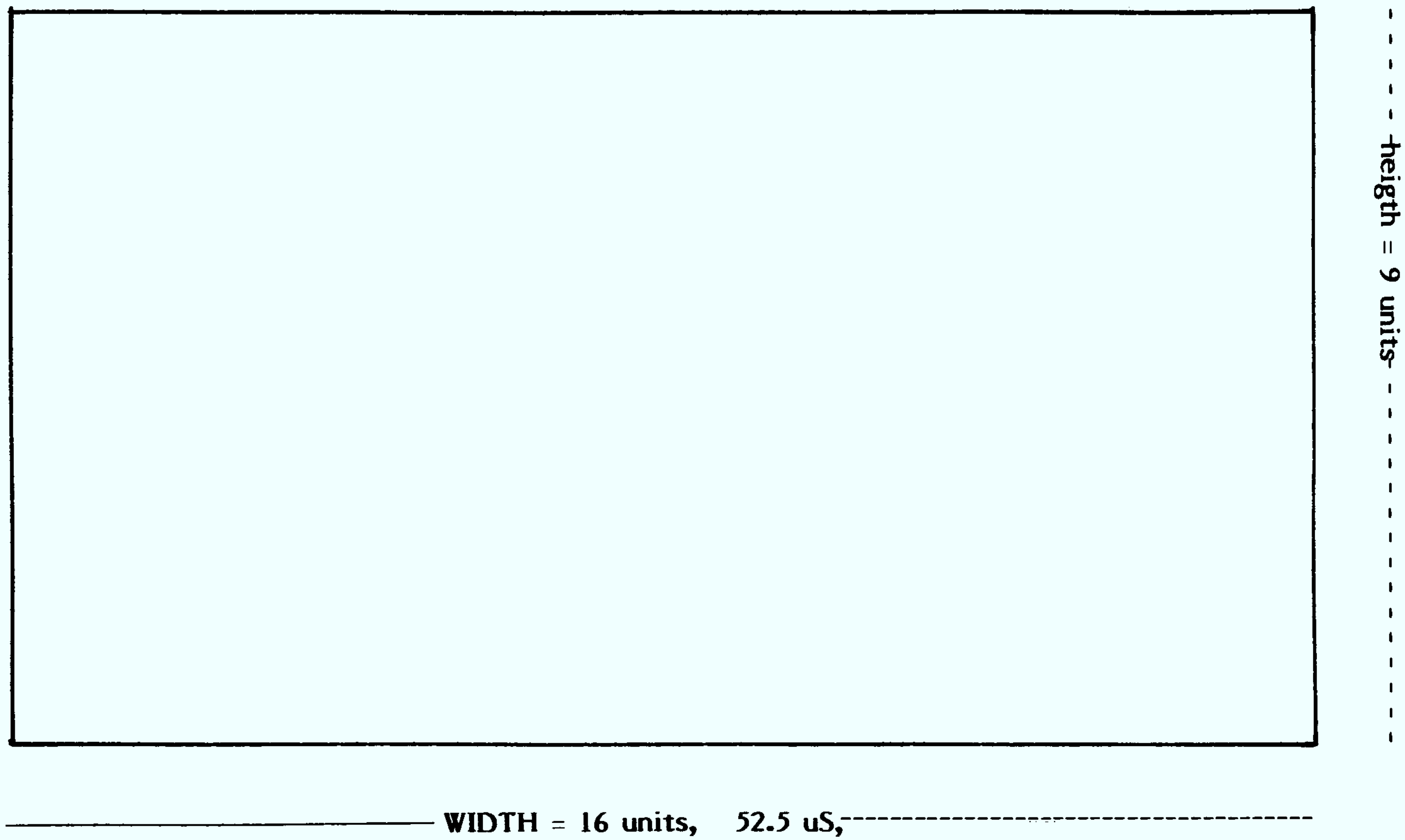
The author would like to express his gratitude to his many collegues world wide whom have made this work possible. Dr. Fujio in particular ,must be regarded as the driving force behind HDTV, and Dr. Keith Lucas, the father of B-MAC. It was professor B. Wendland who first suggested how it might be possible to achieve a compatible HDTV system.

References:

[1] Ralf Schafer, Heinrich-Hertz-Institute, "High Definition Television Production Standard - A Chance for Optimal Colour Processing".

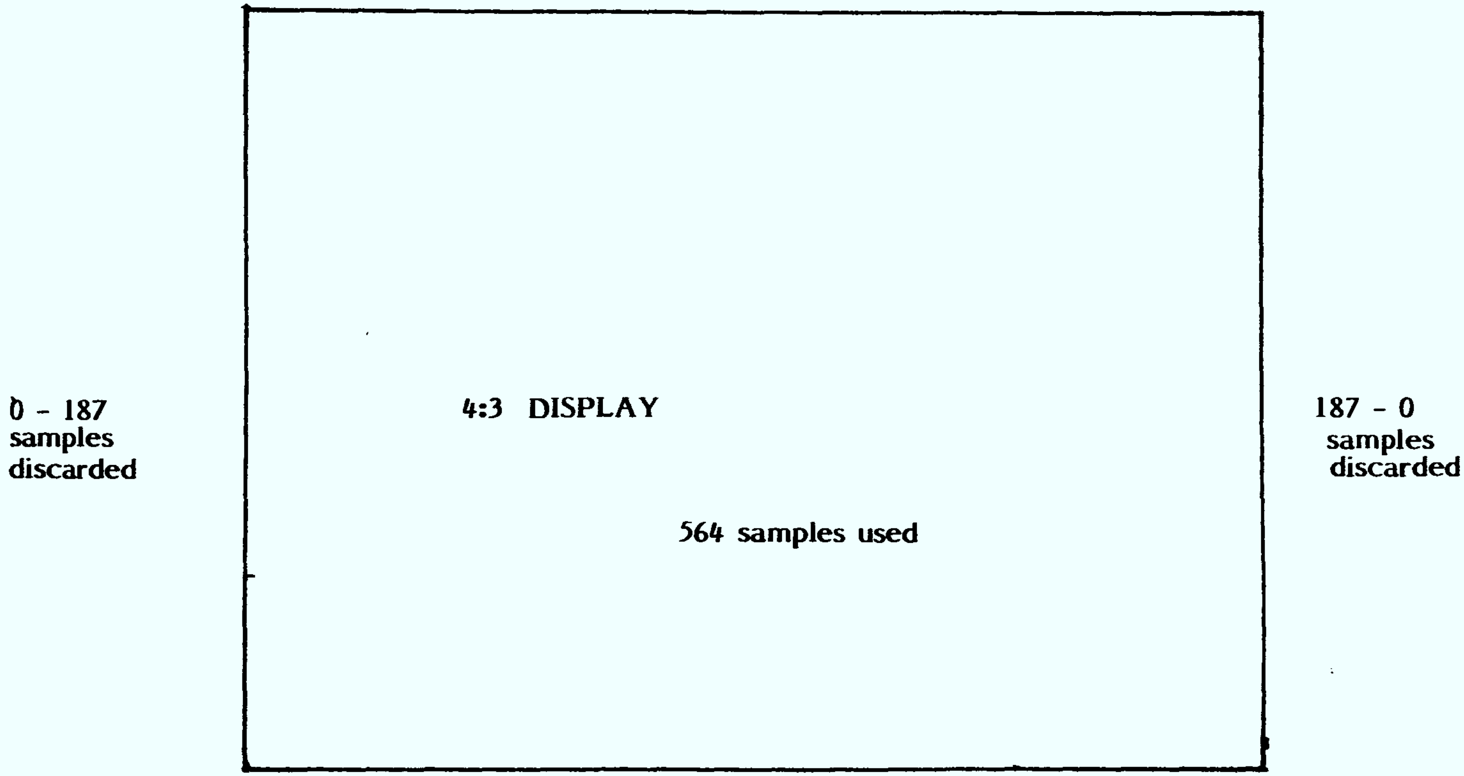
[2] Takashi Fujio, et al, Nippon Hoso Kyokai (Japan Broadcasting Corporation), "Technical Monograph", June, 1982, No. 32, Page 25.

[3] A. A. Goldberg, R. H. McMann, J. P. Rossi, CBS Technology Center, "A Two Channel Compatible HDTV Broadcast System", Report 8/83-A, July 29, 1983.



LUMINANCE READ CLOCK = F_y = 14.318182 MHz. $1/F_y$ = .069+ uS * 752 $\text{SAMPLES}_{(Y)}$ = 52.5 uS

FIGURE 1

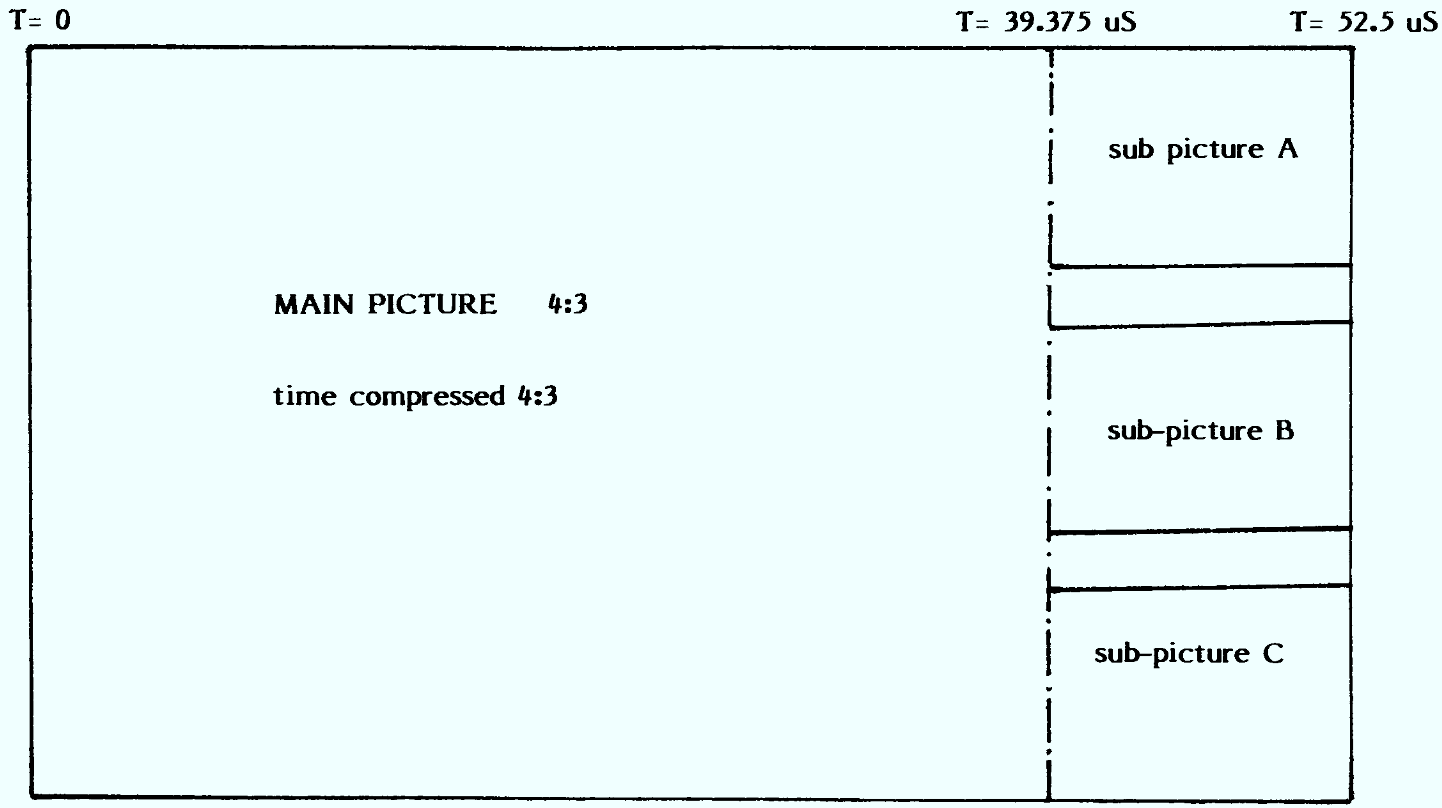


——————— WIDTH = 4 units, 52.5 uS,———————

LUMINANCE READ CLOCK = .75 F_y = 10.738636 MHz. 4/3 F_y = .093 + uS * 564 Samples

= 52.5 uS

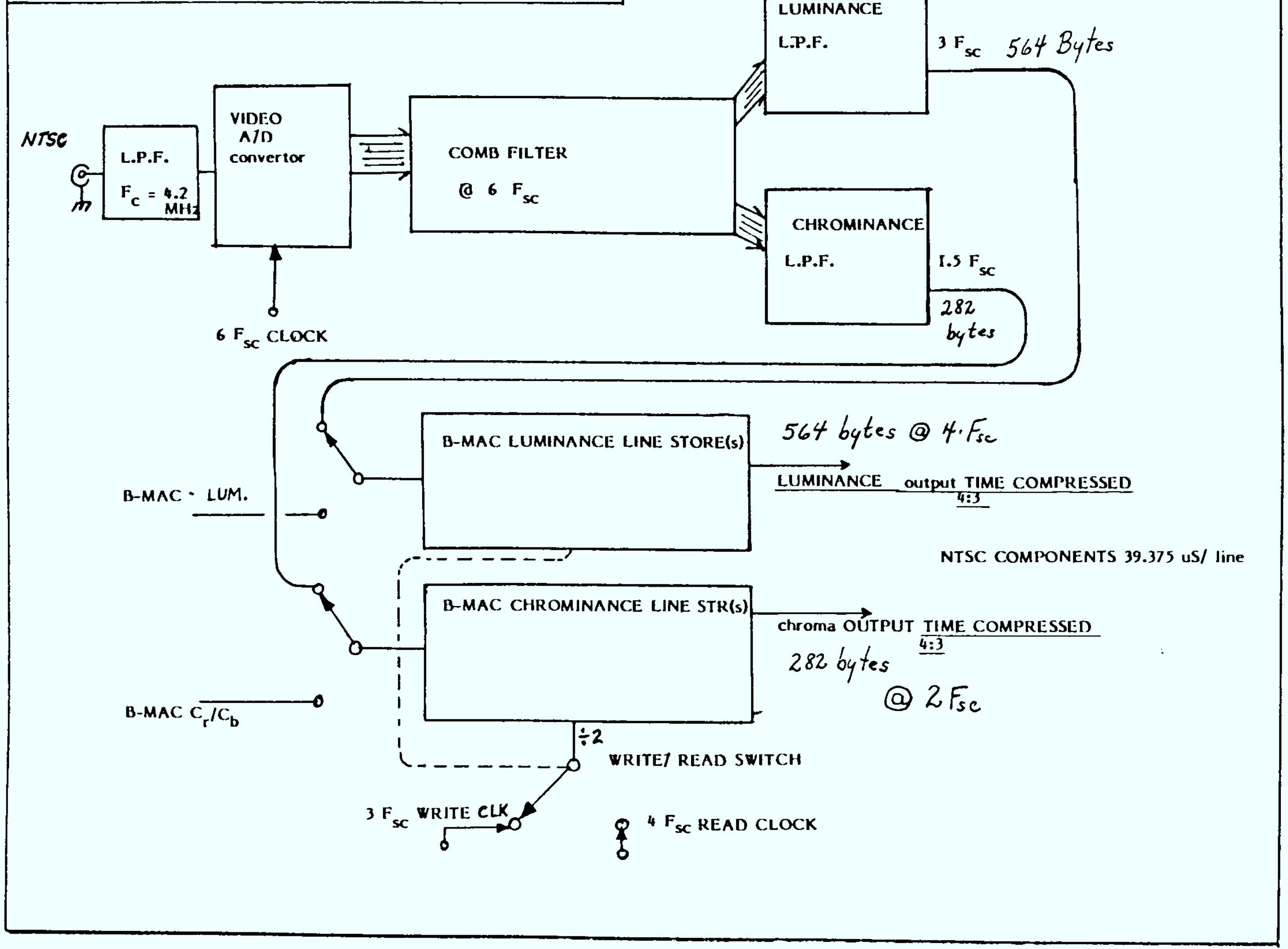
FIGURE 2



1. MULTIPLE 4:3 PICTURES ON A WIDESCREEN DISPLAY
2. MAIN PICTURE (4:3) accompanied by TELETEX PANEL

FIGURE 3

Figure 4 ONE WAY TO PREPARE NTSC for WIDESCREEN DISPLAYS



ENHANCED C-MAC: THE EVOLUTIONARY APPROACH

3.10

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ABSTRACT

The EBU-recommended standard for DBS in Europe, C-MAC/Packets, was designed very much with future developments in mind. This paper describes one method of implementing an Enhanced C-MAC signal which allows transmission of wider-aspect-ratio, higher-definition pictures suitable for large-screen displays and reduced viewing distances. The extra information required for the aspect-ratio increase is carried in parts of the signal not normally used for picture information in the standard C-MAC/Packet format. This technique allows full compatibility between the Standard and Enhanced signals. Owners of DBS receivers or set-top converters for the standard C-MAC/Packet system would receive a high-quality 4:3 aspect-ratio picture when tuned to the Enhanced C-MAC channel, while those who owned Enhanced C-MAC receivers would gain the advantages of the new signal (wider aspect ratio and increased resolution). The signal requires only one WARC satellite channel.

This evolutionary approach to higher definition television transmission achieves the resolution increase required without using new, incompatible line scanning standards for transmission. Horizontal and vertical resolution increases are achieved by using the satellite channel bandwidth to the full and by "upconverting" in the Enhanced C-MAC receiver, to a sequentially-scanned display with 625 lines every fiftieth of a second. The subjective picture quality improvements obtained by this technique are discussed.

Enhanced C-MAC can provide a means of transmitting higher-definition television in a single WARC satellite channel in a way which is compatible with existing television sets and studio equipment. It does not require new studio equipment or a new receiver to start the service as do other DBS HDTV systems. This feature is seen to be very important in ensuring the market penetration and rapid growth required for such a high-risk venture.

SYSTEME C-MAC AMÉLIORÉ - CONCEPTION PROGRESSIVE

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3.10

RÉSUMÉ

La norme recommandée par l'UER pour la radiodiffusion directe par satellite en Europe, c'est-à-dire la transmission par paquets CV-MAC, a été conçue en tenant compte des développements éventuels. Le présent document décrit une méthode de matérialisation du signal C-MAC amélioré permettant la transmission d'images à plus haute définition, a un rapport de dimensions plus grand et de qualité convenable pour affichage sur grand écran et visionnement à distance réduite. L'information supplémentaire nécessaire à l'amélioration du rapport des dimensions est transmise dans certaines parties du signal qui ne sont pas normalement utilisées pour l'information d'image dans le système normalisé de transmission par paquets C-MAC. Cette technique donne une comptabilité intégrale entre les signaux normalisés et les signaux améliorés. Les propriétaires de récepteurs de radiodiffusion directe par satellite ou de convertisseurs adaptés aux téléviseurs pour le système normalisé de transmission par paquets C-MAC recevraient une image de haute qualité de rapport 4:3 sur la voie du système C-MAC amélioré, tandis que les propriétaires de récepteurs du système C-MAC amélioré tireraient profit des avantages du nouveau signal (rapport de dimensions plus grand et définition améliorée). Le signal ne nécessite qu'une seule voie de satellite CAMR.

Cette conception progressive de la transmission d'images télévisées de meilleure définition obtient le résultat voulu sans faire appel pour la transmission à de nouvelles normes incompatibles de balayage lignes. L'amélioration de la résolution horizontale et de la résolution verticale s'obtient en utilisant toute la largeur de bande de radiodiffusion par satellite et en effectuant une "conversion ascendante dans le récepteur du système C-MAC amélioré pour produire un affichage à balayage séquentiel comportant 625 lignes à tous les cinquantièmes de seconde. Le présent document traite également des améliorations de la qualité subjective de l'image obtenue par cette technique.

Le système C-MAC amélioré peut donner un moyen de transmettre des images télévisées de définition supérieure sur une seule voie de satellite CAMR d'une façon qui reste compatible avec les téléviseurs et l'équipement de studio existants. Contrairement à d'autres systèmes de radiodiffusion TVHD par satellite, il n'est pas nécessaire de changer l'équipement de studio et les récepteurs actuels pour utiliser ce système. Cette caractéristique est jugée très importante dans le contexte de la pénétration du marché et du développement rapide nécessaires à une entreprise comportant de si grands risques.

AN ADAPTIVE, EXTENDED-DEFINITION MAC TELEVISION SYSTEM

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ABSTRACT

Multiplexed analog component (MAC) television systems are advantageous because of their freedom from cross-color artifacts and because of their suitability for FM transmission. Nevertheless, MAC systems can be criticized because of their relatively inefficient bandwidth utilization. We show that this disadvantage of MAC systems can be eliminated using an adaptive, "steering bit" approach that provides an extended-definition MAC system with double horizontal resolution.

The absence of a color subcarrier in the MAC format implies that the spectral "holes" occupied by color information in composite systems is available for the transmission of additional high-frequency information, thus providing an evolutionary path to extended-definition television. The backward compatible artifacts of a MAC system using subcarriers would be much less objectionable than those introduced in the transition from black-and-white to color NTSC. This follows because, with MAC systems, only high spatial-frequency information is modulated into the spectral holes. High frequencies occur at edges and areas of high resolution, where artifacts are less visible because of localization in space and because of masking by other information. Just the opposite is true with the NTSC color subcarrier, which superimposes a crawling sinusoidal pattern over the entire picture.

While the user of such an extended-definition subcarrier is thus theoretically attractive, linear systems implementations of such techniques suffer heavily from the effects of non-ideal spatio-temporal filters. Effective utilization of the three-dimensional spatio-temporal MAC spectrum requires multiple fields of storage at both the transmitter and receiver. Compromises that utilize only two-dimensional spatial filtering do not utilize the spectrum as effeciently, and still require many lines of delay and complicated arithmetic processing. In practice it is difficult to implement the nonseparable filters that are desired in a linear system.

This paper describes an adaptive approach to decoding extended-definition subcarriers that circumvents these difficulties. The subcarrier modulation technique employed is essentially a subsampling process. At the encoder, several simple filters, which extract the extended-definition information, can be implemented in parallel. The one that provides the best separation (i.e., best represents the wideband image) is then identified for each sample in the picture. The filter providing the best separation will vary from sample to sample depending upon the local image content. The information thus developed at the encoder may be transmitted to the decoder, "steering" it among the various separation filters to provide a picture-dependent decoding of the extended-definition subcarrier. This process corresponds to instantaneously multiplexing the Nyquist region of the transmitted signal, shaping it to match the energy in the picture. In practice this technique can double the horizontal resolution of a MAC system at the expense of a modest amount of additional transmitted "steering" information.

The "steering" information derived from the source image can potentially comprise a large number of bits per picture. Simply transmitting this information without data compression would require excessive transmission bandwidth, precluding a practical extended-definition system. In practice, however, there are many conditions under which the filter selection is not critical, as in, for example, areas of low resolution. The encoder may thus be modified so that it maintains a particular filter unless a significant advantage is achieved with another filter. The patterns of steering information that result are suitable for run-length encoding techniques, which can reduce the steering data to an amount that is practical to include in the data channel of an extended-definition MAC television system.

SYSTÈME DE TÉLÉVISION ADAPTATIF À DÉFINITION ÉTENDUE À COMPOSANTES ANALOGIQUES MULTIPLEXÉES

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RÉSUMÉ

Les systèmes de télévision à composantes analogiques multiplexées (MAC) sont avantageux, car ils ne présentent pas d'effets secondaires de mélange de couleurs, et aussi parce qu'ils conviennent à la transmission en modulation de fréquence. Néanmoins, leur gros inconvénient est leur utilisation relativement inefficace de la largeur de bande. Nous montrons que ce désavantage des systèmes MAC peut être éliminé en utilisant une méthode adaptative de "bits de pilotage" qui donne un système MAC à extension de définition à double résolution horizontale.

L'absence de sous-porteuse couleur dans le système MAC sous-entend que les "trous" spectraux occupés par l'information couleur dans les systèmes composites sont disponibles pour la transmission d'informations supplémentaires de fréquence élevée, ce qui permet une évolution vers la télévision à extension de définition. Les effets secondaires d'un système MAC à compatibilité régressive utilisant des sous-porteuses seraient bien moins gênants que ceux qu'introduisit la transition du système noir et blanc au système couleur NTSC. Il en est ainsi parce que, dans les systèmes MAC, seule l'information de fréquence spatiale élevée est modulée dans les trous spectraux. Les fréquences élevées se produisent aux limites et dans les zones de résolution élevée, où les effets secondaires deviennent moins visibles à cause de leur localisation dans l'espace du masquage produit par d'autres informations. C'est exactement le contaire de ce qui se passe avec la sous-porteuse couleur NTSC qui superpose une sinusoide rampante sur l'image entière.

Alors que l'utilisation d'une telle sous-porteuse à extension de définition est théoriquement attrayante, la matérialisation des systèmes linéaires faisant appel à de telles techniques souffre fortement des effets des filtres spatio-temporels non idéaux. L'utilisation efficace du spectre tridimensionnel spatio-temporel MAC nécessite de nombreuses trames de mémoire, à la fois dans l'émetteur et dans le récepteur. Les compromis qui font seulement appel aux filtres bidimensionnels spatiaux n'utilisent pas le spectre de manière aussi efficace et exigent encore de nombreuses lignes à retard et un traitement arithmétique complexe. En pratique, il est difficile de matérialiser les filtres inséparables définis dans un système linéaire.

La communication décrit une méthode adaptative de décodage des sous-porteuses à extension de définition qui surmonte ces difficultés. La modulation de sous-porteuse employée est essentiellement un sous-échantillonnage. Au

codeur, on peut matérialiser plusieurs filtres simples, en parallèle, qui extraient l'information à extension de définition. On identifie alors celui qui donne la meilleure séparation (c'est-à-dire qui représente le mieux l'image à large bande), pour chaque échantillon de l'image. Le filtre donnant la meilleure séparation varie d'un échantillon à l'autre, selon le contenu local de l'image. L'information ainsi produite au codeur peut être transmise au décodeur et le "piloter" parmi les divers filtres séparateurs, pour donner un décodage de la sous-porteuses à extension de définition, qui dépend de l'image. Ce processus correspond au multiplexage instantané de la région de Nyquist du signal transmis et à sa conformation de manière qu'il corresponde à l'énergie de l'image. En pratique, cette technique permet de doubler la résolution horizontale d'un système MAC, au prix de la transmission de quelques informations supplémentaires de "pilotage".

L'information de "pilotage" tirée de l'image source peut, en principe, comprendre un grand nombre de bits par image. Transmettre simplement cette informaion sans compression de données nécessiterait une largeur de bande d'émission excessive, ce qui exclurait la réalisation de tout système à extension de définition. Toutefois, en pratique, il existe bien des conditions pour lesquelles la sélection du filtre n'est pas critique comme, pas exemple, dans les zones de faible résolution. On peut ainsi modifier le codeur de sorte qu'il conserve un filtre particulier, à moins qu'un autre filtre ne présente un avantage important. La structure de l'information de pilotage résultante convient aux techniques de codage pour la durée du traitement qui peuvent réduire les données de pilotage à une quantité commode à inclure dans la voie de données d'un système de télévision MAC à extension de définition.

