Industry Canada / Industrie Canada

PROCEEDINGS

DIGITAL RADIO

A Canadian Manufacturing Industry Opportunity

Digital Radio Broadcasting Seminar

27th October 1995
Ottawa Congress Centre

ACTES

LA RADIO NUMÉRIQUE

Une opportunité pour l'industrie manufacturière canadienne

Séminaire sur la radio numérique

Le 27 octobre 1995
Centre des congrès d'Ottawa

CRC Communications Research Centre / Centre de recherches sur les communications

Introduction

On Friday, 27 October 1995, the Communications Research Centre (CRC) and Industry held a seminar which dealt with the opportunities that Digital Radio can bring to the Canadian manufacturing industry. It was held at the Ottawa Congress Centre, just prior to the CAB fall Convention in Ottawa. A group of well recognized speakers in the field of Digital Radio from the CAB, CBC, Industry Canada and the CRC gave a set of presentations covering key topics in the field of Digital Radio Broadcasting (DRB).

This seminar addressed specifically to the Canadian manufacturing industry and the broadcasters who wish to play a role in the development and implementation of this new exciting broadcast medium.

The intent of the seminar was:

- to bring the Canadian manufacturing industry up-to-date with the latest developments leading to the implementation of Digital Radio in the world, and in particular in Canada;
- to indicate the key technical challenges brought about by this new DRB technology as it relates to RF transmission hardware;
- to attempt to indicate the hardware expected to be needed for the provision of the new data services that Digital Radio will carry; and
- to help to identify some niche areas where the Canadian manufacturing industry could have an early start and build a competitive edge.

Along with the seminar, there was a set of exhibits presented to the participants. More details on these exhibits are contained in the last section of these Proceedings.

I hope that these proceedings of the papers presented at the seminar prove to be helpful and give a useful summary of the seminar.

Gérald Chouinard
Seminar organizer
June 1996

Vendredi, le 27 octobre 1995, le Centre de recherches sur les communications (CRC) et Industrie Canada ont tenu un séminaire sur les opportunités que l'implantation de la radionumérique apportera à l'industrie manufacturière canadienne. Ce séminaire s'est tenu au Centre des congrès de Ottawa, le jour précédant la convention d'automne de l'ACR. Un groupe d'experts reconnus de l'ACR, de la SRC, d'Industrie Canada et du CRC ont présenté des communications sur des sujets clef dans le domaine de la radio numérique.

Ce séminaire s'adressait spécifiquement à l'industrie manufacturière canadienne et aux radiodiffuseurs qui veulent jouer un rôle dans le développement et l'implantation de ce nouveau et stimulant médium de radiodiffusion.

Le but de ce séminaire était:

- de faire connaître à l'industrie manufacturière les derniers développements pouvant conduire à l'implantation de la radio numérique dans le monde, et plus particulièrement au Canada;
- de mettre en lumière les principaux défis technologiques amenés par la radio numérique en ce qui a trait à l'équipement de transmission radiofréquence;
- de fournir de l'information concernant l'équipement éventuellement requis pour produire et assembler les nouveaux services numériques qui pourront être distribués par la radio numérique; et
- de tenter d'identifier les créneaux du marché dans lesquels l'industrie manufacturière canadienne pourra se distinguer, s'assurer d'une avance technologique et d'une marge concurrentielle confortable.

A l'occasion du séminaire, des expositions d'équipement ont été présenté aux participants. Des détails supplémentaires sur ces expositions peuvent être trouvés en dernière section de ces Actes.

J'ose espérer que la lecture de ces Actes que donnent un compte rendu des présentations faites lors du séminaire vous seront utile.

Gérald Chouinard
Organisateur du séminaire
Juin 1996

Proceedings of the DRB Seminar

"DIGITAL RADIO: A Canadian Manufacturing Industry Opportunity"

27 October 1995, Ottawa Congress Centre

Table of Contents

Opening Remarks by the Session Chairman

Good afternoon, ladies and gentlemen. It is my pleasure, this afternoon, to act as the chairman of this seminar dealing with Digital Radio Broadcasting, commonly known in Canada as DRB.

Mon nom est Gérald Chouinard et je suis directeur de la recherche en technologies de radiodiffusion au centre de recherches sur les communications, that is, director of the Radio broadcast technologies research at the Communications Research Centre, better known by its acronym: CRC, located here in Ottawa.

This Seminar is specifically directed at the Canadian manufacturing and broadcasting industries and has been organized by the CRC and Industry Canada. This seminar is actually the third in a series dealing with the theme of identifying niche markets for the Canadian Industry that may develop from the introduction of DRB.

The first two seminars were held in 1992 and 1993. In 1994, the Second International Symposium on DRB was held in Toronto and was considered a landmark conference in the evolution of DRB. As you will be able to appreciate, this afternoon, the situation in the area of Digital Radio Broadcasting is evolving rapidly and is getting clearer as time goes by.

Ce séminaire permettra, nous l'espérons, de faire connaître à l'industrie manufacturière et de la radiodiffusion les derniers développements pouvant conduire à l'implantation de la radio numérique dans le monde, et plus particulièrement au Canada.

Ce séminaire tentera aussi d'identifier les créneaux du marché dans lesquels l'industrie manufacturière canadienne pourra se distinguer en s'assurant d'une avance technologique confortable.

I am pleased to say that we have been able to assemble a group of well recognized speakers in the field of Digital Radio to give us a status on the current situation in DRB and lead us to possible niche areas that the Canadian Industry can take advantage of. We also have exhibits of some technologies developed in Canada for DRB that I will invite you to have a close look later this afternoon.

Ce séminaire technique va se dérouler en grande partie en anglais. De fait, les communications techniques seront présentées en anglais. Toutefois, il nous fera plaisir de répondre aux questions de l'auditoire en français ou en anglais. The seminar will be conducted in English although questions from the floor could be entertained in either French or English.

Speech to the DRB Seminar
Jacques Lyrette
Ottawa Congress Centre,
13:05h, 27 Oct. 1995

Bonjour.

Il me fait plaisir de vous acueillir à ce séminaire sur la radio numérique.

I would like first to welcome you all to this seminar and specially welcome representatives from manufacturers and the Broadcasting industry.

J'espère que ce séminaire permettra de mettre en lumière les principaux défis technologiques que nous présente la radio numérique. Nous espérons aussi pouvoir identifier les créneaux du marché dans lesquels l'industrie manufacturière canadienne pourra se distinguer.

As you know, Canada has been at the forefront for a number of years in the investigation and implementation of digital radio broadcasting technology. And now an increasing number of countries are preparing for DRB.

In the near future, as receivers are mass produced and sold at affordable prices, this technology will replace the AM and FM services that have filled the airwaves since the 1920s and 1960s, respectively.

Meanwhile, a number of things have happened and are still to happen which will solidify the infrastructure for this new generation of radio. We believe that Canada is on the right track in its approach to DRB.

> We have selected the L-band frequency spectrum: the best technical solution for a radio service that could be provided from both terrestrial and satellite transmitters.

> We are recommending, for use in Canada, the Eureka 147 DAB technology: the only one that has so far been proven to work effectively under a wide range of conditions and that has been fully endorsed internationally by the ITU-R.

> We have established good industry-government co-operation through the Joint Technical Committee on Advanced Broadcasting, and through the Task Force on the Introduction of Digital Radio.

The theme this afternoon is: "**DRB: Canadian Manufacturing Industry Opportunities**".

This seminar is addressed specifically to both Canadian manufacturers and broadcasters who wish to exploit the opportunities of this new DRB service.

If you do not already realize the commercial potential in this field, I trust that you will leave this afternoon more fully informed.

Furthermore, I hope that all of you realize that if you want to reap the benefits from Canada's advanced position in DRB technology -- if you want to build a competitive edge in this field -- now is the time to get involved.

DRB represents a "paradigm shift" in broadcasting. It is an entirely new service which can provide CD quality audio programming and a wealth of new data services to extend the "information highway" to mobile receivers.

The all-digital nature of the DRB receiver creates a variety of possibilities for new products, both through the requirement to deliver new services and the integration of DRB with existing services, such as cellular telephones. The incentive to develop these new products will depend on the receiver features and on the desire of broadcasters to offer these associated services.

The resulting skills and products developed by Canadian firms, most likely will be internationally marketable. The international production landscape for DRB will be broad, encompassing many companies and products. This could present Canada with significant opportunities for lower-volume, higher-value-added manufacture, either under foreign licensing or through domestic development.

My department, Industry Canada, is interested in identifying Canada's prospects for economic benefits from the introduction of Digital Radio Broadcasting technology. We are prepared to provide assistance in transferring technical knowledge from CRC, and to provide support in identifying potential industrial alliances that would benefit Canada.

J'aimerais souligner qu'au delà des nouveaux services qui vont se développer à partir de la radio numérique, l'impact industriel au Canada de l'implantation de ce nouveau service est un aspect qui nous tient à coeur au ministère.

Nous sommes prêts à apporter l'assistance nécessaire, soit par le transfert de savoir-faire de notre laboratoire, le CRC, soit par toute assistance qui pourrait résulter en des alliances industrielles entre partenaires ayant des technologies complémentaires dans ce domaine.

J'aimerais donc, en terminant, vous souhaiter tout le succès possible pour ce séminaire et j'espère que l'éventuel succès de la radio numérique au Canada sera aussi garant du succès de l'industrie manufacturière canadienne dans ce domaine.

I wish you a very successful and productive seminar. Thank you.

Jacques Lyrette

Mr. Jacques Lyrette is a graduate of the Royal Military College in Kingston where he earned a Master degree in Electrical Engineering. He was with the then Department of Communications for some 20 years where he occupied a number of positions, the last one being Assistant Deputy Minister for the Quebec Region. Mr. Lyrette is currently president of two Research Laboratories, the CRC in Ottawa and CITI in Montréal.

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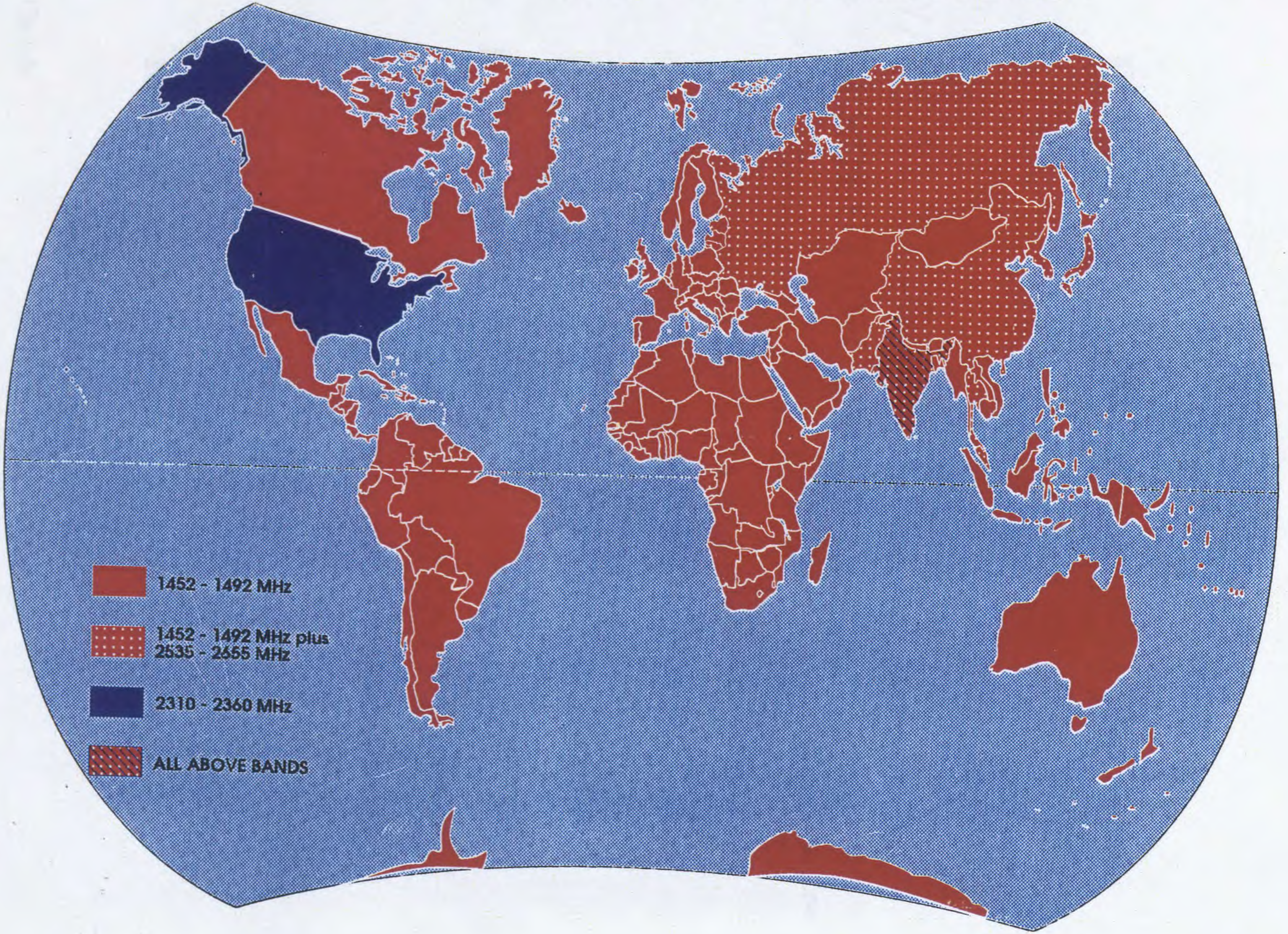
OVERVIEW OF WORLDWIDE SITUATION ON DRB

FRANÇOIS CONWAY, CBC

ITU-R DEVELOPMENTS

- FREQUENCY BANDS ALLOCATION
- USAGE
- ISSUES
  - TECHNICAL FEASIBILITY
  - SHARING
  - CAPACITY
- EMISSION STANDARDS
  - SYSTEMS AND STATUS
  - ITU/R RECOMMENDATIONS.
- CONCLUSION

DAB FREQUENCY ALLOCATIONS



ITU-R DEVELOPMENTS

WARC-92 RESOLUTIONS ON DAB

- **RESOLUTION 528**

  Conference to be held for: 1997- 1999- 200

  - **Planning the S-DAB in three bands**
  - **Review Sharing Procedures**

  Provisions for Interim S-DAB systems

- **RESOLUTION 522**

  Study of characteristics of GSO & N-GSO BSS(Sound) systems & establish sharing criteria.

- **RESOLUTION 527**

  Relates to VHF T-DAB Planning Conference for Region1 & ... Region 3.

FREQUENCY BAND USAGES

	T-DAB		S-DAB
CANADA	1.5 GHz		1.5 GHz
U.S.	FM BAND [1.5GHz]		[2.3 GHz]
MEXICO	1.5 GHz [FM BAND]		1.5GHz
AUSTRALIA	1.5GHz [FM BAND]		1.5GHz
EUROPE	VHF — 1.5GHz		1.5GHz
FRANCE	1.5 GHz	E	1.5GHz
GERMANY	VHF (12) 1.5 GHz	S A	1.5GHz
NETHERLANDS	VHF (12) 1.5 GHz		1.5 GHz
SWITZERLAND	VHF (12) 1.5 GHz		1.5GHz
U.K.	VHF		1.5GHz
SWEDEN	VHF (12)		1.5GHz
JAPAN	?		[2.5 GHz]
CHINA	?		[1.5 or 2.5 GHz]
WORLDSPACE	—		1.5 GHz
INTERNATIONAL	—		1.5GHz.

CAPACITY

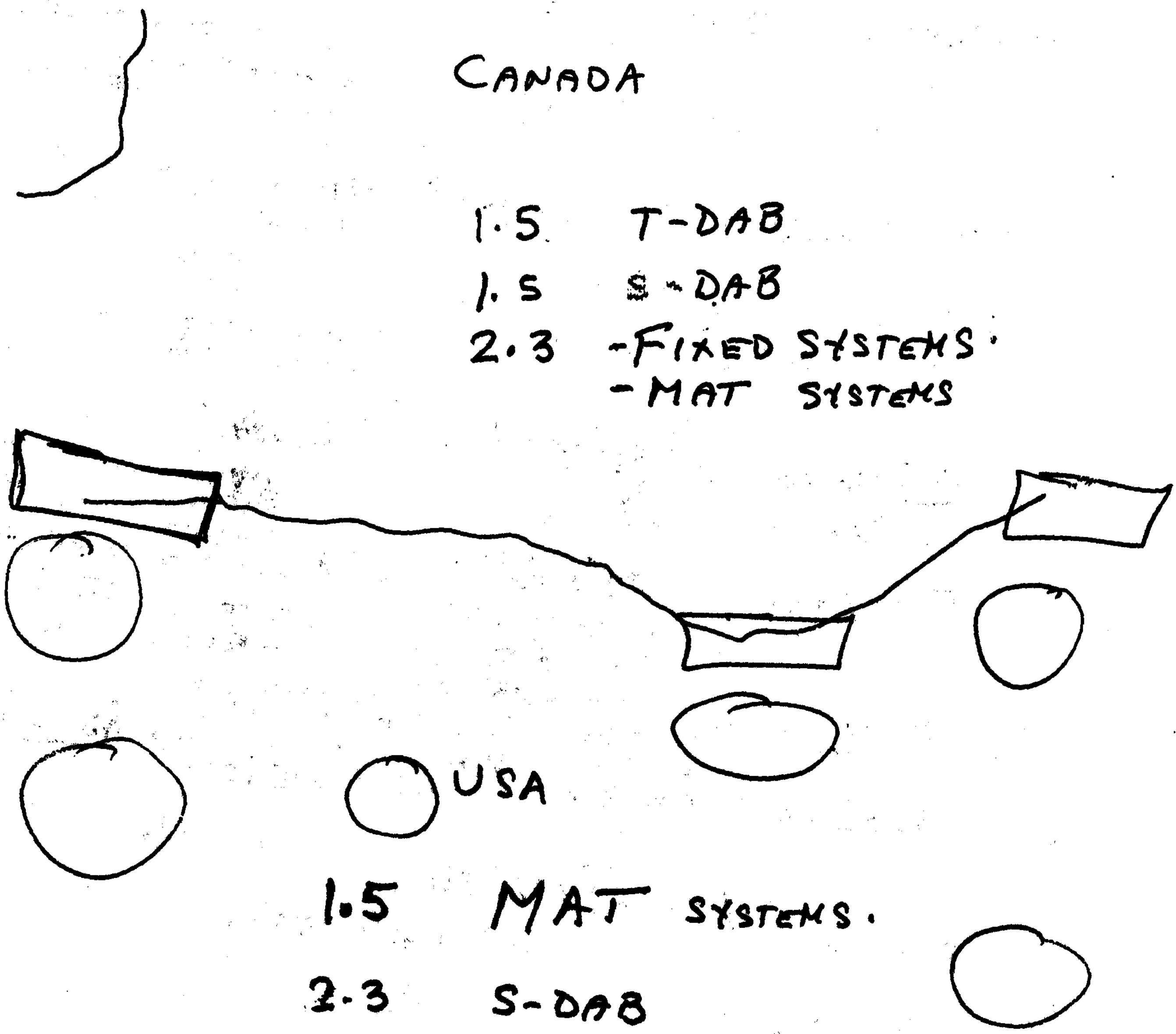
- 1452- 1492 MHz BAND
- 40 MHz ÷ 1.75 MHz ≈ 23 CHANNELS
- IN CANADA ≈ 7 CHANNELS MAXIMUM @ ONE LOCATION FOR T-DRB
  - ⇒ 35 STEREO CD QUALITY PROGR.
  - ⇒ 2 CHANNELS FOR S-DRB 10 PROGRAMMES
  - → NOT SUFFICIENT (MINIMUM GROWTH.)
- WORLDWIDE S-DRB SYSTEM FOR NATIONAL SERVICES (ESA)
- INTERNATIONAL BROADCASTING S-DRB (REPLACEMENT OF SHORTWAVE)
- U.S. USING THE 1452-1492 MHz