An Adaptive Extended-Definition MAC Television System

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3.11

Introduction

By their very design, time-multiplexed analog component (MAC) television systems are free from the cross-color artifacts of composite television systems. This feature makes such systems particularly attractive as a production standard, since special effects, downstream chroma-keying, and other post-production processes demand that their signal processing be performed in the component domain. The absence of a color subcarrier also makes MAC systems better suited for FM modulation, since more appropriate pre-emphasis may be applied, and resultant high frequency noise does not affect low frequency chrominance information. These features make MAC signals attractive for both direct broadcasting satellite (DBS) transmission[1] and magnetic recording. The biggest difficulty with MAC systems lies in their relatively inefficient bandwidth utilization compared to composite systems. In attempting to overcome this limitation of MAC systems, it has been observed that the spectral "holes", which are filled with chrominance information in composite systems, remain empty in a conventional MAC system. This observation is the basis of compatible extended-definition approaches for MAC television systems.[2] In this paper we describe an adaptive technique that can double the horizontal resolution of a MAC signal. The perceptual performance of such a system could approach that of true high-definition systems.[3]

Compatible Extended-Definition MAC

In an extended-definition MAC (ED-MAC) system, it is high frequency information (rather than color) that is modulated on a subcarrier in such a manner that it interleaves with the low-frequency portion of the signal. In the case of composite systems, low-frequency color information, which generally has a large amplitude, is modulated on a subcarrier. The result is that when a composite system is viewed on a monochrome monitor, a crawling sinusoidal pattern is superimposed over the entire picture. While the color subcarrier theorectically disappears when no color is present, real scenes always contain color information, and thus the artifact is always present. An artifact of such severity is clearly unacceptable for providing an extended-definition enhancement to a MAC system. However, high-frequency information is generally of much lower amplitude than low-frequency information. Furthermore, unlike color, high-frequency information is not contained in all portions of a real scene. It is located primarily on edges and in areas of texture. Thus, when such high-frequency information is "folded back" into the low-frequency portion of the spectrum, the artifacts are localized in space and are also masked by the presence of other edge or texture information. The artifacts are similar to aliasing, where high frequencies masquerade as lower frequencies.[4] The extended-definition subcarrier can, in fact, be produced by subsampling and producing the appropriate aliasing, as will be more fully described in the following section.

Linear Approaches to ED-MAC

An analog transmission system can represent a rectangular region of spatial frequencies, the vertical boundary being introduced by the number of scanning lines, and the horizontal boundary introduced by the bandwidth of the channel. The problem of designing an extended definition television system is to efficiently utilize every portion of this available spectral area. What we desire is to take additional horizontal bandwidth, and fold it back into the spectral area allowed by the transmission system as unobtrusively as possible. As the phenomenon of cross-color proves, there is in fact no such thing as a spectral "hole" - each frequency in the analog transmission spectrum uniquely represents a spatial frequency in the image. In order to properly transmit and extract additional horizontal resolution, it is necessary to eliminate some other region of spatial frequencies, so that they may be replaced by the horizontal frequencies modulated on an appropriate subcarrier. The obvious choice is to eliminate the high-frequency diagonal spectral components. It would be nonsensical to eliminate one band of horizontal frequencies in favor of a higher band of frequencies, and vertical resolution in a 525 line system is certainly at a premium. There are also other reasons for sacrificing the ability to transmit high-frequency diagonal information other than the process of elimination. The circularly symmetric spot of both camera and display function as spatial filters with a circularly symmetric passband, which attenuate the high-frequency diagonals. Since conventional aperture correctors are separable filters (horizontal and vertical), which do not properly correct for the true two-dimensional nature of the spots, the high-frequency diagonal information remains attenuated in a typical camera. Finally, human visual system exhibits somewhat less diagonal resolution than either horizontal or vertical resolution.[3]

A linear system for producing and decoding a compatible ED-MAC signal is shown in Fig. 1. The high-frequency diagonal information is eliminated by a prefilter with a diamond-shaped passband (Fig. 1a), and the high-frequency horizontal information is put in its place by modulating it on a diagonal subcarrier, which moves the horizontal information up in vertical frequency and folds it back into the baseband spectrum as a lower sideband. The modulation on a diagonal subcarrier is equivalent to performing a subsampling in a line interleaved pattern (Fig. 1b). Such a pattern can be shown to support higher horizontal and vertical resolution than diagonal resolution, and its Nyquist region is in fact diamond-shaped, corresponding to the passband of the prefilter. A low-pass filter that matches the transmission channel eliminates the portion of the modulated spectrum that is not folded back into the passband of the transmission channel, completing the synthesis of the ED-MAC signal (Fig. 1c). At the decoder, modulating the ED-MAC signal on another diagonal subcarrier by resampling in an interleaved pattern places the extended-definition information back in its original spectral location (Fig. 1d). A diagonal filter is required to eliminate the imbedded extended-definition portion of the signal and the portion of the modulated spectrum that is the replicated baseband signal.

While such systems are theoretically attractive, the implementation of this or similar techniques suffer heavily from the effects of non-ideal spatial filters. Reasonable filter rolloffs require many lines of delay and complicated arithmetic processing. Even with good filters, the spectral regions cannot be cleanly separated, and degradations occur. More effective utilization of the transmission spectrum can be achieved with spatio-temporal processing in a similar manner. This, however, requires multiple fields of storage at both the transmitter and the receiver. At such a point, MAC loses its advantage over composite systems, since composite systems can be freed of all cross-color artifacts by similar processing. Therefore, we will consider an adaptive approach to decoding an extended-definition subcarrier that circumvents these difficulties.

Adaptive ED-MAC

Since a linear filter performs the same function at each point in the picture, a filter that can extract all of the information in Fig. 1d must work well in all spatial directions all of the time, thus requiring an extreme amount of complicated arithmetic. In practice, implementation tradeoffs result in a design that does not work well in any spatial direction all of the time, thus resulting in the practical difficulties of linear systems for ED-MAC. In fact, a good filter in one spatial direction would be sufficient to extract the extended-definition information, if the filter could be implemented in a direction, which changed depending upon the instantaneous frequency composition of local image content. Such a system has been presented in the context of a 2:1:1 member of the digital video hierarchy.[5] For example, consider the spectrum shown in Fig. 1d, produced by line-interleaved sampling. If the instantaneous frequency spectrum is horizontal, then a simple vertical interpolation filter will remove the diagonal repeat spectra. That is, this filter reconstructs an orthogonal sampling pattern with full horizontal resolution. Similarly, if the instantaneous frequency spectrum is vertical, then a simple horizontal interpolation filter will be adequate. That is, this filter reconstructs an orthogonal sampling pattern with full vertical resolution. This approach requires the transmission of additional information that specifies which filter is appropriate to apply at each point to form the reconstructed image. This can be achieved by applying both a horizontal and a vertical interpolating filter at the encoder, where the original high resolution image exists, to determine which one best decodes the extended-definition subcarrier (i.e., best represents the original) at each point in the image. This information can be encoded and transmitted as 1 bit per sample, which tells the ED-MAC decoder which decoding filter to apply at each point.

This adaptive system is shown in Fig. 2. The original image (Fig. 2a) is subsampled in an interleaved pattern, while information about the local spectrum is derived as described above. (Fig. 2b) The subsampling performs a modulation, which allows aliasing of high-frequency horizontal information as vertical information, and aliasing of vertical information as high-frequency horizontal information. A low-pass filter that matches the transmission channel eliminates the high-frequency horizontals and aliased verticals, transmitting the baseband spectrum and the aliased high-frequency horizontal. (Fig. 2c) At the receiver, the signal is resampled in an interleaved pattern, and the decoder control information is used to reconstruct an orthogonal pattern, applying a horizontal filter where high vertical resolution is present in the original image, and elsewhere applying a vertical filter to extract the aliased high frequency horizontal information. The resulting range of transmittable frequencies which arise from thus multiplexing the Nyquist region (Fig. 2d), is greater than a linear ED-MAC system. (Fig. 1d) Although high resolution and horizontal information may not be simultaneously present at a given point, the ability to clearly preserve either resolution results in a better tradeoff than a practical linear system, which constantly degrades both directions of resolution.

While the scheme as described so far is preferable to a linear system, it does contain some artifacts, which occur from aliasing in diagonal directions. To help recover this information, note that the interleaved sampling pattern also includes samples that are diagonally opposed, which may be used to form diagonal interpolating filters. We thus may make a choice among four alternatives for decoding the aliased spectra: horizontal, vertical, right and left diagonal filters, the choice being represented by 2 bits per sample. This results in a much improved diagonal response, due to the inclusion of diagonally oriented passbands in the multiplexed Nyquist region, (Fig. 3) as opposed to the rolloff of both horizontal and vertical filters at diagonal frequencies. The additional complexity at the encoder is quite small, as in the impact on the amount of data after encoding, as will be seen.

Transmission of the Control Information

The adaptive approach that has been described achieves excellent results, but requires the transmission of the control information. If each control bit were simply transmitted directly (as one bit per sample), then a large amount of data would be required, on the order of 200,000 bits per frame. This number of bits is not as outrageous as it first appears, since a high bit error rate (BER) is acceptable for the decoding of high frequency information. One way to transmit the control data would be to utilize a data sub-carrier located above the video bandwidth. Since tramsmitting a reasonable number of bits per frame would require a wide bandwidth, which is always at a premium, and considering the TDM nature of MAC signals, it seems more sensible to use lines in the vertical blanking interval. Assuming a 6MHz channel, and using all lines of vertical blanking with a four-level code, there exists capacity to transmit approximately 28,000 bits per frame. It is therefore obvious that some coding must be performed on the control information to efficiently represent the changes in image resolution that are being represented.

Experiments were performed to gain some insight into this problem by examining the patterns of control bits generated for actual pictures. The four filter selections were respectively coded as black, white, or two intermediate gray levels and used to construct a pattern that illustrated the distribution of filter selections. The resulting patterns of the filter selections were "noisy" in appearance, indicating very little correlation between the spatial filters selected for adjacent samples. Since the resolution in real pictures tends to vary in regions, rather than randomly, one would ideally expect to see this fact reflected in the patterns of filter selection. The random nature of the results indicated that the filter selection was in fact responding to either noise or small differences in filter performance, which should be perceptually insignificant.[6]

A slight modification to the encoding algorithm can be made so that the previous filter is selected for use by the decoder unless a significantly better decoding is achieved with another filter. The criterion for "significantly better" is simply the error magnitude difference between the previously selected filter and the actual best filter. By adjusting this parameter, the number of changes in filter selection can be reduced to the range of 1000 to 3000 filter selections per frame. By applying run-length encoding techniques, the amount of data required, including overhead, is practical to transmit using the 28,000 bits per frame in the vertical interval.

Implementation of Adaptive ED-MAC

The block diagram of the adaptive ED-MAC encoder (Fig.4a) illustrate this system's relative simplicity. Two 1H delay lines and several latches provide access to a spatial neighborhood in the luminance signal. Four adders provide the horizontal, vertical, right and left diagonal reconstructions of the sample to be deleted. Minimum error logic encodes the two control bits that indicate which filter provided the minimum-error decoding of the aliased signal, and they are input to a run-length encoding circuit. Equalizing delays in the chrominance channel compensate for the luminance delay, and the component signals are subsampled by appropriately clocked latches. They are then MAC encoded and delayed by one field, so that the output of the run length encoder may be inserted in the vertical interval preceding the field to which the control information pertains.

The decoder (Fig. 4b) is similar to the encoder. The encoded control data is extracted from the vertical interval and input to a run-length decoder. The components of the ED-MAC signal are resampled in interleaved patterns, and decoded from MAC format into luminance and chrominance signals. Delay lines provide access to a spatial neighborhood of samples and control bits derived for the run length decoder. The two control bits control four-to-one multiplexors which direct the appropriate surrounding samples to an adder, the output of which is a reconstruction of a "deleted" sample with the minimum-error estimate. A multiplexor and an output latch reassemble the reconstructed samples with the transmitted signal samples, and final chrominance demultiplexing produces a component signal having very nearly the original resolution, despite the intermediate reduction in bandwidth.

Conclusions

While MAC television systems have certain advantages today, they must also form the basis of compatible extended-definition television systems and provide for evolutionary growth if they are to survive the future. In this paper, we have discussed the practical difficulties using linear systems to encode and decode extended definition subcarriers. The adaptive system presented here results in minimal backward-compatible artifacts to a simple MAC decoder, yet provides a doubling of horizontal bandwidth to an adaptive extended-definition decoder. It requires no increase in transmission bandwidth, simply the transmission of control data during the vertical interval. It is a practical system which we feel could provide a viable extended-definition television system for the future.

(1) Windram, M.D., Tonge, G., and Morcom, R., "TDMC - A Television System for High Quality Satellite Broadcasting" IBA Report No. 118/82 (1982).

(2) Tonge, G. "Signal Processing for Higher Definition Television" IBA Report (1983).

(3) Carlson, C.R. and Bergen, J.R., "Perceptual Consideration for High-Definition Television Systems", SMPTE Journal, Vol. 93, pp. 1121-1126 (1984).

(4) Reitmeier, G.A. "The Effects of Analog Filtering on the Picture Quality of Component Digital Television Systems" SMPTE Journal, Vol. 90, pp. 949-955 (October, 1984).

(5) Reitmeier, G.A. and Dishert, R.A. "A Multiplexed Nyquist Region Approach for High Quality 2:1:1 Digital Video," Proceedings of the 13th International Television Symposium, Montreux, Switzerland, May 1983.

(6) Carlson, C.R. and Cohen, R.W., "A Simple Psychophysical Model for Predicting the Visibility of Displayed Information", Proc. of the SID, 21, pp. 229-246 (1980).

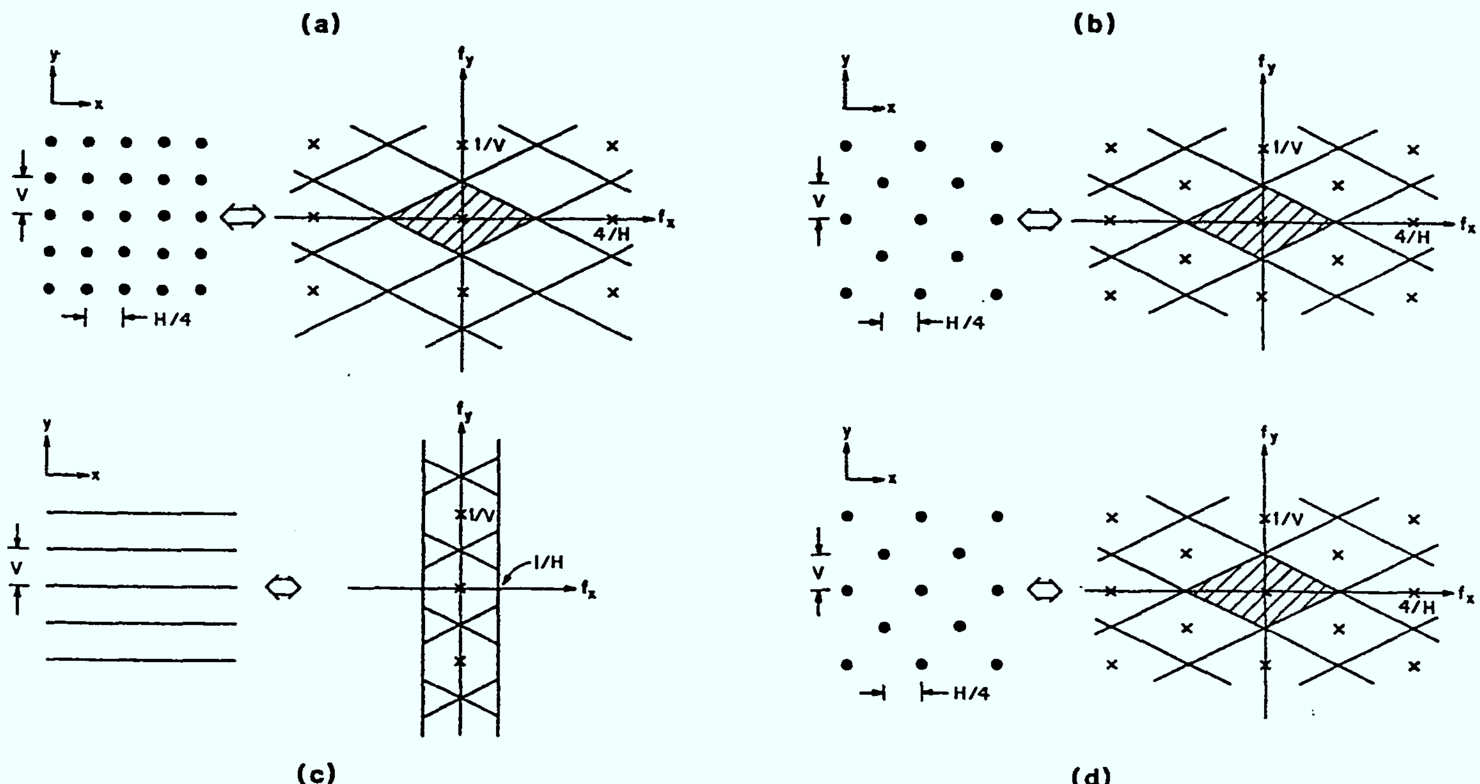


FIGURE 1

Linear ED-MAC system showing (a) diagonal prefiltering
(b) modulation of an extended-definition subcarrier
(c) transmission over an analog channel (d) reconstruction
of the extended-definition signal.

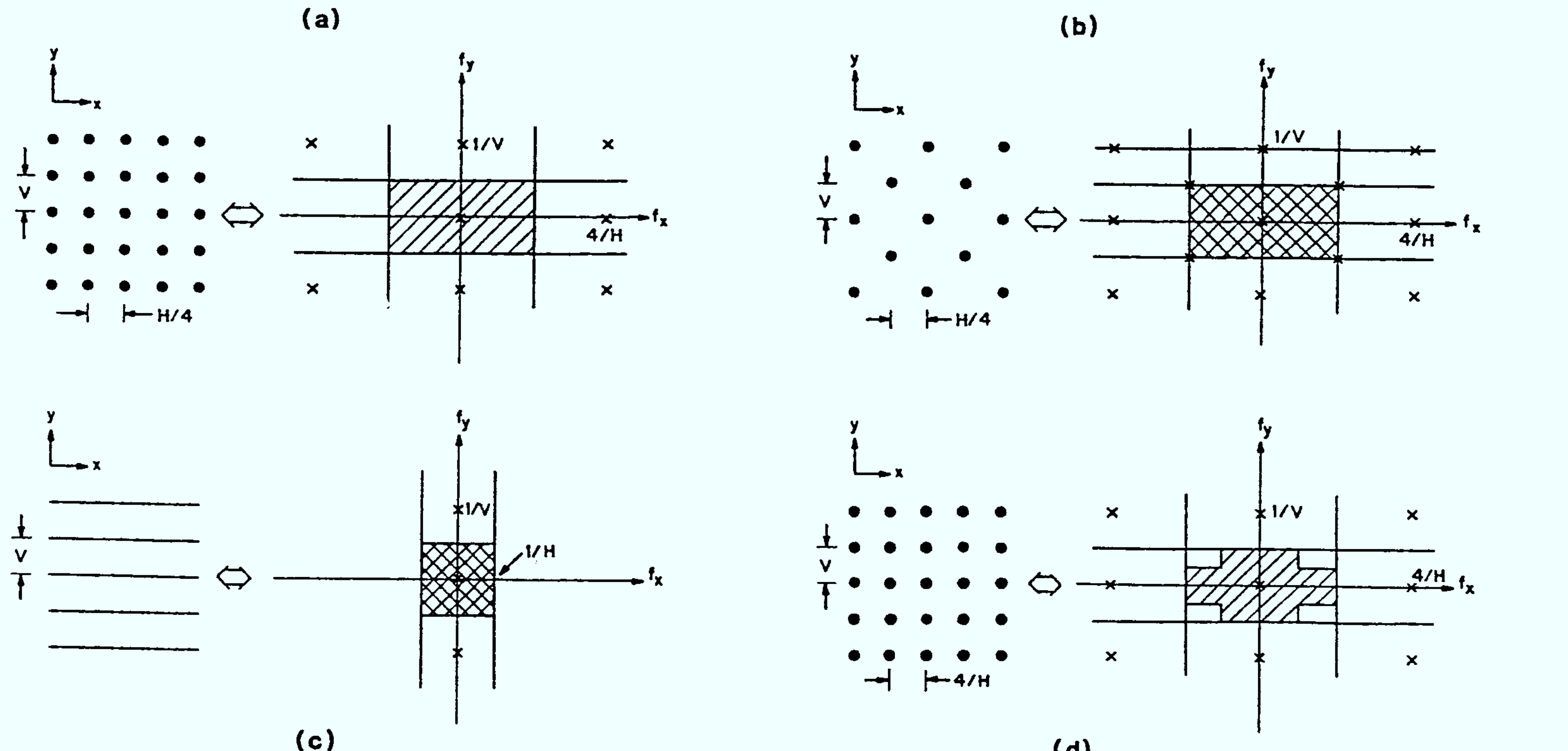
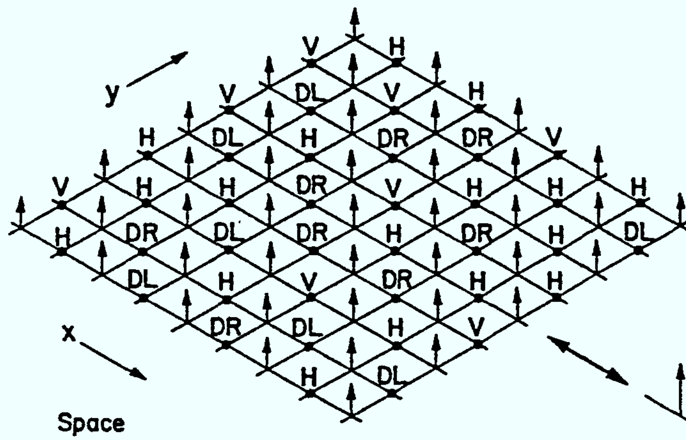


FIGURE 2

Adaptive ED-MAC system showing (a) original full resolution signal (b) modulation of an extended-definition subcarrier (c) tranmission over an analog channel (d) reconstruction of the extended-definition signal.

ADAPTIVE SUBSAMPLING



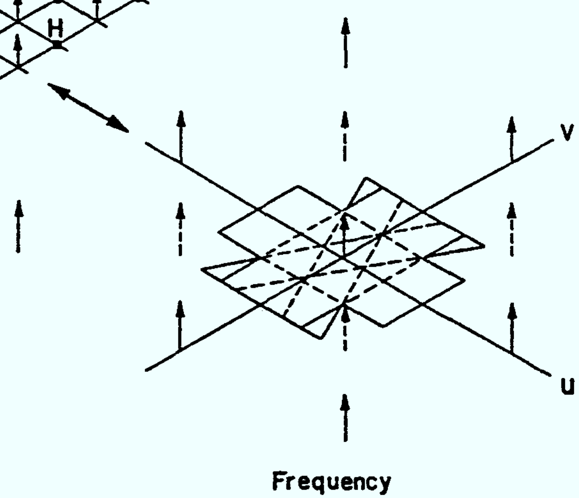
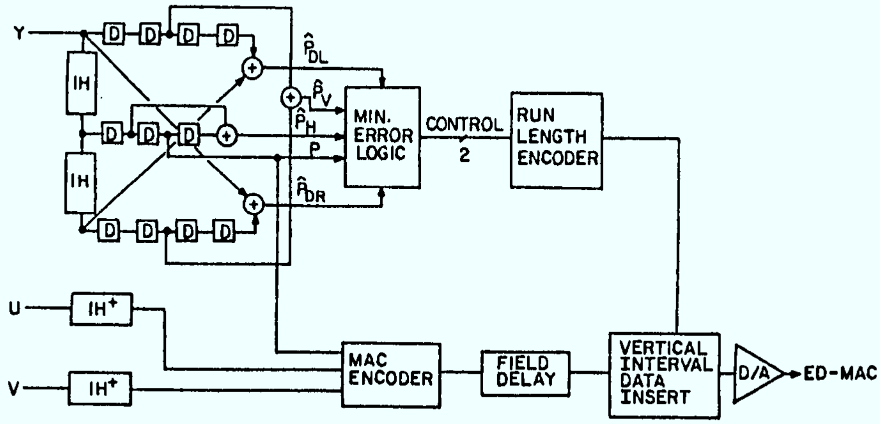


FIGURE 3

Subsampling in a line-interleaved pattern and determining which interpolation filter (horizontal, vertical, right diagonal or left diagonal) best reconstructs each deleted sample corresonds to multiplexing the Nyquist region to instantaneously conform to the corresponding filter passband.



(a)

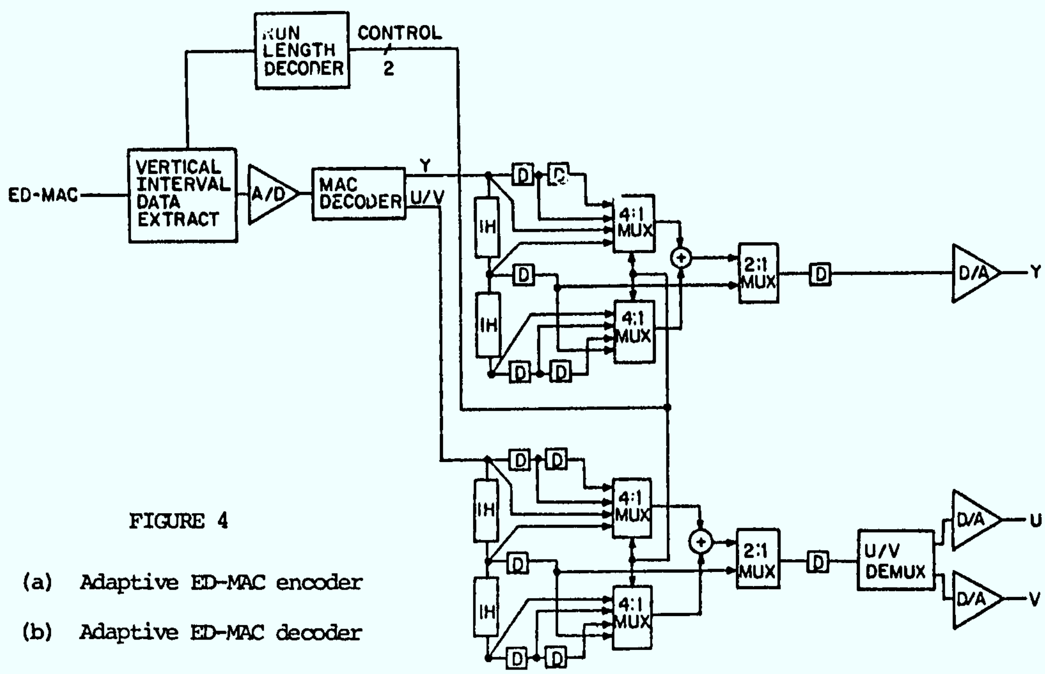


FIGURE 4

(a) Adaptive ED-MAC encoder

(b) Adaptive ED-MAC decoder

(b)

CONCEPTION PROGRESSIVE D'UNE NORME TVHD BASÉE SUR LES TECHNIQUES DE TRAITEMENT DE L'IMAGE AVEC COMPENSATION DE MOUVEMENT

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3.12

RÉSUMÉ

Le présent document décrit un nouveau système adapté à la radiodiffusion directe par satellite des signaux de télévision haute définition (TVHD). Le système TVHD proposé adopte une approche progressive pour l'implantation du système TVHD sur trois générations. Le système initial (c'est-à-dire génération zéro) est le système classique de définition télévisuelle utilisant une des techniques de transmission des composantes analogiques multiplexées (MAC). La première génération TVHD est un système de balayage séquentiel à 525 lignes, avec rapport de dimensions 5:3. La deuxième génération est un système de balayage entrelacé à 1050 lignes, avec rapport de dimensions 5:3.

Le système MAC utilise une voie de transmission par satellite pour transmettre les signaux nécessaires. La première génération TVHD utilise une voie et un quart pour transmettre les signaux. La première voie (ou la voie compatible) transmet l'information nécessaire au récepteur MAC et au récepteur TVHD de la première génération, et elle est pratiquement identique à la voie MAC. Dans les débuts du service de la première génération TVHD, l'information transmise sur chaque voie MAC existante sera augmentée pour tenir compte d'une voie "compatible" de radiodiffusion TVHD. La principale différence entre la voie MAC et la voie TVHD compatible vient de la plus grande largeur de bande nécessaire à la TVHD compatible. La deuxième voie (ou la voie complémentaire) transmet les éléments d'image qui ne sont pas nécessaires au récepteur MAC. Les signaux transmis sur la voie compatible représentent des informations d'image destinées à la zone centrale de l'image de rapport 4:3. Les signaux transmis sur la voie complémentaire représentent les zones latérales restantes de rapport 5:3. Ces zones latérales nécessitent approximativement 1/4 de la capacité de transmission d'une voie compatible pour chaque émission HDTV.