OPTIONS: VHF, UHF-TV, 1.5GHz EXTENSION

ITU-R DEVELOPMENTS

SHARING CONSIDERATIONS

- TG 2-2 Studied Sharing between BSS(S) /BS(S) and Other Services;
- Frameworks for 3 PDRs that establishes threshold pfd levels to determine the need for coordination between BSS(S) and: [Doc 2-2/TEMP/93]
  - MAT stations operating in 1.5 GHz & 2.3 GHz Bands;
  - Fixed systems operating in 1.5, 2.3 & 2.5 GHz Bands;
  - LMS operating in 1.5 GHz Band
- Conclusions of TG 2/2 on sharing:
  - Sharing between BSS(S) and other services not feasible;
  - Recommends sharing matter be referred to WRC for resolution;


CANADA
1.5 T-DAB
1.5 S-DAB
2.3 -FIXED SYSTEMS.
-MAT SYSTEMS
USA
1.5 MAT SYSTEMS.
2.3 S-DAB

TECHNICAL FEASIBILITY

- TERRESTRIAL DRB

  - BAND I (47-68 MHz)
    - LIMITED AVAILABILITY
    - MAN-MADE NOISE
    - ANTENNA DIMENSIONS
    - NIR
  - BAND II (87.5-108 MHz)
    - LIMITED AVAILABILITY
    - NIR.
  - IBOC / IBAC
    - MUTUAL INTERFERENCE WITH FM.
  - [-] BAND III (174- 230 ... 240 MHz)
    - LIMITED AVAILABILITY
    - FREQUENCY RE-USE LIMITED
    - TV INTERFERENCE
    - TOWER SPACE
    - NIR.
  - [-] 1452- 1492 MHz
    - COVERAGE GAPS
    - HIGHER HEIGHTS
    - HIGHER ERP THAN VHF (DRB) BUT MUCH LOWER THAN VHF (FM) → ADVANTAGES

- SATELLITE DRB

  - 1452- 1492 MHz
    → THE BEST ONE
  - 2310- 2360 MHz
    → NOT PROVEN
    → $
  - 2535- 2655 MHz
    → NOT PROVEN.
    → $

CEPT T-DAB PLANNING CONFERENCE

- **T-DRB PLANNING CONFERENCE , WIESBADEN GERMANY JULY 3-21, 1995**
- **PLANNING FOR THE INTRODUCTION OF T-DRB IN CEPT COUNTRIES**
- **PREPARATION OF AN ALLOTMENT PLAN IN PARTS OF THE FOLLOWING FREQUENCY BANDS:**
  - **47 - 68 MHz** [87.5 - 108 MHz]
  - **174 - 240 MHz** [230 - 240 MHz]
  - **1452 - 1467.5MHz**

EMISSION STANDARDS

SYSTEM	FORUM	SPECIFICATION	REC.	Rx
EUREKA-147	- ITU/R - ETSI - EIA - EBU - WBU	DETAILED ETSI ETS 301-400 PUBLIC.	ITU/R 1130 1114	PHILIPS BOSH GRUNDIG THOMSON SONY PIONER KENWOOD DELCO
U.S IBOC IBAC	EIA /NRSC [ITU/R]	NOT DETAILED NOT PUBLIC	— NONE	NONE [NS]
NASA / VOA	- ITU/R - EIA - WBU	NOT DETAILED NOT PUBLIC	NONE	NONE
WORLD SPACE	— ITU/R (only IFRB)	—	—	(MOTOROLA) ?
U.S 2.3GHz SAT PROPONENT	— ITU/R only (IFRB)	—	—	—
INDO STAR	— ITU/R only (IFRB)	—	—	—
⋮				

ITU-R DEVELOPMENTS

ITU-R RECOMMENDATIONS

BSS (SOUND) [S-DAB]

Rec. ITU-R BO.789

"Service Requirements for Digital Sound Broadcasting to Vehicular, Portable and Fixed Receivers for BSS(Sound) in the Frequency Range 1400 - 2700 MHz "

- **Provides a list of 12 recommended technical and operational characteristics and capabilities for a total BSS/BS (Sound) system**
- **EUREKA-147 DAB System (System A) meets all of the requirements**

ITU-R DEVELOPMENTS

ITU-R RECOMMENDATIONS

BSS (SOUND) [S-DAB]

Rec. ITU-R BO. 1130

"Systems for Digital Sound Broadcasting to Vehicular, Portable and Fixed Receivers for BSS(Sound) Bands in the Frequency Range 1400 -2700 MHz"

- **Recommends Digital System A [EUREKA-147 DAB System] as a world wide system standard;**
- **Annex 1 contains a description of Digital System A**
- **Note to recommendation refers to future consideration of Digital System B and other systems that meet requirements of Rec. ITU-R BO.789**

ITU-R DEVELOPMENTS

ITU-R RECOMMENDATIONS

BS (SOUND) [T-DAB]

Rec. ITU-R BS.774-1

"Service Requirements for Digital Sound Broadcasting to Vehicular, Portable and Fixed Receivers Using Terrestrial Transmitters in the VHF/UHF Bands"

- **Similar to Rec. ITU-R BO.789 but identifies characteristics applicable to Terrestrial Digital Sound Broadcasting;**
- **Identifies Digital System A as example system that meets all the recommended characteristics;**

SERVICE/SYSTEM REQUIREMENTS/CHARACTERISTICS

- HIGH QUALITY STEREOPHONIC SOUND (CD QUALITY EQUIVALENT) AND LOWER QUALITY (STEREO AND MONO)
- SERVICE TO VEHICULAR, PORTABLE AND FIXED
- POWER AND SPECTRUM EFFICIENT
- IMPROVED PERFORMANCE IN A MULTIPATH AND SHADOWING ENVIRONMENT USING:
  - FREQUENCY DIVERSITY
  - TIME DIVERSITY
  - CO-CHANNEL SPACE DIVERSITY AT THE TRANSMITTER END
- COMMON SIGNAL PROCESSING IN RECEIVERS FOR TERRESTRIAL AND SATELLITE DRB
- FLEXIBLE/DYNAMIC RECONFIGURATION ALLOWING VARIABLE BIT-RATES ALLOCATION IN THE MULTIPLEX FOR SOUND AND DATA

* ALLOWING FOR A COMMON RECEIVER FOR
  - TERRESTRIAL OFF-AIR VHF/UHF
  - SATELLITE
  - CABLE

* LOW COST RECEIVERS (MASS PRODUCTION)
* VALUE ADDED SERVICES

INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION
STUDY GROUPS

Document 10/22-E
12 December 1994
Original: English

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Source: Docs. 10/BL/22 and 10B/TEMP/5

Working Party 10B

DRAFT REVISION OF RECOMMENDATION ITU-R BS.774-1

SERVICE REQUIREMENTS FOR DIGITAL SOUND BROADCASTING TO VEHICULAR, PORTABLE AND FIXED RECEIVERS USING TERRESTRIAL TRANSMITTERS IN THE VHF/UHF BANDS

(Question ITU-R 107/10)

(1992)

The ITU Radiocommunication Assembly,

considering

a) that there is an increasing requirement worldwide for suitable means of broadcasting high-quality stereophonic sound of two or more channels with subjective quality indistinguishable from high-quality consumer digital recorded media ("CD quality") to vehicular, portable and fixed receivers;

b) the limitations of the existing VHF/FM sound broadcasting services to fulfil such requirements, particularly for vehicular and portable reception;

c) that the present congestion in some countries on the utilization of the VHF/FM frequency band causes a generally increasing level of interference and limits the number of programmes which can be transmitted;

d) that technical developments in source and channel coding, modulation and advanced digital signal processing, have demonstrated the technical feasibility and maturity of digital sound broadcasting systems;

e) that a large series of demonstrations and field trials in various parts of the world have confirmed the technical feasibility and economic viability from a system design point of view of digital sound broadcasting systems;

f) that an advanced digital sound broadcasting system can provide better spectrum and power efficiency as well as better performance in multipath environments than conventional analogue systems;

g) that the complementary use of terrestrial and satellite systems, for the UHF broadcasting bands, can result in better power and spectrum efficiency through the implementation of hybrid and mixed terrestrial/satellite digital sound broadcasting service;

h) that a digital broadcasting system can be employed in both terrestrial and satellite applications using closely related emission signal parameters, thus allowing common receiver design with common processing VLSI circuits;

j) that sound broadcasting has always used similar modulation techniques throughout the world, such as AM or FM and similar, if not identical, frequency bands, leading to a receiver that could be used worldwide, for the benefit of the listener;

k) that extensive sound broadcasting services, both public and private, exist throughout the world that provide sound programmes to listeners,

recommends

that, when digital sound broadcasting services from terrestrial transmitters, intended for vehicular, portable and fixed reception, are introduced into the VHF and UHF bands, digital sound broadcasting systems to be used should have the following technical and operational characteristics and capabilities:

1 be capable of providing high-quality stereophonic sound of two or more channels with subjective quality indistinguishable from high-quality consumer digital recorded media ("CD quality") to vehicular, portable and fixed receivers;

2 provide better spectrum and power efficiency than conventional analogue FM systems;

3 provide significantly improved performance in a multipath and shadowing environment through the use of frequency and time diversity and co-channel space diversity at the transmitting end when needed;

4 be capable of utilizing common signal processing in receivers for terrestrial and satellite broadcasting applications;

5 allow configuration/reconfiguration in order to transmit sound programmes with lower bit rates to trade-off quality and number of sound programmes available;

6 allow for a trade-off between extent of coverage for a given emission power, service quality and number of sound programmes and data services;

7 be capable of allowing, with a common receiver, the use of all means of programme delivery, such as:

- local, sub-national and national terrestrial VHF/UHF network services;
- mixed/hybrid use of terrestrial and national/supranational UHF satellite service;
- cable distribution networks;

8 be capable of providing enhanced facilities for programme-related data (e.g. service identification, programme labelling, programme delivery control, copyright control, conditional access, dynamic programme linking, services for visually and hearing-impaired, etc.);

9 allow for flexible assignment of services within a given multiplex;

10 a system multiplex structure capable of complying with the layered ISO open system interconnect model and permitting interfacing to information technology equipment and communications networks;

11 be capable of providing value-added services with different data capacities (e.g. traffic message channels, business data, paging, still picture/graphics, future integrated services digital broadcasting (ISDB), low bit rate video/multiplex, etc.);

12 allow the manufacturing of low cost receivers and antennas through mass production.

Note 1 - An example of a digital sound broadcasting system (digital system A) that meets the above technical and operational requirements and capabilities is described in the Annex to Recommendation ITU-R BS.1114.

Note 2 - System and service characteristics as well as radio-frequency aspects of digital sound broadcasting systems are considered in detail in the Special ITU Publication on Digital Sound Broadcasting and the related Report.

Note 3 - There is a closely related Recommendation ITU-R BO.789 for satellite sound broadcasting.

Received: 12 December 1994

Source: Docs. 10/BL/19 and 10B/TEMP/4

Working Party 10B

DRAFT REVISION OF RECOMMENDATION ITU-R BS.1114

SYSTEMS FOR TERRESTRIAL DIGITAL SOUND BROADCASTING TO VEHICULAR, PORTABLE AND FIXED RECEIVERS IN THE FREQUENCY RANGE 30 - 3 000 MHz

(Question ITU-R 107/10)

The ITU Radiocommunication Assembly,

considering

a) that there is an increasing interest worldwide for terrestrial digital sound broadcasting to vehicular, portable and fixed receivers in the frequency range 30 - 3 000 MHz for local, regional and national coverage;

b) that the ITU-R has already adopted Recommendations ITU-R BS.774 and ITU-R BO.789 to indicate the necessary requirements for digital sound broadcasting systems to vehicular, portable and fixed receivers for terrestrial and satellite delivery, respectively;

c) that Recommendations ITU-R BS.774 and ITU-R BO.789 recognize the benefits of complementary use of terrestrial and satellite systems, and call for a digital sound broadcasting system allowing a common receiver with common processing VLSI circuits and manufacturing of low-cost receivers through mass production;

d) that Digital System A described in the Annex meets all the requirements of Recommendations ITU-R BS.774 and ITU-R BO.789, and that the system has been field-tested and demonstrated in a number of countries;

e) that a standard for satellite digital sound broadcasting to vehicular, portable and fixed receivers in the frequency range 1 400 - 2 700 MHz is under consideration;

f) that at the 7th World Conference of Broadcasting Unions (Mexico, 27-30 April 1992), the World Broadcasting Unions unanimously resolved (literal quote):

"1 that efforts should be made to agree on a unique worldwide standard for DAB, and

2 to urge administrations to give consideration to the benefits for the consumer of common source and channel coding and implementation of digital sound broadcasting on a worldwide basis at 1.5 GHz.";

g) that WARC-92 has allocated the band 1 452 - 1 492 MHz to the broadcasting-satellite service (sound) and complementary terrestrial broadcasting service for the provision of digital sound broadcasting. Also, additional footnote allocations were included for specific countries in the band 2 310 - 2 360 MHz and in the band 2 535 - 2 655 MHz in RR 750B and 757A. In addition, Resolution No. 527 adopted at WARC-92 addresses the subject of terrestrial VHF digital sound broadcasting;

h) that a standardization process in Europe has resulted in the adoption of Digital System A (Eureka 147 as an ETSI Standard ETS 300 401) for BSS/BS (Sound) to vehicular, portable and fixed receivers,

recommends

1 that Digital System A, as described in the Annex, be used for terrestrial digital sound-broadcasting services to vehicular, portable and fixed receivers in the frequency range 30 to 3 000 MHz.

Note - Technology in this area is developing rapidly. Accordingly, if additional systems meeting the requirements given in Recommendation ITU-R BS.774 are developed, they may also be recommended for use when brought to the attention of the ITU-R. Administrations engaged in the development of digital sound broadcasting standards should make efforts to bring about, as much as possible, harmonization with other system standards already developed or currently under development. For example, digital sound broadcast systems are in development that transmit a digital signal associated with an existing analogue service (generally transmitting the same programme) either on the same channel or on an adjacent channel.

ANNEX 1

Digital system A

1 Introduction

Digital system A is designed to provide high-quality, multiservice digital radio broadcasting for reception by vehicular, portable and fixed receivers. It is designed to operate at any frequency up to 3 000 MHz for terrestrial, satellite, hybrid (satellite and terrestrial), and cable broadcast delivery. The system is also designed as a flexible, general-purpose Integrated Services Digital Broadcasting (ISDB) system which can support a wide range of source and channel coding options, sound-programme associated data and independent data services, in conformity with the flexible and broad-ranging service and system requirements given in ITU-R Recommendations ITU-R BO.789 and ITU-R BS.774, supported by the ITU Special Publication on Digital Sound Broadcasting and Reports 1203-2 and 955-3.

The system is a rugged, yet highly spectrum and power-efficient sound and data broadcasting system. It uses advanced digital techniques to remove redundancy and perceptually irrelevant information from the audio source signal, then it applies closely-controlled redundancy to the transmitted signal for error correction. The transmitted information is then spread in both the frequency and time domains so that a high quality signal is obtained in the receiver, even when working in conditions of severe multipath propagation, whether stationary or mobile. Efficient spectrum utilization is achieved by interleaving multiple programme signals and a special feature of frequency re-use permits broadcasting networks to be extended, virtually without limit, using additional transmitters all operating on the same radiated frequency.

A conceptual diagram of the emission part of the system is shown in Fig. 1.

Digital system A has been developed by the Eureka 147 (DAB) consortium and is known as the Eureka DAB system. It has been actively supported by the EBU in view of introducing digital sound-broadcasting services in Europe in 1995. Since 1988, the system has been successfully demonstrated and extensively tested in Europe, Canada, the United States and in other countries worldwide. In this Annex, Digital System A is referred to as "the system". The full system specification is available as European Telecommunications Standard ETS 300 401*.

2 Use of a layered model

The system is capable of complying with the ISO Open System Interconnection (OSI) basic reference model described in ISO 7498 (1984). The use of this model is recommended in Recommendation ITU-R BT.807 and Report 1207, and a suitable interpretation for use with layered broadcasting systems is given in the Recommendation. In accordance with this guidance, the system will be described in relation to the layers of the model, and the interpretation applied here is illustrated in Table 1.

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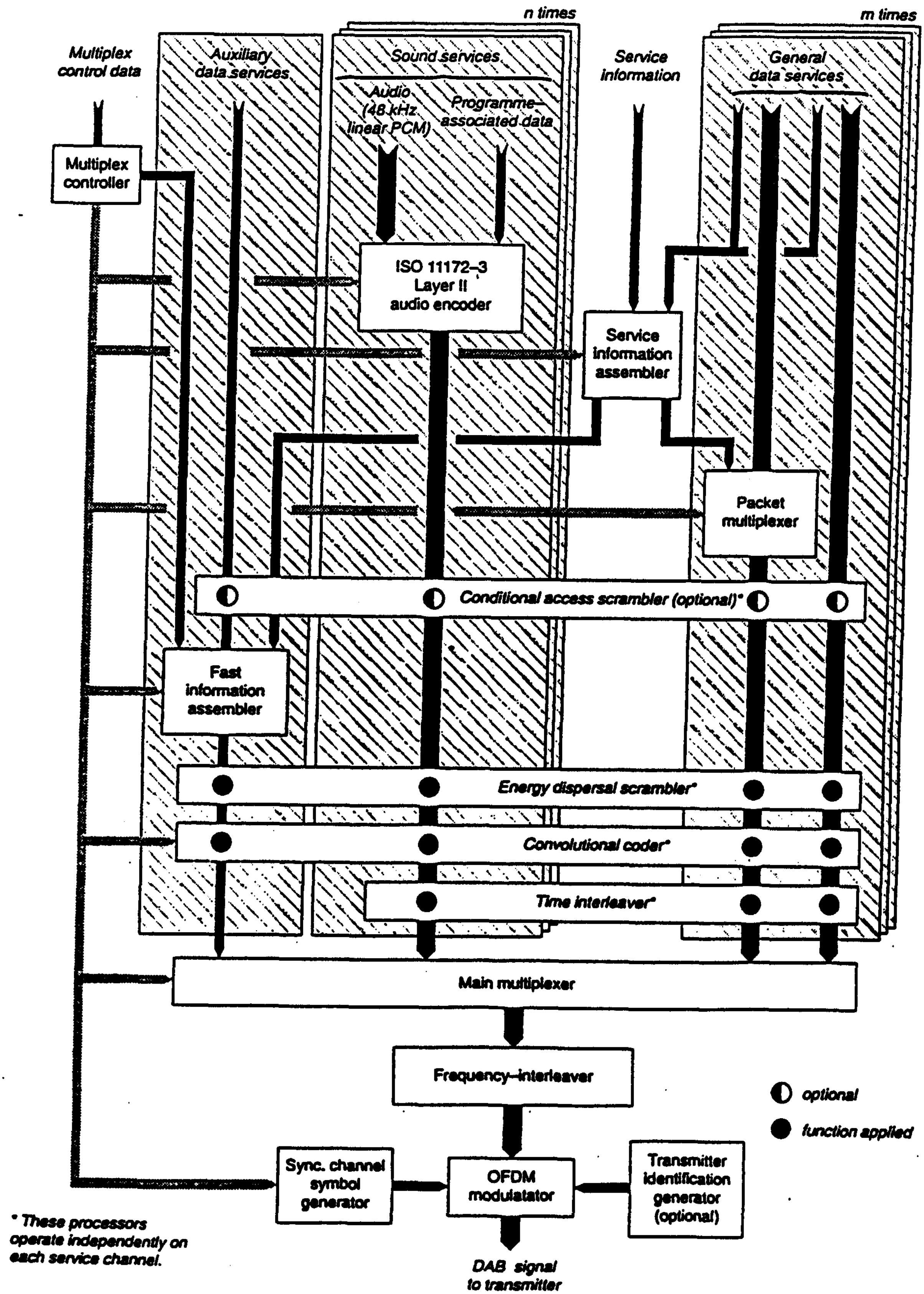
* The addition of a new transmission mode, bridging the gap between current Modes I and II, has been found to be desirable, and is being considered as a compatible enhancement to Digital System A to allow for larger separation distances between co-channel re-transmitters used in a single-frequency-network, or used as coverage extenders or gap-fillers, thus resulting in better flexibility and lower cost in implementing terrestrial DSB in the 1 452 - 1 492 MHz band.

FIGURE 1

Conceptual diagram of the transmission part of the system



* These processors operate independently on each service channel.