* Le présent document est basé sur des travaux effectués aux laboratoires COMSAT sous l'égide de la Satellite Television Corporation.

Le système TVHD de la deuxième génération est une extension du système de la première génération. La voie compatible reste identique. La voie

complémentaire, en plus de l'information des zones latérales, transmet également des signaux d'augmentation. Ces signaux transportent de l'information supplémentaire qui, ajoutée aux signaux de la voie compatible, peut augmenter les résolutions horizontale et verticale pour faciliter l'affichage 1050 lignes, balayage entrelacé 2:1.

Le système proposé peut être considéré comme la combinaison de la conception à deux voies de la CBS et de la conception MUSE des laboratoires NHK. Toutefois, les algorithmes de traitement de l'image ne sont pas identiques. Par rapport au système à deux voies de la CBS, cette conception nécessite au départ une segmentation spatiale inférieure car une émission TVHD ne nécessite qu'un répéteur et un quart au lieu de deux. La conception proposée nécessite également une puissance de répéteur inférieure dans le cas du service essentiel à 1050 lignes, en raison de la largeur de bande plus étroite demandée par la technique de sous-échantillonnage avec compensation de mouvement (6.75 MHz au lieu de 8 MHz par voie). Par rapport au système MUSE des laboratoires NHK, qui utilise également une technique de traitement avec compensation de mouvement, d'un type différent, le système proposé comporte l'avantage d'être compatible avec les systèmes à définition classique, et l'avantage d'une résolution spatiale plus équilibrée entre les zones avec mouvement et les zones sans mouvement sur une même image.

AN EVOLUTIONARY APPROACH TO HDTV BASED ON MOTION-ADAPTIVE IMAGE PROCESSING TECHNIQUES*

3.12

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ABSTRACT

An evolutionary, three-generation approach to HDTV systems is proposed. The path of evolution begins with an NTSC-compatible multiplexed analog component (N-MAC) format with 525-line, 2:1 interlaced scanning, and a 4:3 aspect ratio. This is the zero-th generation HDTV. The first-generation HDTV system is a 525-line, noninterlaced system with a 5:3 aspect ratio. The second-generation system is a 1,050-line, 2:1 interlaced system with a 5:3 aspect ratio. The ability of the system to evolve from one generation to another is guaranteed by the use of image processing techniques based on a motion-adaptive sub-Nyquist sampling (MASS) algorithm.

The bandwidth requirement of the zero-th generation signal for satellite direct broadcast, using practical high-power satellite and low-cost receivers, is one 24-MHz DBS transponder. The first- and second-generation HDTVs require 1.25 and 2 transponders, respectively. The signal sent through the first transponder, which is the compatible channel, is the same for all three generations to ensure the compatibility of newer generations with the older ones. The additional transponder, or supplemental channel, used in the first- and second-generation HDTV systems carries additional image information to enhance the resolution for these two systems.

The MASS algorithm, which is adopted for bandwidth reduction as well as for system evolution purposes, is performed on a block-by-block rather than pixel-by-pixel basis. In the transmitter, all pixels in each block are processed in either an intrafield or an interfield mode, depending on whether the image contents of the block are classified as moving or stationary. One bit per block is transmitted through the channel to indicate the mode used. The receiver performs image reconstruction based on the mode bits received.

An evolutionary HDTV system has the advantages of flexibility, market introduction considerations, and minimal initial operational cost.

*This paper is based on work performed at COMSAT Laboratories under the sponsorship of the Communications Satellite Corporation.

INTRODUCTION

Background

The investigation of HDTV system design approaches has attracted much attention in recent years. The establishment of basic objectives for HDTV has been investigated by researchers worldwide. The thorough psycho-visual studies conducted by NHK [1] have pointed out that, for HDTV

a. A spatial resolution of 14 cycles per degree of visual angle is required.

b. The optimal viewing distance is from three to four times the picture height.

c. The preferred aspect ratio is 5:3 at these viewing distances.

d. The preferred ratio of spatial resolution for luminance over chrominance is 3:1 to 4:1.

The use of an HDTV system has also been proposed because of the following deficiencies of image quality inherent in the present NTSC standard and the 525-line interlaced scanning displays:

a. crosstalk between luminance and chrominance signals,

b. interline flicker due to the 2:1 interlacing,

c. visibility of line structure, and

d. insufficient spatial resolution when the picture is displayed on a large-screen projection system.

The effect of luminance-chrominance crosstalk can be eliminated by adopting separate component transmission techniques, such as the Multiplexed Analog Component (MAC) system [2]. The remaining three deficiencies cannot be improved by transmission method alone.

Based on these observations, it has been concluded [1] that an HDTV system using a 2:1 interlaced scanning method with a 30-Hz frame rate must have about 1,000 scanning lines per frame. A natural choice of line number is 1,050, which is double that for the NTSC standard (525). The horizontal resolution which matches the 1,050-line, 2:1 interlaced scan format is about 6.4 MHz in NTSC-equivalent bandwidth. The NTSC-equivalent bandwidth means that the HDTV signal under discussion will have the same horizontal resolution as an NTSC signal having such a bandwidth.

HDTV System Design Considerations

The amount of image information contained in a 1,050-line, 2:1 interlaced scanned system with a 30-Hz frame rate and a 5:3 aspect ratio is more than two times that of regular-definition TV. Bandwidth economy is an essential issue which determines the number of broadcasts deployable. Recent developments in digital signal processing [3], and the trend of IC technology, make it feasible to perform bandwidth reduction which requires digital signal processing on both sides of the transmission channel.

This type of processing will raise the cost of the HDTV receiver, however. Since receiver cost is the factor which most directly affects the market penetration of HDTV, and since the number of customers who will actually require a full 1,050-line HDTV system can only be estimated, it is preferred that the transition from regular-definition TV to HDTV be evolutionary, rather than revolutionary. Thus, HDTV broadcasters can retain the flexibility to respond to feedback from the marketplace.

OVERALL SYSTEM CONCEPT

The proposed evolutionary HDTV system is designed with a view toward flexibility, ease of market introduction, and minimal initial operation cost [4]. The evolution process consists of three generations, each with different image resolutions and aspect ratios. In each generation, audio information and data are transmitted during the horizontal synchronization periods.

Zero-th Generation System

The zero-th generation HDTV system is the N-MAC system [5], originally designed as a means of encoding the conventional 525-line, 2:1 interlaced scanned TV signal for DBS service. Figure 1 illustrates the N-MAC system concept. This system transmits YUV component signals in a time-compressed multiplexing manner. The Y signal bandwidth is 4.2 MHz, and is time-compressed at a ratio of 4:3. The U and V components have bandwidths of 1 MHz each and are transmitted in alternate lines with a time-compression ratio of 4:1. Figure 2 shows the time-domain signal format for transmission.

First-Generation System

The first generation HDTV system is an enhancement of the zero-th generation system, in that the aspect ratio is increased from 4:3 to 5:3 and both the horizontal and vertical resolutions are increased. The horizontal resolution becomes 5.06 MHz in NTSC-equivalent frequency, and is 20 percent higher than that of the N-MAC system. The vertical resolution is also enhanced by adopting non-interlaced scanning instead of interlaced scanning. Non-interlaced scanning is used in the source images and displayed images only, the transmitted image signal is still in the 525/30 interlaced scanning format. This is made possible by using the motion-adaptive image processing techniques discussed in subsequent sections.

Signals are transmitted through two channels. The first (or compatible) channel carries the image content of the center 4:3 aspect ratio portion of the TV picture and is used by both the zero-th and first-generation HDTV receivers. The remaining side portions of the 5:3 aspect ratio image require the 25-percent transmission capacity of the second transponder (the supplemental channel). In this and the following figures, Y and X represent luminance and chrominance signals, respectively. Subscripts 1 and 2 denote primary signal and augmentative signal, respectively. Subcripts L, C, and R represent left-side portion, center (4:3 aspect ratio) portion, and right-side portion, respectively. The prime of Y and X denotes that these signals are time-compressed versions of the unprimed signals.

The supplemental channel is shared by four first-generation HDTV broadcasts in a time-multiplexed manner. Figure 3 shows the time-domain signal format of the supplemental channel. The system concept is shown in Figure 4. It can be seen

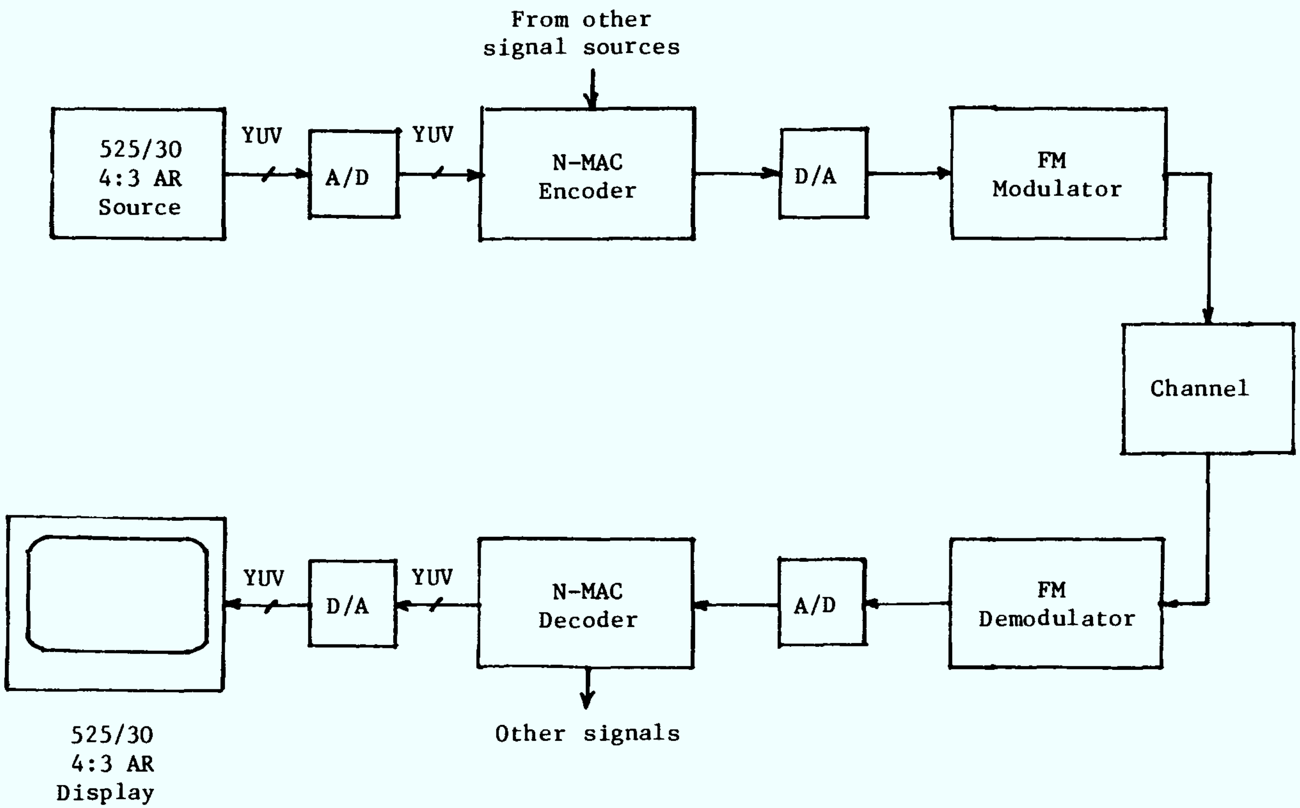

Figure 1. N-MAC System (Zero-th Generation HDTV)

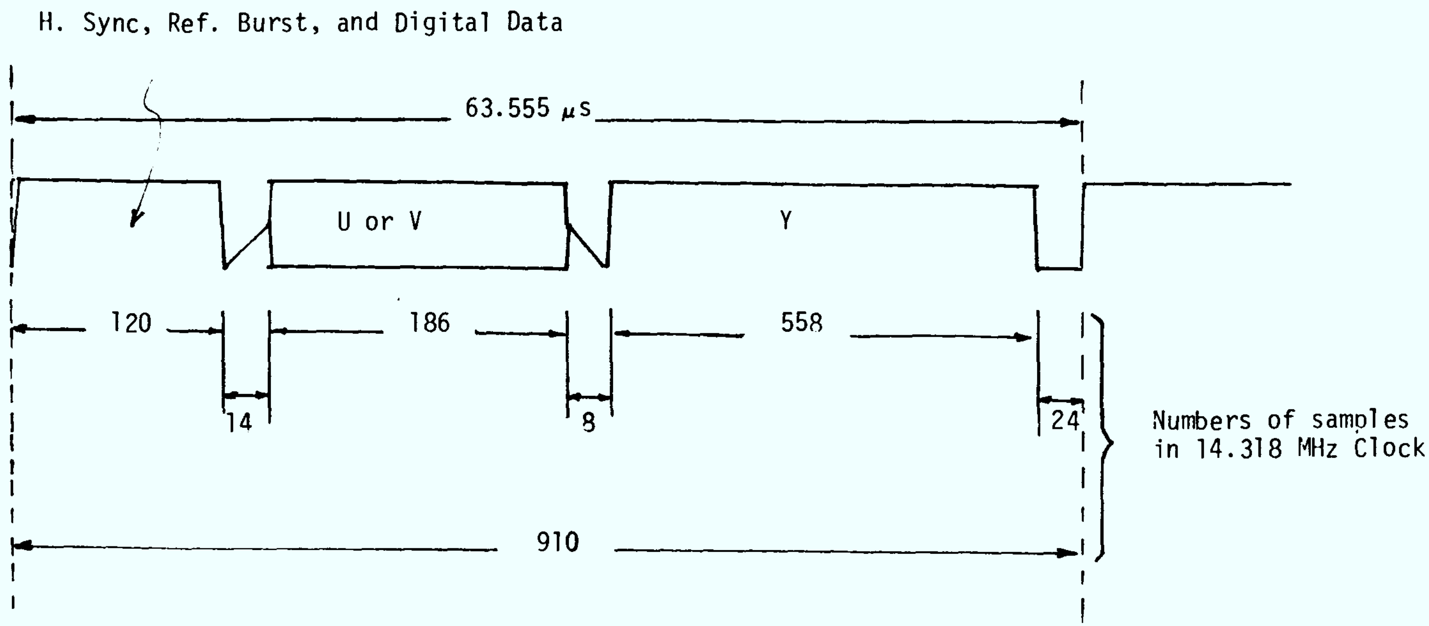

Figure 2. N-MAC Signal Format in Time Domain

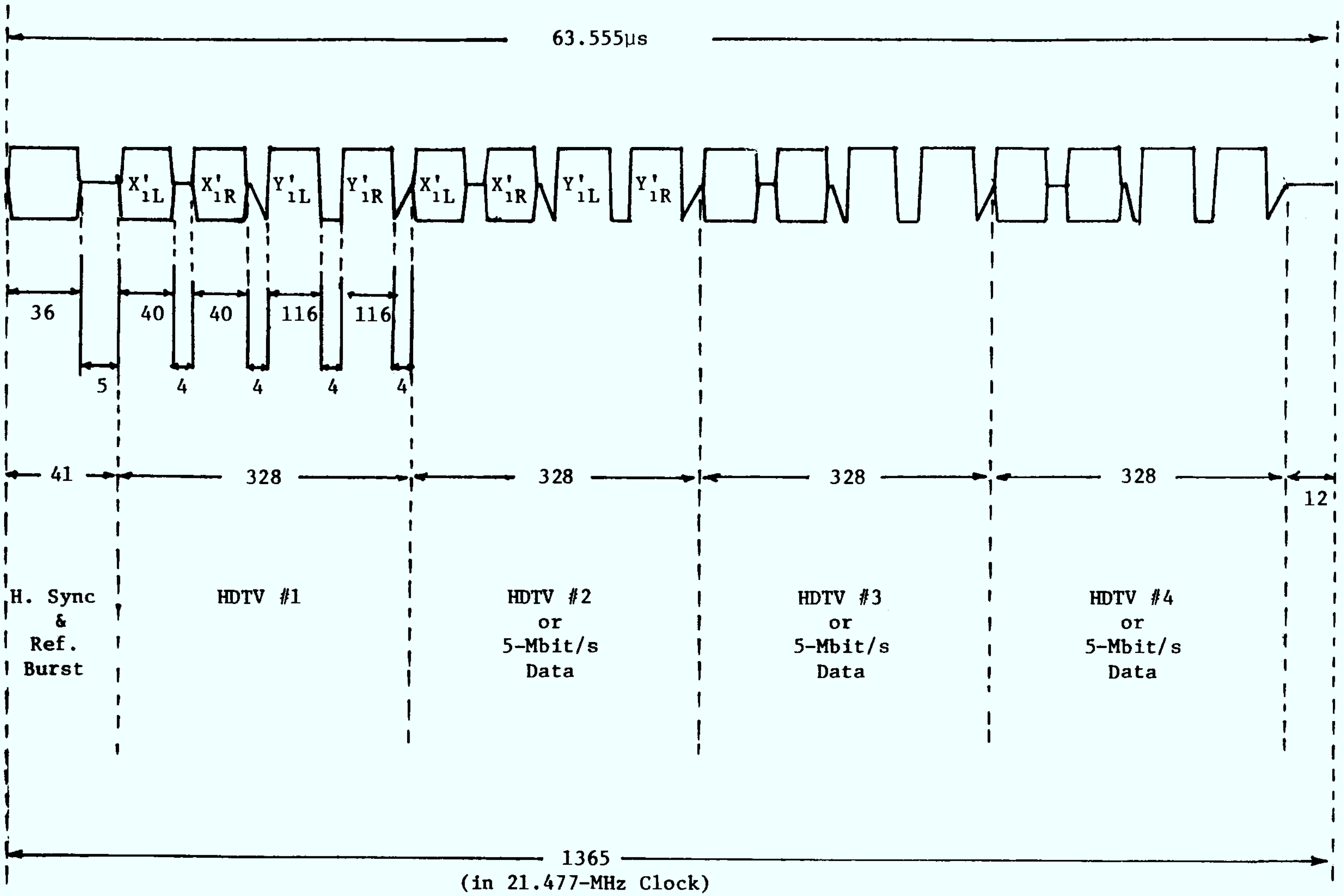

Figure 3. Time-Slot Allocation of Supplement Channel for First Generation HDTV

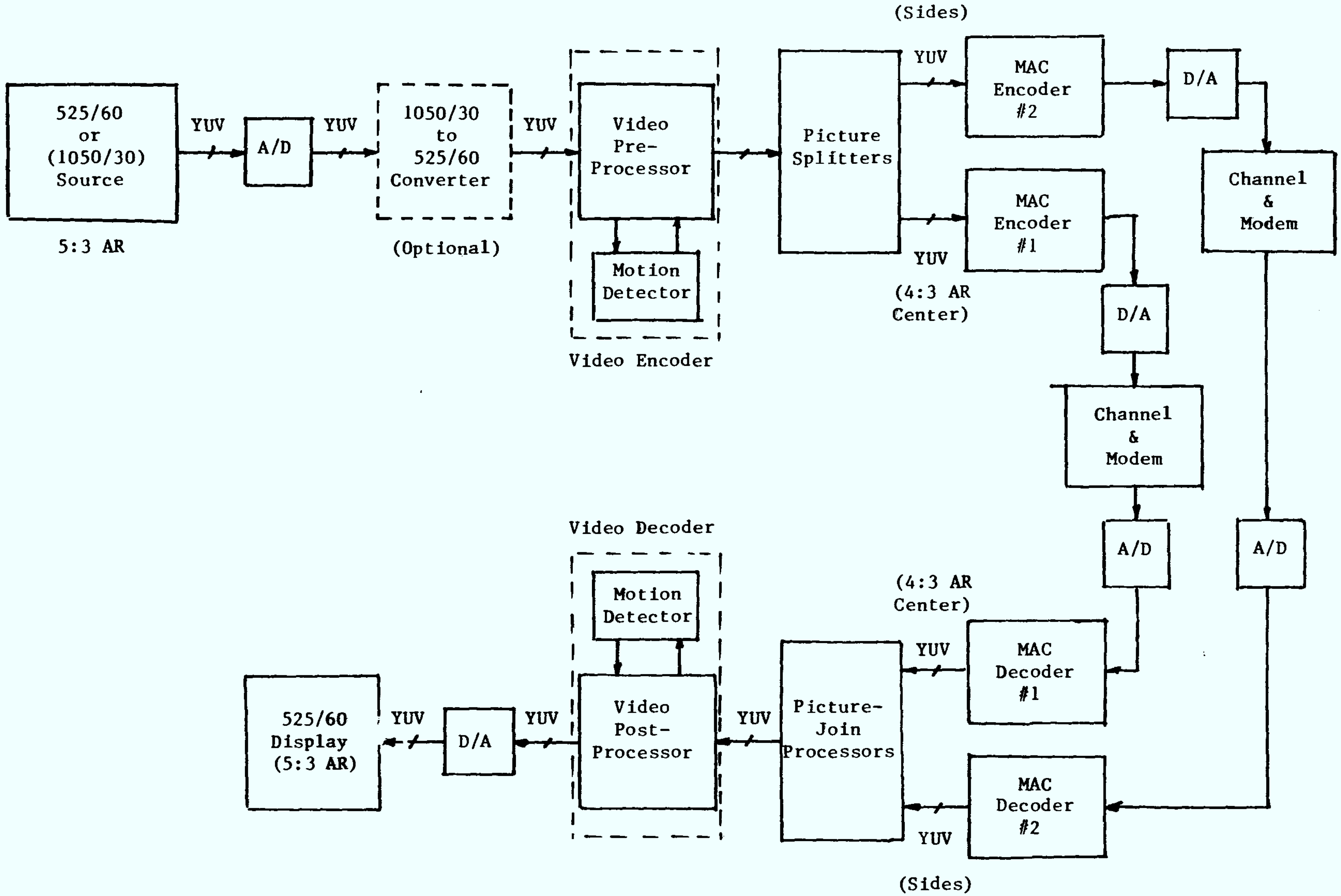

Figure 4. System Concept of First Generation HDTV

that the first-generation HDTV system includes the zero-th generation system as a subset. Note that in either the zero-th or the first-generation HDTV systems, the U and V chrominance components are transmitted in alternating lines of a field. Both bandwidths used are 1 MHz in NTSC-equivalent frequency.

Second-Generation System

The second-generation HDTV system is a further expansion of the first--generation system. The supplemental channel, which was originally used for the transmission of the side-portion image contents of four HDTV broadcasts in the first generation, will be dedicated to one HDTV broadcast only. The 25-percent of channel capacity originally used by this HDTV broadcast remains unchanged. The remaining 75-percent of capacity is used for the transmission of additional high--frequency information required by the 1,050-line, 2:1 interlaced scanning standard of the second-generation HDTV display. In this arrangement, each HDTV broadcast requires two full transponders instead of one and one-quarter. The other three HDTV broadcasts which originally shared the same supplemental channel will be relocated into three different transponders.

The second-generation HDTV system also increases the horizontal resolution to 6.4 MHz in NTSC-equivalent frequency. This additional information is transmitted through the supplemental channel, making use of the spectral gaps within the signal bandwidth as a result of sub-Nyquist sampling [4] performed in the video encoder of the transmitter. Figure 5 shows the time-domain signal format of the supplemental channel for the second-generation HDTV system. Figure 6 illustrates the system concept of second-generation HDTV.

IMAGE PROCESSING TECHNIQUES FOR BANDWIDTH REDUCTION

The description given in the previous section reveals that, compared with zero-th generation HDTV, second-generation HDTV must send double the number of video lines with a 25-percent wider picture size per line over the transmission channels. This represents 2.5 (= 2 x 1.25) times more information, in addition to the increase in signal bandwidth needed to enhance the horizontal resolution. However, the channel capacity available is only doubled. Unless certain bandwidth reduction techniques are used, second-generation HDTV will operate at much poorer S/N ratio than in the zero-th generation, which is unacceptable.

The motion-adaptive sub-Nyquist sampling (MASS) algorithm is a bandwidth reduction technique which enables the transmission of the second-generation HDTV signal over two transponders. The algorithm performs similar processing on both the luminance and the chrominance signals. Only luminance signal processing will be discussed here. Chrominance signal processing, which is much simpler, will not be discussed here due to page limitations.

The MASS algorithm for the three system generations is hierarchical in structure, with the zero-th generation as the bottom level, the first generation as the middle level, and the second generation as the top level. Another way of expressing this relationship is to consider the second generation as the complete system, the first generation as a subset of the second generation, and the zero-th generation as a subset of the first generation. Therefore, the three generations of system evolution may be considered as three phases in the implementation of the ultimate, or second-generation, system.