TABLE 1

Interpretation of the OSI layered model

Name of layer	Description	Features specific to the system
Application layer	Practical use of the system	System facilities Audio quality Transmission modes
Presentation layer	Conversion for presentation	Audio encoding and decoding Audio presentation Service information
Session layer	Data selection	Programme selection Conditional access
Transport layer	Grouping of data	Programme services Main service multiplex Ancillary data Association of data
Network layer	Logical channel	ISO audio frames Programme associated data
Data link layer	Format of the transmitted signal	Transmission frames Synchronization
Physical layer	Physical (radio) transmission	Energy dispersal Convolutional encoding Time interleaving Frequency interleaving Modulation by 4-DPSK OFDM Radio transmission

Descriptions of many of the techniques involved are most easily given in relation to the operation of the equipment at the transmitter, or at the central point of a distribution network in the case of a network of transmitters.

The fundamental purpose of the system is to provide sound programmes to the radio listener, so the order of sections in the following description will start from the application layer (use of the broadcast information), and proceed downwards to the physical layer (the means for radio transmission).

3 Application layer

This layer concerns the use of the system at the application level. It considers the facilities and audio quality which the system provides and which broadcasters can offer to their listeners, and the different transmission modes.

3.1 Facilities offered by the system

The system provides a signal which carries a multiplex of digital data, and this conveys several programmes at the same time. The multiplex contains audio programme data, and ancillary data comprising Programme-Associated Data (PAD), Multiplex Configuration Information (MCI) and Service Information (SI). The multiplex may also carry general data services which may not be related to the transmission of sound programmes.

In particular, the following facilities are made available to users of the system:

a) the audio signal (i.e. the programme) being provided by the selected programme service;

b) the optional application of receiver functions, for example dynamic range control, which may use ancillary data carried with the programme;

c) a text display of selected information carried in the SI. This may be information about the selected programme, or about others which are available for optional selection;

d) options which are available for selecting other programmes, other receiver functions, and other SI;

e) one or more general data services, for example a Traffic Message Channel (TMC).

The system includes facilities for conditional access, and a receiver can be equipped with digital outputs for audio and data signals.

3.2 Audio quality

Within the capacity of the multiplex, the number of programme services and, for each, the presentation format (e.g. stereo, mono, surround-sound, etc.), the audio quality and the degree of error protection (and hence ruggedness) can be chosen to meet the needs of the broadcasters.

The following range of options is available for the audio quality:

a) very high quality, with audio processing margin;

b) subjectively transparent quality, sufficient for the highest quality broadcasting;

c) high quality, equivalent to good FM service quality;

d) medium quality, equivalent to good AM service quality;

e) speech-only quality.

The system provides full quality reception within the limits of transmitter coverage; beyond these limits reception degrades in a subjectively graceful manner.

3.3 Transmission modes

The system has three alternative transmission modes which allow the use of a wide range of transmitting frequencies up to 3 GHz. These transmission modes have been designed to cope with Doppler spread and delay spread, for mobile reception in presence of multipath echoes.

The following table gives the constructive echo delay and nominal frequency range for mobile reception. The noise degradation at the highest frequency and in the most critical multipath condition, occurring infrequently in practice, is equal to 1 dB at 100 km/h.

Parameter	Mode I	Mode II	Mode III
Guard interval duration:	246 µs	62 µs	31 µs
Constructive echo delay up to:	300 µs	75 µs	37.5 µs
Nominal frequency range (for mobile reception) up to:	375 MHz	1.5 GHz	3 GHz

From this table, it can be seen that the use of higher frequencies imposes a greater limitation on the maximum echo delay. Mode I is most suitable for a terrestrial Single-Frequency Network (SFN), because it allows the greatest transmitter separations. Mode II is most suitable for local radio applications requiring one terrestrial transmitter, and hybrid satellite/terrestrial transmission up to 1.5 GHz. However, Mode II can also be used for a medium-to-large scale SFN (e.g. at 1.5 GHz) by inserting, if necessary, artificial delays at the transmitters and/or by using directive transmitting antennas. Mode III is most appropriate for satellite and complementary terrestrial transmission at all frequencies up to 3 GHz.

Mode III is also the preferred mode for cable transmission up to 3 GHz.

4 Presentation layer

This layer concerns the conversion and presentation of the broadcast information.

4.1 Audio source encoding

The audio source encoding method used by the system is ISO/IEC MPEG-Audio Layer II, given in the ISO Standard 11172-3. This sub-band coding compression system is also known as the MUSICAM system.

The system accepts a number of PCM audio signals at a sampling rate of 48 kHz with programme-associated data (PAD). The number of possible audio sources depends on the bit rate and the error protection profile. The audio encoder can work at 32, 48, 56, 64, 80, 96, 112, 128, 160 or 192 kbit/s per monophonic channel. In stereophonic or dual channel mode, the encoder produces twice the bit rate of a mono channel.

The different bit rate options can be exploited by broadcasters depending on the intrinsic quality required and/or the number of sound programmes to be provided. For example, the use of bit rates greater than or equal to 128 kbit/s for mono, or greater than or equal to 256 kbit/s for a stereo programme, provides not only very high quality, but also some processing margin, sufficient for further multiple encoding/decoding processes, including audio post-processing. For high-quality broadcasting purposes, a bit rate of 128 kbit/s for mono or 256 kbit/s for stereo is preferred, giving fully transparent audio quality. Even the bit rate of 192 kbit/s per stereo programme generally fulfils the EBU requirement for digital audio bit-rate reduction systems*. A bit rate of 96 kbit/s for mono gives good sound quality, and 48 kbit/s can provide roughly the same quality as normal AM broadcasts. For some speech-only programmes, a bit rate of 32 kbit/s may be sufficient where the greatest number of services is required within the system multiplex.

A block diagram of the functional units in the audio encoder is given in Fig. 2. The input PCM audio samples are fed into the audio encoder. One encoder is capable of processing both channels of a stereo signal, although it may, optionally, be presented with a mono signal. A polyphase filter bank divides the digital audio signal into 32 sub-band signals, and creates a filtered and sub-sampled representation of the input audio signal. The filtered samples are called

* See EBU Contribution JIWP 10-CMTT/1-7(Rev.1) (October 1990) entitled: "Digital audio bit-rate reduction systems requirements for broadcast emission and primary distribution".

sub-band samples. A perceptual model of the human ear creates a set of data to control the quantizer and coding. These data can be different, depending on the actual implementation of the encoder. One possibility is to use an estimation of the masking threshold to obtain these quantizer control data. Successive samples of each sub-band signal are grouped into blocks, then in each block, the maximum amplitude attained by each sub-band signal is determined and indicated by a scale factor. The quantizer and coding unit creates a set of coding words from the sub-band samples. These processes are carried out during ISO audio frames, which will be described in the network layer.

4.2 Audio decoding

Decoding in the receiver is straightforward and economical using a simple signal processing technique, requiring only demultiplexing, expanding and inverse-filtering operations. A block diagram of the functional units in the decoder is given in Fig. 3.

The ISO audio frame is fed into the ISO/MPEG-Audio Layer II decoder, which unpacks the data of the frame to recover the various elements of information. The reconstruction unit reconstructs the quantized sub-band samples, and an inverse filter bank transforms the sub-band samples back to produce digital uniform PCM audio signals at 48 kHz sampling rate.

4.3 Audio presentation

Audio signals may be presented monophonically or stereophonically, or audio channels may be grouped for surround-sound. Programmes may be linked to provide the same programme simultaneously in a number of different languages. In order to satisfy listeners in both hi-fi and noisy environments, the broadcaster can optionally transmit a Dynamic Range Control (DRC) signal which can be used in the receiver in a noisy environment to compress the dynamic range of the reproduced audio signal. Note that this technique can also be beneficial to listeners with impaired hearing.

4.4 Presentation of Service Information

With each programme transmitted by the system, the following elements of Service Information (SI) can be made available for display on a receiver:

- basic programme label (i.e. the name of the programme);
- time and date;
- cross-reference to the same, or similar programme (e.g. in another language) being transmitted in another ensemble or being simulcast by an AM or FM service;
- extended service label for programme-related services;
- programme information (e.g. the names of performers);
- language;
- programme type (e.g. news, sport, music, etc.);
- transmitter identifier;
- Traffic Message Channel (TMC, which may use a speech synthesizer in the receiver).

Transmitter network data can also be included for internal use by broadcasters.

FIGURE 2

Block diagram of the basic system audio encoder

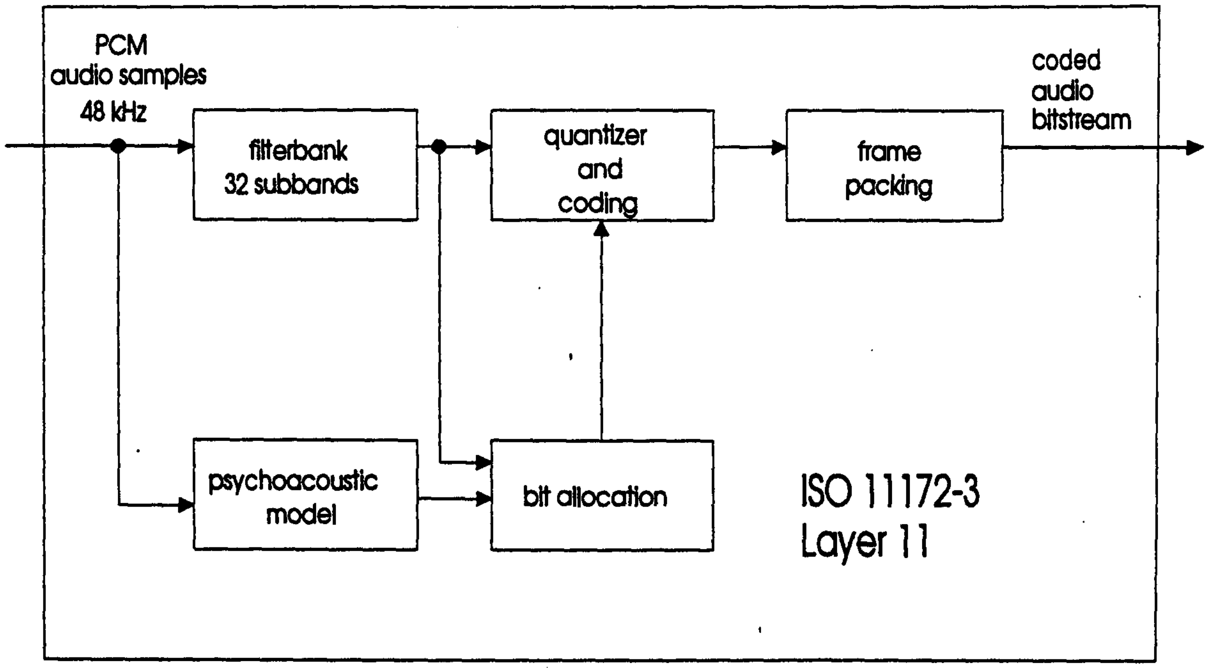
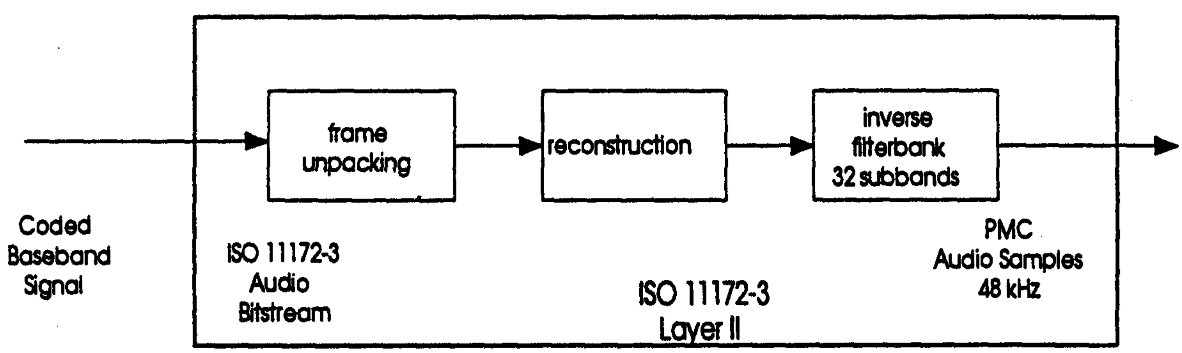


FIGURE 3

Block diagram of the basic system audio decoder



5 Session layer

This layer concerns the selection of, and access to, broadcast information.

5.1 Programme selection

In order that a receiver can gain access to any or all of the individual services with a minimum overall delay, information about the current and future content of the multiplex is carried by the Fast Information Channel (FIC). This Information is the MCI, which is machine-readable data. Data in the FIC are not time-interleaved, so the MCI is not subject to the delay inherent in the time-interleaving process applied to audio and general data services. However, these data are repeated frequently to ensure their ruggedness. When the multiplex configuration is about to change, the new information, together with the timing of the change is sent in advance in the MCI.

The user of a receiver can select programmes on the basis of textual information carried in the SI, using the programme service name, the programme type identity or the language. The selection is then implemented in the receiver using the corresponding elements of the MCI.

If alternative sources of a chosen programme service are available and an original digital service becomes untenable, then linking data carried in the SI (i.e. the "cross-reference") may be used to identify an alternative (e.g. on an FM service) and switch to it. However, in such a case, the receiver will switch back to the original service as soon as reception is possible.

5.2 Conditional access

Provision is made for both synchronization and control of conditional access.

Conditional access can be applied independently to the service components (carried either in the MSC or FIC), services or the whole multiplex.

6 Transport layer

This layer concerns the identification of groups of data as programme services, the multiplexing of data for those services and the association of elements of the multiplexed data.

6.1 Programme services

A programme service generally comprises an audio service component and optionally additional audio and/or data service components, provided by one service provider. The whole capacity of the multiplex may be devoted to one service provider (e.g. broadcasting five or six high-quality sound programme services), or it may be divided amongst several service providers (e.g. collectively broadcasting some twenty medium quality programme services).

6.2 Main service multiplex

With reference to Fig. 1, the data representing each of the programmes being broadcast (digital audio data with some ancillary data, and maybe also general data) are subjected to convolutional encoding (see § 9.2) and time-interleaving, both for error protection. Time-interleaving improves the ruggedness of data transmission in a changing environment (e.g. reception by a moving vehicular receiver) and imposes a predictable transmission delay. The interleaved and encoded data are then fed to the main service multiplexer where, each 24 ms, the data are gathered in sequence into the multiplex frame. The combined bit stream output from the multiplexer is known as the Main Service Channel (MSC) which has a gross capacity of 2.3 Mbit/s. Depending on the chosen code rate (which can be different from one service component to another), this gives a net bit rate ranging from approximately 0.8 to 1.7 Mbit/s, through a 1.5 MHz bandwidth. The main service multiplexer is the point at which synchronized data from all of the programme services using the multiplex are brought together.

General data may be sent in the MSC as an unstructured stream or organized as a packet multiplex where several sources are combined. The data rate may be any multiple of 8 kbit/s, synchronized to the system multiplex, subject to sufficient total multiplex capacity, taking into account the demand for audio services.

The Fast Information Channel (FIC) is external to the MSC and is not time-interleaved.

6.3 Ancillary data

There are three areas where ancillary data may be carried within the system multiplex:

a) the FIC, which has limited capacity, depending on the amount of essential MCI included;

b) there is special provision for a moderate amount of PAD to be carried within each audio channel;

c) all remaining ancillary data are treated as a separate service within the MSC. The presence of this information is signalled in the MCI.

6.4 Association of data

A precise description of the current and future content of the MSC is provided by the MCI, which is carried by the FIC. Essential items of SI which concern the content of the MSC (i.e. for programme selection) must also be carried in the FIC. More extensive text, such as a list of all the day's programmes, must be carried separately as a general data service. Thus, the MCI and SI contain contributions from all of the programmes being broadcast.

The PAD, carried within each audio channel, comprises mainly the information which is intimately linked to the sound program and therefore cannot be sent in a different data channel which may be subject to a different transmission delay.

7 Network layer

This layer concerns the identification of groups of data as programmes.

7.1 ISO audio frames

The processes in the audio source encoder are carried out during ISO audio frames of 24 ms duration. The bit allocation, which varies from frame to frame, and the scale factors are coded and multiplexed with the sub-band samples in each ISO audio frame. The frame packing unit (see Fig. 2) assembles the actual bit stream from the output data of the quantizer and coding unit, and adds other information, such as header information, CRC words for error detection, and PAD, which travel along with the coded audio signal. Each audio channel contains a PAD channel having a variable capacity (generally at least 2 kbit/s), which can be used to convey information which is intimately linked to the sound programme. Typical examples are lyrics, speech/music indication and Dynamic Range Control (DRC) information.

The resulting audio frame carries data representing 24 ms duration of stereo (or mono) audio, plus the PAD, for a single programme and complies with the ISO 11172-3 Layer II format, so it can be called an ISO frame. This allows the use of an ISO/MPEG-Audio Layer II decoder in the receiver.

8 Data link layer

This layer provides the means for receiver synchronization.

8.1 The transmission frame

In order to facilitate receiver synchronization, the transmitted signal is built up with a regular frame structure (see Fig. 4). The transmission frame comprises a fixed sequence of symbols. The first is a null symbol to provide a coarse synchronization (when no RF signal is transmitted), followed by a fixed reference symbol to provide a fine synchronization, AGC, AFC and phase reference functions in the receiver; these symbols make up the synchronization channel. The next symbols are reserved for the FIC, and the remaining symbols provide the MSC. The total frame duration T_F is either 96 ms or 24 ms, depending on the transmission mode as given in Table 2 below:

FIGURE 4

Multiplex frame structure

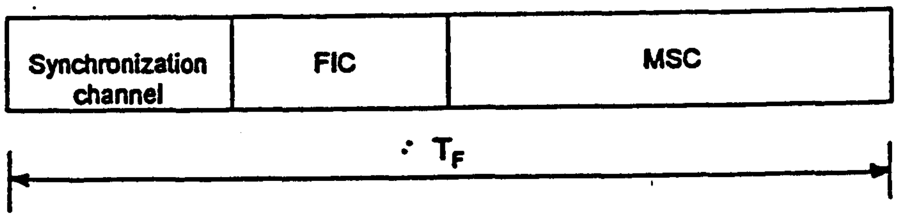


TABLE 2

Transmission parameters of the system

	Mode I	Mode II	Mode III
T_F	96 ms	24 ms	24 ms
T_{NULL}	1.297 ms	324 µs	168 µs
T_S	1.246 ms	312 µs	156 µs
T_u	1 ms	250 µs	125 µs
Δ	246 µs	62 µs	31 µs
K	1 536	384	192

The following notation is used:

T_F transmission frame duration

T_{NULL} null symbol duration

T_s the duration of OFDM symbols

T_u the inverse of the carrier spacing

Δ the duration of the time interval called guard interval
$T_s = T_u + \Delta$

K number of transmitted carriers

Each audio service within the MSC is allotted a fixed time slot in the frame.

9 The physical layer

This layer concerns the means for radio transmission (i.e. the modulation scheme and the associated error protection).

9.1 Energy dispersal

In order to ensure appropriate energy dispersal in the transmitted signal, the individual sources feeding the multiplex are scrambled.

9.2 Convolutional encoding

Convolutional encoding is applied to each of the data sources feeding the multiplex to ensure reliable reception. The encoding process involves adding deliberate redundancy to the source data bursts (using a constraint length of seven). This gives "gross" data bursts.

In the case of an audio signal, greater protection is given to some source-encoded bits than others, following a preselected pattern known as the Unequal Error Protection (UEP) profile. The average code rate, defined as the ratio of the number of source-encoded bits to the number of encoded bits after convolutional encoding, may take a value from 1/3 (the highest protection level) to 3/4 (the lowest protection level). Different average code rates can be applied to different audio sources, subject to the protection level required and the bit rate can be applied to different audio sources, subject to the protection level required and the bit rate of the source-encoded data. For example, the protection level of audio services carried by cable networks may be lower than that of services transmitted in radio-frequency channels.

General data services are convolutionally encoded using one of a selection of uniform rates. Data in the FIC are encoded at a constant 1/3 rate.

9.3 Time interleaving

Time interleaving of interleaving depth of 16 frames is applied to the convolutionally encoded data in order to provide further assistance to a mobile receiver.

9.4 Frequency interleaving

In the presence of multipath propagation, some of the carriers are enhanced by constructive signals, while others suffer destructive interference (frequency selective fading). Therefore, the system provides frequency interleaving by a rearrangement of the digital bit stream amongst the carriers, such that successive source samples are not affected by a selective fade. When the receiver is stationary, the diversity in the frequency domain is the prime means to ensure successful reception.

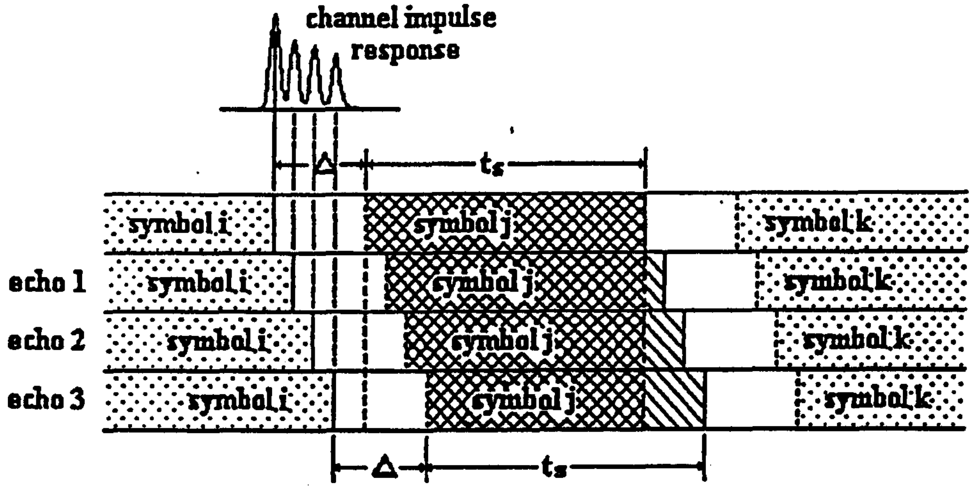
9.5 Modulation by 4-DPSK OFDM

The system uses 4-DPSK OFDM (Orthogonal Frequency Division Multiplex). This scheme meets the exacting requirements of high bit rate digital broadcasting to mobile, portable and fixed receivers, especially in multipath environments.

The basic principle consists of dividing the information to be transmitted into a large number of bit-streams having low bit rates individually, which are then used to modulate individual carriers. The corresponding symbol duration becomes larger than the delay spread of the transmission channel. In the receiver any echo shorter than the guard interval will not cause inter-symbol interference but rather contribute positively to the received power (see Fig. 5). The large number N of carriers is known collectively as an ensemble.

FIGURE 5

Constructive contribution of echoes



In the presence of multipath propagation, some of the carriers are enhanced by constructive signals, while others suffer destructive interference (frequency selective fading). Therefore, the system includes a redistribution of the elements of the digital bit stream in time and frequency, such that successive source samples are affected by independent fades. When the receiver is stationary, the diversity in the frequency domain is the only means to ensure successful reception; the time diversity provided by time-interleaving does not assist a static receiver. For the system, multipath propagation is a form of space-diversity and is considered to be a significant advantage, in stark contrast to conventional FM or narrow-band digital systems where multipath propagation can completely destroy a service.

In any system able to benefit from multipath, the larger the transmission channel bandwidth, the more rugged the system. In the system, an ensemble bandwidth of 1.5 MHz was chosen to secure the advantages of the wideband technique, as well as to allow planning flexibility. Table 2 also indicates the number of COFDM carriers within this bandwidth for each transmission mode.

A further benefit of using COFDM is that high spectrum and power efficiency can be obtained with single frequency networks for large area coverage and also for city area dense networks. Any number of transmitters providing the same programmes may be operated on the same frequency, which also results in an overall reduction in the required operating powers. As a further consequence distances between different service areas are significantly reduced.

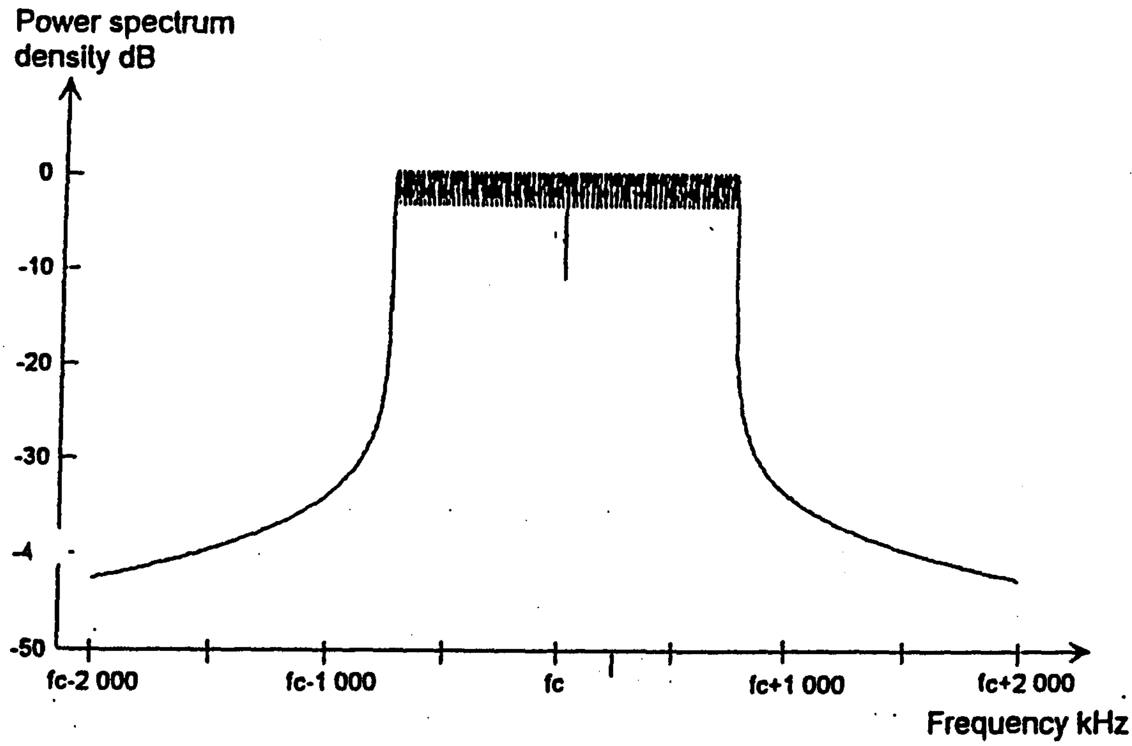
Because echoes contribute to the received signal, all types of receiver (i.e. portable, home and vehicular) may utilize simple, non-directional antennas.

9.6 Transmission signal spectrum of Digital System A

As an example, the theoretical spectrum of Digital System A is illustrated in Fig. 6 for transmission Mode II.

FIGURE 6

Theoretical transmission signal spectrum for transmission Mode II of Digital System A



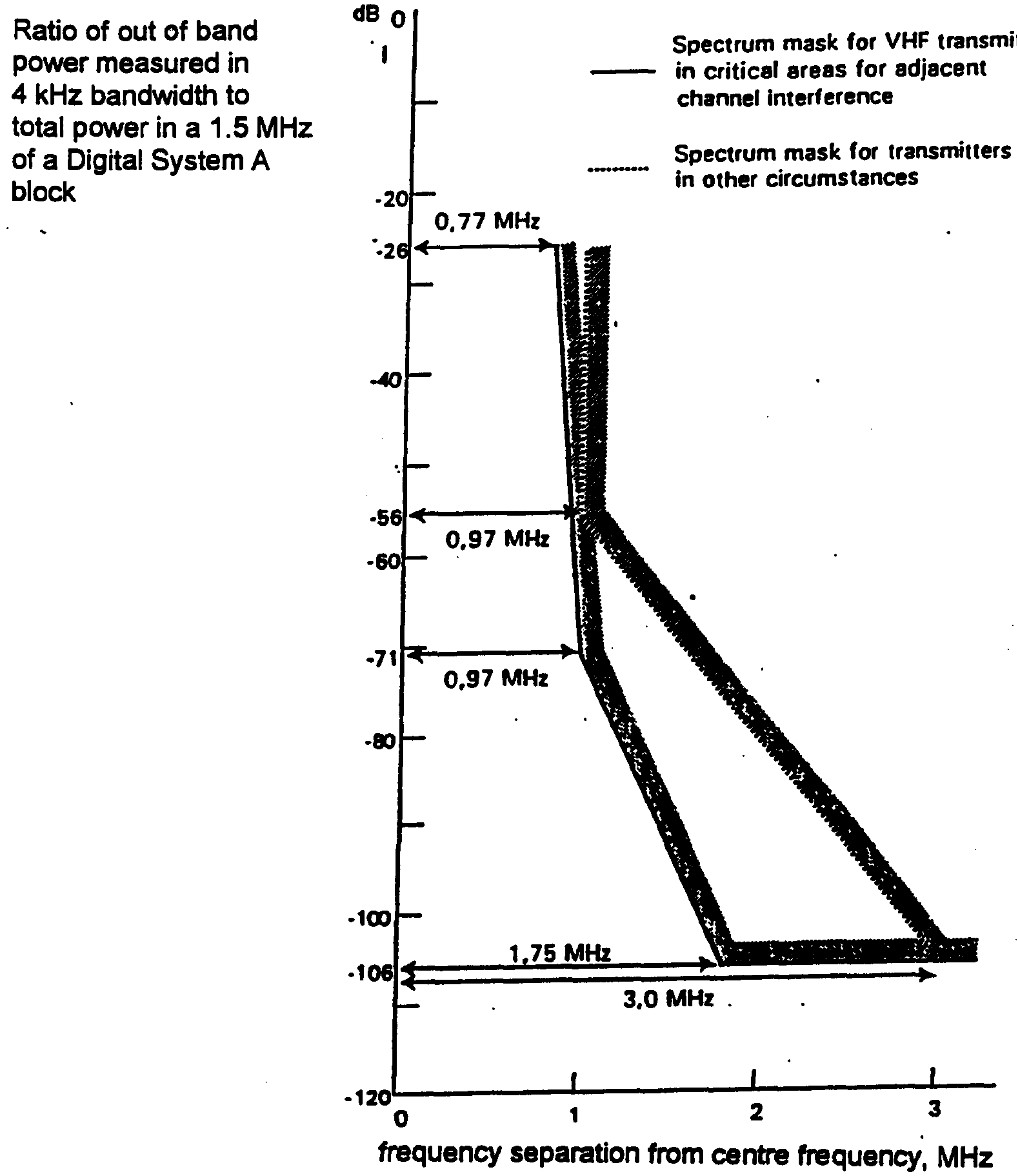
The out-of-band radiated signal spectrum in any 4 kHz band should be constrained by one of the masks defined in Fig. 7.

The solid line mask should apply to VHF transmitters in critical areas for adjacent channel interference. The dotted line mask should apply to VHF transmitters in other circumstances and to UHF transmitters in critical cases for adjacent channel interference.

The level of the signal at frequencies outside the normal 1.536 MHz bandwidth can be reduced by applying an appropriate filtering.

FIGURE 7

Out-of-band spectrum mask for a transmission signal of Digital System A (all transmission modes)



10 RF performance characteristics of Digital System A

RF evaluation tests have been carried out on Digital System A using Mode I at 226 MHz and Mode II at 1480 MHz for a variety of conditions representing mobile and fixed reception. Measurements of BER vs. S/N in the transmission channel were made on a data channel using the following conditions:

D = 64 kbit/s, R = 0.5

D = 24 kbit/s, R = 0.375

where D is the source data rate and R is the average channel code rate.

10.1 BER vs. S/N (in 1.5 MHz) in a Gaussian channel

Additive, Gaussian white noise was added to set the S/N at the input of the receiver. The results are shown in Fig. 8-9. As an example, for R = 0.5, the measured results in Fig. 8 can be compared with those from a software simulation, to show the inherent performance of the system. It can be seen that an implementation margin of less than 1.0 dB is obtained at a bit-error ratio (BER) of 10^{-4}.

10.2 BER vs. S/N (in 1.5 MHz) in a Rayleigh channel simulated in urban environment

Measurements of BER vs. S/N were made on the data channels, using a fading channel simulator. The Rayleigh channel simulations correspond to Fig. 5 in Cost 207 documentation (typical urban area, 0 - 0.5 µs) and the receiver travelling at a speed of 15 km/h.

The results are shown in Figs. 10 and 11.

10.3 BER vs. S/N (in 1.5 MHz) in a Rayleigh channel simulated in rural environment

Measurements of BER vs. S/N were made on the data channels using a fading channel simulator. The Rayleigh channel simulations correspond to Fig. 4 in Cost 207 documentation (rural area, non-hilly, 0 - 5 µs) and the receiver travelling at 130 km/h. The results are shown in Figs. 12 and 13.

10.4 Sound quality versus RF signal-to-noise ratio

A number of subjective assessments have been performed in order to evaluate the sound quality versus the S/N. The transmission path included equipment for establishing the S/N in a Gaussian channel and, using a fading channel simulator, in a Rayleigh channel. Two different simulation 'models' were used in the case of a Rayleigh channel, the same as those described in §§ 10.2 and 10.3.

In each case a listening test was conducted in which the average S/N was reduced in 0.5 dB steps to establish, in sequence, the following two conditions:

a) The onset of impairment, which is the point at which the effects of errors start to become noticeable. This was defined as the point where 3 or 4 error-related events could be heard in a period of about 30 seconds.

b) The point of failure, which is the point at which a listener would probably stop listening to the programme because it became unintelligible or because it no longer provided the enjoyment sought. This was defined as the point where the error-related events occurred virtually continuously, and muting took place two or three times in a period of about 30 seconds.

Two values of S/N were recorded for each test, representing the consensus view of the panel of audio engineers. The results presented here are the mean values of several tests using different programme material.

TABLE 1

Sound quality vs. signal-to-noise ratio for Digital System A (Transmission Mode 1): Gaussian channel

Source-coding bit rate (kbit/s)	Source-coding mode	Channel-coding average rate	Onset of impairment S/N (dB)	Point of failure S/N (dB)
256	stereo	0.6	7.6	5.5
224	stereo	0.6	8.3	5.9
224	stereo	0.5	7.0	4.8
224	joint stereo	0.5	6.8	4.5
192	joint stereo	0.5	7.2	4.7
64	mono	0.5	6.8	4.5

TABLE 2

Sound quality vs. signal-to-noise ratio for Digital System A (Transmission Mode 2 or 3): Gaussian channel

Source-coding bit rate (kbit/s)	Source-coding mode	Channel-coding average rate	Onset of impairment S/N (dB)	Point of failure S/N (dB)
256	stereo	0.6	7.7	5.7
224	stereo	0.6	8.2	5.8
224	stereo	0.5	6.7	4.9
224	joint stereo	0.5	6.6	4.6
192	joint stereo	0.5	7.2	4.6
64	mono	0.5	6.9	4.5

TABLE 3

Sound quality vs. signal-to-noise ratio for Digital System A Simulated Rayleigh channels (224 kbit/s stereo, rate 0.5)

Mode	Frequency (MHz)	Channel mode	Speed (km/h)	Onset of impairment S/N (dB)	Point of failure S/N (dB)
1	226	urban	15	16.0	9.0
2	1500	urban	15	13.0	7.0
1	226	rural	130	17.6	10.0
2	1500	rural	130	18.0	10.0

FIGURE 8

Bit-error ratio vs. signal-to-noise ratio for Digital System A (Transmission Mode 1): Gaussian channel

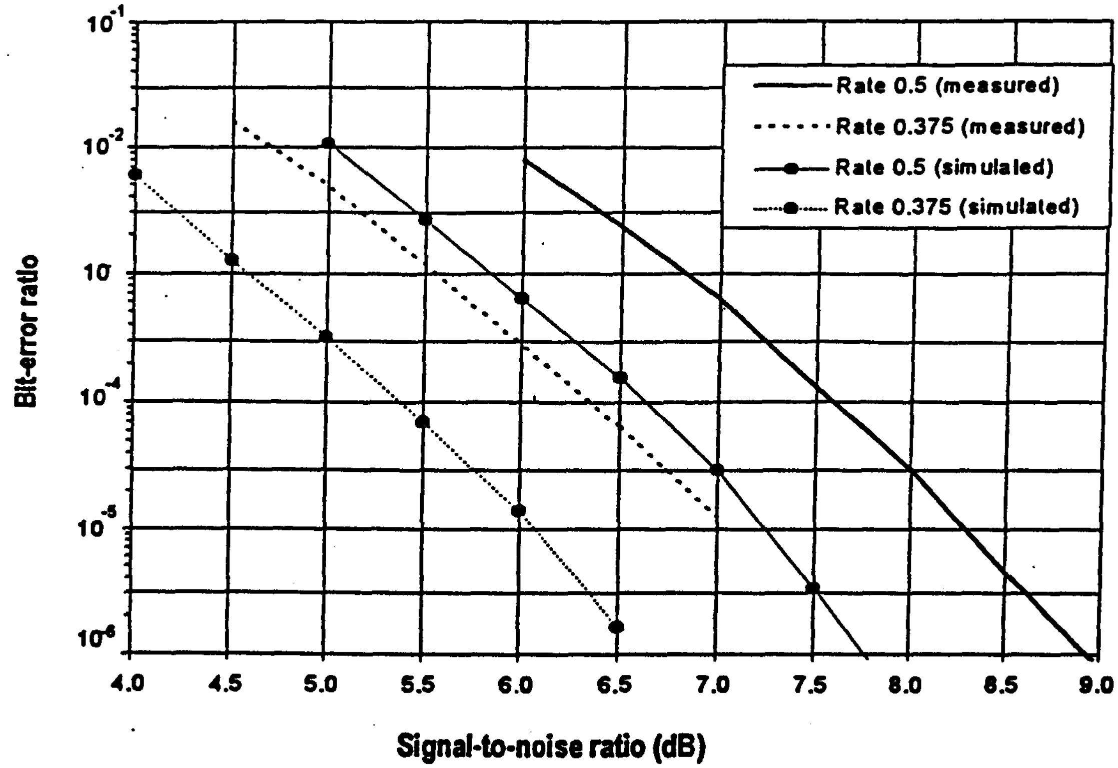


FIGURE 9

Bit-error ratio vs. signal-to-noise ratio for Digital System A (Transmission Mode 2 or 3): Gaussian channel

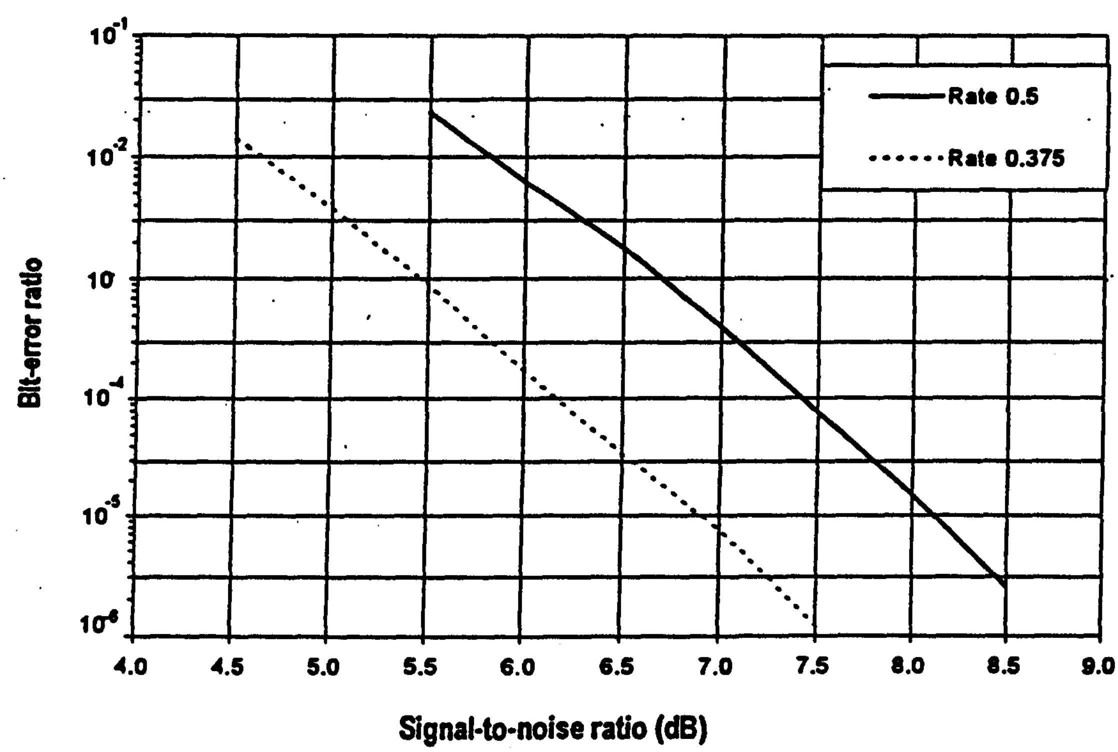


FIGURE 10

Bit-error ratio vs. signal-to-noise ratio for Digital System A (Transmission Mode 1, 226 MHz)