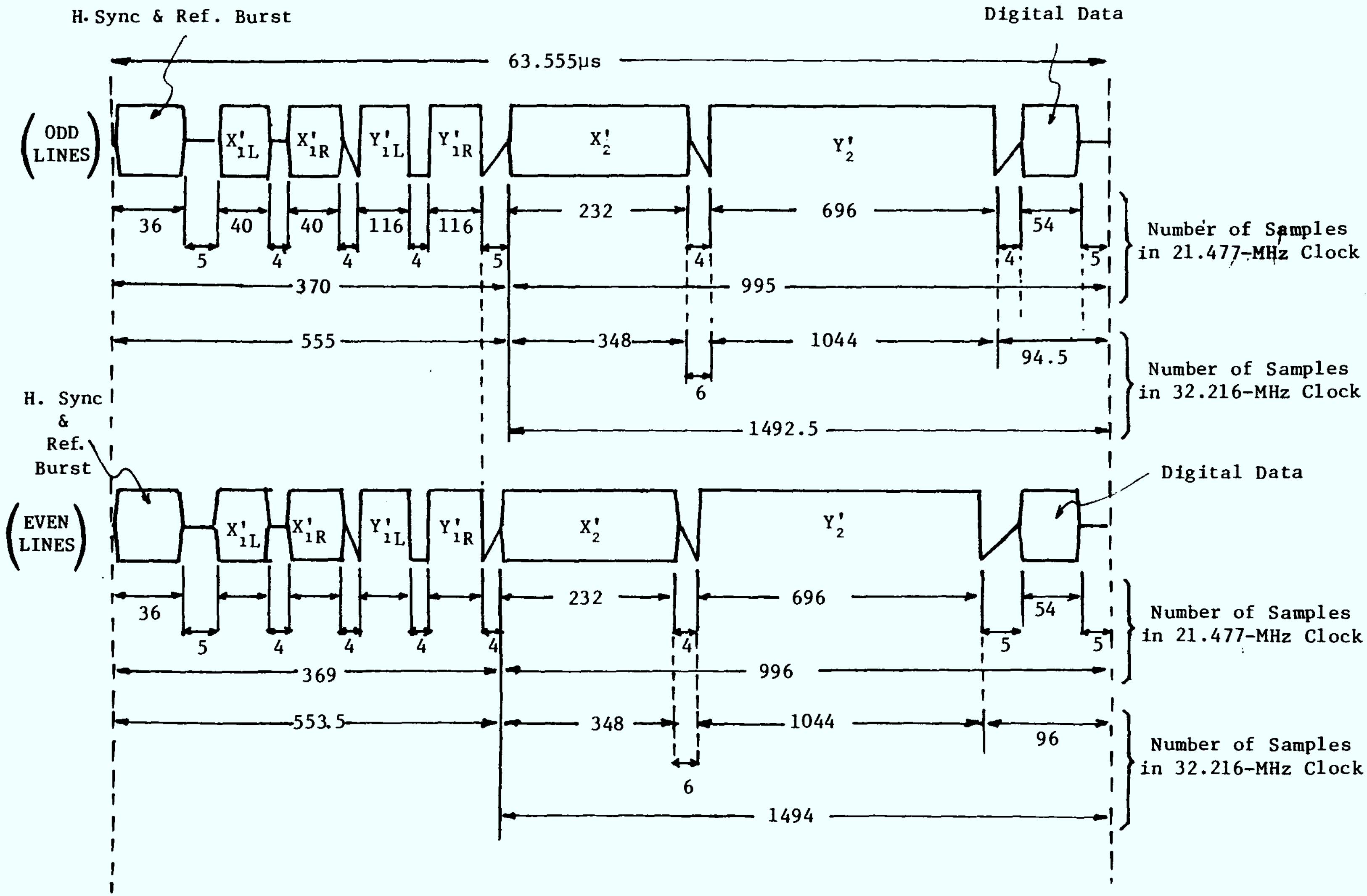

Figure 5. Time-Slot Allocation of Supplement Channel for Second Generation HDTV

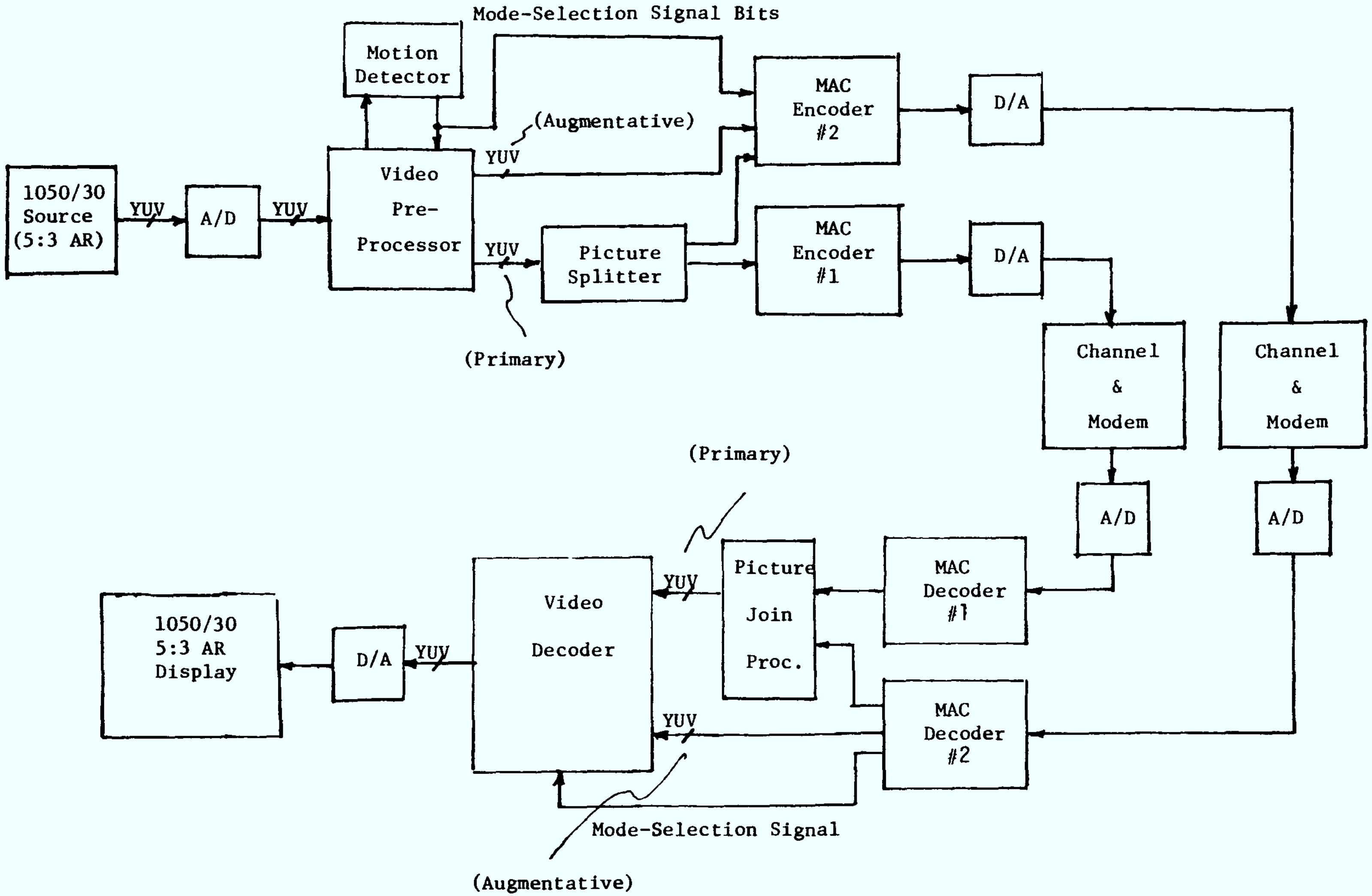

Figure 6. System Concept of Second Generation HDTV

In the following subsections, the luminance signal processing scheme of the second-generation HDTV system will be discussed first. The first generation and the zero-th generation systems will be treated subsequently, and the evolution procedure should become apparent.

Second-Generation System

The image source for the second-generation HDTV system is in a 1,050-line, 2:1 interlaced scanning format with a 5:3 aspect ratio. The primary signal and the augmentative signal generated from the source image, as shown in Figure 6, are both in a format equivalent to the 525-line, 2:1 interlaced scanning scheme. The primary signal is needed for all three generations while the augmentative signal is needed for the second-generation system only.

Figures 7 and 8 are block diagrams of the luminance encoder and luminance decoder, respectively. The MASS algorithm processes moving scenes and stationary scenes differently, so that either the temporal or the spatial resolutions can be emphasized under different image circumstances. The scan conversion matrices for the primary signal, as shown in Figure 7, can be represented by the following matrix equations:

$$C_i = A_i \ , \qquad i = 1, 2, 3, \ldots, 525 \tag{1}$$

for stationary scenes, and

$$C_i = \begin{cases} A_i & , \quad \text{for } i = 1, 3, 5, \ldots, 525 \\ (B_{i-1} + B_i)/2 & , \quad \text{for } i = 2, 4, 6, \ldots, 524 \end{cases} \tag{2}$$

for moving scenes, where A_i and B_i represent the i-th line luminance signals of the 1,050-line source in the odd field and the even field, respectively.

The scan conversion matrices for the augmentative signal shown in Figure 9 can be represented by the following matrix equations:

$$D_i = B_i \ , \qquad i = 1, 2, 3, \ldots, 525 \tag{3}$$

for stationary scenes, and

$$D_i = \begin{cases} A_{i+1} & , \quad \text{for } i = 1, 3, 5, \ldots, 525 \\ (B_{i-1} + B_i)/2 & , \quad \text{for } i = 2, 4, 6, \ldots, 524 \end{cases} \tag{4}$$

for moving scenes. The D_i's with odd and even values of i are transmitted during the odd and the even field periods, respectively. Equations (1) through (4) can be illustrated graphically, as shown in Figures 9 and 10.

The two-dimensional (2-D) spectral domain of the luminance encoding and decoding procedures for stationary images are depicted in Figure 11 and 12, respectively. The key concepts in this procedure are the 2-D sub-Nyquist sampling and the 2-D interpolation.

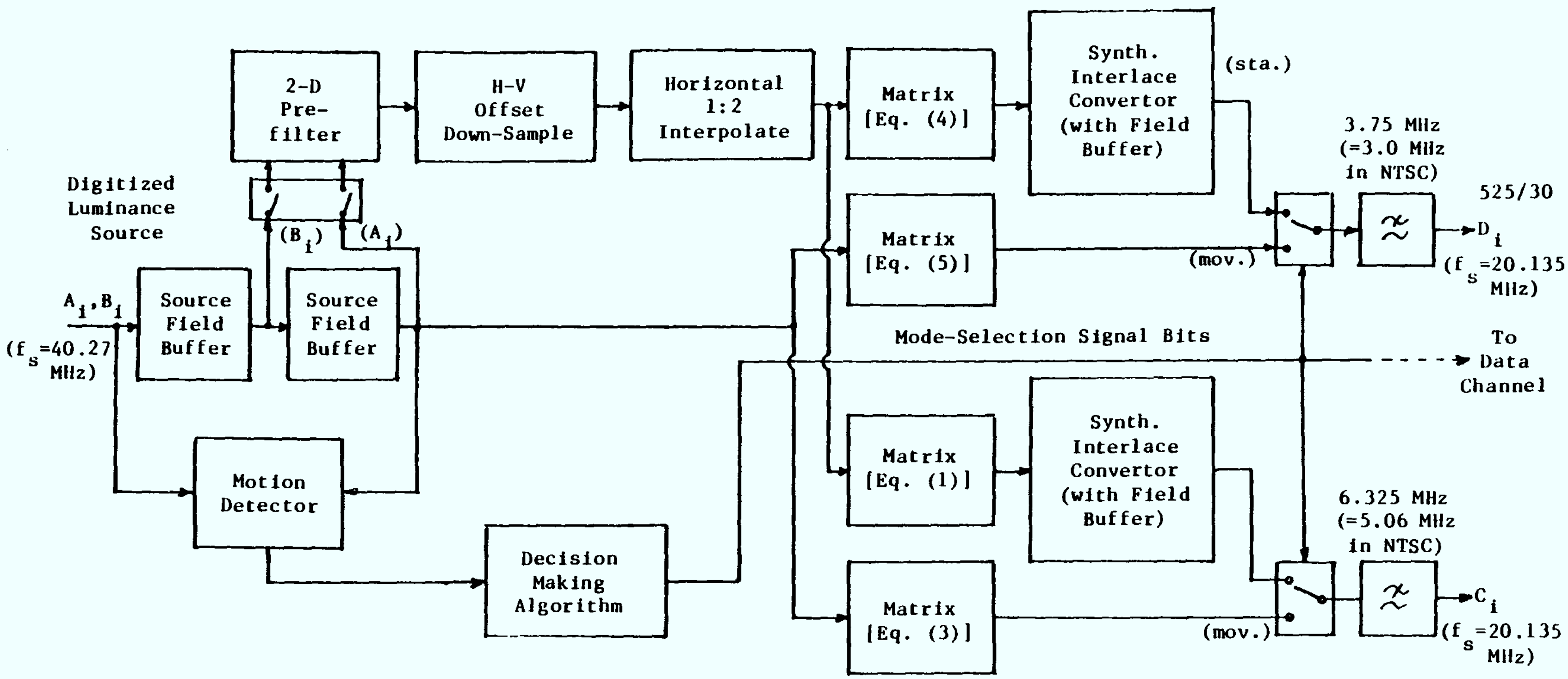

Figure 7. Luminance Encoder of Second Generation HDTV

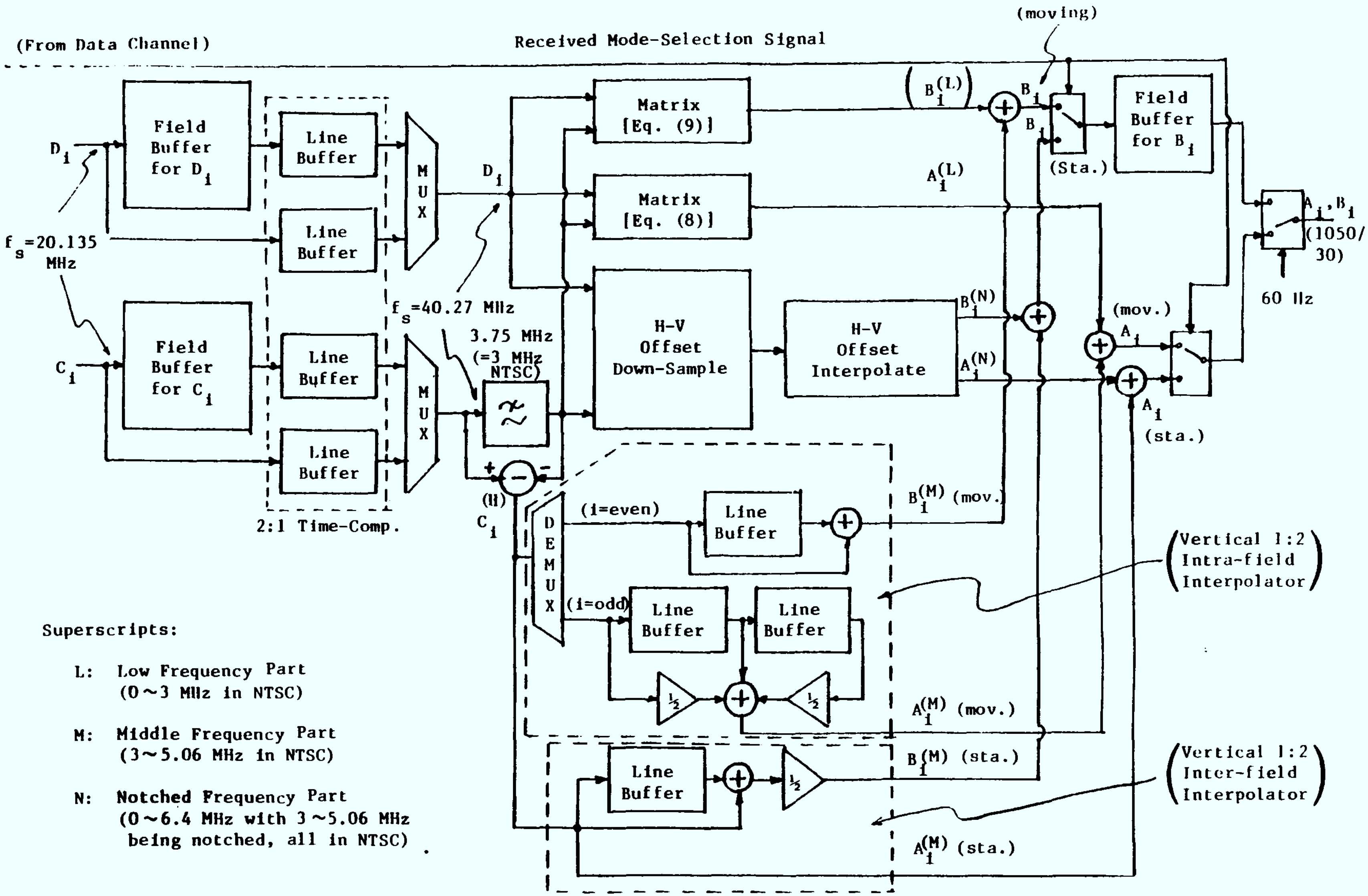

Figure 8. Luminance Decoder of Second-Generation HDTV

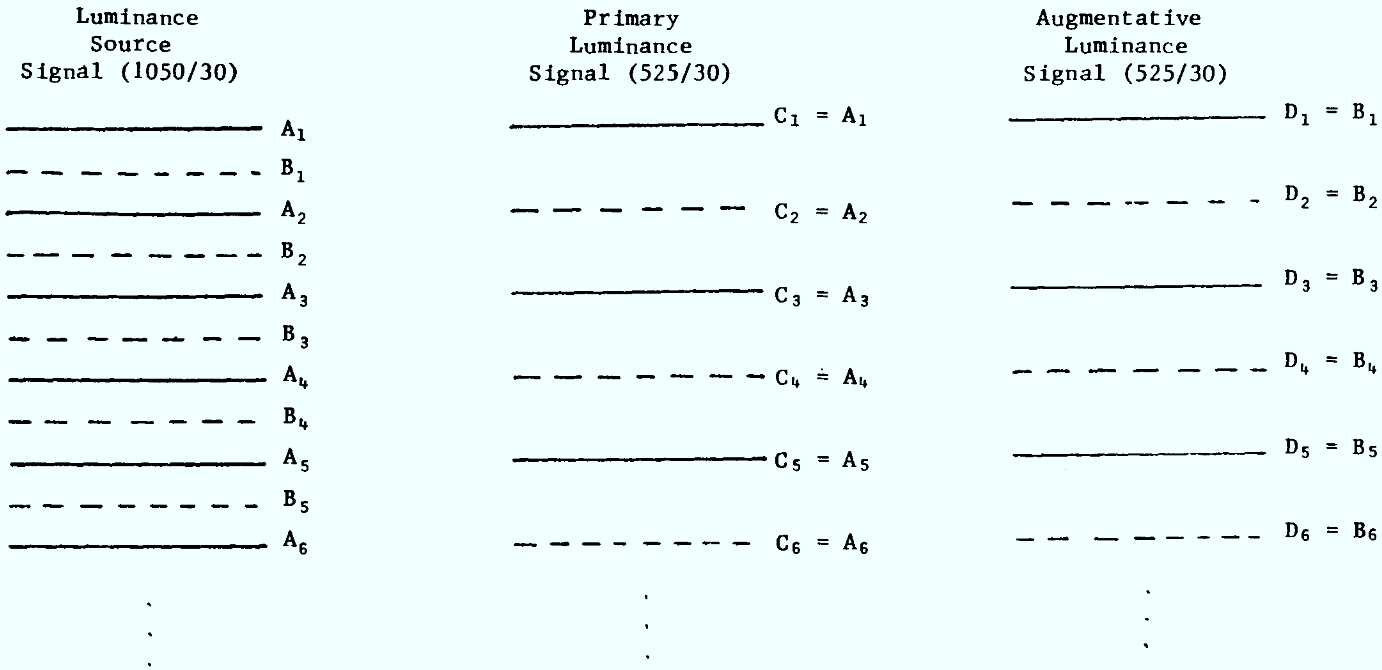

Figure 9. Primary and Augmentative Luminance Matrices for Stationary Images

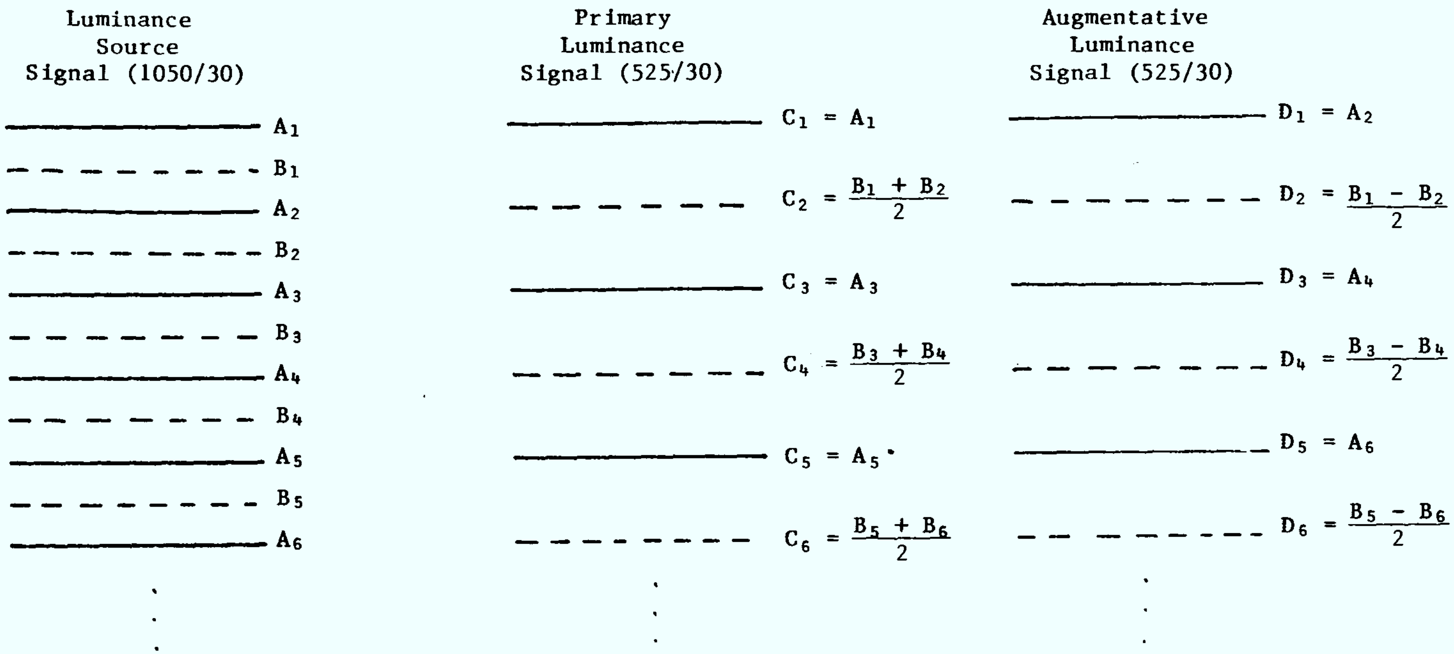

Figure 10. Primary and Augmentative Luminance Matrices for Moving Images

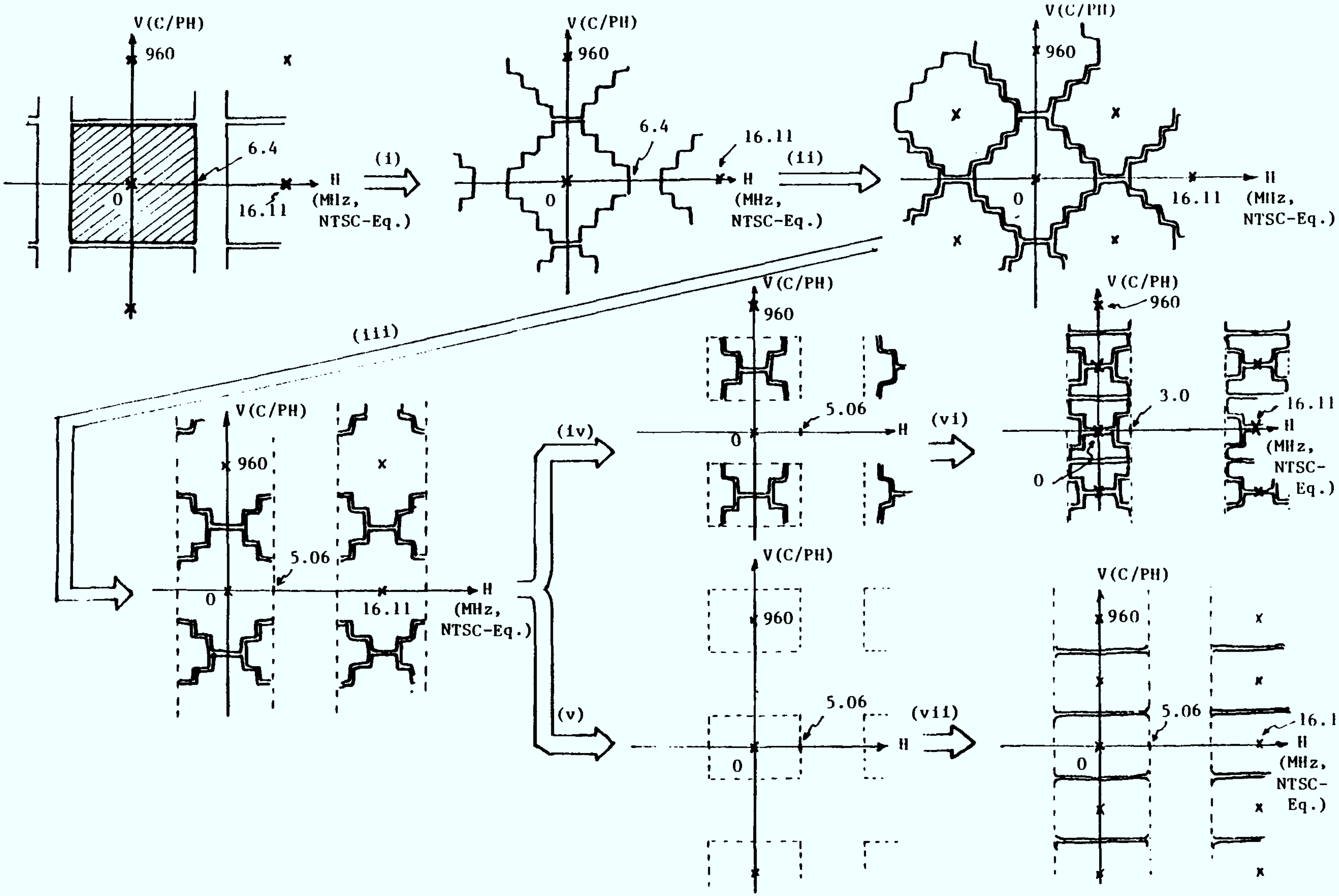

Figure 11. Luminance Signal Encoding for Stationary Images

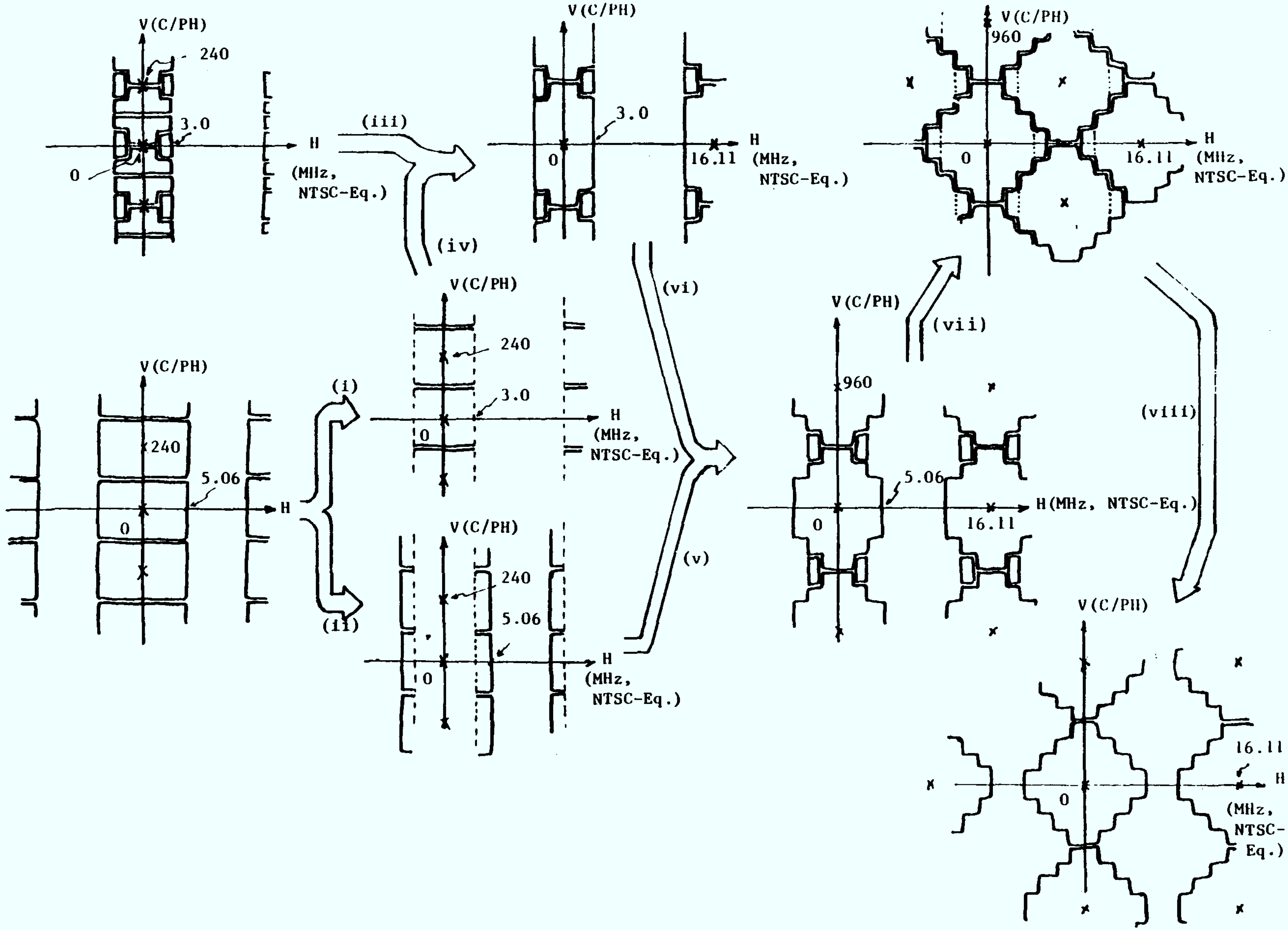

Figure 12. Luminance Signal Decoding for Stationary Images

The matrices that appear in the decoder block diagram can be represented by the following matrix equations:

$$A_i = C_i \quad , \qquad i = 1, 2, 3, \ldots, 525 \tag{5}$$

and

$$B_i = D_i \quad , \qquad i = 1, 2, 3, \ldots, 525 \tag{6}$$

for stationary scenes, and

$$A_i = \begin{cases} C_i \quad , & i = 1, 3, 5, \ldots, 525 \\ D_{i-1} \quad , & i = 2, 4, 6, \ldots, 524 \end{cases} \tag{7}$$

and

$$B_i = \begin{cases} (C_{i+1} + D_{i+1}) \quad , & i = 1, 3, 5, \ldots, 525 \\ (C_i - D_i) \quad , & i = 2, 4, 6, \ldots, 524 \end{cases} \tag{8}$$

for moving scenes. Figures 13 and 14 illustrate these procedures graphically.