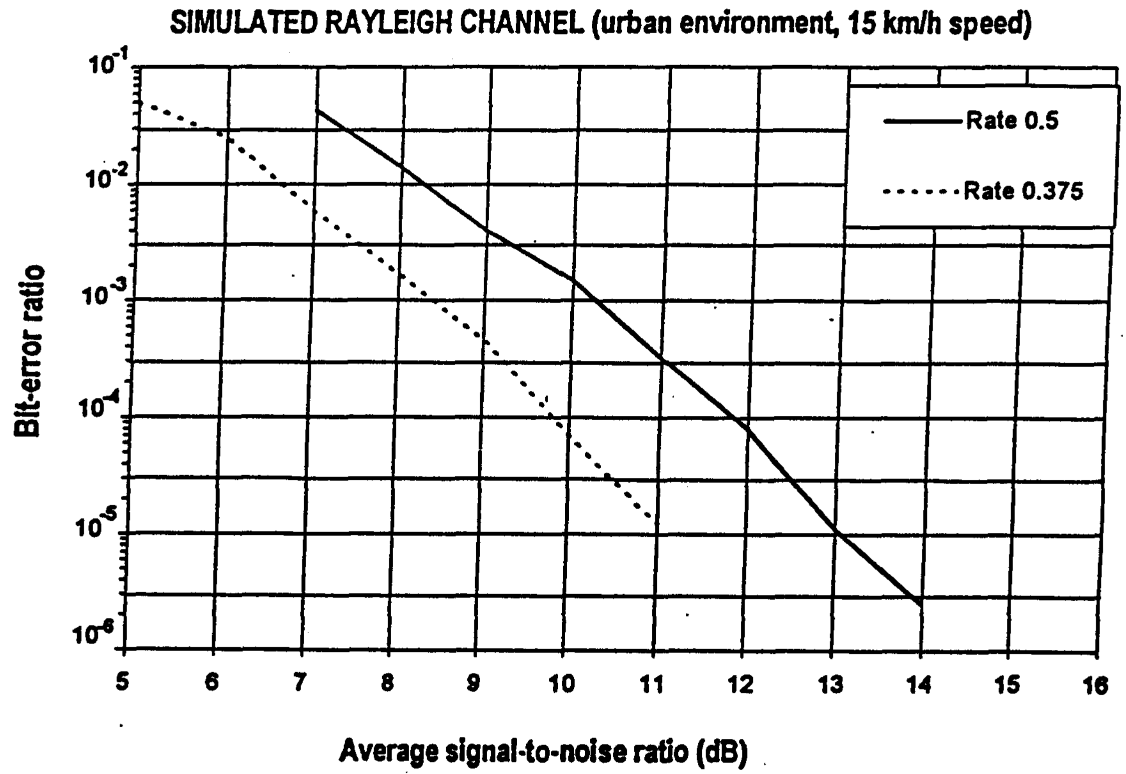


FIGURE 11

Bit-error ratio vs. signal-to-noise ratio for Digital System A (Transmission Mode 2, 1 480 MHz)

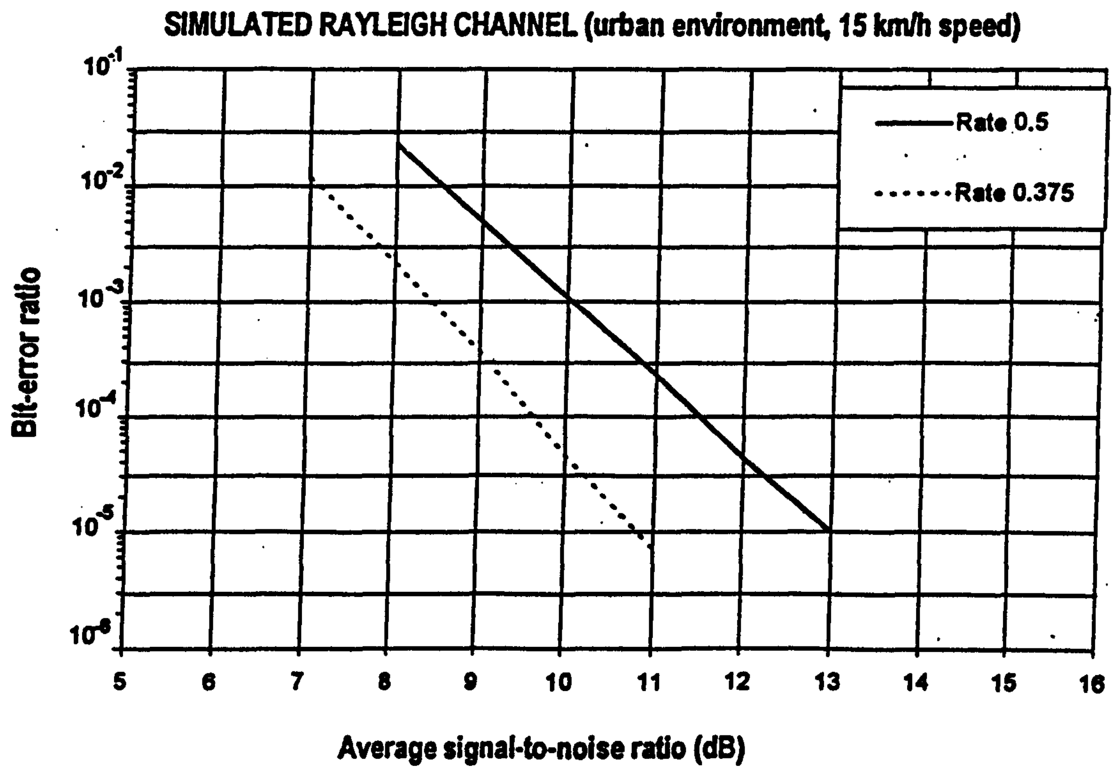


FIGURE 12

Bit-error ratio vs. signal-to-noise ratio for Digital System A (Transmission Mode 1, 226 MHz)

SIMULATED RAYLEIGH CHANNEL (rural environment, 130 km/h speed)

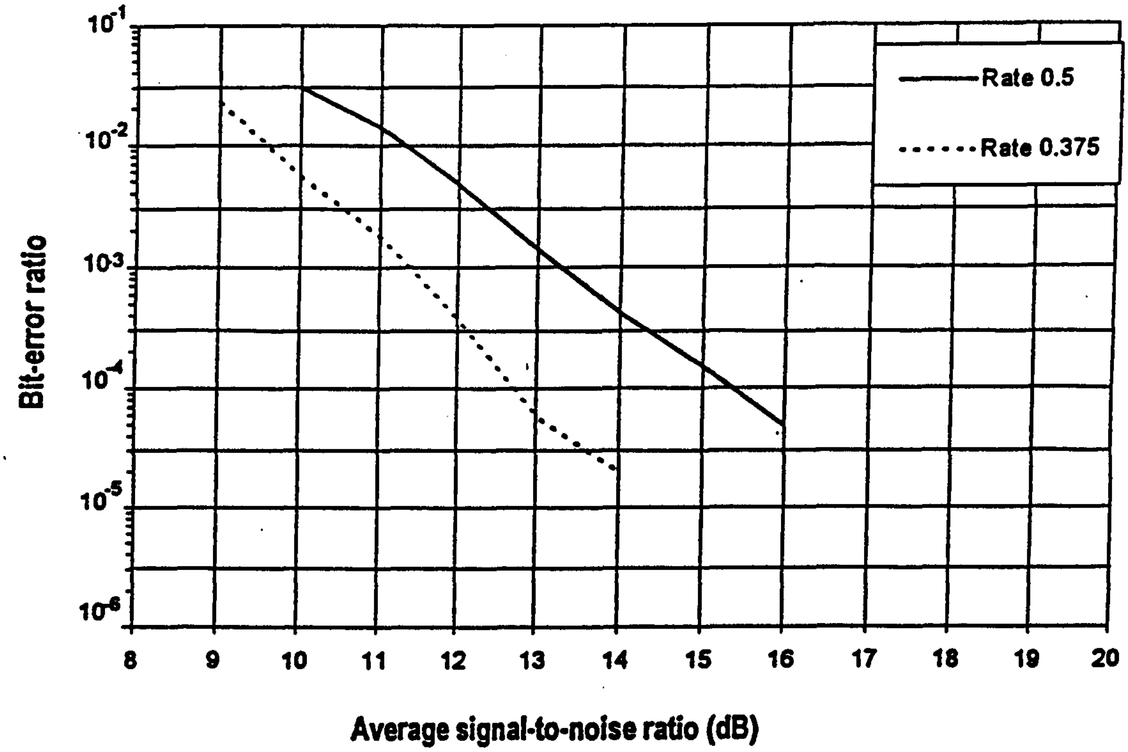
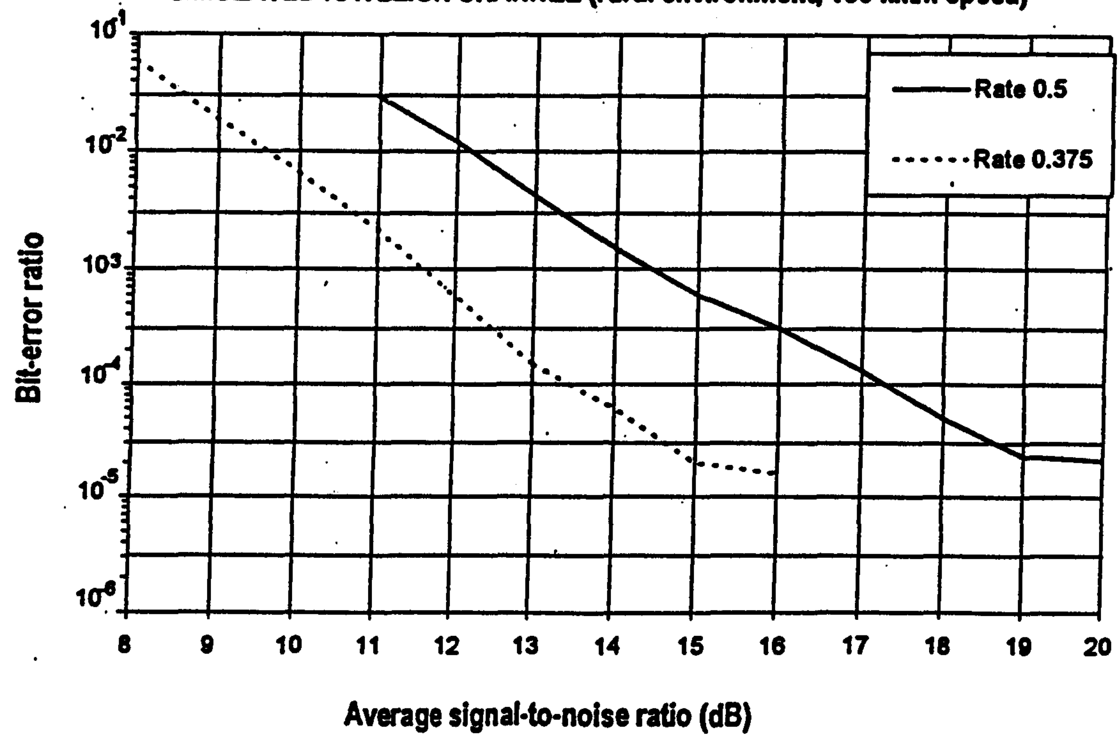


FIGURE 13

Bit-error ratio vs. signal-to-noise ratio for Digital System A (Transmission Mode 2, 1 480 MHz)

SIMULATED RAYLEIGH CHANNEL (rural environment, 130 km/h speed)



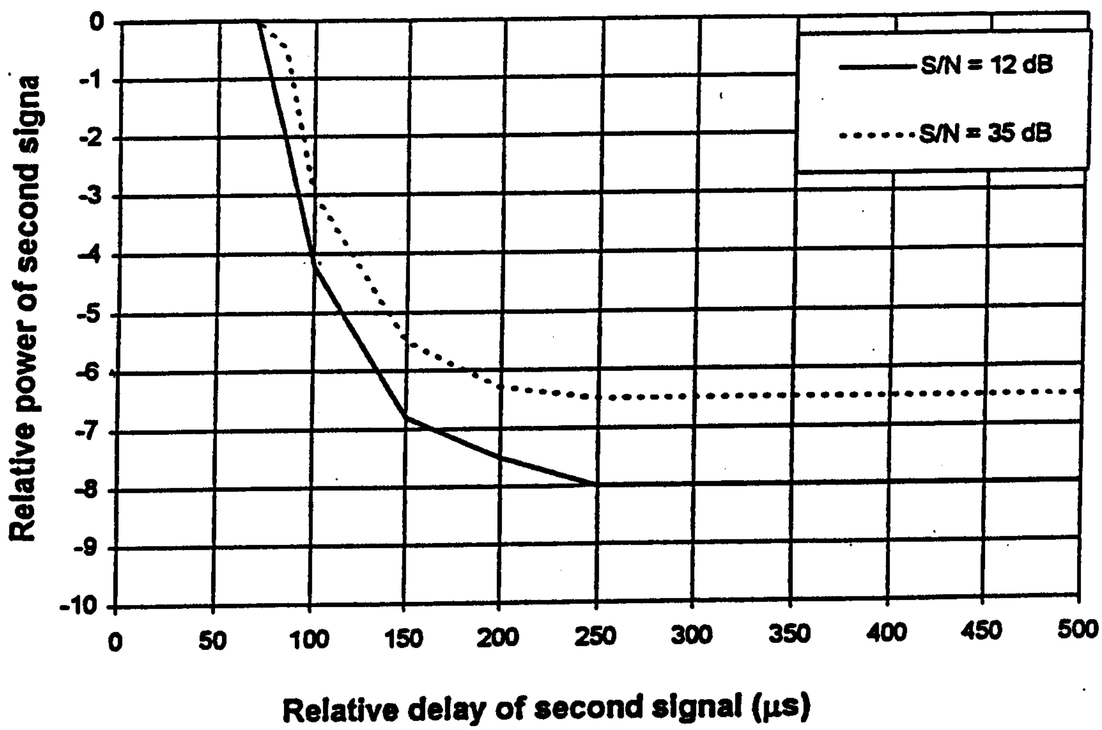
10.5 Capability for operating in single-frequency networks

A "Digital System A" signal (Transmission Mode II) was processed by a channel simulator to produce two versions of the signal; one representing the signal received over a reference, undelayed transmission path with constant power, and one representing a delayed signal from a second transmitter in a single-frequency network (or some other long delay echo). The Doppler shift applied to the second signal was compatible with the limit of the capability of Digital System A. Two sets of measurements were carried out setting the S/N of the total received signal to 12 dB and 35 dB. The relative power of the second, delayed, signal was measured for a BER of 10^{-4} in the 64 kbit/s, rate 0.5, data channel, as the delay was increased. The results are shown in Fig. 14.

The magnitude of the guard interval is 64 μs in transmission Mode 2, so the results illustrate that no impairment is caused as long as the second signal falls within the guard interval.

FIGURE 14

Example of single-frequency network capability for "Digital System A" (Transmission Mode II)



ITU-R DEVELOPMENTS

SPECIAL PUBLICATION ON DSB

SUBJECT INDEX

Françoís Conway

Mr. Conway graduated with a Bachelor's degree in Electrical Engineering from the Ecole Polytechnique, Université de Montréal in 1982. He then joined the Transmission Group of CBC Engineering in Montréal.

He has been appointed to his current position of supervising engineer in 1990 where he is involved in long term strategic planning and investigation of the impact of new technologies such as DRB, ATV, etc. on the CBC.

Mr. Conway is currently chairman of the JTCAB Group responsible for coordinating the implementation of the Canadian DRB Test Facilities and Experimental stations in L-band.

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STEVE EDWARDS, ROGERS BROADCASTING

"DIGITAL RADIO - A CANADIAN MANUFACTURING INDUSTRY OPPORTUNITY"

International Situation - Deployment

INTRODUCTION

Good afternoon, ladies and gentlemen. Gerald has asked me to brief you on the general topic of deployment of DAB technology around the world. I will look first at the status of demonstration, experimentation, and operational activity around the world followed by a discussion of the status of receiver development, and concluding with a more detailed look at what is happening in the United States.

DEMONSTRATIONS

The Eureka 147 consortium has received many requests from around the world for demonstrations of the Eu147 DAB technology. Among the higher profile countries, demonstrations are planned or have already been carried out in Tunisia, South Africa, India, China, and Japan. Such demonstrations used to be difficult, expensive, and time-consuming to carry out, but the technology is now sufficiently refined and the hardware is sufficiently compact and reliable enough to make such promotional demonstrations almost routine. Two years ago, DRRI worked with the CIRT, the Mexican private broadcasters' umbrella organization, to carry out a demonstration of the technology in Mexico City. The fact that a single 100 watt amplifier was able to provide complete coverage to a city of over 20 million people was very impressive indeed!

EXPERIMENTATION

Canada has been at the forefront of L-band DAB experimentation for several years now. In fact, the first ever broadcast transmission in the L-band was carried out in Toronto in December of 1991. Since then, we have provided to the ITU-R study groups the bulk of experimental results concerning L-band coverage planning, single-frequency networks, and optimal transmission parameters. It is accurate to say that the experimental work done in Canada was instrumental not only in the achievement of 1452 to 1492 MHz as a world spectrum allocation but also that it stimulated much earlier utilization of the L-band in France and Germany than had initially been planned. We have had experimental sites in Toronto and Montreal since 1993, we commenced operation in Ottawa last week, and Vancouver should be on the air by the end of November.

After Canada, Germany has been most aggressive in DAB experimentation in the L-band. The German government, and Deutsche Telekom are committed to achieving a terrestrial DAB network in each federal state by 1997. In support of the goal, the German government will provide 20 million D marks to subsidize the sale of an initial 8000 receivers for pilot projects in Baden Wurtenburg and Bavaria. Other pilot projects are planned for Berlin, North Rhine-Westphalia, Rhineland-Palatinate, Saxony, Saxony-Anhalt, and Thuringia. Over 100 million D marks in total has been committed to these pilot projects.

France is also active, with pilot projects in Paris and Rennes, and many other European countries such as Sweden, Norway, Holland, and the UK have established experimental sites. Finally, Australia is committed to establishing four experimental DAB sites, two sponsored by the Australian government and two by Telstra, the Australian telephone company.

In June and July of this year, very interesting experiments involving satellite services were carried out in Mexico and Australia. The experiments in each case utilized newly-launched L-band satellites intended for use for mobile communications. In both cases very encouraging results were achieved, supporting our expectation that Eureka 147 DAB technology can successfully provide mixed satellite and terrestrial services.

OPERATION

The race to be the first country to implement public DAB service was recently won by the U.K., followed very closely by Sweden.

In the UK, the BBC now covers 20% of the British population with DAB signals, and this is scheduled to increase progressively to 60% by mid 1998 and 100% by the turn of the century.

Swedish Radio commenced broadcasting virtually the same day in Stockholm, and plans to reach one-third of the population of Sweden by the middle of 1996 and 80% by mid 1997.

Canada will not be far behind. We hope to have as many as 15 to 20 broadcasters in Toronto and similar numbers in Montreal in mid 1996, providing DAB coverage to 25% of the population of Canada. In all, some 13 countries intend to implement full-time public DAB broadcasting by the end of 1996. Many others expect to have DAB service in place before the end of the century. For example, the Australian Minister of Communications recently announced that national DAB service would be available to broadcast the Sydney Olympics in the Summer of the year 2000.

RECEIVERS

All this talk of demonstration, experimentation and operation is fine, but means little without equivalent progress on DAB receivers. In fact, there is good news in this area too.

At this point, there are no less than 17 receiver manufacturers who are formally members of the Eureka 147 consortium. The list reads like the "Who's Who" of receiver manufacturers. All the big groups are there:

1. Philips
2. Thomson
3. Grundig
4. Blaupunkt
5. Becker
6. Nokia

7. Delco
8. Sony
9. Panasonic
10. JVC
11. Pioneer
12. Kenwood
13. Clarion
14. Alpine
15. NEC
16. Mitsubishi
17. Fujitsu Ten

Discussions continue with others such as Denon and Motorola. All are busy designing receivers but, typically, none is willing to discuss progress until they are ready to announce a product. Up to this point, Philips has provided most of the progress, both for silicon devices and for complete receivers. The first generation of VLSI chips, known as the JESSI chip-set, is being supplied by Philips to most of the other receiver manufacturers, while they work on their own implementations. The second generation silicon devices from Philips will appear in early 1996 and will incorporate some key improvements which arose from research conducted in Canada.

There has been an interesting sequence of receivers available to date. The first self-contained receiver, known as the third-generation receiver, cost $27,000. The current receiver, which you can see here today, the Philips 452, costs $7,000. Grundig (wholly owned by Philips) has just announced a receiver to be available this Fall at a cost of about $2,200. The Grundig receiver is notable in that it has a dash-mounted AM-FM-DAB control head with a trunk-mounted DAB chassis - much the same architecture as a typical in-car CD charger.

Current projections by a number of receiver manufacturers indicate that the first sub - $1,000 receiver will appear in late 1996 or early 1997, that power requirements will delay the walkman-size receiver until perhaps 1999, and that the total parts cost for a receiver will ultimately reach about $30 in today's terms.

Of interest to Canada, Delco representatives have said they will be building DAB receivers for the European market and that they would definitely be made available for General Motors products in Canada.

RECEIVER FEATURES

Bill Coombes will be discussing some of the new services DAB will make possible, but I would like to take a few minutes to discuss some of the receiver features that will make such new services possible.

Following is a list of some of the more important features we will be expecting in future consumer receivers:

1. LCD Screen - a small display (about 32 characters by 8 lines) for the presentation of information, the selection of services, presets, and receiver setup.

2. Data Port - a bidirectional communications port to connect to useful devices such as printers, computers, GPS terminals, and interactive devices such as cellular telephones.

3. Encryption - a standard encryption scheme is required to allow for secure coding and decoding of value-added services.

4. Addressability - each receiver must have a unique identifier code to allow for interactive or value-added services.

5. Automatic Dynamic Range Control - DAB receivers should have the ability to adjust the dynamic range of the output audio to match the dynamic range available in the listening environment, to ensure that music programming is presented in the best possible quality.

6. "Tell Me More" Button - Since it will be possible to send multiple levels of information using the primary service in conjunction with auxiliary data services, some means of first signalling the existence of secondary layers, then of choosing those layers will be needed.

7. Buffering - A large buffer memory in the receiver will allow for storage and later retrieval of desired information such as the most recent traffic report.

8. Compatibility - Full AM and FM compatibility will be needed for at least 15 years.

There are many other receiver features that are less fundamental but just as important; features such as easy set up, automatic service scanning, master reset, programmable preset buttons, small size, accessory inputs, integration with cellular telephones, voice activation, and others.

ACTIVITIES IN THE U.S.

Gerald has asked me to give you some background on the situation in the United States and to provide a current status report.

As early as 1990, DAB was identified in Canada as key to the future prosperity of radio. Early on a partnership was forged between the CAB, the CBC, and Industry Canada; a partnership that has served us well over the past five years as we have worked step by step toward the realization of the best possible DAB system.

The situation in the U.S. is very different. Because radio stations are much easier to buy and sell, broadcasters tend to be focused much more on short term issues than on the long term health of the industry. Because the FCC licences stations on the basis of channel availability rather than on the basis of economic viability, there are simply too many radio stations (twice as many per capita than in Canada). The poor technical performance of AM relative to FM has led to a drastic decline in AM listening and thus to a similar decline in its ability to compete for revenue. All of the above factors led some key FM-oriented broadcasters to view L-band DAB as a major threat to their current success, and they succeeded in forcing the NAB to drop its early support of Eureka 147 technology and to support, instead, the concept of digital radio systems contained within the current AM and FM spectrum allocations. This way they felt that current broadcasters would control the implementation of digital radio in the U.S., and that the competitive differences between AM and FM would be perpetuated.

This led to the development of a number of so-called in-band-on-channel or IBOC digital radio systems. Our view has always been that these systems would neither be technically viable in the real world of gross spectrum congestion and increasing man-made noise, nor sophisticated enough to offer the quality, reliability, and flexibility needed to compete in the coming world of digital communications. In short, the IBOC systems would offer, at best, improved quality radio services in a world that is demanding the highest quality radio services.

Compounding the problem in the U.S. is the odd fact that the U.S. government has had effectively no involvement at all in the process to date. No one is speaking for the AM broadcaster, the consumer, or future broadcasters. The only body that has become involved is the EIA, representing the receiver manufacturers. In order to protect their position by gathering unbiased comparitive data on the various systems proposed, they sponsored a testing process open to all proponents including Eureke 147. The process was to consist of two phases - an exhaustive laboratory evaluation to generate quantitative comparisons, and a wide-ranging field test to validate the laboratory data and to provide input on more subjective issues such as quality and consistency of coverage.

The laboratory phase is now essentially complete after about 18 months of effort and some 2000 pages of test results have been made public. Testing examined performance in three general areas; sound quality of the audio coder/decoder, multipath performance, and RF compatibility (both digital to analogue and digital to digital). In general, the results confirmed our longstanding expectations. There was some controversy in areas such as interpretation of the statistical results of the audio coder testing, and the models chosen for multipath simulation. However, the testing process was rigorous and so far none of the proponents has been able to refute any of the results.

To summarize the results, I am going to quote from a document prepared for distribution to CAB members by Wayne Stacey, who will be speaking later this afternoon.

> "On 24-25 August, 1995, the Electronic Industries Association (EIA) sponsored a technical workshop in Monterey CA, at which it released the results of lab tests conducted in the US on seven proponent digital radio

(DRB) systems. The key findings, as reported by technical representatives from the CAB and the CBC, are:

- The Eureka 147 System would produce results that are far superior to any of the In-Band, On-Channel (IBOC) systems with respect to audio quality, signal reliability and non-interference to existing analog services.
- Any of the FM IBOC systems would produce interference to their 'host' FM stereo services, as well as to nearby stations that operate on adjacent frequencies.
- Both AM and FM IBOC systems would have substantially-reduced service areas, compared to that of their analog 'host' stations.
- The performance of FM IBOC systems degrades considerably, even to the point of failure, in the presence of multipath.
- The AM IBOC system proposed by USA Digital cannot provide CD-Quality audio and produces impairments that expert listeners judge as "annoying".

Although some of the poor performance of the IBOC systems could be attributed to inadequate hardware implementation, there are a number of fundamental flaws in the technology itself. At the very least, much work will be required before the IBOC systems can even be considered for implementation. However, concerns by broadcasters about interference to their primary analogue services, by receiver manufacturers about market size and system robustness, and by consumers about the degree of improvement over existing analogue services all combine to make it highly unlikely that any of the IBOC systems will ever be implemented. For me personally, it is not a question of whether L-band DAB will be used in the U.S., but rather a question of when.

INTERNATIONAL SITUATION - DEPLOYMENT

INTRODUCTION

ACTIVITIES

DEMONSTRATION
EXPERIMENTATION
OPERATION

U.S. STATUS

1

INTERNATIONAL SITUATION - DEPLOYMENT

DEMONSTRATIONS

TUNISIA
SOUTH AFRICA
INDIA
CHINA
JAPAN
MEXICO

2

INTERNATIONAL SITUATION - DEPLOYMENT

EXPERIMENTATION

CANADA

- FIRST L-BAND BROADCAST
- KEY CONTRIBUTOR
- FOUR SITES

GERMANY

- SUBSIDIZED RECEIVERS
- MANY PILOT PROJECTS
- 100 MILLION D-MARKS COMMITTED

FRANCE

- PROJECTS IN PARIS AND RENNES

MANY OTHERS INCLUDING:

- SWEDEN
- NORWAY
- HOLLAND
- U.K.
- AUSTRALIA
- MEXICO

3

INTERNATIONAL SITUATION - DEPLOYMENT

OPERATION

U.K.

- OPERATIONAL SEPTEMBER 25, 1995
- 20% OF POPULATION COVERED INITIALLY
- 60% MID 1998
- 100% 2000

SWEDEN

- OPERATIONAL (STOCKHOLM) SEPTEMBER 25, 1995
- 33% OF POPULATION COVERED BY MID 1996
- 80% MID 1997

CANADA

- OPERATIONAL MID 1996
- TORONTO AND MONTREAL INITIALLY

TEN OTHER COUNTRIES BY END OF 1996

4

INTERNATIONAL SITUATION - DEPLOYMENT

RECEIVERS

17 MANUFACTURERS HAVE JOINED EU147

PHILIPS	DELCO	CLARION
THOMSON	SONY	ALPINE
GRUNDIG	PANASONIC	NEC
BLAUPUNKT	JVC	MITSUBISHI
BECKER	PIONEER	FUJITSU TEN
NOKIA	KENWOOD	

OTHERS PENDING

DENON MOTOROLA

5

INTERNATIONAL SITUATION - DEPLOYMENT

RECEIVERS

THIRD GENERATION	COST	-	$27,000
FOURTH GENERATION	COST	-	$ 7,000
FIFTH GENERATION	COST	-	$ 2,200
SIXTH GENERATION - END 96		-	$ 1,000
PARTS COST-MATURE			$ 30

6

INTERNATIONAL SITUATION - DEPLOYMENT

RECEIVER FEATURES

LCD SCREEN

DATA PORT

ENCRYPTION

ADDRESSABILITY

AUTOMATIC DYNAMIC RANGE CONTROL

"TELL ME MORE" BUTTON

BUFFERING

COMPATIBILITY

OTHERS

7

INTERNATIONAL SITUATION - DEPLOYMENT

U.S. STATUS

BACKGROUND

- VERY DIFFERENT SITUATION
- SHORT-TERM THINKING
- OVER-LICENSING
- AM IN DECLINE
- L-BAND DAB SEEN AS THREAT

IBOC

- DIGITAL AND ANALOG SHARE SAME SPECTRUM
- BROADCASTERS IN CONTROL
- AM/FM DIFFERENCES PERPETUATED

VIEW FROM CANADA

- IBOC NOT VIABLE IN REAL WORLD
- IBOC SETS BAR TOO LOW

INTERNATIONAL SITUATION - DEPLOYMENT

U.S. STATUS

EIA TESTING PROCESS

- OPEN TO ALL PROPONENTS
- LABORATORY PHASE
- FIELD TEST PHASE

LABORATORY TEST RESULTS

- 18 MONTHS WORK
- 2000 PAGES OF DATA
- SOME CONTROVERSY
- EUREKA PERFORMED WELL
- IBOC PERFORMED POORLY

FUTURE OUTCOME

- FURTHER IBOC DEVELOPMENT REQUIRED
- ULTIMATE DEPLOYMENT DOUBTFUL
- USE OF EUREKA IN L-BAND INEVITABLE

9

Steve Edwards

Mr. Steve Edwards graduated in Electrical Engineering from the University of British Columbia in 1970 and subsequently received an M. Sc. degree from the University of Wales.

Following his return to Canada, Steve gained extensive experience in all engineering aspects of radio and television first as a Consulting Engineer and latterly as Vice-President, Corporate Engineering for Rogers Broadcasting Limited.

Steve is also widely involved in industry activities including being a Director of the Canadian Association of Broadcasters, and Chairman of the CAB's Engineering and Technology Council.

His industry activities have included close involvement in all national and international aspects of Digital Radio Broadcasting over the past six years, including being a member of both the CAB and NAB Digital Radio Committees and Canada's representative on the Eureka 147 Programme Board.

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"DIGITAL RADIO: A Canadian Manufacturing Industry Opportunity"

DRB Seminar, October 27, 1995
Colonel By Room, Ottawa Congress Centre

An Address by Bill Coombes, Digital Radio Chair, Canadian Association of Broadcasters

When today's seminar was being planned, it wasn't exactly clear who might attend. Who is here? Is it the same old suspects or are some of you quite new to the Digital Radio scene?

I hope some of you are entrepreneurs. We are at the stage where we need more entrepreneurs. In fact, this is what I call the third phase in the DR process. The first was the Technology phase.....but we know it works....we've known that for a long time. So we have a technology.....and it really is quite an amazing system. The second phase was, what I call, the Regulartory phase..... when government and the regulator developed a policy and licencing approach.....but that's petty well a done deal. And so, we come to the third and, what I believe is the most important phase....and that's the Implementation phase. We've got something wonderful.....and the basis on which we can use it..... now what are we going to do with it?

I have to thank Steve Edwards for being so cooperative. Gerald sent us each a speech outline for today.....and I noticed that Steve was also being asked to comment on the Canadian situation. So I called him and suggested that we coordinate our presentations. It was rather amusing when he faxed me a copy of his speech.....it was almost the same as my speech. I could just imagine coming into this room late, following Steve and giving practically the same speech. Known forever as Steve's little echo.

So, I changed my speech. And I want to concentrate on the extent of the broadcaster's commitment to Digital Radio.....and why we are so committed.

I have to reflect back, briefly, on our accomplishments, as Steve did. Because they demonstrate our determination. We have done everything possible to control and influence the DR agenda since 1989. And we've done remarkably well. The Digital Demos, the tests at L-Band, the WARC-92 victory, the creation of DRRI, permanent transmitters in major Canadian cities and a start on consumer awareness. Canada has been the leading force behind the transition to digital outside of Europe. When it comes to Digital Radio any notion of Canadian inferiority does not apply. The cooperative effort of both the private and public sector, along with government, has led to accomplishments that are disproportionate to our size and has enhanced our influence. We've taken a uniquely Canadian approach.....and it's worked incredibly well.

**So, why are broadcasters so committed? Well, it comes from having your backs against the wall. We've been in survival mode for a number of years.....in pretty tough economic times. And we realized that if we are to have any kind of future.....we must diversify. Our single revenue stream is too unpredictable and we must seek new business opportunities. That's what Digital Radio allows us to do. That's why we are not following the U.S.
Which may seem strange. But, their circumstances are very different and they have decided to pursue a course that will provide very limited opportunities....if any at all. This is maybe the boldest aspect to the Canadian approach....that it is different from the Americans. But you have to remember a couple of things. We still intend to operate an analogue system for a very long time and the digital receivers will pick up existing AM and FM stations as well as digital so listeners will not be inconvenienced in any way. The Canadian communications industry has always been innovative and it is appropriate that we sometimes do things differently than our friends to the South**

I believe that we are literally re-inventing radio. There are so many possibilities. With a system that is addressable and encryptable....you can, all of a sudden, have subscriber supported services.....specialty pay services that can be narrowly focused. Today radio stations provide their listeners with constant information.....with DR we will have new, consumer friendly ways to deliver timely surveillance information, weather, traffic and emergency messages. Because the automotive sector is well advanced in receiver development, it is likely that many of the first digital receivers will be in your car.....and so it makes sense that radio will play a big part in any Intelligent Vehicle Highway System. IVHS of ITS is a natural use of the GPS and surveillance capabilities of Digital Radio. And the receiver will be integrated with other devises....such as a cell phone and personal computers. This will give us interactivity and additional storage capacity. The consumer will be able to capture and time shift programs. The 'Tell me More' button will provide additional information. This will be a natural extension of the information services that we offer now.

Then there are new, unrelated business opportunities. All types of datacasting, including paging, electronic billboards, energy management, security systems, inventory control, downloading of data.....possibly software or updates to databases such as electronic yellow pages of transportation and traffic management.

We need new revenue sources.....new businesses. And, datacasting is vital to our future. It is the prospect of these new ventures that will attract the capital and justify the investment that our industry is about to make. We won't be doing this by ourselves. We will be forming alliances.....some of them quite non-traditional. You will see more cooperation between competitors. It will take our combined effort to make some of this activity viable. Some additional datacasting activity will soon start, even in analogue. We must develope an expertise in some of these new business areas. The opportunities will only expand with the additional capacity of digital.

And we must have a well developed strategy for the balance of phase three. The Implementation Phase. Our Association is putting in place a roll-out coordination team which will keep the industry fully up-to-date and assist, wherever possible, with strategies in specific markets. We also hope to develope a major, joint marketing plan by working with consumer receiver manufacturers. We need a launch strategy which will have significant impact on consumers and this must be done in close cooperation with receiver manufacturers and retailers. Although most major manufacturers have full access to the specifications of the Eureka-147 technology, we do not anticipate reasonably priced, integrated Digital car receivers until well into 1997. However, competitive forces along with technology advances could speed this up.

Nevertheless, we must assume that there will not be a significant receiver penetration for several years. And so it is understandable that some people think we are nuts to proceed where there is uncertainty. I believe it is just another aspect that requires our combined commitment to overcome. We need a computer card for Digital Radio. In fact, they now exist....and can give us access to millions of Canadian personal computers. Ultimately it is through computers that people will receive most of their communications anyway.....so we might as well get started.

We have been successful in obtaining the right policy framework from government and a licencing model from the CRTC. The Eureka-147 technology will soon be confirmed as both a Canadian and World standard. Industry Canada has released a draft allotment plan for DR frequencies. These developments put Canadian broadcasters in a position to start commercial service in 1996. Several broadcasters are likely to start transmitting in digital next year for strategic reasons and to experiment with new applications that conditional access and the data transmission capacity of DR make possible. Our experimental transmitters in the top four markets will cover 35% of the Canadian population. This percentage could rapidly rise to 50% by adding just the next six markets.

Digital Radio is happening in Canada.....as it is in most of the world. The radio industry will be transformed by digitization. We will become bits broadcasters and will stand alongside every other communications sector delivering all manner of data.....some of which will be translated into audio.... but much of which could be anything else. Our success will depend on our efficient use of the bandwidth made available to us. It will be enhanced by some of the qualities that digital radio affords. It is unique in its flexibility and is a great system for point to multi-point communications and for mobile reception. In planning its introduction, we have managed to resist the inclination that we should compromise tomorrow's technology in order to protect what we have today. There has been very little compromise. The Canadian proponents see this as a tremendous chance to raise radio's prospects to a much higher level.

I couldn't be more excited about the future prospects for our industry. I hope that other, associated industries will also benefit from all of this activity. Any advances that we make here in Canada are very exportable. The Eureka-147 consortium may be based in Europe.....but there are many opportunities to support and enhance what they are doing. I believe that is often what Canadians do best.

If you have any questions, I would be pleased to try and answer them.
Thank you very much.

Bill Coombes

Mr. Coombes is President and CEO of Fraser Valley Radio Group which operates radio stations in British Columbia.

He is immediate past joint Chair of the Canadian Association of Broadcasters (CAB) and continues to chair the CAB Radio Committee.

He has been involved with all aspects of the CAB digital radio work since it began in 1989.