These signals are transmitted through two transponders (the compatible and supplement channels) in the form of time-multiplexed signal bursts. The burst-forming procedure for the second-generation HDTV system can be summarized as shown in Figure 15.

The compatibility of the second-generation HDTV signal with the zero-th and first-generation receivers ensures the evolution of the system, as follows:

a. Reception by the First-Generation Receiver. During deployment of the second-generation system, the first-generation HDTV display uses the 525-line, 1:1 non-interlaced scanning format with a 60-Hz frame rate and a 5:3 aspect ratio. The non-interlaced scanned image is obtained by interpolating the received, 2:1 interlaced scanned primary signal. Moving scenes and stationary scenes are processed differently, as represented by matrix equations (7) and (5). Motion-adaption is provided by a motion detector, which compares pixels in consecutive fields or consecutive frames.

b. Reception by the Zero-th Generation Receiver. The N-MAC receiver will only receive the center portion of the primary signal transmitted through channel 1. This primary signal is band-limited to 4.2 MHz before being displayed. The resulting images should be indistinguishable from those of the N-MAC signal.

First-Generation System

The first generation system transmits only the primary signal (both the center portion and the side portions) through the channel. The primary signal may be generated from a 1,050-line, 2:1 interlaced scanned source (as in the second generation) or from a 525-line, 1:1 non-interlaced scanned source. In the latter case, the encoding matrix equations become

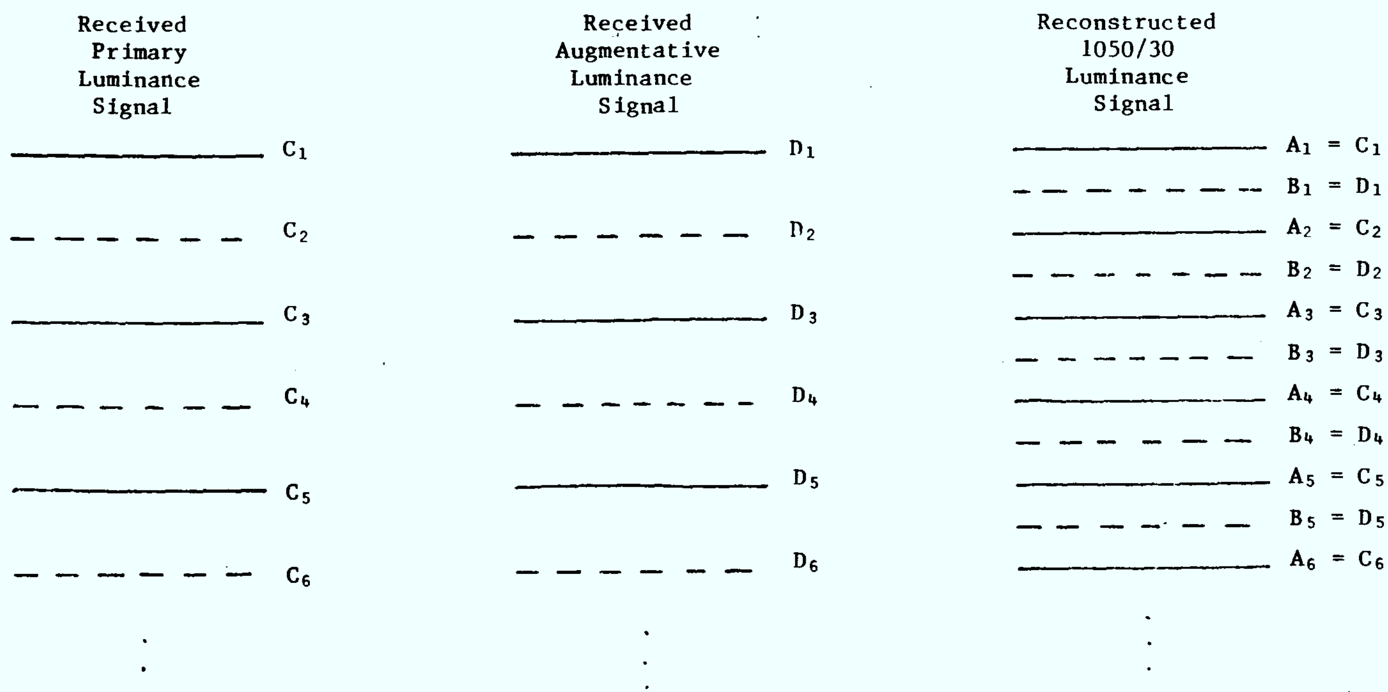

Figure 13. De-Matrixing for Stationary Images (Luminance Signal)

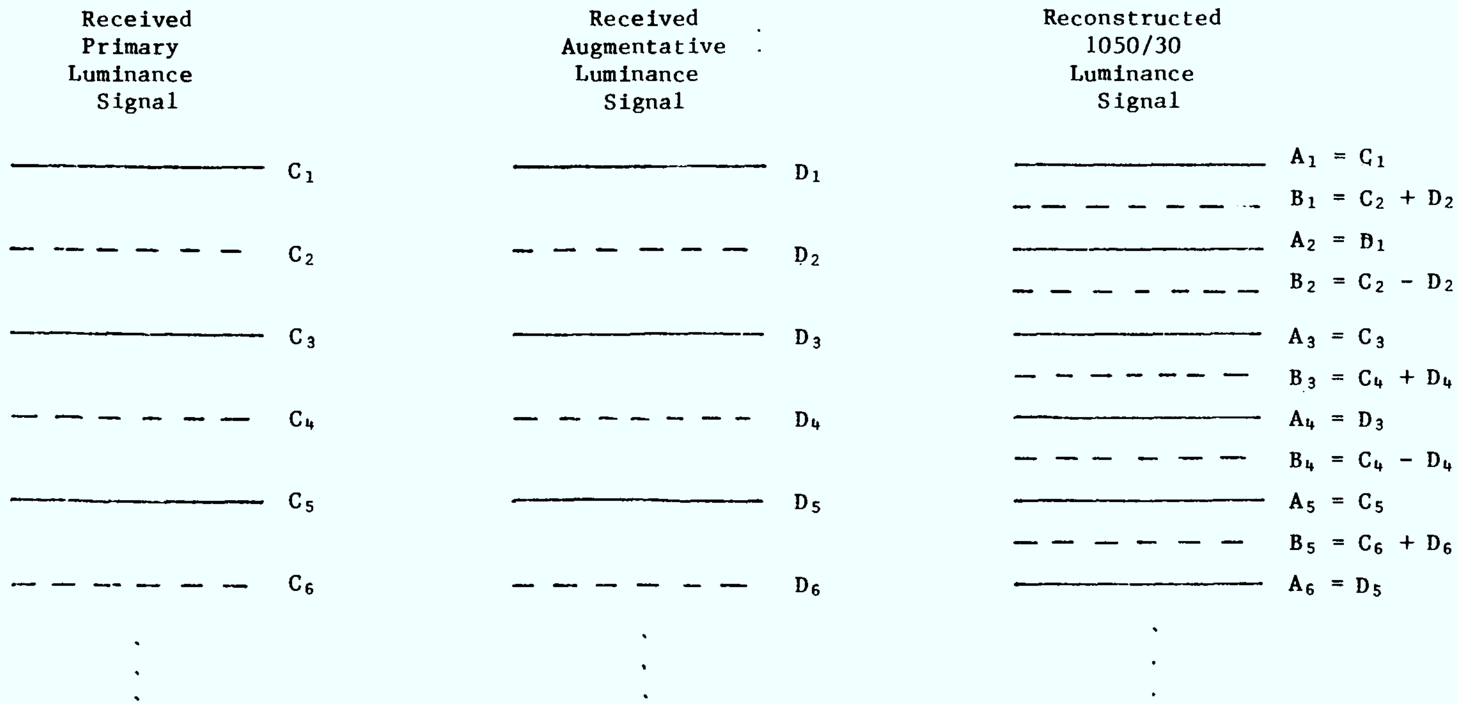

Figure 14. De-Matrixing for Moving Images
(Luminance Signal)

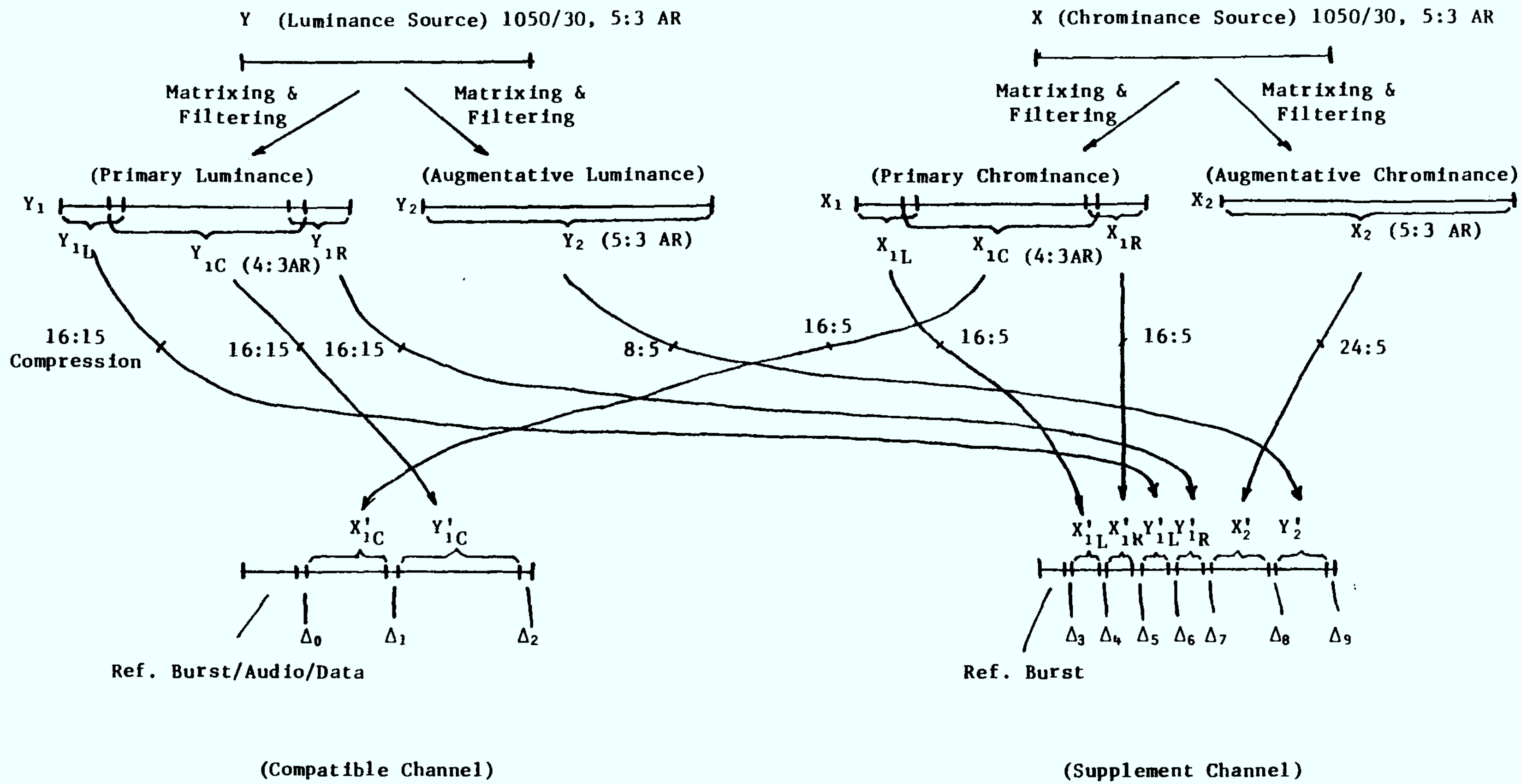

Figure 15. Signal Formation for Second-Generation HDTV

$$C_i = A_i \,, \qquad i = 1, 2, 3, \ldots, 525$$

for stationary scenes, and

$$C_i = \begin{cases} A_i \,, & i = 1, 3, 5, \ldots, 525 \\ a_i \,, & i = 2, 4, 6, \ldots, 524 \end{cases} \tag{9}$$

where a_i is the i-th line in the even field of the 525-line non-interlaced source, for moving scenes.

In the receiver, the received signal C_i is either vertically interpolated or temporally repeated, depending on whether the scene is catergorized as moving or stationary. Motion detection is performed in the receiver by a local motion detector which compares pixel values one field or one frame away.

Again, the N-MAC receiver is indifferent to the encoding scheme of the primary signal and will display the center portion primary signal sent through channel 1 (the compatible channel) as if it is the N-MAC signal. No motion adaption is needed in the N-MAC receiver.

Zero-th Generation System

The zero-th generation (N-MAC) system uses a 525-line, 2:1 interlaced scanned image source having a 4:3 aspect ratio. There is no motion adaption on either side of the transmission channel.

PERFORMANCE

Signal-to-Noise Ratio

Table 1 shows the calculated video signal-to-noise ratio (S/N) of all three generations of HDTV systems, based on a C/N_o value of 90.8 dBHz and a transponder bandwidth of 24 MHz (which results in a C/N value of 17 dB). Overdeviation of 3 dB, based on Carson's rule, is assumed. It is shown that a S/N of 48.4 dB is achievable in both the first- and second-generation HDTV systems.

Spatial Resolutions

Table 2 shows the calculated spatial resolution of luminance and chrominance signals in all three generations of HDTV systems. The overall baseband signal bandwidth is 6.75 MHz or less for each signal burst, depending on the compression ratio used.

CONCLUSION

Based on the above discussion, it can be concluded that an evolutionary approach to the deployment of HDTV system through three generations with gradually increased image quality is both technically possible and bandwidth-effective. The MASS algorithm provides a way to reduce the bandwidth requirement while maintaining balanced spatial resolutions for stationary and moving scenes. Efforts are

Table 1. Signal-To-Noise Ratio in dB

		Luminance: Y				Chrominance: U or V			
		Type M De-emp.		Without De-emp.		Type M De-emp.		Without De-emp.	
		Type M Weight.	Without Weight.	Type M Weight.	Without Weight.	Type M Weight.	Without Weight.	Type M Weight.	Without Weight.
N-MAC		51.40	41.39	48.61	38.26	51.01	47.47	48.27	44.59
1st Generation HDTV		48.63	37.33	45.71	34.12	44.86	39.96	41.81	36.80
2nd Generation HDTV	Primary Signal	48.63	37.33	45.71	34.12	44.89	39.96	41.87	36.80
	Augment Signal	48.04	39.96	45.09	36.80	43.57	39.96	40.49	36.80
	Average	48.34	38.65	45.40	35.46	44.22	39.96	41.15	36.80

Assume: C/N_o = 90.8 dB-Hz
Transponder B.W. = 24 MHz
Deviation: Carson's Rule + 3 dB

Table 2. Spatial Resolutions

Resolutions / Systems	Luminance: Horizontal (MHz, NTSC-Eq.)		Luminance: Vertical (C/PH)		Chrominance: Horizontal (MHz, NTSC-Eq.)		Chrominance: Vertical (C/PH)	
	Stationary	Moving	Stationary	Moving	Stationary	Moving	Stationary	Moving
N-MAC	4.2	4.2	170 *	85[+]	1.0	1.0	85[+]	42.5[+]
1ST Generation HDTV	5.06	5.06	200 *	100[+]	1.5	1.5	100[+]	50[+]
2nd Generation HDTV	6.4	5.06	340[+]	170[+]	1.5	1.5	170[+]	170[+]

* based on subjective evaluation using resolution chart

\+ estimated assuming this subjective evaluation is true continuing to finalize the system design details, including the 2-D filter and the motion detector.

ACKNOWLEDGMENT

Thanks are due to E. Yam, T. Kao, and E. Martin for their contributions to the study [4] upon which this paper is based.

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DEVELOPMENTAL STATE OF VARIOUS HDTV EQUIPMENT INCLUDING THE MUSE SYSTEM

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3.13

ABSTRACT

Fifteen years have passed since the research and development of HDTV were started at the Science and Technical Research Laboratories of NHK. In three years, various HDTV studio equipment and signal processing equipment have been developed such as TV camera, telecine, VTR, laser-beam film recorder, CRT, projection-type display, TCI system (Time Compression Integration), and MUSE system (Multiple Sub-Nyquist Sampling and Encoding). Recently, a system converter for converting HDTV signal to NTSC or PAL signal was developed.

Using the MUSE system which reduces the HDTV signal bandwidth to about 1/3, it has become possible not only to broadcast the HDTV signal through one channel of a broadcast satellite, but also to record the HDTV signal on a consumer VTR or an optical video disc, so that the MUSE opens the way to new package media.

System converter which is essential for an exchange of programs between HDTV and conventional TV plays an important role in considering the unified worldwide standard of HDTV.

Using these equipment, a lot of programs of HDTV have been produced and they are experimentally broadcast at Tsukuba Exposition now being held in Japan.

3.13

ÉTAT DU DÉVELOPPEMENT DE DIFFÉRENTS SYSTEMES DE TVHD, Y COMPRIS LE SYSTEME MUSE

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RÉSUMÉ

Quinze années ont passé depuis le début des travaux de recherche et développement du matériel de TVHD au Laboratoire de recherche scientifique et technique de la NHK. Cette période a connu le développement de différents équipements de studio et de traitement des signaux de TVHD comme les caméras de télévision, le matériel de télécinéma, de magnétoscopie (VTR), les enregistreurs de film à laser, le TRC, l'affichage par projection, le système ICT (intégration par compression du temps) et le système MUSE (sous-échantillonnage avec compensation de mouvement). Un convertisseur de système a été mis au point récemment pour la conversion des signaux de TVHD en signaux NTSC ou PAL.

Grâce au système qui réduit la largeur de bande du signal de TVHD à environ 1/3, il est devenu possible non seulement de radiodiffuser le signal de TVHD sur une seule voie de satellite de radiodiffusion mais aussi d'enregistrer ce signal de TVHD sur un magnétoscope domestique ou un vidéodisque optique. Le système MUSE ouvre donc la voie à de nouveaux supports d'information.

Le convertisseur de système qui est essentiel dans l'échange des programmes entre le système de TVHD et le système de télévision classique joue un rôle important dans les considérations relatives à la norme unifiée internationale de TVHD.

A l'aide du matériel de TVHD, bon nombre de programmes TVHD ont été produits et ils sont radiodiffusés à titre expérimental à l'exposition de Tsukuba tenue actuellement au Japon.

TWO-CHANNEL NTSC-COMPATIBLE HDTV TRANSMISSION METHODS

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3.14

ABSTRACT

It is now time to begin serious consideration and demonstration of cost effective methods for the delivery of high definition television signals to the home of the consumer. This paper outlines what we believe is the evolutionary path to HDTV in the home; specifically, NTSC - PIP - POP - pHDTV - HDTV. Pseudo-HDTV, or pHDTV, is a market driven and technology based method of delivering most of the value of an HDTV production standard to the consumer. At its lowest implementation level it requires less memory in the receiver than PIP (Picture-In-Picture). As its performance increases so does the amount of required memory and hence its cost. Eventually, when affordable frame stores become available, full HDTV can be achieved.

This paper reviews methods of analyzing two-channel NTSC-compatible HDTV transmission methods. The process of converting from a production to transmission standard is also considered. Finally, methods of transmitting improved studio signals are presented.

MÉTHODES DE TRANSMISSION TVHD A DEUX CANAUX COMPATIBLES AU NTSC 3.14

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RÉSUMÉ

Le moment est venu d'examiner et d'éprouver sérieusement des méthodes économiques de distribution des signaux de TVHD à domicile. Le document décrit comment s'entrevoit l'évolution de la TVHD vers le consommateur selon la progression NTSC - télévision avec insertion d'image (PIP) - télévision avec sur impression (POP) - pseudo-télévision à haute définition (pTVHD), et enfin télévision à haute définition. La pseudo-TVHD est une méthode inspirée de la technologie et motivée par le marché, qui permet d'offrir au consommateur la plupart des avantages d'une norme de production pour TVHD. A son niveau de matérialisation le plus élémentaire, elle exige moins de mémoire dans le récepteur que n'en requiert l'insertion d'image (PIP). Plus la performance est grande, plus il faut de mémoire et plus le prix augmente. Le jour où des mémoires de trame seront disponibles à prix abordable, la TVHD intégrale deviendra réalité.

Le mémoire passe en revue des méthodes d'analyse des procédés de transmission de TVHD dans deux canaux, qui sont compatibles avec la NTSC. On y aborde aussi la conversion d'une norme de production à une norme de transmission. Enfin, des méthodes de transmission d'un son de meilleure qualités sont présentées.

RESEAUX A FIBRES OPTIQUES A CAPACITE DE TVHD

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3.15

RESUME

Les réseaux de services intégrés à large bande des prochaines décennies emprunteront des techniques de transmission optique et des signaux numériques et ils assureront la distribution ou la commutation des signaux de télévision. Etant donné que l'introduction de ces systèmes se fera à long terme, on peut s'attendre à ce qu'ils puissent aussi transmettre des signaux de télévision à haute définition (TVHD).

En l'absence de réduction de données, un signal numérique de TVHD a un débit de l'ordre de 1 Gbit/s, lequel peut être ramené à environ 280 Mbit/s grâce aux techniques de compression de données. Si l'on en juge d'après les systèmes pilotes actuels qui doivent transmettre simultanément plusieurs signaux de télévision à l'abonné, le système à capacité de TVHD de l'avenir devra avoir un débit de transmission d'au moins 1 Gbaud dans la ligne d'abonné.

Il existe trois grand moyens d'augmenter le débit de transmission de la ligne optique d'abonné.

i. Utiliser les techniques optiques classiques de multiplexage en longueurs d'onde (MLO) et des fibres à gradient d'indice ou des fibres monomodes.

ii. Employer les techniques de multiplexage par répartition dans le temps (MRT) à 1 Gbit/s et des fibres monomodes.

iii. Utiliser des émetteurs à multiplexage en longueurs d'onde inférieures au nanomètre, des fibres monomodes et des récepteurs optiques hétérodynes.

A l'heure actuelle, nous n'avons pas encore atteint ce stade de développement. Des systèmes MLO sont déjà sur le marché, mais les systèmes MRT à 1 Gbit/s en sont à l'étape expérimentale et la technique hétérodyne optique en est à la phase de la recherche de base. La possibilité de mettre au point des lignes d'abonné économiques dépendra en grande mesure de l'avancement du développement des circuits intégrés optoélectroniques.

Le document analyse les caractéristiques et les perspectives des trois principaux moyens de fournir à l'abonné un débit de transmission convenant à la TVHD. On y traite aussi des problèmes associés à la commutation des signaux de TVHD.

Optical Fiber Networks with HDTV-Capability

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3.15

Abstract

Future service integrated broadband networks of the next decades will use optical communication techniques and digital signals and will include distributing or switching of TV signals. Due to the long-term scope of introduction of these systems it may be expected that they have to be also capable for the transmission of HDTV signals.

Without data reduction, a digital HCTV signal has a data rate in the order of 1 Gbit/s, which can be decreased by data reduction techniques to rates of about 280 Mbit/s. Considering the requirement on todays pilot systems to transmit several TV signals simultaneously to the subscriber a HDTV-capable system of the future must have a transmission capacity of at least 1 Gbaud for the subscriber loop.

There are three main ways to increase the transmission capacity of the optical subscriber loop:

i. The use of conventional optical wave length division multiplex (WDM) techniques together with graded index or with single mode fibers,

ii. the use of Gbit/s time division multiplex (TDM) techniques and of single mode fibers and

iii. the use of sub nm WDM transmitters, single mode fibers and of optical heterodyning receivers.

At present the state of development is very different: Systems using WDM are already commercially available, Gbit/s TDM systems are in the state of laboratory experiments and the optical heterodyning technique is in the state of basic research. The possibility to develop economical subscriber loops will depend to a high degree on the progress of the development of opto-electronic integrated circuits (OEIC).

The paper discusses features and outlooks of the three main ways to supply the subscriber with a transmission capacity capable for HDTV. Further, problems connected with switching of HDTV signals are treated.

1. Introduction

It may be stated that the majority of experts believe that, taking long views, public communications systems of the future will be based on digital optical communication techniques and will include all services up to broadband services. In Japan the Nippon Telegraph and Telephone Public Corporation (NTT) and in the Federal Republic of Germany the Deutsche Bundespost (DBP) have published schedules for the step by step development from nowadays analog systems to digital service integrated narrowband systems and, finally, towards broadband systems including TV-distribution /1/, /2/. In addition, in Europe the RACE-Program considers the development of a uniform system concept for a service integrated broadband system for the European area /3/. Whatever the name of such systems might be, INS in Japan, IBFN in Germany or IBC in Europe, there will be a long period of technological development and standardization and administration work until economic acceptable system solutions will become available.

The long-term aspect of this development implies that systems of this kind should be capable for handling digital HDTV-signals since the rapid progress on the field of HDTV techniques during the last years makes it very probable that besides TV services with nowadays standards also HDTV services will have to be offered in the future. Within the next sections the impacts on future communications systems resulting from this requirement are discussed, samples of possible system concepts are given.

2. Digital Transmission of HDTV Signals

2.1 Required Transmission Capacity

The high bandwidth of 20 - 30 MHz of analog HDTV signals leads to bit rates of about 1 Gbit/s per HDTV-channel when the signal is converted into the digital form with a quantizing of 8 bits. By means of time-compressing multiplexing (TCM) and following interframe coding the channel rate may be reduced up to about 30 MHz /4/. However, it should be considered that TV services integrated into future public networks must be low-cost services, otherwise they will find no acceptance. For this reason the degree of data reduction discussed at present for standard TV is rather low: whereas following CCIR Rec. 601 /5/ the unreduced bit rate amounts to 216 Mbit/s, the bit rates used for one TV channel at the subscriber lines of present systems with IBFN features varied between 140 and 70 Mbit/s /6/. Probably, future progress in microelectronics will lead to single-chip decoders suitable for some higher degree of data reduction. On the other hand, it could be that this only holds for TV signals of the present standard. The considerably higher bit rates required for HDTV signals will make the development of low-cost coding techniques more difficult so that no high degrees of data reduction may be expected. Therefore, work on HDTV coding techniques started this year at the Heinrich-Hertz-Institut (HHI) with the objective to attain a bit rate of about 280 Mbit/s for one HDTV channel /7/.

It may be assumed that the number of broadband channels to be provided simultaneously by future IBFN systems will be at least the same as for pilot experiments like the BIGFON systems /8/, say three channels. Thus, a data rate of 1 Gbaud or, at lower degrees of data reduction, even more is required for future HDTV capable IBFN systems.

2.2 Network Topology and Spectrum of Services

The integration of broadband services like picture phone and TV or HDTV with individual multi-channel subscriber access excludes the use of network topologies as the ring or the tree type, the star topology as shown by Fig. 1 is prerequisite for IBFN systems. Further, it must be taken into account that an IBFN will have to supply subscribers with very different requirements e.g. one being a telephone subscriber only and the other an HDTV fan. In the following integration of the different services is only treated for the case that special impacts on the TV or HDTV services integration occur. The considerations will be concentrated on the crucial problem that is to provide the subscriber with a sufficient number of broadband channels, especially with HDTV channels.