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DRB PLANNING & REGULATORY MATTERS

- GAZETTING OF DRB SYSTEM STANDARD
- GAZETTING OF TERRESTRIAL DRB ALLOTMENT PLAN
- APPROACH FOR INTRODUCTION OF DRB (CRTC Notice 1995-95)

10/27/95

CANADIAN DRB SYSTEM STANDARD

- *GAZETTE NOTICE **SMBR-003-95** ISSUED JULY 28, 1995 PROPOSES THE ADOPTION OF **EUREKA-147 (DAB) SYSTEM** FOR DRB IN CANADA IN THE **1452-1492 MHz** BAND.*

- *SYSTEM CHARACTERISTICS DESCRIBED IN ANNEXES OF RECOMMENDATIONS*

- *ITU-R RECOMMENDATIONS **BS .1114** & **BO.1130** RECOMMEND EUREKA-147 (DIGITAL SYSTEM A) AS A WORLD STANDARD*

- *DETAILED SYSTEM SPECIFICATION IN ETSI **ETS 300 401** STANDARD.*

10/27/95

CANADIAN DRB SYSTEM STANDARD (Cont)

➡ *SYSTEM CAPABILITIES:*

- *CD quality reception to Mobile & Fixed receivers;*
- *Operational frequency range of 30-3000 MHz;*
- *Operational over satellite and terrestrial facilities;*
- *Use of on-channel repeaters;*

➡ *SYSTEM PERFORMANCE EXTENSIVELY DEMONSTRATED;*

➡ *BROADCASTERS FULLY SUPPORT ITS ADOPTION AS DRB STANDARD;*

10/27/95

T-DRB ALLOTMENT PLAN

- *DRAFT PLAN GAZETTED SEPT. 16, 1995 [NOTICE **SMBR-004-95**];*
- *PLAN BASED ON:*
  - *EUREKA-147 (DAB) SYSTEM;*
  - *Implementation in the **1452-1492 MHz** Band;*
  - *Planning Principals Based On Recommendations of **Government/Industry DRB Task Force** Regarding:*
    - *DRB to be a **replacement** service;*
    - ***Duplication** of existing coverage;*
    - *Coverage/Performance based on **Mobile** Reception;*
    - *Provision for:*
      - ◆ *Future growth;*
      - ◆ *Ancilliary Data Services;*
      - ◆ *Future Satellite Service;*

DRB ALLOTMENT PLAN (CONT)

ELEMENTS OF THE PLAN:

- *40 MHz of spectrum divided into 23 DRB Channels;*
- *Each DRB Channel can accommodate five AM or FM Stations plus Ancilliary Services;*
- ***D**RB **S**ervice **A**rea (**DSA**)*
- *Each DSA consists of:*
  - *specified geographical coverage area;*
  - *grouping of up to five AM/FM Stations;*
  - *a **F**requency **R**euse **C**ontour (**FRC**);*
  - *a DRB channel (frequency) assignment;*
- *Identification of Fixed Systems that could be affected by implementation of a DRB Allotment (DSA);*

T-DRB ALLOTMENT PLAN (Cont)

DRAFT PLAN RESULTS

The Draft Plan Accommodates:

➡All Regular and Low Power AM and FM Stations;

➡All AM and FM unused allotments;

➡Future growth in most areas;

➡A future complementary satellite service;

T-DRB ALLOTMENT PLAN (Cont.)

COORDINATION WITH THE USA

➡*USA USE THE L-BAND FOR MOBILE AERONAUTICAL TELEMETRY (MAT)*

➡**POTENTIAL FOR UNACCEPTABLE INTERFERENCE OCCURING FROM:**

- *T-DRB EMISSIONS INTO MAT RECEIVERS;*
- *MAT EMISSIONS INTO T-DRB RECEIVERS;*

➡**FIRST COORDINATION MEETING HELD IN AUGUST**

DRB LICENSING

PUBLIC NOTICE CRTC 1995-95

- **Issued June 14, 1995;**
- **Proposes two-stage licensing approach:**
  - **Short term licensing of Experimental DRB stations (3 years);**
  - **Hold a Public Hearing to address issues of:**
    - ***Ownership;***
    - ***New Services;***
    - ***Technical Issues;***
    - ***Regulations;***
  - **Establish a long term DRB licensing procedure;**
- **Comment period ended July 17, 1995; Decision expected before end of 1995;**

GOVERNMENT NOTICE

DEPARTMENT OF INDUSTRY

RADIOCOMMUNICATION ACT

Notice No. SMBR-003-95

Adoption of a System Standard for Digital Radio Broadcasting (DRB) In Canada

The purpose of this Notice is to propose the adoption of the EUREKA-147 (DAB) system for digital radio broadcasting in Canada in the band 1452-1492 Megahertz.

Digital compact disk and tape sound reproduction systems have led consumers to also expect very high quality sound from radio broadcasting systems. Although AM and FM broadcasting systems can provide adequate service to most stationary receivers, frequency congestion, multipath and interference are making it increasingly difficult to deliver high quality sound to mobile or portable receivers. In order to meet higher quality expectations, broadcasters around the world have decided that a new digital sound broadcasting system is needed. Such a system should be designed at the outset to meet enhanced quality as well as provide innovative features possible with digital techniques.

The 1992 World Administrative Radio Conference (WARC-92) allocated the frequency band 1452-1492 MHz on a world-wide basis to the terrestrial broadcasting service and the satellite-broadcasting service for the provision of digital radio broadcasting (DRB). Development work in Europe, which started in the eighties, resulted in the EUREKA-147 (DAB) system being adopted by the European Telecommunications Standard Institute (ETSI) as the ETS 300 401 Standard. This system has also been recommended world-wide for digital radio broadcasting by Sound Broadcasting Study Group 10 of the International Telecommunications Union. It's formal adoption by the Union for terrestrial and satellite DRB is expected in October.

EUREKA-147 (DAB) is a wideband system designed to provide high-quality digital radio broadcasting and data services to mobile, portable and fixed receivers at frequencies below 3 GHz. Field tests and demonstrations in Canada, Europe, Australia and other countries have shown the system to be highly spectrum and power-efficient for the provision of terrestrial DRB services in stationary and mobile environments. In Canada, extensive studies and field tests of the characteristics and performances of the EUREKA-147 (DAB) system were undertaken by industry and government experts over the past few years. Stations were established in Montreal and Toronto for experimentation and demonstration purposes. An industry/government task force on digital radio was established, and it provided comprehensive recommendations on a policy and licensing framework for its introduction into national service.

In addition, Canadian industry and government officials have cooperated with other countries in demonstrating the system, in exchanging technical information and carrying out joint studies.

All these activities have confirmed that the EUREKA-147 (DAB) system meets the needs of the Canadian broadcasting system for a high quality digital radio service. The broadcasting industry in Canada has endorsed this conclusion and has asked that the EUREKA-147 (DAB) system be adopted as the DRB standard for Canada in the 1452-1492 MHz band.

The intention is that AM and FM terrestrial broadcasting services will migrate to the new digital service over time. The data transmission capability of the digital service will make possible innovative enhancements to broadcasting. It is expected that the same system will be used for satellite DRB when the need arises for a complementary satellite/terrestrial service in the future.

The essential characteristics of the EUREKA-147 (DAB) system are described in the Revised Recommendation ITU-R BS 1114 Annex 1 (Digital System A) - Ref. ITU-R Document No. 10/21 dated December 12, 1994, ITU, Geneva. Copies of this document may be obtained from: Industry Canada, Publishing Services Centre, 300 Slater Street, Ottawa, Ontario, K1A 0C8, or from regional offices in Vancouver, Winnipeg, Toronto, Montreal and Moncton.

Interested parties may submit comments on this proposal to the Director General, Spectrum Engineering Branch, Department of Industry, 300 Slater Street, Ottawa, Ontario, K1A 0C8, or at the internet address ***broadcast.gazette@ic.gc.ca***.

Comments should be submitted no later than 60 days from the date of publication of this notice. Comments received will be made available on written request to the Director General.

Dated at Ottawa this 28th day of July 1995.

G.R. Begley

Director General

Spectrum Engineering Branch

INDUSTRY CANADA

RADIOCOMMUNICATION ACT

Notice No. SMBR-004-95—Draft Allotment Plan for Terrestrial Digital Radio Broadcasting (DRB)

Introduction

Industry Canada announces the publication of a *Draft Allotment Plan for Terrestrial Digital Radio Broadcasting* for stations operating within the 1452 to 1492 MHz frequency band (L-band) using the EUREKA 147 (DAB) system.

The EUREKA 147 (DAB) system is a wide-band digital transmission technology proposed for adoption in Canada as an eventual replacement for existing AM and FM analog sound broadcasting. This system was the subject of *Canada Gazette* SMBR-003-95, *Adoption of a System Standard for Digital Radio Broadcasting (DRB) in Canada*, which was published on August 5, 1995.

DRB Allotment Plan Strategy

The Draft Allotment Plan is based on principles developed in government/industry discussions following the world-wide allocation of the 1452 to 1492 MHz frequency band for DRB at the 1992 World Administrative Radio Conference (WARC-92). These include the following, which were taken into account to the extent possible in the development of the Draft Allotment Plan:

—DRB should be introduced as a replacement service to AM and FM services.
—For FM stations, the plan should accommodate DRB facilities which will provide for the replacement of their existing coverage and have the potential to expand to the highest class of FM station in the community.
—For wide-coverage AM stations, the plan should accommodate stereophonic DRB facilities equivalent to the highest class of FM station in the community. For limited coverage AM stations, the plan should permit the replacement of existing coverage, with potential to expand to the highest class FM station in the community.
—Coverage should be based on service in more than 90 percent of locations, 90 percent of the time for mobile reception.
—Provision should be made for additional terrestrial DRB services.
—Provision should be made for ancillary services.
—Provision should be made for a future satellite component.
—Systems in the fixed service should be taken into account to the extent possible.

DRB Plan—Description

The 40 MHz of available spectrum was divided into 23 DRB channels. Each DRB channel can accommodate up to five CD-quality stereophonic programs and ancillary data. Up to five existing AM and /or FM broadcasters are grouped together to share the same transmitting facility.

The Plan includes:

—DRB service areas and groupings for existing AM and FM stations

INDUSTRIE CANADA

LOI SUR LA RADIOCOMMUNICATION

Avis n° SMBR-004-95 — Projet de plan d'allotissement pour la radiodiffusion audionumérique (DRB) terrestre

Introduction

Industrie Canada annonce la publication d'un *Projet de plan d'allotissement pour la radiodiffusion audionumérique (DRB) terrestre*, applicable aux stations qui sont exploitées dans la bande des fréquences de 1452 à 1492 MHz (bande L) au moyen du système EUREKA-147 (DAB).

Le système EUREKA-147 (DAB), faisant appel à une technologie de transmission numérique à large bande, est proposé aux fins d'adoption au Canada, en remplacement de la radiodiffusion sonore analogique AM et FM existante. Ce système a fait l'objet de l'avis SMBR-003-95 dans la *Gazette du Canada*, *Adoption d'une norme pour le système de radiodiffusion audionumérique (DRB) au Canada*, qui a été publié le 5 août 1995.

Stratégie du plan d'allotissement pour la DRB

Le projet de plan d'allotissement pour la DRB repose sur les principes établis au cours des discussions entre le gouvernement et l'industrie qui ont fait suite aux attributions mondiales dans la bande des fréquences de 1452 à 1492 MHz, établies pour la DRB à la Conférence administrative mondiale des radiocommunications de 1992 (CAMR-92). Ces principes, qui sont entrés en ligne de compte dans l'élaboration du projet de plan d'allotissement, comprennent les suivants :

— La DRB doit être implantée en remplacement des services AM et FM.
— Dans le cas des stations FM, le plan doit prévoir des installations DRB assurant le remplacement de la couverture existante et offrant des possibilités de passage à la classe supérieure de stations FM dans la communauté.
— Dans le cas des stations AM à couverture étendue, le plan doit comporter des installations DRB stéréophoniques équivalant à la classe supérieure de stations FM dans la communauté. Dans le cas des stations AM à couverture limitée, le plan doit permettre le remplacement de la couverture existante et offrir des possibilités de passage à la classe supérieure de stations FM dans la communauté.
— La couverture doit se fonder sur un service dans plus de 90 p. 100 des emplacements, 90 p. 100 du temps pour la réception des systèmes mobiles.
— La possibilité de services DRB terrestres supplémentaires doit être prévue.
— La possibilité de services auxiliaires doit être prévue.
— La possibilité d'une future composante à satellite doit être prévue.
— Dans la mesure du possible, on devra tenir compte des stations appartenant aux services fixes.

Plan DRB — Description

La plage de fréquences disponible de 40 MHz a été divisée en 23 canaux DRB. Chaque canal DRB peut servir à transmettre jusqu'à cinq émissions stéréophoniques de qualité CD ainsi que les données connexes. Jusqu'à cinq radiodiffuseurs AM et/ou FM existants sont regroupés pour partager les mêmes installations émettrices.

Le plan traite des aspects suivants :

— zones de service DRB et regroupements pour les stations AM et FM existantes

—frequencies for each of the DRB service areas

—frequency re-use contours for the DRB service areas

—identification of fixed systems impacted by DRB

As usual allotments near the border area will need to be coordinated with the United States. Industry Canada has started discussions with U.S.A. officials in this regard.

Further Information

Copies of the *Draft Allotment Plan for Terrestrial Digital Radio Broadcasting (DRB)* may be obtained from the Publishing Services Centre, DOSP-P, 300 Slater Street, Ottawa, Ontario K1A 0C8, or from the Department's regional offices in Vancouver, Winnipeg, Toronto, Montréal and Moncton.

Submission of Comments

Interested parties may submit comments concerning the *Draft Allotment Plan for Terrestrial Digital Radio Broadcasting* to the Director General, Spectrum Engineering Branch, Industry Canada, 300 Slater Street, Ottawa, Ontario K1A 0C8, or at the Internet address *broadcast.gazette@ic.gc.ca* in the case of E-mail submissions.

Comments should be postmarked no later than 90 days from the date of publication of this notice. Comments received will be made available on written request to the Director General.

September 7, 1995

G. R. BEGLEY
Director General
Spectrum Engineering Branch
[37-1-o]

— fréquences pour chaque zone de service DRB

— contours de réutilisation des fréquences pour les zones de service DRB

— détermination des systèmes fixes touchés par la DRB

Comme d'habitude, les allotissements près de la région frontalière devront faire l'objet de coordination avec les États-Unis. Industrie Canada a entamé des discussions à ce sujet avec les représentants des États-Unis.

Autres renseignements

On peut obtenir des exemplaires du *Projet de plan d'allotissement pour la radiodiffusion audionumérique (DRB) terrestre* en s'adressant au Centre de services de publication, DOSP-P, 300, rue Slater, Ottawa (Ontario) K1A 0C8, ou aux bureaux régionaux du Ministère situés à Vancouver, à Winnipeg, à Toronto, à Montréal et à Moncton.

Présentation d'observations

Les intéressés sont invités à faire parvenir leurs observations sur le *Projet de plan d'allotissement pour la radiodiffusion audionumérique (DRB) terrestre* au Directeur général, Génie du spectre, Industrie Canada, 300, rue Slater, Ottawa (Ontario) K1A 0C8, ou à l'adresse Internet *broadcast.gazette@ic.gc.ca* pour les observations présentées par courrier électronique.

Les observations doivent être envoyées au plus tard 90 jours après la publication du présent avis. Les observations reçues seront mises à la disposition des intéressés qui en auront fait la demande par écrit au directeur général.

Le 7 septembre 1995

Le directeur général
Génie du spectre
G. R. BEGLEY
[37-1-o]

Industry Canada

DRB Plan
September, 1995
Draft 2

Spectrum Engineering Branch

Draft Allotment Plan for Terrestrial Digital Radio Broadcasting (DRB)

Canada

Aussi disponible en français - Plan DRB

PREAMBLE

1. Introduction

In 1992, the World Administrative Radio Conference (WARC-92) allocated the frequency band 1452-1492 MHz (L-Band) to the broadcasting and the broadcasting satellite services, for digital audio broadcasting.

Subsequently, in September 1992, a government/industry Task Force was created by the Minister of Communications and was given the mandate to provide advice and make recommendations on a broad range of issues related to the introduction of DRB in Canada. The Task Force established two Working Groups, one to deal with matters related to coverage and service, and the other to deal with policy/regulatory issues. The Working Groups produced two reports - *Non-Technical Coverage and Service Area Issues* and *Non-Technical Policy and Regulatory Issues*. These reports contain principles intended to offer guidance in planning the introduction of DRB.

In August 1995, a Canada Gazette Notice No. SMBR-003-95 was published, proposing the adoption of the EUREKA-147 (DAB) system as the standard for digital radio broadcasting in the L-Band. The next element required towards implementation of the new DRB service is a national Channel Allotment Plan, the first draft of which is presented herein. A comprehensive plan of this type could only be developed by making a number of assumptions about how the new service will develop in each radio market. For example, the proposed DRB technology requires that transmitters be shared by several local licensees and assumptions had to be made concerning suitable station groupings. It is recognized that future adjustments to the plan may be required in certain areas for regulatory, technological developments and/or business reasons. Such changes will be accommodated on a case by case basis, so long as the overall integrity of the plan is not compromised.

2. Development of the Draft DRB Allotment Plan

2.1 Planning Principles

The planning principles enunciated by the Task Force, which were prepared in consultation with Working Groups of the Joint Technical Committee on Advanced Broadcasting (JTCAB), included the following:

- DRB should be introduced as a replacement service to AM and FM services
- for FM stations, the plan should accommodate DRB facilities which will provide for replacement of their existing coverage and have the potential to expand to the highest class of FM station in the community
- for wide-coverage AM stations, the plan should accommodate stereophonic DRB facilities equivalent to the highest Class of FM station in the community. For limited coverage AM stations, the plan should permit replacement of existing coverage, with potential to expand to the highest class FM station in the community
- provision should be made for additional terrestrial DRB services
- there should be provision for ancillary services
- provision should be made for a satellite component

To the extent possible, these principles were taken into account in the development of the attached Draft Allotment Plan.

Throughout the process of planning, the Spectrum Engineering Branch of Industry Canada kept in close consultation with representatives of the Canadian Broadcasting Corporation and the Canadian Association of Broadcasters as well as with other members of the JTCAB working groups.

2.2 The Plan

The Draft Plan makes provision for a digital radio service for each existing AM and FM station (including low and very low power) as well as for AM and FM allotments and some additional services. The target was to reach the mobile receiver which operates in the most critical receiving environment. Initially, the terrestrial DRB service will simulcast the programs of the existing AM and FM stations which will be phased out at an appropriate time in the future.

The 40 MHz between 1452 and 1492 MHz has been divided into 23 DRB channels with a guard band of 200 kHz between adjacent channels and a 159 kHz guard-band at the band edges. The channels have been numbered from 1 to 23 with centre frequencies as tabulated below:

DRB Channel	Frequency	DRB Channel	Frequency	DRB Channel	Frequency
1	1452.926	9	1466.798	17	1480.670
2	1454.660	10	1468.532	18	1482.404
3	1456.394	11	1470.266	19	1484.138
4	1458.128	12	1472.000	20	1485.872
5	1459.862	13	1473.734	21	1487.606
6	1461.596	14	1475.468	22	1489.340
7	1463.330	15	1477.202	23	1491.074
8	1465.064	16	1478.936		

The listings in the attached Draft Plan have an entry for each existing broadcasting station or allotment in the ten Canadian provinces. Due to time constraints, stations and allotments in the Territories were not included in this Draft Plan, however, with the large distances between population centres and broadcasting stations in the north, there will be no shortage of available channels for DRB. The plan is sorted alphabetically by province and then by city name.

There are two characteristics of the EUREKA-147 (DAB) system proposed for adoption which require explanation to facilitate understanding the implementation of this form of digital radio. In order to alleviate multipath effects, particularly for mobile reception, the data in a DRB channel is distributed over 1.5 MHz bandwidth. This channel can accommodate five stereophonic programs with CD-quality and will also have capacity for ancillary services. This is reflected in the attached Draft Plan where up to 5 existing AM and/or FM broadcasters are grouped together to share the same transmitting facility.

Another characteristic that affects implementation allows the use, without interference, of low power on-channel repeaters within service areas to fill gaps in coverage, the use of on-channel repeaters near the periphery of a service area to extend coverage, and Single Frequency Networks to provide a service area of virtually any size or shape. This flexibility allows systems to be implemented in phases, starting with a single transmitter covering the core market within the DRB service area and expanding coverage at a later date.

The following methodology was generally used in the development of the allotment plan:

- the 0.5 millivolt/metre contour of each existing FM station was recalculated using digitized topographical terrain data, where available, in order to determine a more realistic contour. For AM stations, the measured 0.5 millivolt/metre daytime contours were used.

- up to 5 existing stations or allotments with similar coverage areas were placed in a group and given a unique **Group ID**. AM stations with wide area coverage were treated as if they were FM stations of the highest class in the community. All existing assignments including those with low power were accommodated as well as all existing allotments.