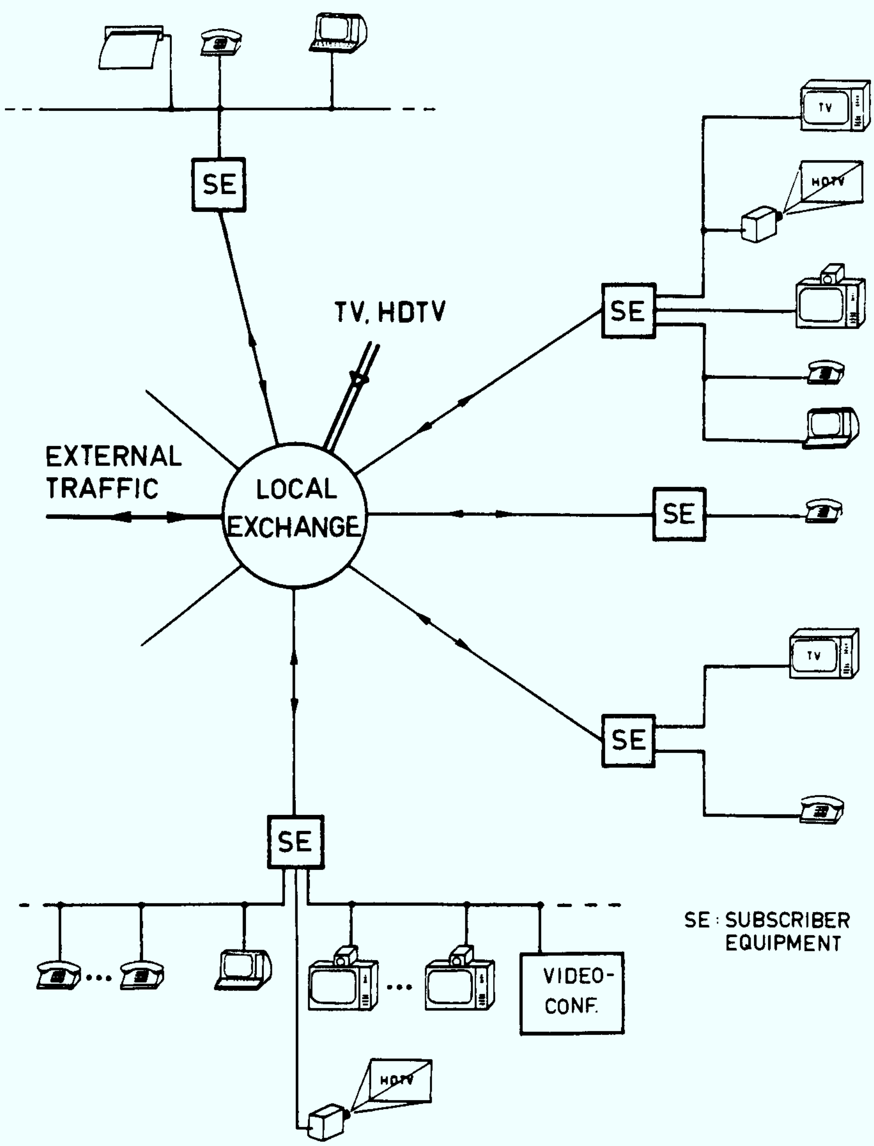


Fig. 1: Local network of an integrated services broadband communication system (IBFN)

2.3 Transmission with Electronic Time Division Multiplexing

Within the last years considerable advances in the development of high bit rate optical transmission systems could be observed /9/, /10/. Thus one solution of the problem to provide the subscriber with data rates of 1 Gbaud or more could be to establish an optical link, which operates with sufficient high bit rate, between the central office and the subscriber. By cyclical assigning of distinct parts of the bit stream to distinct data channels (Time Division Multiplexing, TDM) a number of channels can be established depending on the transmission bit rate, on the channel bit rates and on the multiplexing structure (TDM frame) which has to include synchronization information too.

It must be emphasized that optical transmission systems with transmission rates of more than 1 Gbit/s have been developed until now only for long haul transmission purposes. The development of low-cost systems for subscriber line applications has to be considered as an outstanding problem which may be solved perhaps only be means of future optoelectronic integrated circuits (OEIC).

A concept for a Gbit/s optical subscriber line has been developed at the HHI /11/. Some features of this concept will be commentated in the following in order to point to some problems connected with optical high bit rate TDM systems.

Fig. 2 shows a block diagram of the subscriber line. A main feature of the optical transmission system is that narrowband (NB) and broadband (BB) signals are transmitted separately by means of Wavelength Division Multiplexing (WDM). The utilization of this technique not for increasing the transmission capacity but for separate transmission of signals assigned to different classes of services has the following main advantages:

- The integration of broadband services into the basic narrowband ISDN can be carried out optionally. With other words, it is not necessary to provide a plain telephone subscriber with Gbit/s rates.

- NB and BB channel bit rates differ extremely, in the case of HDTV integration by a factor of about 2000. Furthermore, the standard sample rates of telephony and of video signals are not very well compatible. Both together results in rather complex TDM frame structures for the case that a common TDM frame is used for both signal classes. Separate transmission allows the use of simple specific frames for NB and BB signals respectively. This is especially important for BB signals since the amount of high speed electronic elements needed for multiplexing and for demultiplexing can be reduced considerably in case of simple TDM frame structures.

- Battery buffering of NB services (telephone) in case of outages of the main is facilitated since all the NB assigned electronics can utilize low speed and that means low power technologies (CMOS).

A main feature of the optical subscriber line is a bit rate of 1.12 Gbit/s towards the subscriber. This bit rate, which is high enough to make the sytem capable for HDTV, requires the employment of single mode fibers (SMF) since the achievable bit rates of systems using graded index fibers (GIF) are below

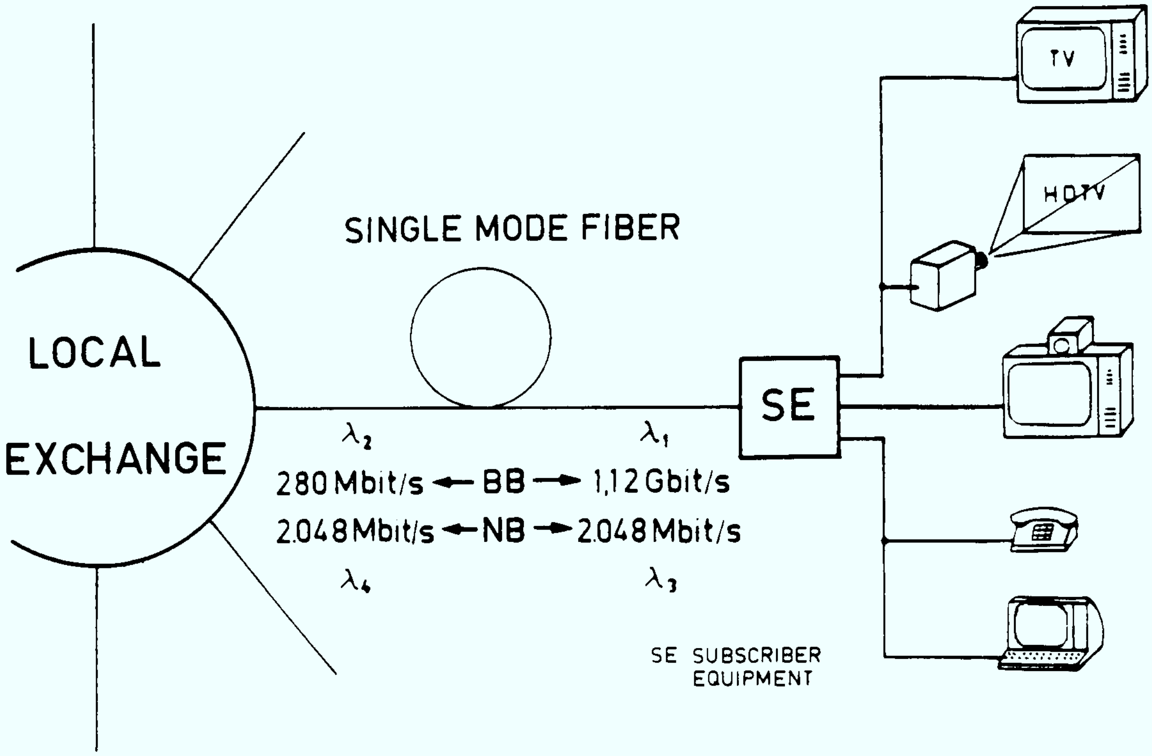


Fig. 2: High speed optical subscriber line

the Gbit/s range due to modal noise effects /9/. In the past, the use of SMF for subscriber loops has been excluded because their very low core diameter of about 5 µm leads to very high precision requirements on splicing and connection techniques. However, there were considerable improvements of this techniques within the last years so that the use of SMF throughout the system seems to be quite probable now.

On condition that bit rates of 70 Mbit/s and of 280 Mbit/s are assigned to a TV and to an HDTV channel respectively, the 1.12 Gbit/s transmission rate is sufficient for up to 15 TV or up to 3 HDTV channels. Fig. 3 shows the corresponding bit interleaved 16 bit TDM frame. The first bit of each frame is assigned by turns to synchronization information and to audio services transmission. Each of the subsequent bits is dedicated to one of fifteen 70 Mbit/s channels. A 280 Mbit/s HDTV channel can be achieved by assigning four time-equidistant bits of the frame to a common channel. The capacity of the optical link can be used in a very flexible manner e.g.

- transmission of 15 TV and 32 audio programs without any switching (fiber-optic CATV system),

- transmission of 10 non-switched TV programs and of 4 more programs which can be selected out of a greater number of programs by switching in the central office, one picture phone channel and audio distribution services or

- same as above but only 6 non-switched TV programs and one switched HDTV program.

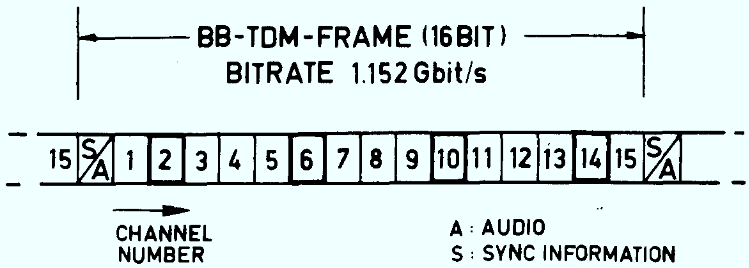


Fig. 3: Broadband TDM frame

Fig. 4 shows a more detailed block diagram of the subscriber line for the transmission direction towards the subscriber. Critical high speed components are the 1.12 Gbit/s multiplexer, broadband channel selector modules in the subscriber station which single out one TV or HDTV channel from the 1.12 Gbit/s data stream and of course the 1.12 Gbit/s optical transmission system.

The high speed multiplexer, which combines four 280 Mbit/s signals to an 1.12 Gbit/s data stream, was developed for the HHI as an custom integrated circuit in bipolar technology by the Ruhr-University Bochum /12/. Its typical maximum operating speed amounts to 1.5 Gbit/s, with a modified version 2 Gbit/s have been obtained. The data inputs of the circuit are ECL compatible, the power dissipation is 220 mW. At the 280 Mbit/s level four multiplexers are required which each combine four 70 Mbit/s signal to a 280 Mbit/s data stream. These four multiplexers were developed by means of commercially available ECL circuits and dissipate 2.5 W.

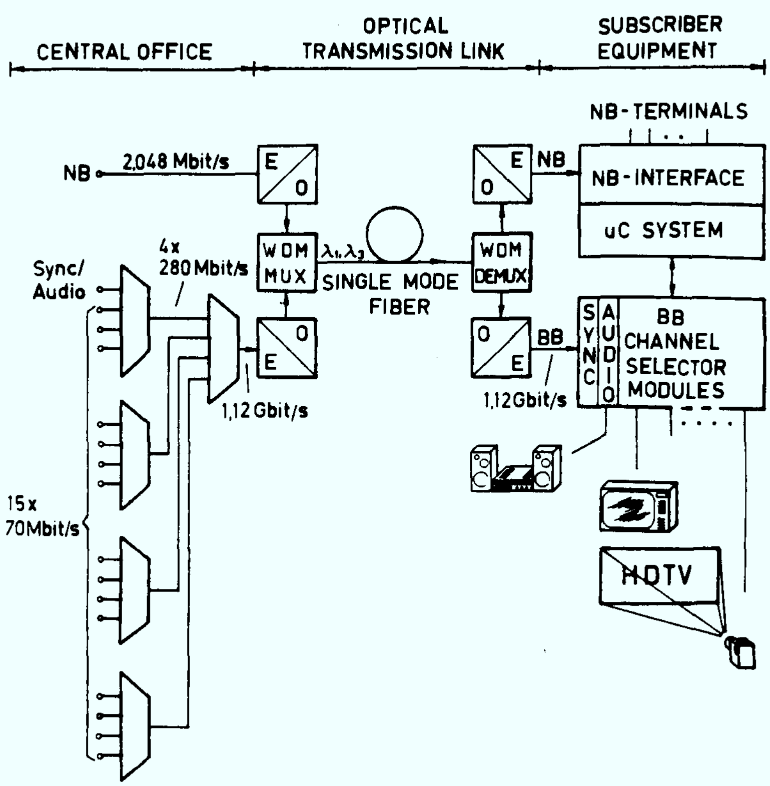
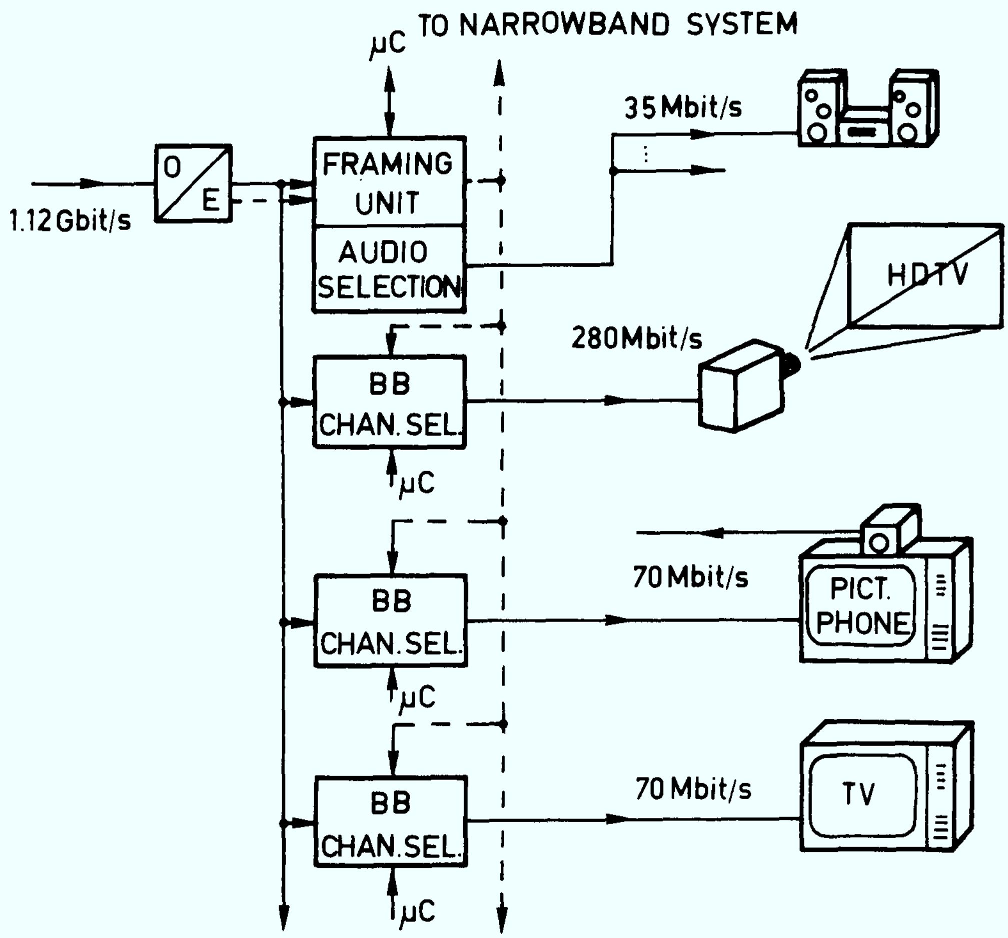


Fig. 4: Subscriber line (from central office to subscriber)

The broadband part of the subscriber station is shown by Fig. 5 : an opto-electronic receiver regenerates the 1.12 Gbit/s data signal and a 1.12 GHz clock from the incoming optical signal. Since most of the subscribers will operate only a few of broadband sets, it is appropriate to demultiplex not all broadband channels by means of complete serial/parallel conversion but to assign a so-called channel selector to each broadband set which singles out the channel wanted by the subscriber for the respective broadband set. The amount of electronic high speed components required for such channel selectors is rather low and the selection of HDTV channels is very simple provided that a TDM frame as shown by Fig. 3 is used. A channel selector following a principle described in /13/ has been developed in the HHI using thickfilm technology /11/. This module has a size of 1 x 2 inch and a power consumption of about 1.5 W which could be reduced of course by future monolithic integration.

As mentioned above the development of optical transmission systems with Gbit/s capacity for subscriber line applications is a task for the future. Due to the essential requirement of low-cost solutions for the integration of TV and of HDTV services two prerequisites should be considered :



<u>Fig. 5</u>: Broadband part of the subscriber station

- The costs of optical fibers must decrease considerably so that their use for narrowband ISDN subscriber lines becomes an economic solution. In this case the integration of broadband services would be possible without additional costs for cabling.

- There must be rather complex optoelectronic integrated circuits (OEIC) available which reduce the number of optic and of high speed electronic connections by integrating the critical optic and electronic functions on one and the same chip.

Fig. 6 shows a sketch of such a future consumer OEIC which would be ideal to replace a lot of components of the receiver station shown by the right part of Fig. 4. One optical subscriber line fiber is connected to this chip besides some more fibers which connect the different broadband sets with this chip. Some electronic connections are provided for narrowband ISDN communications and for separated power supply for NB and BB services to maintain NB services in case of outages of the main. Further, an electronic input is provided to control the channel selector functions.

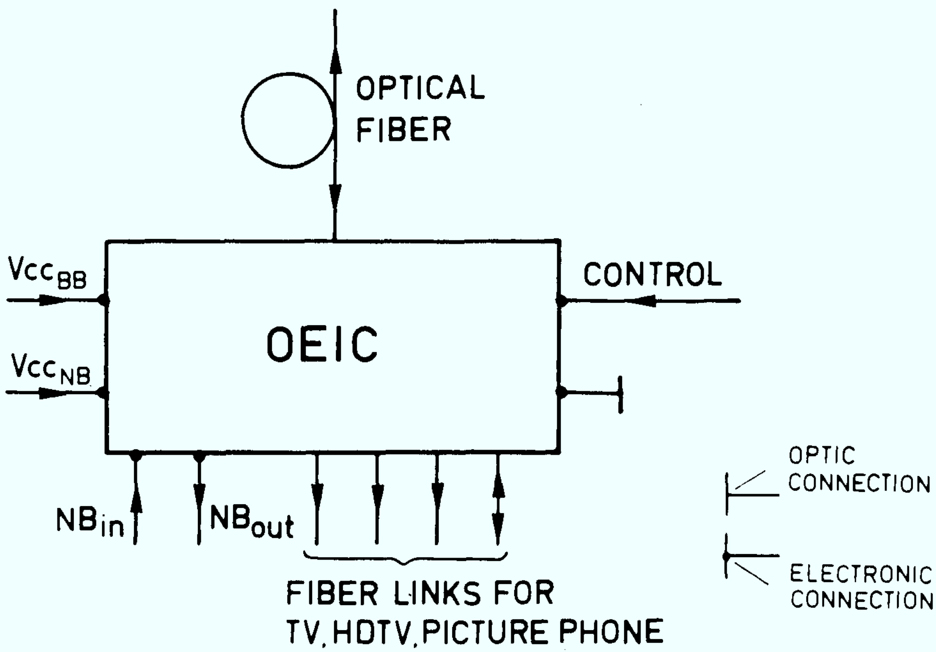


Fig. 6: Sketch of a future consumer OEIC for an optical TDM subscriber line

An OEIC which combines so many functions seems to be a rather utopia. However, the reason why it is discussed here is to show, that, provided a corresponding OEIC exists in the central office, the achievable transmission rate depends only on the operating speed attainable on the OEIC, which may be very high, but not on problems of electronic connection techniques. However, if one considers the development of microelectronics a future development of such OEIC elements of medium complexity is not an utopian idea but more an imperative necessity to achieve low-cost TV or HDTV integration. From this follows, that there is a further reason to use SMF for subscriber lines since GIF are not compatible to OEIC which are, in the main, single mode devices.

Although an ultimate solution of the problem of IBFN subscriber connection depends on the advances in integrated optics a step by step development towards IFBN is appropriate to get experiences of the IBFN problems. Therefore, an experimental system is developed at present by the HHI which take aim of the features of an IBFN using the present technological possibilities /14/. Within this system, TDM transmission techniques as discussed in this section are applied.

2.4 Transmission with Wavelength Division Multiplexing

Another possibility to increase the transmission capacity to the Gbit/s range is multiple exploitation of the optical fiber by means of Wavelength Division Multiplexing (WDM). Fig. 7 shows the principle: the signals emitted by n lasers of different wavelength are combined via an optical multiplexer, fed into the fiber, separated at the receiving site by means of an optical wavelength demultiplexer and converted into electronic signals by n optoelectronic receivers. Due to the limited selectivity of optical filters a distance of the optical carriers of at least 20 nm must be observed.

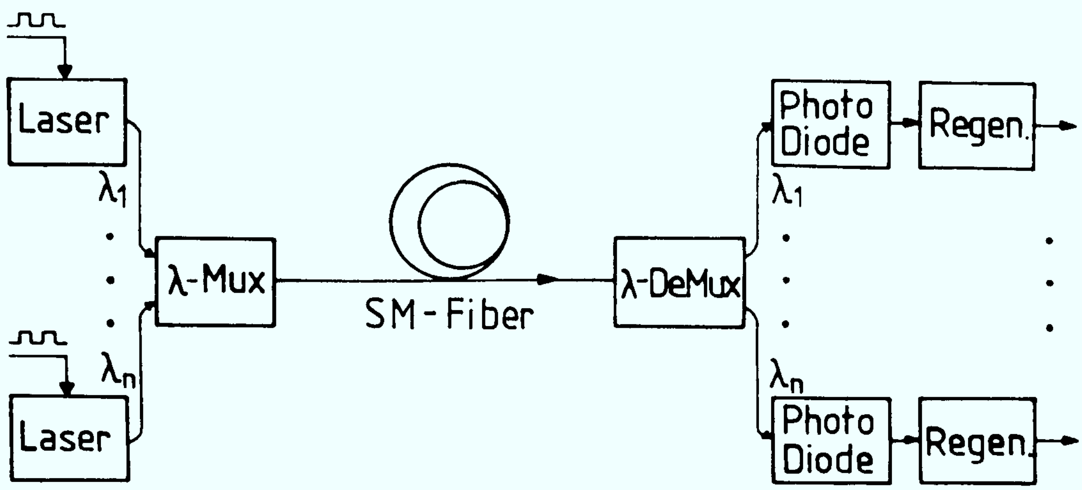


Fig. 7: Principle of Wavelength Division Multiplexing

By this for instance four 280 Mbit/s signals can be transmitted so that a Gbit/s capacity is achieved. In this case graded index fibers could be applied. However, the use of microoptic WDM components and of discrete transmitter and receiver modules will not result in low-cost solutions for which the application of OEIC is indispensible. Therefore, also in case of WDM transmission single mode fibers must be used within an IBFN in order to be compatible to OEIC technology.

It would be rather easy to sketch an OEIC for WDM transmission similar to Fig. 6, but it is rather difficult to estimate which OEIC can be developed with less difficulties and which would be cheaper since the OEIC technology is still in its beginnings. From the systems point of view it seems that the TDM transmission is more appropriate since there is no need for low operating speeds within an OEIC and only one transmitter and receiver function has to be realized respectively.

2.5 Multi-Channel WDM Transmission with Optical Heterodyne Detection

Several years ago research has been started into the field of coherent optical transmission /15/. Fig. 8 illustrates this principle of transmission which is very similar to the principle of heterodyne receiving used for radio transmission since decades: A transmitter laser is modulated by the digital signal to be transmitted. The modulated optical wavë is led via the optical fiber to the receiving site and there to a photodiode at the input of the optical heterodyne receiver. The optical wave of a receiver assigned laser (local laser, LL) is led to the photodiode too. Provided that the mean frequency difference (intermediate frequency, IF) of the two optical wave is low, say a few GHz, an electronic IF-signal occurs at the output of the photodiode. This signal can be amplified and filtered by an IF amplifier and demodulated.

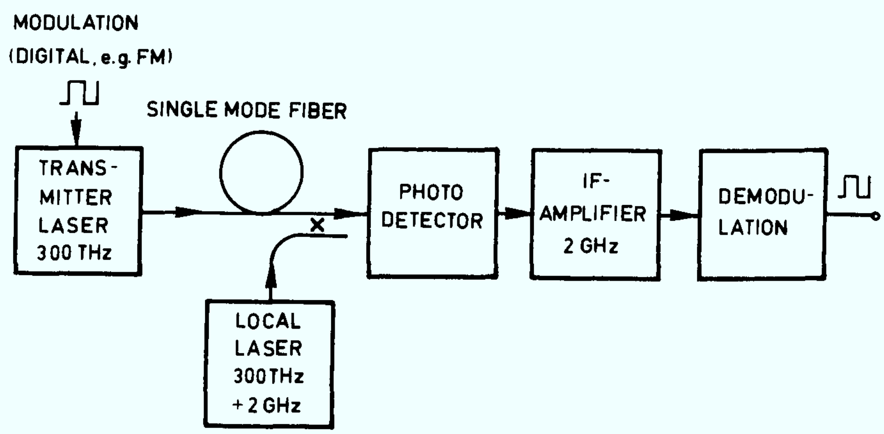


Fig. 8: Coherent optical transmission system

Optical heterodyne detection promises two advantages, that is a higher receiver sensitivity (10 - 20 dB higher compared to direct detection) and the possibility to establish optical multi-channel systems with very low channel distances, e.g. a few GHz, since electronic IF filters have a high selectivity compared to optical filters. Especially the latter aspect may be of great interest for TV and HDTV integration into future IBFN-like systems.

It should be stressed that optical heterodyning is an exacting technique: as Fig. 8 shows the optical carrier frequencies are in the order of 300 THz whereas the IF amounts to a few GHz. This leads to high requirements on the long term stability of the lasers which must have single mode behaviour. Further, modulation methods have to be used which are adapted to the achievable spectral linewidth of the lasers.

Within the last years many experiments have been carried out in the field of coherent optical transmission. Using a gas laser with a wavelength of 1.5 µm as transmitter, a sensitivity gain of 14 dB has been achieved /16/. A first two-channel transmission experiment with a carrier distance of 2 GHz has been carried out last year /17/. At this experiment semiconductor lasers (CSP type) with 0.83 µm wavelength were applied. One optical heterodyne receiver was used which could be tuned to one of the two channels by frequency variation of the local laser.

The prospects to establish multi-channel systems with very low carrier distances together with the possibility of tuning the optical heterodyne receivers by tuning their local lasers gave reason for ideas for the implementation of fiber optic TV distribution systems /18/. Fig. 9 shows a basic diagram of such a system: A number of transmitter lasers are aligned to equidistant carrier frequencies. Each laser is assigned to one TV or HDTV program and modulated by the corresponding digital signal. By optical connections the signals of all lasers are combined within a single mode star coupler. The output signals of the star coupler are transmitted via optical fibers to the respective subscribers. By tuning his optical heterodyne receiver the subscriber can select the channel wanted by him out of the number of offered channels.

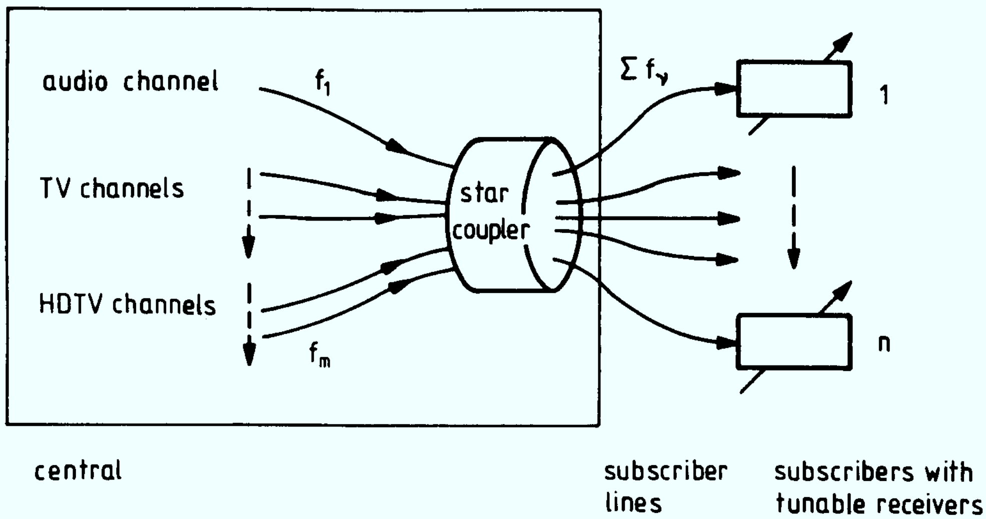


Fig. 9: Multichannel distribution network

At present it is not known how many channels can be established following this principle. There is no relevant limitation with respect to the bandwidth of the optical fiber: due to the low carrier distances an enormous number of channels would fit into the optical window of the fiber. In practice, the achievable number of channels will be limited by the division loss of the star coupler, by decreasing signal/noise ratio at increasing channel numbers and maybe by nonlinear effects of the optical fiber.

One essential component for the feasibility of systems of this kind is a single mode star coupler with a great number of inputs and outputs. Last year a concept to build up great star couplers by cascading of basic elements has been published /19, 20/ and verified as well on the basis of fiber optic couplers as in integrated form on $LiNbO_3$ /21/.

The work on the field of coherent optical communications is still in an experimental stage. However, there are many activities to establish these techniques up to developments with the aim to make an polarization independent optical heterodyne receiver in form of an OEIC available. With respect to HDTV transmission it should be pointed out that it seems to be reasonable to transmit HDTV signals without any data reduction, i.e. with about 1 Gbit/s, since the expenditure for high speed IF amplifiers and demodulators will be considerably lower as for HDTV decoding techniques. Basic experiments to develop such a HDTV capable distribution system are carried out at present at the HHI within a project supported by the Deutsche Bundespost.

3. Optical Switching

Since the field of optoelectronic switching is treated in a special paper of this proceedings /22/, only a few remarks are made in this section to the prospects of two methods of optical switching for IBFN and HDTV applications.

Especially for switching of HDTV signals optical switching may be advantageous since optical paths are not critical with respect to high data rates. One possibility for optical switching is to use a optical multi-channel system as sketched in Fig. 9 not for distributing but for switching /18/. In this case the multi-channel system is considered as a Frequency Division Multiplex (FDM) system. For each connection to be switched a transmitter laser and an optical heterodyne receiver is required. A connection is established by setting the respective receiver/transmitter pair to the same frequency. It will depend on the future development of OEIC technology whether this principle will become competitive compared to electronic broadband switching techniques which are at present also fast advancing.

Another possibility for optical switching is to use switched optical couplers which can be realized on $LiNbO_3$ or, in the future, on InP substrates. Due to the rather great size of a couple element, the number of switches which can be placed on the same chip is low compared to the possibilities of microelectronic integration. This, together with unavoidable insertion losses, make the development of great optical coupling fields, e.g. with a size of 5.000 inputs, for switching broadband point-to-point connections not very probable. On the other hand, for switching of TV and HDTV signals within a central office, decentralized subscriber assigned coupling elements are a suitable mean. This may be a first field of application for optical matrices operating after the principle of switched optical couplers.

4. Conclusions

It has been shown that the higher demands on transmission capacity connected with the integration of HDTV services into future IBFN-like systems could be fulfilled for instance by high bit rate TDM transmission or, in a more far future, by multi-channel WDM transmission and heterodyne detection. In any case, from the low-cost requirement connected with TV and HDTV services follows, that the development of complex OEIC components is prerequisite for a transition from the broadband ISDN to a future IBFN-like system.

Acknowledgement

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PHOTOCONDUCTIVE BROADBAND SWITCHING FOR HDTV

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ABSTRACT

Recent results from the research project in broadband switching carried out by the Optical Communications Program at CRC are significant to HDTV. Using photoconductive detectors, monolithically integrated switch arrays with over 50 dB isolation in the band 0-1.3 GHz have been demonstrated. The crosspoint spacing in these devices is of the order of 100 μm, indicating the possibility of very compact, very broadband switching matrices with performance levels that would permit the switching of analogue HDTV signals. In addition, with high rate digital signals the elementary matrix size can be very large: nonblocking switchers for 100x1000 lines can be envisaged. The design of such apparatus is simplified by the fact that no power is consumed in off-state crosspoints, and no impedance matching is necessary in the signal delivery networks. Large-scale, single-stage matrices may be as convenient to build as sub-Clos arrangements. A comparison of photoconductive broadband switching with other techniques indicates that the hybrid offers many of the advantages of purely electrical or purely optical switching, while avoiding many of the disadvantages of each.

COMMUTATION À LARGE BANDE PAR PHOTOCONDUCTION POUR TÉLÉVISION À HAUTE DÉFINITION

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RÉSUMÉ

Les résultats récents du programme de recherche portant sur la commutation à large bande, mené par le Groupe des communications optiques au CRC, sont importants pour la télévision à haute définition. Des réseaux de commutateurs intégrés monolithiques, utilisant des détecteurs à photoconduction, présentant plus de 50 dB d'isolation dans la bande de 0 à 1.3 GHz ont été mis au point. L'espacement des points de croisement de ces dispositifs est de l'ordre de 100 um, ce qui laisse prévoir des matrices de commutation très compactes et à très large bande, dont les niveaux de fonctionnement permettraient la commutation de signaux analogiques de télévision à haute définition. En outre, avec les signaux numériques à débit élevé, les dimensions de la matrice élémentaire peuvent être très importantes: on peut envisager des commutateurs sans verrouillage de 100 X 1000 lignes. La conception de tels dispositifs est simplifiée par le fait qu'il n'y a aucune consommation de puissance aux points de croisement hors tension et qu'aucune adaptation d'impédance ne s'impose à l'intérieur même du dispositif. Les matrices à étage unique, à grande échelle, peuvent être aussi commodes à construire que les arrangements simplifiés par rapport au modèle analysé par M. Clos. La comparaison de la commutation à large bande par photoconduction avec d'autres techniques indique que les dispositifs hybrides présentent un grand nombre des avantages des dispositifs purement électriques ou purement optiques de commutation, sans en présenter la plupart des inconvénients.

PHOTOCONDUCTIVE BROADBAND SWITCHING FOR HDTV

by

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R.I. MacDonald and D.K.W. Lam

1. INTRODUCTION

High definition television production will require new types of switches to handle the wideband signal standards that have been proposed. The eventual distribution of HDTV signals to the public may even require a large scale wideband switched network because of constraints on the number of signals that could be broadcast or carried over FDM or TDM tree-type cable systems. While present switching technologies can probably be improved to handle extended-definition formats, which have two to three times the baseband occupancy of current standards, the switching of proposed signals with greater bandwidth, 20 MHz and more will require new approaches.

Present techniques of televison switching include frequency division and (with digital signals) time division. These methods are not available for very broadband switching because the large bandwidth of each signal to be switched limits the number that can be multiplexed together. The overall bandwidth requirement is the limit in the former case, and the bit rate of the multiplexed digital signals in the latter. Switches for HDTV will therefore employ space division [1]. A suitable space division switch, however, is not yet available. At high frequencies, coupling between circuit paths and the reactive leakage through crosspoint switches makes difficult the construction of circuit switching matrices.

Recently there have been a number of developments in switching that address the problem of wideband space division matrices. In this context we review here a new switching technology which has been under investigation at the Communications Research Centre for several years and present some important recent results. These indicate the possibility of integrating very large scale broadband switch matrices using a hybrid optoelectronic technique.

2. WIDEBAND SWITCHING METHODS

(a) Electronic Techniques

Several different electronic techniques for constructing wideband switch matrices have recently been investigated. For signals in the 100-300 Mb/s range, circuit switching using integrated MOS or bipolar devices has been developed [2,3,4]. Integrated circuits can fairly readily be constructed using standard methods to create quite large matrices for digital signals at rates up to about 100 Mb/s. Analogue signals of very wide bandwidths are more difficult to handle because of the more stringent requirements on crosstalk rejection. By using dicrete two or three transistor networks at each crosspoint good isolation (60 dB at 10 MHz) has been achieved [5]. An integrated circuit using a similar technique is reported to offer the same performance [6].

In developments related to satellite-switched time domain multiple access, electronic switches with bandwidths around 1 GHz have been developed [7]. These matrices, which use FETs, are intended to switch the signal on an IF carrier in the 1-10 GHz range, and use tuned circuit techniques to improve the isolation and aid in the signal distribution. They are therefore unsuited to baseband signals.

(b) Optical Techniques

As is now well-known, signals carried optically, for example in fibre optic cable, are usually very immune to crosstalk. Furthermore the frequency response of an optical network is entirely determined by the optical transmitters and receivers, and is essentially independent of impedance conditions along the signal paths. The fundamental reason for this independence is that even wideband modulation involves frequencies tiny by comparison with that of the light, so that the transmission properties are governed wholly by the optical properties of the transmission medium.

Considerable interest has arisen in using optical methods to switch wideband signals such as HDTV [8-9]. The method usually envisaged consists of directing a signal carrying beam of light to one of a number of detectors. Several methods to accomplish this have been proposed, but the most practical and most commonly studied uses directional coupler switches fabricated in waveguides in an electro-optic material such as $LiNbO_3$. There are two problems currently faced by developers of optical switch matrices. First, the optical switches presently available do not have high isolation, although in principle adequate isolation is possible if the optical waveguides are single mode and the polarization of the light is maintained. Second, the switches are two-state branching devices, and many switches are therefore required in tandem to construct a large array. The insertion losses of these switches is, however not insignificant, so that there is a limit on matrix size. Furthermore, the provision of one input signal to more than one output line is difficult because most optical switches do not operate well in an intermediate state which optical input power is branched out simultaneously to the two output waveguides.

(c) Hybrid Methods

The benefits of the high isolation in optical signal distribution networks can be obtained without the disadvantage of using optical switches by a method proposed at CRC in 1978 [10]. The concept is shown diagrammatically in Fig. 1. Electrical signals entering the switching matrix are converted into optical signals and launched into optical waveguide, as is also done with purely optical switching arrangements. However in this case, the waveguides contain passive branching elements that distribute the launched optical power to a number of photodetectors. There are no active elements in the optical distribution array, which can therefore be optimized for low-loss input and output coupling and transmisson, for example by the use of multimode, rather than single mode waveguides. Switching occurs in the detectors. These have two bias states, one rendering them sensible to the optical signal, and the other establishing an insensitive state. The outputs from the detectors are electrical signals which are combined in the direction orthogonal to the optical distribution lines into output ports, thus completing the matrix.

Since the optical signals do not cross-couple with each other, nor with the electrical output lines, the only possibilities for crosstalk are coupling between the electrical output lines, and leakage through the optoelectronic detectors acting as crosspoint switches. The output lines need not cross: indeed they can be isolated from each other to an arbitrary degree, since the only connections between them are by optical means. The leakage through the crosspoints has been measured for many optical detectors and has been found very low in many cases (50 - 90 dB up to 1 GHz).

Switching matrices using this hybrid principle have been studied in a number of laboratories [11,12,13], and have shown promising performance. Both PIN diode photodetectors and avalanche photodiodes have been employed as crosspoints, and switching isolation as high as 90 dB has been recorded at microwave frequencies for these devices.

The construction of a commercially successful optoelectronic switching matrix, however, has not been achieved for a number of reasons. The essential problem is that the fabrication of arrays of discrete detectors coupled to individually manufactured optical fibre power dividers is too complex. Some form of integration is necessary to make the hybrid technique practical. Another problem is the difficulty of performing the electrical summing of signals into the output ports. Photodiodes in most cases require both reverse bias to establish the 'on' state, and forward bias to establish the 'off' state [11]. As a result, d.c. blocking is required in the signal summation network. Certain kinds of avalanche photodiodes can be used without forward bias, but these generally are slow, require high reverse bias for the on-state and are of exotic construction not amenable to circuit integration.

3. PHOTOCONDUCTIVE BROADBAND SWITCHING

In the broadband switching project at CRC we have addressed these problems by selecting a different type of detector for use as the crosspoint element: the GaAs broadband photoconductor. A sketch of such a device is shown in Fig. 2. In photoconductors the incoming light generates electron-hole pairs that separate under an applied bias to yield an incremental photocurrent. When no bias is applied they recombine with high probability, yielding no response. Since off-state photoconductors are unbiassed, the electrical signal summation can be performed merely by connecting one terminal of each detector in common as shown in Fig. 3 which is a photomicrograph of some photoconductive detectors manufactured in our programme. A photoconductor can actually yield detection gain because the different transit times of the holes and electrons requires numerous charges to transit the device for every charge-pair generated. As detectors for optical communications, broadband photoconductors have recently shown promise [14]. Photoconductive switch arrays consist fundamentally of optical communication links, and the same promise pertains to them.

(a) Integration of Photoconductive Switch Arrays

Since the success of optoelectronic switching clearly rests on the possibility of integrating the optical and electronic components, we have performed extensive studies on the manufacture and performance of monolithic arrays of GaAs photoconductors. The devices shown in Fig. 3 form small integrated arrays; one of three simple photoconductors, the other of eight interdigitated photoconductors. In both arrays one terminal is common to all devices and is used to extract the signal, while the other is free on each device, and is used to apply the bias that establishes the on state for each detector. The simple photoconductors offer low noise performance, but are small (20 μ square) and correspondingly more difficult to illuminate. The interdigitated devices are larger (100 μ) but also have higher bias currents (up to 10 mA) with the associated noise.

Integrated switching matrices have been constructed by butt-coupling fibres to the monolithic detector arrays. In an initial experiment, a 2x2 matrix with 100 μ switch spacing was built, and found to have isolation in excess of 70 dB up to 130 MHz (15). Electrical crosscoupling in the output leads and circuit prevented operation at higher frequency. The switching performance of this array would support its use for any currently proposed analogue HDTV standard. The 2x2 array was very small, as shown in Fig. 4. The actual chip used carried enough photoconductors to make a 5x5 array with no increase in package size. The frequency response and crosstalk of this device are shown in Fig. 5.

At frequencies above 130 MHz the 2x2 array suffered from strong crosstalk due to coupling among the output leads and circuit. A key question is whether the high optical isolation of the optoelectronic matrix is unavoidably compromised in a monolithic array by the necessity of bringing out many electrical lines in close proximity on the chip itself. Electrical crosstalk among output lines that occurs on the jig used to mount the monolithic chip is controllable by using careful techniques. The crosstalk due to direct coupling on the chip is more difficult to alter. It is important therefore to determine the crosstalk properties of the chip alone.

Recently we have tested carefully mounted monolithic arrays, in which crosstalk on the microstripline mount is measured to be (at least 10 dB) lower than on the chip itself. By including on the chip a ground plane that isolates each detector, we have demonstrated that integrated arrays of optoelectronic switches can have overall crosstalk less than -50 dB over the entire band 0 Hz to 1.3 GHz as shown in Fig. 6. This result confirms the feasibility of very dense integrated switching matrices capable of circuit switching even FM or digital HDTV signals.

This result is particularly significant to the comparison of photoconductive with optical switch matrices. It confirms that in practice as well as in principle, optoelectronic switches can offer the same performance as purely optical switches. In addition, it should be noted that the photoconductive switch array is significantly easier to manufacture. There are no constraints on the size and shape of the photodetector crosspoint analogous to the constraints imposed on monomode and multimode optical switches by coupling and crossing angle considerations. Optical switches usually involve Y-junctions in optical waveguides that have branching angles of the order of 1°. They are therefore long and narrow. Since many must be connected in tandem, the physical layout of a purely optical switch matrix is problematic. As noted earlier the optoelectronic matrix offers a time "broadcast mode" state as a consequence of its operating principle. Such a state is difficult to achieve with optical switching.

A major area for development in optoelectronic switching is the integrated delivery of optical signals to detector arrays. In general two approaches are possible: a monolithically integrated one, in which the optical distribution waveguides are made on the same semiconductor substrate as the photoconductors themselves, and a hybrid approach, in which the distribution waveguides are made separately on another substrate material, and then mated with the detector array. The latter method has the advantage that the processes and materials used to make the optical distribution waveguide can be optimised for that purpose, independently of the processes and materials used to make the detector array. Another important advantage of the hybrid method arises because optical waveguides cannot be bent sharply without causing the light to leak out. The routing of optical signals thus requires a fair amount of space and the waveguides must be made in an inexpensive low loss material. Glass as a material is suitably inexpensive, and very high quality waveguides can easily be fabricated in it. We have concentrated on the distribution of light by means of diffused waveguide in glass substrates, which also act as carriers for the monolithic gallium arsenide detector arrays.

(b) Digital Switching with Photoconductor Arrays

Historically, optoelectronic switching has usually been associated with wideband analogue signals. There is now a possibility that wideband signals such as HDTV may be carried in digital form. Even compressed, such signals will run at very high bit rates - 300 Mb/s to 1 Gb/s. We have recently considered the design of an optoelectronic matrix to handle high rate digital data, and found that very large matrix sizes are possible. In combination with the very small physical size of the optoelectronic crosspoint arrays themselves, this would indicate that a very powerful switch matrix might be constructed for high rate digital data using this technique.

One initial concern in a digital crosspoint is the speed with which it can be switched off or on. Ideally this should be of the order of the bit period of the signal. We have measured these switching times [16] and found both to be of the order of 1 ns. The optoelectronic crosspoints are therefore fast enough to reconfigure the matrix at GHz rates.

The size of an optoelectronic switch matrix is chiefly determined by the noise properties of the crosspoint photodetectors. Each must be delivered sufficient optical signal power to receive the signal with the required SNR. The number of output lines in the fundamental matrix unit is determined by the optical source power, detector noise power and required bit error rate. The photoconductors we have made have noise equivalent power of the order of 10^{-11} W/$\sqrt{}$Hz. Semiconductor lasers capable of coupling 50 mW into an optical fibre are now commercially available. We have calculated that 100 Mb/s signal could be delivered with a BER of 10^{-9} from a single laser input to as many as 2500 photoconductors. (This calculation includes a 3 dB margin.) A convenient optoelectronic switch unit might therefore have more than 1000 output lines. The number of inputs would be limited only by the very low crosstalk level through the switches, and would also be of the order of 1000.

We have considered in some detail the construction of a 100x1000 matrix for 100 Mb/s [17]. The basic layout is shown in Fig. 7. Many semiconductor chips are bonded to optical glass substrates which deliver the signals to them via an integrated optical waveguide power division network, and also carry electrical connections. The laser signal sources are situated in a separate bank, and feed the integrated optical substrates by means of an optical fibre power pre-division network. The entire 100x1000 crosspoint array would consist of 20 optical substrates and the laser bank with its fibre power dividers, plus the power supply. In optoelectronic switching, off-state crosspoints consume no power, so that almost all power is used to drive the laser sources and the output line amplifiers. Approximately 300 W would be used by the 100x1000 line array.

The apparatus described above has a full matrix non-blocking configuration, in spite of the large number of lines it serves. It has been recognized [1] that switched HDTV distribution, in common with other switched TV distribution, requires a very low blocking probability because of the long circuit holding times expected of TV viewers. The use of sub-Clos arrangements of smaller matrices is not necessary with optoelectronic switching because there is no penalty on increasing the matrix size up to the limit where all the optical power is used up. All the required power has already been dissipated in optical sources and output amplifiers. Fully populating a sparse optoelectronic matrix thus costs nothing extra in power and very little in material. The chief cost would be in additional control circuitry, which would be required in any case.

4. CONCLUSION

HDTV will require switching performance that strains current techniques, and may also require switching on a far greater scale than current television does, if switched wideband networks are required for delivery. We have experimentally demonstrated that photoconductive optoelectronic switch arrays have wideband switching performance easily capable of accommodating HDTV signals, in either analogue or digital forms, and are also very suitable for large scale, nonblocking matrices such as are needed for television distribution. Integration of both the optical and electronic elements of a photoconductive matrix are necessary to keep costs low; such integration has been demonstrated to be compatible with the wideband performance of the switches. While considerable development, particularly in associated electronics would be required to achieve a commercially useful optoelectronic matrix for HDTV, the practicality of the idea and its potential advantages over competing technologies seem to be established.

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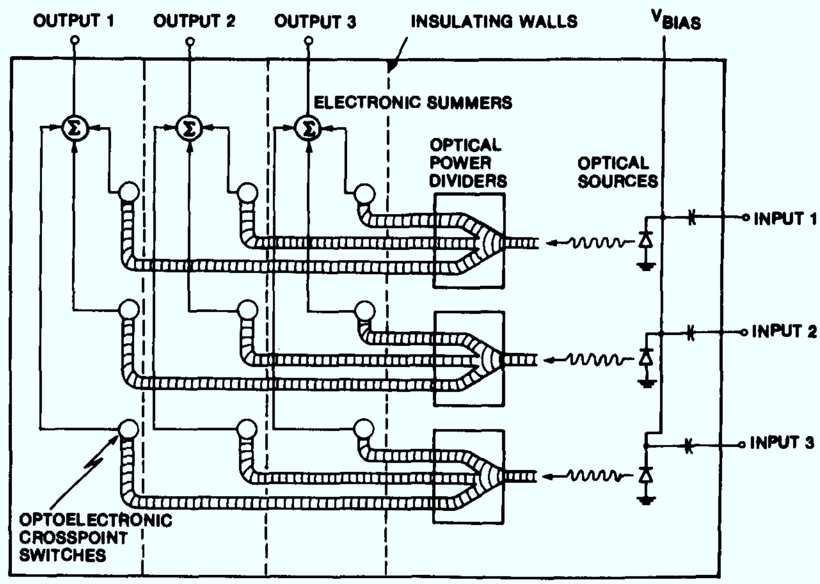

Fig. 1. Schematic diagram of an optoelectronic switch matrix. Input signals are converted to light and distributed in that form to the crosspoints. Output electrical signals are generated in the on-state crosspoint photodetectors and summed into the output lines.

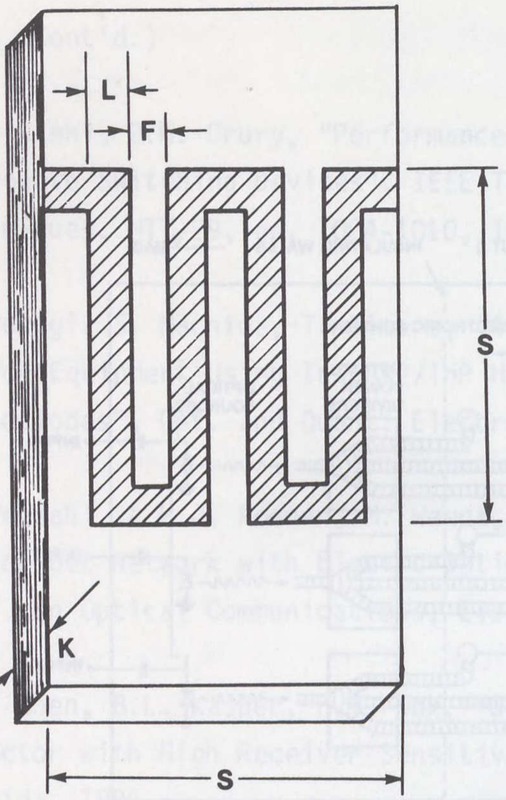

Fig. 2. Schematic diagram of GaAs broadband photoconductor. The sensitive area is a square of side S which consists of a mesa of lightly doped GaAs of thickness K on a high resistivity substrate. The interdigitated contact pattern defines a channel of length L by means of fingers of width F. In some cases the fingers are not used. The device is simple and inexpensive to make and is highly compatible with GaAs integrated circuit techniques.

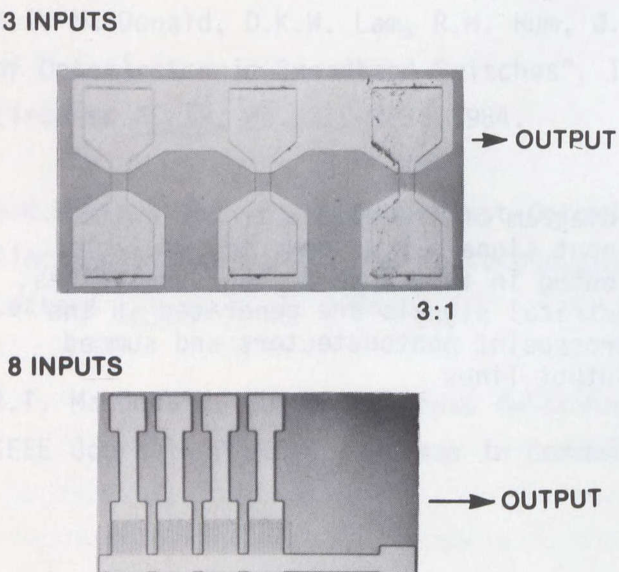

Fig. 3. GaAs integrated photoconductor switching arrays. The upper photograph shows a 3x1 array of simple photoconductors. The lower shows an 8x1 array of interdigitated devices. The upper detectors are 20 microns square, the lower are 100 microns square.

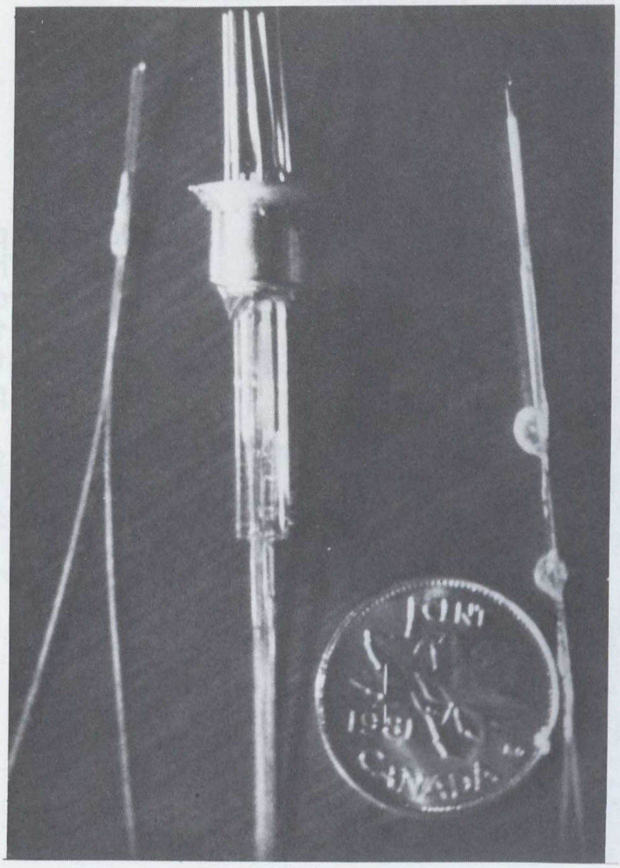

Fig. 4. Experimental packaged 2x2 array with optical fibre signal distribution.

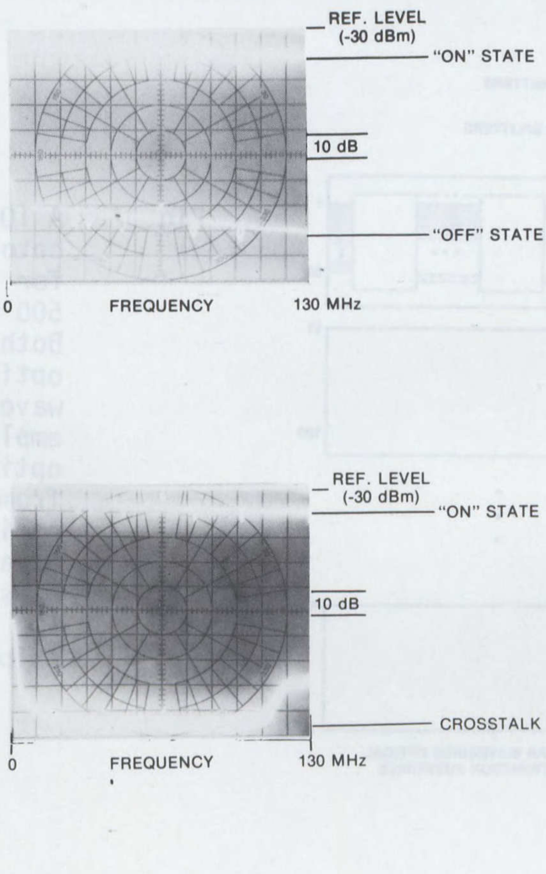

Fig. 5. Crosstalk measurements over the frequency range 0-130 MHz for the experimental 2x2 array - typical case. The output crosstalk is about 80 dB below the signal, and the switch crosstalk between 60 and 70 dB below the on-state response. The package actually contains a 5x5 crosspoint array of which only a submatrix is connected.

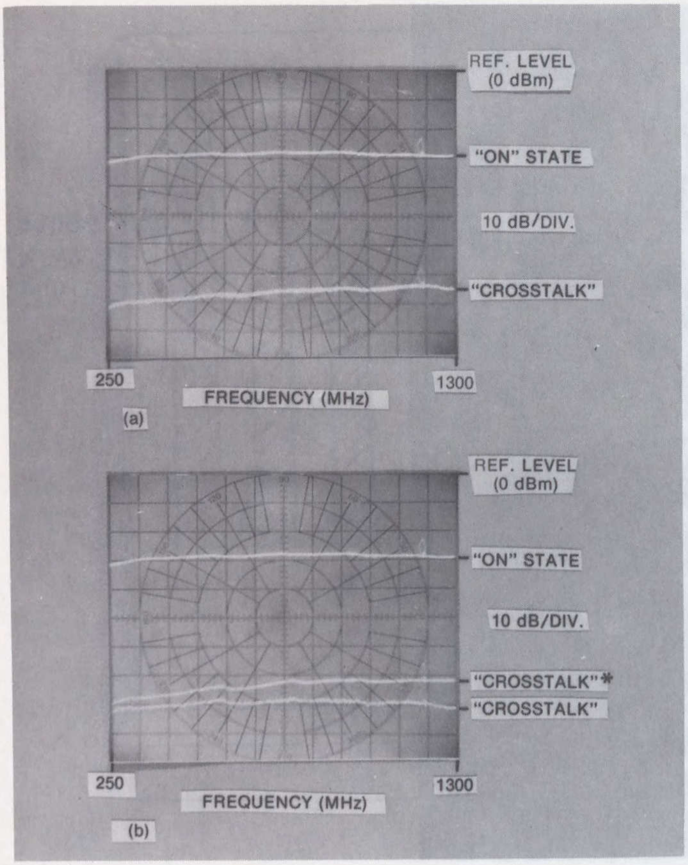

Fig. 6. Crosstalk of a microstripline-mounted array. The level marked crosstalk* demonstrates the effects of removing an on-chip isolation element. Crosspoint spacing is
(a) 100 μm
(b) 300 μm.

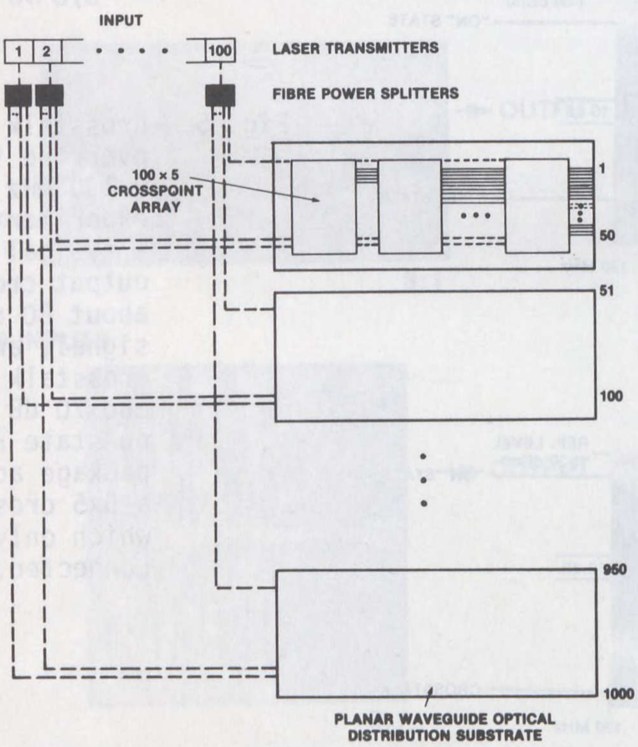

Fig. 7. A 100x1000 optoelectronic matrix for 100 Mb/s and 500 Mb/s signals. Both fibre and optical planar waveguides are employed to achieve optical distribution from a bank of semiconductor lasers to a bank of optical substrates that carry the semiconductor chips.

HIGH-DEFINITION TELEVISION: TOWARDS A WORLDWIDE STANDARD

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International Technical Affairs
NHK

4.1

ABSTRACT

An Interim Working Party (IWP) on HDTV was established in 1983 under the Study Group 11 of CCIR. At the coming CCIR Final Meeting in October 1985, a draft Recommendation of HDTV studio standards will most probably be produced. Activities of the IWP and the future work of the working party will be described.

TÉLÉVISION HAUTE DÉFINITION VERS UNE NORME INTERNATIONALE

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Laboratoire de la NHK

RÉSUMÉ

Un groupe de travail intérimaire sur le système de TVHD a été établi en 1983 sous l'égie de la Commission d'étude 11 du CCIR. A la réunion finale du CCIR, prévue pour octobre 1985, un projet de recommandation portant sur les normes de studio HDTV sera probablement présenté. Les activités du groupe de travail intérimaire et ses travaux futurs seront décrits.

HIGH-DEFINITION TELEVISION: TOWARDS A WORLDWIDE STANDARD

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Director, International
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4.1

1. Introduction

Research work on the HDTV system has been done for about 20 years in various parts of the world.

An Interim Working Party on HDTV was established in 1983 under the Study Group 11 of CCIR, and since then especially there has been keen interest and the research has progressed very rapidly. At the coming CCIR Final Meeting in October 1985, a draft Recommendation of HDTV studio standards will most probably be produced.

This paper gives a short history of the study of the HDTV system at the CCIR, and describes activities of the IWP and then discusses prospects for the future work of the working party.

2. Contributions to the CCIR concerning HDTV

(1) 1969 - 1974 Study Period

To the Interim Meeting of 1972, Japan contributed a draft Study Programme on the HDTV system, under the umbrella of Question 1/11 COLOUR TELEVISION STANDARDS. After discussions at the meeting, it was proposed to establish a new Question about the HDTV system, because Question 1/11 was concerned with colour television systems of existing 525/60 or 625/50 standards. Then, in 1974 new Questions 27/11, 12/CMTT, and a new Study Programme 12A/CMTT, HIGH-DEFINITION TELEVISION were established at the XIIIth Plenary Assembly in Geneva.

During this study period an information paper was contributed from Japan to the 1974 Final Meeting, though there were no contributions from other countries.

(2) 1974 - 1978 Study Period

To the 1976 Interim Meeting and the 1977 Final Meeting, contributions describing technical status of HDTV techniques were submitted from Japan, and in 1978 at the XIVth Plenary Assembly in Kyoto, a new Report 801 THE PRESENT STATE OF HIGH-DEFINITION TELEVISION was established.

The Q12/CMTT and SP12A/CMTT were combined into a single Question and Question 22/CMTT was produced, at this time.

(3) 1978 - 1982 Study Period

In 1980, Japan reported a paper describing the state of HDTV development to the Interim Meeting.

To the 1981 Final Meeting, Japan contributed a report concerned with HDTV system parameters for experimental purposes. To the same Meeting, the USSR submitted a paper about how to choose HDTV scanning lines. On the basis of these contributions Report 801 was revised and Report 801-1 was established at 1982 XVth Plenary Assembly in Geneva.

(4) 1982 - 1986 Study Period

Before and after the 1982 Plenary Assembly of the CCIR, HDTV equipment was brought to the USA and Europe by NHK to be demonstrated to the SMPTE, EBU and other organizations. Stimulated by those demonstrations, to the 1983 CCIR Interim Meeting, fifteen technical papers were contributed from Canada, Japan, the USA and EBU as listed in Table 1.

Based on these contributions, the following were produced at the Interim Meeting:

1) Establishment of an IWP 11/6 (HDTV)
   (Decision 58)

2) Revision of Report 801-1
   THE PRESENT STATE OF HIGH-DEFINITION TELEVISION

3) Revision of Question 27/11
   HIGH-DEFINITION TELEVISION

4) Establishment of a draft Study Programme AK/11
   THE COMPATIBILITY OF THE HDTV STANDARD WITH EXISTING STANDARDS AND BROADCAST CHANNEL ASSIGNMENTS

5) Establishment of a draft Study Programme AL/11
   EFFECT OF DISPALY TECHNOLOGY ON THE HDTV STANDARD

6) Establishment of a draft Study Programme 2M/10/11
   SATELLITE BROADCASTING OF HIGH-DEFINITION TELEVISION (HDTV)

3. Establishment of IWP 11/6 (HDTV)

On the basis of the US proposal, the DECISION 58 to establish an Interim Working Party for HDTV technical standards was approved at the SG11 of the Interim Meeting on 28 September 1984, and a terms of reference of the IWP was provided as below.

Table 1 Contributions on HDTV to CCIR
Interim Meeting 1983

Submitted by	Input Documents
Canada	Satellite Broadcasting of High-Definition Television
Japan	Present State of the Development of High-Definition Television
"	Transmission Systems and Paramenters for High-Definition Television by Broadcasting Satellite
"	A System for Bandwidth Reduction of High-Definistion Television using Sub-Sampling with Motion Compensation
USA	The Present State of High-Definition Television
"	Draft New Study Programme; Parameters for High-Definition Signals in Television Studio
"	High-Definition Television Broadcast Satellite Service in Region 2
"	Draft New Study Programme; Satellite Broadcasting of High-Definition Television (HDTV)
"	Establishment of an Interim Working Party on High-Definition Television
EBU	Draft New Study Programme; The Relationship of the HDTV Standard with Existing Standards and Broadcast Channel Assignments
"	Draft New Study Programme; Effect of Display Technology on the HDTV Standard
"	Proposed Modification to Q. 27/11; High-Definition Television
"	Draft Recommendation; Parameters for a High-Definition Standard for Television Studio
"	EBU Studies in High-Definition Television
"	Draft New Report; High-Definition Television by Satellite

(1) to encourage Administrations to participate in a coordinated way in the study of a high-definition television standard for the studio for international programme exchange and for broadcasting;

(2) to prepare within the present study period, a draft Recommendation for a single world-wide high-definition television standard for the studio and for international programme exchange, to be submitted to Study Group 11;

(3) subsequently to prepare a draft Recommendation on the processing of the HDTV studio signal to adapt it, as many be required, to the specific constraints of transmission, distribution and broadcasting, as these constraints become more clearly defined;

(4) to prepare regularly updated draft Reports on the progress of such study.

According to the second paragraph of the terms of reference, the IWP is obliged to prepare a draft Recommendation for a single world-wide high-definition television standard for the studio and for international programme exchange, to be submitted to the Study Group 11, within the present study period. According to the third paragraph of the mandate, the IWP has further responsibility to prepare a draft Recommendation on the processing of the HDTV studio signal to adapt it to the specific constraints of transmission, distribution and broadcasting, as these constraints become more clearly defined. Those terms mean that the IWP should prepare a draft Recommendation for the studio and for international programme exchange by the time of the CCIR Final Meeting in October 1985, and as for a draft Recommendation on transmission, distribution and broadcasting, it should continue its activities after the XVIth Plenary Assembly in 1986.

As far as the chairmanship and vice-chairmanships of the IWP 11/6 are concerned, the following gentlemen were elected.

Chairman: Y. TADOKORO (JAPAN)
Japan Broadcasting Corporation (NHK)
2-2-1 Jinnan
Shibuya-Ku
Tokyo 150, Japan

Vice-Chairmen: R.GREEN (United States of America)
ATSC
1771 N Street, N.W.
Washington, D.C. 20036

and

W.HABERMANN (Germany (Federal Republic of))
Institut für Rundfunktechnik GMBH
Floriansmühlstrasse 60
8000 München 45

In the first stage, the following administrations and organizations participated in the work of the IWP as regular members.

Germany (Federal Republic of)
Australia
Canada
United States of America
France
India
Italy
Japan
The Netherlands
United Kingdom
U.S.S.R.
EBU
NANBA
OIRT

But later, China, Egypt, Sweden, Yugoslavia and ABu joined in the work of the IWP.

4. Activities of IWP 11/6

(1) The first meeting

The first meeting of the IWP was held on 28 September 1984 at the CICG in Geneva with the attendance of 11 members.

Some delegates said that the IWP should have technical demonstrations before making draft specifications. Some other delegates considered it necessary to exchange views among members by correspondence as well as in meetings.

On the basis of those comments, the three following occasions were suggested for demonstrations and discussions:

1984	IBC	Brighton
1985	ITS	Montreux
1985	EXPO '85	Tokyo

It was pointed out by a delegate that the choice of the field-rate would be a most critical question to be answered by the IWP.

The Canadian, US, and EBU delegates introduced activities of the SMPTE, the ATSC and EBU V1/HDTV group, respectively, and said that they would be able to make some contributions to the IWP with the results of activities of those organizations.

(2) The second meeting

In the first part of 1984, a number of specialists' meetings on HDTV were held in various parts of the world. At the ATSC in the USA, the EBU V1/HDTV in Europe and an Advisory Council meeting in Japan, various factors of the HDTV studio standards were discussed. The most difficult and hottest debates were concentrated on the question of a choice of the field rate.

In Europe, experiments were done on field rates of 50, 60, 75, 80, 90, and 100 from the point of view of conversion from these figures to 50 field/sec, because they wanted to convert HDTV signals to the present PAL or SECAM ones which use 50 field/sec, in order to see HDTV pictures on existing receivers. A paper, was produced, "EBU Comments on the HDTV production standard" in which 50, 60 and 80 field rates were written in parallel, and among them 80 field/sec was asterisked, because the 80 field/sec system could be convertable to the 60 field/sec and the 50 field/sec systems with equal degradation of picture quatity to both systems.

In Japan, NHK had had established HDTV studio standards shown in Table 2, based on psychophysical experiments for many years, so Japan proposed these figures to the IWP to be adopted as the draft Recommendation of the HDTV system.

Table 2 Provisional HDTV Studio standards by NHK

Number of scanning lines	1125
Aspect ratio	5:3
Interlace ratio	2:1
Field frequency	60 Hz

In the USA, the field rate was also discussed comparing 60 and 59.94 fields/s, 60 field/sec was preferred in the interest of a worldwide standard.

However, the US administration proposed the aspect ratio to be 5.33:3 because film engineers wanted to have some stretched pictures in a horizontal direction.

With these world-wide discussions as a background, the second meeting of the the IWP was held at the BBC's Research Department, Kingswood Warren, from 13 until 15 September 1984, where about 30 people gathered from member countries and organizations.

At the meeting, first, four demonstrations about HDTV field rate studies were presented by the BBC

The first was designed to show the difference in subjective quality, associated with increased spatial resolution, between and HDTV display (1249 lines was used as an example), a 625-line standard display, and a 625-line up-converted display by use of field storage in the receiver.

The second demonstration concerned the difference in subjective quality, associated with temporal resolution, when field rates of 50, 60 and 80 Hz were used.

The third demonstration concerned bandwidth compression techniques for HDTV signals. An overall 5:1 compression was achieved in the experimental system by field-discarding, some reduction of horizontal resolution, and quincunx sampling.

The fourth demonstration concerned standards conversion from 80-50 Hz and 60-50 Hz, with reference to the subjective quality of critical moving pictures.

There was a discussion on the demonstrations during which the following points emerged:

- The demonstrations showed that for critical moving material, there is a progressive increase in subjective quality (i.e. picture sharpness) in moving from 60 Hz to 80 Hz and from 50 Hz to 80 Hz. This can largely be attributed to the reduction in camera integration time.

- The demonstrations showed that on critical moving pictures, there was certainly an improvement in the quality of the resulting 50 Hz standard-converted pictures when the source field rate is increased from 60 Hz to 80 Hz, for the kind of standards conversion system used. However, before an overall judgment is made on potential conversion quality, it will be necessary to evaluate the improvement which could be obtained from motion adaptive conversion systems.

Twenty-three papers on HDTV systems were contributed by members and there was much discussion about them. The field rate in particular was a most central item of debate. After the discussion, the meeting agreed on a common view of the field rate as follows.

"From the contributions received, it is possible to conclude that a 60 Hz 2:1 interlace system will be actively considered as a candidate for a worldwide HDTV studio standard, provided certain technical aspects can be shown to be satisfactory. By far the major aspect, which could be seen as globally about 75-80% of the issue, is satisfactory conversion to systems which use a 625-line 50 Hz 2:1 standard, e.g. PAL, SECAM, C-MAC/packet. The remaining issues include motion portrayal."

The meeting produced a paper of a draft Recommendation, in which, the field rate was expressed as "60 Hz or 80 Hz," and the aspect ratio was written as "5:3 or 5.33:3."

Then a table of contents of the final report of the IWP was produced after discussion. Some members were assigned to make draft taxts for relevant sections.

(3) The third meeting

The third meeting of the IWP11/6 was held from 9 to 11 January 1985 at NHK Broadcasting Centre in Tokyo.

The purpose of the IWP11/6 gathering in Tokyo was mainly to have a demonstration of a converter between the 1125/60, 2:1 interlace, 5:3 aspect ratio system and the 625/50, 2:1 interlace, 4:3 aspect ratio sytem, which had been developed by NHK quite recently.

Some test material pictures through the converter were demonstrated to the participants, comparing them with pictures of a camera output of the 625/50 system and a conventional 525/60 - 625/50 standards converter. (The original 1125/60 material signals had been converted into the 525/60 system, then converted to the 625/50 system.)

After the first look at the demonstrations of the converted pictures, there were some questions and comments from members. Then additional demonstrations were offered by NHK on the second day of the meeting, followed by technical discussions. As a conclusion, the following notes on the discussions of the converter were issued, and approved with unanimous agreement by members present.

"There was unanimous agreement that the NHK-developed 1125/60 - 625/50 standards converter based on motion adaptive techniques is a technical accomplishment of the highest order and that the output quality is significantly better than the most sophisticated currently available converter based on fixed interpolation.

A number of delegates wondered whether the residual impairments were to be ascribed to contingent instrumental imperfections, or were intrinsic in the algorithm adopted, and in the latter case, whether they were related to the field rate conversion or to the line rate conversion. But it was pointed out by NHK experts that most of the residual impairments could be eliminated by the appropriate change of circuit design.

Several delegates wished to complete formal subjective tests before they could confirm their initial positive impression; the chairman requested that such tests should be completed in the immediate future, and reported promptly to the IWP, in order that the IWP may come to a final conclusion no later than at its next meeting.

The merit of a shingle worldwide HDTV studio standard is firmly recognized by all members of the IWP, and the possibility of adopting the 60 Hz 2:1 interlace system has been increased by the development of the NHK developed converter."

After a lengthy discussion, a revised version of the draft recommendation for the HDTV studio standard was produced. As far as the fundamental parameters are concerned, the following figures in Table 3 were described with a note and 3 remarks. This note reflected an idea in the USA, where a progressive scanning system had been considered.

Table 3 Fundamental parameters of HDTV studio standards to which IWP11/6 agreed in the 3rd meeting

picture structures

a) No. of horizontal lines	1125
b) No. of active horizontal lines	1035
c) Field rate (Hz)	60.00 (1)
d) Aspect ratio	5:3 (2)
e) Interlace system	2:1
f) Samples per active line	1800 (900) (3)

Note: A 1:1 progressive scanning system is under consideration by one national administration.

Remarks:

(1) 80 fields/s will be considered if standards conversion from 1125/60 to 625/50 is assessed to produce unacceptable (as expressed in Draft Report-801 Annex 1) picture artifacts and other factors such as mains frequency, transfer to and from film, intrinsic, quality of movement portrayal, etc., present insuperable problems.

(2) As aspect ratio of 5.33:3 has also been proposed, further study is required.

(3) This is based on the need for compatibility with Rec. 601

(4) Future work

The IWP is planning to have its fourth meeting in the latter part of May, 1985 in Geneva.

At this moment, there are still some different views about these parameters which should be resolved at the coming IWP meeting, in order to establish an HDTV world-wide studio standard at the Final meeting of CCIR in October 1985.

It was quite an occasion for the CCIR to have a single world-wide Digital Television Standard "Recommendation 601" in 1982, and this time we hope to have a single world-wide HDTV studio standard approved unanimously.

However the IWP is given a further mandate to consider in making a draft Recommendation of transmission or broadcasting, and this should be done during the next study period of CCIR after the Plenary Assembly of 1986.

5. Conclusions

Since the 1972 Interim meeting of CCIR, much research work has been done world-wide and the speed of work has accelerated after the establishment of the IWP11/6 in the CCIR.

If we could get a unanimous worldwide studio standard of HDTV, programme exchange between nations would become very easy, and the HDTV techniques could also be applied to the film picture or printing industries. Therefore, it would be a great contribution not only to the engineering field but also to human culture to have a common standard for HDTV. In this sense, every effort should be made in producing a single world-wide studio standard for High-Definiton Television System.

HIGH DEFINITION PRODUCTION STANDARDS
How broad their application?

4.2

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ABSTRACT

The Broadcasting Unions of the world have called upon their members to work toward the achievement of a single worldwide high definition television production standard to achieve lower equipment costs and to ease exchange of programs internationally. The motion picture industry has been studying the possible application of HDTV technology to the production and post-production of feature films for theatrical release. Although historically the television and motion picture industries have been separate entities, the distinctions between their objectives and indeed between the participants themselves is becoming more cloudy.

The potential for achieving through the world standardizing bodies a common worldwide standard for both applications will be explored and the thorny issues requiring compromises on both sides will be discussed.

NORMES RELATIVES À LA PRODUCTION HAUTE DÉFINITION
Quelle est l'étendue de leur champ d'application?

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4.2

RÉSUMÉ

Les unions de radiodiffusion du monde entier ont enjoint à leurs membres de travailler à l'établissement d'une norme mondiale commune de production de télévision à haute définition (TVHD), afin de réduire le coût de l'équipement et de faciliter l'échange international des émissions. L'industrie cinématographique étudie l'applicaton possible de la technique de la TVHD à la production et à la postproduction des longs métrages destinés aux salles de projection commerciales. Par le passé, la télévision et l'industrie du film étaient deux entités bien distinctes. Toutefois, les divergences entre leurs objectifs et, à vrai dire, entre les participants mêmes, tendent de plus en plus à s'estomper.

Les possibilités d'en arriver, par le truchement des organismes de normalisation internationaux, à une norme mondiale commune à ces deux secteurs seront examinées et les questions épineuses au sujet desquelles il faudra en arriver à un compromis seront discutées.

HEROICS IN POLICY ADVISING : THE AUSTRALIAN EXPERIENCE IN PLANNING BROADCASTING SERVICES BY NATIONAL SATELLITES

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ABSTRACT

A major emphasis in the decision of the Australian Government to establish a national communications satellite system was the removal of disadvantages in communications services of people in remoter areas of Australia.

The decision was founded on the capability of a satellite system of relatively modest size and cost to deliver television, radio, and telephony services to people who lacked some or all of the above services, or who were receiving sub-standard services. Successive Australian Governments have stressed the capacity of the satellite system to deliver these services to remote Australia.

The planning for the delivery of television and radio services to outback communities and homes, was that each of the higher powered transponders on the Australian satellites would deliver one television and at least two radio services. These radio services would be provided using SCPC signals in the same transponder as the PAL television. Tests over a period of years gave confidence that the PAL/SCPC approach was technically feasible and would provide an acceptable grade of service. Within twelve months of the planned introduction date of satellite services, ongoing investigation revealed that the successful introduction of PAL/SCPC was unlikely due to a combination of operational, technical and economic factors. The planners and policy advisers were then forced to either look at possible alternative technical solutions or to accept that the broadcasting services to remote areas would be restricted to one television service only.

VISÉES AUDACIEUSES:

L'EXPÉRIENCE DE L'AUSTRALIE DANS LA PLANIFICATION DE SERVICES DE RADIODIFFUSION PAR SATELLITES DOMESTIQUES

4.3

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RÉSUMÉ

La décision du gouvernement de l'Australie d'instaurer un système national de télécommunications par satellite visait principalement à améliorer le sort de la population des régions reculées de l'Australie en matière de communications.

Elle était motivée par la capacité d'un système à satellites de dimensions et de prix relativement modestes de distribuer des services de télévision, de radio et de téléphonie aux Australiens qui sont privés d'une partie ou de tous ces services ou qui reçoivent des services de qualité inférieure à la norme. L'un après l'autre, les gouvernements australiens ont souligné la capacité d'un système à satellites de fournir ces services jusqu'aux confins de l'Australie.

Selon le plan de distribution des services de radio et de télévision aux localités et aux foyers situés dans les terres intérieures, chacun des répéteurs de puissance plus élevée des satellites australiens transmettrait un signal de télévision et au moins deux signaux de radio. Ces services de radio emprunteraient des signaux à une seule voie par porteuse qui passeraient par le même répéteur que le signal de télévision PAL. Des essais menés au cours des années donnaient l'assurance que la méthode était réalisable sur le plan technique et qu'elle fournirait un service de qualité acceptable. Moins de douze mois avant la date prévue d'introduction des services par satellite, les recherches en cours ont montré qu'il était peu probable que la mise en oeuvre de la transmission de signaux PAL et de signaux à une seule voie par porteuse par un même répéteur réussisse à cause d'une combinaison de facteurs opérationnels, techniques et économiques. Planificateurs et conseillers en politique se sont alors vue contraints d'envisager des solutions techniques de rechange ou d'accepter que les services de radiodiffusion dans les régions reculées soient limités à un seul service de télévision.

"HDTV: WHO PAYS FOR THE DREAM?"

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4.4

ABSTRACT

"HDTV" is likely to be introduced first through digital receivers and second via new bandwidth compressed formats of television distribution and display (E-MAC, MUSE, etc.). Interim stages will consist of tape or disc to home player/display devices and specialized services to mini-theatres, hotels, and bars. By the late 1990s, HDTV could become a mass market home entertainment product and service.

Technological development paths toward HDTV can be identified, but more difficult is to determine the combination of investment and consumer interest that will lead to the world-wide introduction of HDTV. Past consumer behaviour in receiver and analogous product purchases help project likely demand given the appropriate price/performance characteristics of HDTV receiver/display products and above all the programming available.

While the origin of the critical mass of investment for Japan and Western Europe is relatively clear, who will take the initiative in North America is not easy to predict. The likely driving forces are the major programming producers seeking higher margins and the incremental investment of, first, direct-to-home and, second, satellite-to-cable delivery systems.

La TVHD : Qui paie la note du rêve?

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Selon toute vraisemblance, la télévision à haute définition (TVHD) sera implantée initialement au moyen des récepteurs numériques, mais elle empruntera ensuite de nouveaux formats de distribution et de présentation de télévision par compression de la largeur de bande (E-MAC, MUSE, etc.). Les étapes intermédiaires comporteront l'exploitation sur bandes ou disques pour des dispositifs de reproduction et d'affichage domestiques et la prestation de services spécialisés destinés aux petites salles de cinéma, aux hôtels et aux bars. Vers la fin des années 90, la TVHD pourrait bien devenir un marché de masse comme produit et service de divertissement à domicile.

Il est possible d'entrevoir les avenues de développement technique de la TVHD. Par contre, il est plus difficile d'identifier l'heureuse combinaison prix/intérêt du consommateur qui conduira à l'essor mondial de cette technique. Le comportement antérieur des consommateurs face à l'acquisition de récepteurs et de produits semblables aide à extrapoler la demande probable, compte tenu d'un rapport qualité/prix approprié pour les récepteurs et les supports de présentation de TVHD et, surtout, du contenu offert.

Si l'on se doute d'où viendra la masse critique des investissements au Japon et en Europe Occidentale, il n'est pas aussi facile qui relèvera le défi en Amérique du Nord. Les forces agissantes les plus probables seront les grands producteurs d'émissions, qui cherchent à accroître leur marge de bénéfices, et l'investissement marginal connexe dans les systèmes de diffusion directe à domicile, puis dans les systèmes de transmission satellite-câble.