- a replacement Digital Service Area (DSA) was determined for each **Group**, approximating the coverage of the AM/FM stations forming that **Group**.

- a DRB coverage area approximating each **DSA** was synthesized using an assumed ensemble of transmitters with appropriate operating parameters. The coverage target was 90% of the locations within the **DSA** for 90% of the time at a receive antenna height of 1.5 metres. This receive antenna height is suitable for reception in automobiles.

- a Frequency Reuse Contour (FRC) was generated for each **DSA** based on each ensemble of transmitters. The **FRC** was not allowed to overlap more than 1% of another **DSA** allotted the same DRB channel. The **FRC** has a value of 42 dB above 1 μVolt/metre, not to be exceeded at more than 10% of the locations, 10% of the time.

- the **FRC** and **DSA** are essential elements in the allotment plan. The ensemble of transmitters and the resultant DRB coverage contour associated with each **DSA** no longer have a use and are therefore not part of the plan. However, they will be retained for reference purposes.

- once the **FRCs** were determined, one of the 23 DRB channels was assigned to each **Group** by a computer program designed to optimize frequency spectrum usage. In assigning the DRB channels, provision was made for 2 DRB channels for a future satellite service at all locations in Canada.

- In addition, the computer program was designed to, wherever possible, avoid allotting a channel which would conflict with assignments in the fixed service currently operating in the band. In the majority of cases this was possible. Those fixed services which could be impacted were identified by means of notes in the Draft Plan, with details appended to the plan.

One of the difficulties encountered in the development of the Draft Plan was the lack of complete information on some aspects of planning. For example, the **FRCs** were generally determined by a computer program which took terrain elevation data into consideration. Where such data were not available the **FRC** had to be estimated by other means. Also, the front-end characteristics of DRB receivers are not known since they have yet to be specified, so assumptions had to be made in this regard. Factors such as these will require a review of the Draft Plan when additional information becomes available.

3. Use of Channels in the Plan

Procedures and rules for establishing and operating DRB facilities are currently under development by Industry Canada. In addition, it is expected that the CRTC will have its own application and regulatory requirements.

In the attached Draft Plan, a unique **Group ID** is formed by combining the contents of the first two columns. For example, **Group** 'AB5' uses DRB channel 1 and constitutes 5 entries for Calgary, Alberta chosen to be CKRY-FM, CFFR, CHQR, CFAC and CKMX. To implement DRB, these 5 broadcasters would share the same transmitting plant.

Making assumptions about possible station groupings was a technical pre-requisite to developing the Draft Plan. The groupings shown in the Draft Plan were based upon similarities in existing coverage areas. In most areas, alternative groupings will be possible so long as such changes do not have a negative impact upon the total number of services available in each market, the maximum coverage available to each station listed, or the overall efficiency of spectrum utilization.

Broadcasters planning to implement a DRB service will generally have to ensure that their design of the transmitting facilities produces a frequency reuse contour which does not exceed the **FRC** contained in the allotment plan for their particular **Group**. In the event the proposed frequency reuse contour does exceed the **FRC**, the broadcasters will have to demonstrate that it does not overlap more than 1% of the **DSA** of another **Group** allotted the same DRB channel. In many cases, the **FRC** is made up of multiple contours comprising 'islands' of potential interference which are located outside the primary contour.

As mentioned earlier, every effort was made to avoid allotting a DRB channel which conflicts with fixed services currently using this band. However, some conflicts could not be avoided. In cases of incompatibility with a particular allotment, if there are other suitable DRB allotments at the same location which do not conflict with the fixed service, they will be assigned first. If this is not possible, the fixed service stations will have to take the necessary steps to avoid the problem when the allotment is implemented[1].

As usual, allotments near the border will require coordination with the USA. Industry Canada officials have started discussions with officials of the USA in this regard.

Although there is a diagram showing the **FRC** and **DSA** for each **Group**, it has not been published with the Draft Plan because it would not be practical to distribute the volume of paper involved. The diagram for **Group** AB5 is attached for illustrative purposes. The contour represents the **FRC** while the shaded area represents the **DSA**. These diagrams also include information on the grids used to generate the **FRCs**. Each grid consists of a matrix of 40 by 40 points. The horizontal span of a particular grid is as specified and the reference point given is the centre of the grid.

To obtain a paper copy of a particular diagram, a request should be sent to the Director General, Spectrum Engineering branch at Department of Industry, 300 Slater Street, Ottawa, Ontario, K1A 0C8, specifying the **Group ID**. Electronic copies as an E-Mail attachment, suitable for WordPerfect printing, are available by sending an E-Mail request to the internet address ***broadcast.gazette@ic.gc.ca***

Attach.

In the Canadian Table of Frequency Allocations (1994), the following footnote refers:

C29 Existing fixed stations may continue to use the band 1452-1492 MHz provided they protect and not claim protection from, stations operating in the broadcasting service which are in accordance with a domestic allotment plan.

Note: With regard to this footnote, a schedule is included in the Department's Spectrum Utilization Policy SP1-20 GHz (dated January 1995). It indicates that during the two year period after the allotment plan has been formally adopted, fixed service licensees would be given a minimum of a two year notification by Industry Canada for displacement of specific installations in order to accommodate the implementation of conflicting DRB assignments. After the two year period following the adoption of the plan has elapsed, the minimum notification period will be one year.

Explanatory Notes

The columns in the table of the Draft Plan are headed by characters which have the following meanings:

A: This column identifies provinces as follows:

BC	British Columbia	AB	Alberta
SA	Saskatchewan	MB	Manitoba
ON	Ontario	QU	Quebec
NB	New Brunswick	NS	Nova Scotia
PE	P. E. I.	NF	Newfoundland

B: DRB group #

C: City name

D: DRB channel #

E: Area of DSA in km^2

F: North Latitude of centroid of DSA in decimal degrees

G: West Longitude of centroid of DSA in decimal degrees

H: Call sign of existing AM/FM station ('AL' = allotment)*

I: Channel # of FM station or frequency of AM station (kHz)

J: Class of AM/FM station

K: Notes as follows:

1. potential interference to DRB from fixed service station**
2. potential interference from DRB to fixed service station**
3. interference from co-channel DRB allotment (Group ID) exceeds 1 % criteria
4. topographical data incomplete, extrapolations used for determining CRF
5. no topographical data available, CRF contour is an estimate

* Information generally reflects status as of September 1994.

** see Appendix to identify relevant stations.

Notes explicatives

Les colonnes figurant dans le tableau du Projet de plan ont pour en-têtes des caractères ayant les significations suivantes :

A: Cette colonne identifie les provinces comme suit :

BC	Colombie-Britannique	AB	Alberta
SA	Saskatchewan	MB	Manitoba
ON	Ontario	QU	Québec
NB	Nouveau-Brunswick	NS	Nouvelle-Écosse
PE	Île-du-Prince-Édouard	NF	Terre-Neuve

B: N° de groupe DRB

C: Ville

D: N° de canal DRB

E: Aire de l'ADN en km^2

F: Latitude nord du centroïde en degrés décimaux

G: Longitude ouest du centroïde de l'ADN en degrés décimaux

H: Indicatif de la station AM/FM existante («AL» = allotissement)*

I: N° de canal de la station FM ou fréquence de la station AM (en kHz)

J: Classe de la station AM/FM

K: Notas, comme suit :

1. brouillage possible de service DRB par station du service fixe**
2. brouillage possible de station du service fixe par le service DRB**
3. brouillage par un allotissemnt DRB canal (no. du Group) dépassant le critère de 1 %
4. données topographiques incomplètes, utilisation de l'extrapolation pour déterminer le CRF
5. aucune donnée topographique disponible, le contour CRF est un estimé

* Le renseignement reflète l'état du plan en septembre 1994.

** Voir l'Annexe pour identifier la station Pertinente.

A	B	C	D	E	F	G	H	I	J	K
AB	79	ALSANDS	3	4775	57.5	111.4169	AL	201	A	4
AB	79	ALSANDS	3	4775	57.5	111.4169	AL	206	A	4
AB	70	ANZAC	1	201	56.4354	111.1192	VF2241	210	VLP	
AB	1	ATHABASCA	5	12268	54.6241	113.1176	AL	201	B	
AB	1	ATHABASCA	5	12268	54.6241	113.1176	AL	217	A	
AB	1	ATHABASCA	5	12268	54.6241	113.1176	CKUA-FM-10	252	LP	
AB	1	ATHABASCA	5	12268	54.6241	113.1176	AL	273	A	
AB	1	ATHABASCA	5	12268	54.6241	113.1176	CKBA	850	B	
AB	80	BANFF	5	448	51.1309	115.5915	AL	232	A	
AB	2	BANFF	3	495	51.1309	115.5915	CJAY-FM-1	236	B	
AB	2	BANFF	3	495	51.1309	115.5915	CHFM-FM-1	257	A	
AB	2	BANFF	3	495	51.1309	115.5915	CKUA-FM-14	282	A	
AB	2	BANFF	3	495	51.1309	115.5915	CBRB	860	LP	
AB	37	BANFF	7	338	51.3225	115.7378	CBPG-1	1230	LP	
AB	37	BANFF	7	338	51.3225	115.7378	CBPG-2	1230	LP	
AB	2	BANFF	3	495	51.1309	115.5915	CFHC-1	1340	C	
AB	37	BANFF	7	338	51.3225	115.7378	CBPH-1	1490	LP	
AB	37	BANFF	7	338	51.3225	115.7378	CBPH-2	1490	LP	
AB	88	BARRHEAD	4	8124	54.0443	113.8565	AL	239	B	
AB	36	BASSANO	3	452	50.7752	112.5112	CJAY-FM-4	291	LP	
AB	81	BATTLE RIVERS	3	4775	57.4501	117.5022	AL	202	A	
AB	51	BEAVER LAKE	3	353	54.7434	111.9329	VF2242	210	VLP	
AB	3	BLAIRMORE	1	1669	49.6219	114.275	CBXL	860	LP	
AB	3	BLAIRMORE	1	1669	49.6219	114.275	CJPR	1490	C	
AB	27A	BONNYVILLE	10	13618	54.1277	110.642	AL	225	B	4
AB	27A	BONNYVILLE	10	13618	54.1277	110.642	AL	254	B	4
AB	27A	BONNYVILLE	10	13618	54.1277	110.642	AL	274	B	4
AB	82	BONNYVILLE	9	13265	54.182	110.8657	AL	284	A	4
AB	82	BONNYVILLE	9	13265	54.182	110.8657	AL	292	B	4
AB	62	BOYER RIVER	6	798	58.3405	116.1084	VF2176	210	VLP	
AB	4	BROOKS	5	3522	50.4947	111.8848	AL	284	B	
AB	4	BROOKS	5	3522	50.4947	111.8848	AL	810	B	
AB	4	BROOKS	5	3522	50.4947	111.8848	CIBQ	1340	C	
AB	77	BROWNVALE	5	201	56.1023	118.126	VF2243	210	VLP	4
AB	83	BURMIS	5	4775	49.5504	114.1762	AL	211	A	
AB	83	BURMIS	5	4775	49.5504	114.1762	AL	216	A	
AB	23	BUSHE RIVER	2	4392	58.5224	117.1195	VF2177	210	VLP	
AB	67	CADOTTE LAKE	1	451	56.4711	116.2607	VF2084	210	VLP	
AB	84	CALGARY	8	20202	51.0379	114.0867	AL	205	C	
AB	84	CALGARY	8	20202	51.0379	114.0867	AL	209	C	
AB	7A	CALGARY	7	1293	51.0253	113.966	CJSW-FM	215	A	
AB	7	CALGARY	3	14261	51.0487	114.0568	CJAY-FM	221	C	
AB	84	CALGARY	8	20202	51.0379	114.0867	AL	225	B	
AB	7	CALGARY	3	14261	51.0487	114.0568	CKUA-FM-1	229	B	
AB	84	CALGARY	8	20202	51.0379	114.0867	AL	234	B	
AB	7	CALGARY	3	14261	51.0487	114.0568	CHFM-FM	240	C	
AB	7	CALGARY	3	14261	51.0487	114.0568	AL	253	B	
AB	6	CALGARY	2	20202	51.0379	114.0867	CBR-FM	271	C	
AB	84	CALGARY	8	20202	51.0379	114.0867	AL	276	C	
AB	7	CALGARY	3	14261	51.0487	114.0568	CBRF-FM	280	B	
AB	5	CALGARY	1	19695	51.0408	114.0884	CKRY-FM	286	C	
AB	85	CALGARY	10	14261	51.0487	114.0568	AL	291	B	
AB	6	CALGARY	2	20202	51.0379	114.0867	CKIK-FM	297	C	

Ottawa, 14 June 1995

Public Notice CRTC 1995-95

Call for Comments on a Proposed Approach to the Introduction of Digital Radio

Introduction

In this notice, the Commission outlines its general plans for the introduction of digital radio broadcasting in Canada and seeks public comment on a proposed short-term licensing approach.

The Canadian radio industry has been at the forefront in the development and testing of digital radio broadcasting. Accordingly, the Commission expects that many parties will be interested in establishing digital radio services in Canada in the near future. The introduction of digital radio services on an experimental basis could well provide operational and market data useful to all parties interested in examining the broad policy and regulatory issues relating to digital radio broadcasting. At the same time, the Commission does not wish to proceed on a basis that might prejudice future policy development in any way. For these reasons, it considers that a two-stage approach will ensure a timely and non-disruptive transition to digital radio which will allow Canadian radio broadcasters to retain their technological lead in this emerging environment.

Background

Digital radio broadcasting refers to the over-the-air transmission and reception of radio signals using digital technology. The technology makes possible the reproduction of sound that rivals the quality of compact disks. It has the potential of providing new kinds of broadcasting services to the public, as well as non-programming services, such as paging and datacasting, using its ancillary capacity.

In 1992, the Minister of Communications announced the formation of the Task Force on the Introduction of Digital Radio. The Task Force included public and private radio broadcasters, representatives of the Department of Communications (now the Department of Canadian Heritage and the Department of Industry), and observers from the CRTC. The Task Force was mandated to provide leadership, focus and co-ordination for the technical, policy and regulatory tasks required for the introduction of digital radio.

Working Group I was established by the Task Force to examine coverage and service area issues; Working Group II was asked to consider policy and regulatory issues. Both working groups presented final reports to the Ministers of the Department of Canadian Heritage and the Department of Industry in 1994.

Digital Radio Research Inc. (DRRI), a consortium of private broadcasters and the CBC, was established for the purpose of financing and managing facilities for digital radio research and field trials. DRRI currently operates experimental digital radio transmission facilities in Toronto and in the MontrΘal region, using a digital radio technology known as Eureka-147. Since its creation in 1992, DRRI has completed several other successful field trials using this technology. Canadian digital radio services using Eureka-147 will operate in a part of the radio spectrum known as the L-band (1452-1492 MHz).

The Radiocommunications Branch of the International Telecommunications Union (ITU-R), is that body of the United Nations responsible for co-ordinating the development of international standards. In December 1994, the ITU-R recommended Eureka-147 technology for use as a global technical standard for both terrestrial and satellite-delivered digital radio broadcasting. This is expected to become an official ITU recommendation later this year.

The Department of Industry is expected to release a gazette notice shortly outlining its proposed spectrum allocation plan for L-band digital radio broadcasting in Canada. This plan has been deve-
loped in accordance with the principles outlined by Working Group I of the Task Force. Under the plan, each existing AM and FM radio undertaking will be assigned spectrum in the L-band for the purposes of broadcasting a digital radio signal.

Regulatory Issues Associated withâDigital Radio

The Commission fully supports the transition from conventional AM and FM radio to digital radio broadcasting in Canada, and considers that digital technology will prove an effective and efficient method of providing high quality radio service to the public. The Commission also considers that digital radio should be a replacement technology for existing AM and FM radio services. It therefore endorses the Department of Industry plan to allocate spectrum in the digital radio band to each existing AM and FM radio undertaking. The Commission notes, however, that digital radio also has the potential to increase the diversity of programming services available to the public. For this reason, it considers that existing radio services should have priority access, but not exclusive access, to the digital radio band.

Digital radio broadcasting remains in the early experimental stage in Canada. In the Commission's view, many complex and important issues relating to the development of digital radio technology and the structure of the digital radio industry in the long term have not been clearly defined, and will need to be addressed in the context of a broad public process. Based on the data currently available, these issues raise questions that, in some cases, may be difficult to resolve in the short term, thus preventing any full or meaningful public exploration of the issues at this time.

The major long-term issues with respect to digital radio can be grouped into the broad areas summarized below.

Ownership of transmitter facilities: With AM and FM broadcasting, the signal of each station is broadcast from a single transmitter, and the licensee is required by regulation to own its own transmitter. With Eureka-147 technology, groups of up to five stations will broadcast from a single transmitter. This raises issues concerning who should be permitted to own digital radio transmitters, how facilities should be shared, and how fair access to these transmitters can be ensured.

New Services: While it is expected that digital radio services will eventually replace existing AM and FM stations, the technology will also allow for the establishment of new radio services that may be delivered by either terrestrial transmitters or satellite. The Commission will need to decide how long existing AM and FM stations should be given to convert to digital technology before their digital allocations are offered to other parties. There may be a need to determine whether licensees of existing stations who choose not to move to the digital band, should be permitted to continue broadcasting on the AM or FM band indefinitely. It may also be necessary to establish what uses will be made of the AM and FM bands as they become vacated. Further, the Commission will need to determine how and under what circumstances new services will be introduced.

Technical Issues: It will be necessary to determine what technical standards should be established to ensure that each digital radio service provides high quality programming while also being ensured a reasonable amount of capacity to transmit ancillary data. Depending on how channel capacity is assigned, there may be a need to ensure that all stations sharing a digital radio channel have access to an equal share of the capacity. The use of ancillary capacity to provide programming services may also be an issue.

Regulations: The Commission will need to determine what types of regulations are appropriate for digital radio services that originate

programming.
Coverage Issues: Several digital radio stations will share a single transmitter, and all stations sharing a transmitter will have equal coverage areas. As a result, the digital service contour of some stations may be significantly different from their existing AM or FM coverage patterns. The Commission will need to decide the extent to which stations should be allowed to expand from their current coverage areas, and how to deal with any impact such expansion may have on competition between existing services.

Two-stage Approach

In light of the many unresolved issues, including those discussed above, the Commission proposes to proceed with a two-stage approach to the introduction of digital radio broadcasting. For the short term, the Commission intends to establish a process for licensing digital radio undertakings under certain terms and conditions, and on an experimental basis. At the appropriate time, the Commission also intends to undertake a public process to consider all aspects of a policy approach to govern digital radio broadcasting in the long term.

The Commission does not foresee this broad public policy process commencing prior to the fall of 1996, or until sufficient information is available to consider fully all of the questions that may arise. The Commission therefore reminds interested parties that any course of action or approach it may take regarding a licensing process for experimental digital radio undertakings in the short term shall not constrain the Commission from modifying this approach or adopting another framework for the long term. The Commission's proposals for a short-term approach are discussed below.

Short-term Approach

In order to allow for the broadcast of digital radio services on an experimental basis before the Commission initiates the broad public process discussed above, it proposes to establish a new Experimental Digital Radio Licence. The Commission, however, does not wish to create a situation that might unduly alter the circumstances of existing radio broadcasters or affect the scope of any long-term policy for digital radio. Accordingly, an experimental licence would be subject to the terms and conditions set out in the following section of this notice.

Given that existing radio undertakings have already satisfied the Commission|s concerns regarding ownership, finances, marketing and programming, the Commission considers that it would be reasonable to adopt a streamlined application and licensing process for existing AM and FM licensees who wish to simulcast their programming using digital technology. Applications for Experimental Digital Radio Licences from parties who do not currently operate an existing AM or FM radio service would be considered on a case-by-case basis, subject tothe Radio Market Criteria contained in Public Notice CRTC 1991-74 entitled "Radio Market Policy".

Conditions Governing ExperimentalâLicences

The Commission considers that it may be necessary to place certain restrictions on undertakings operating an Experimental Digital Radio service during the short term. Specifically, it proposes to apply the following terms and conditions to Experimental Digital Radio Licences, with any exceptions to be considered on a case-by-case basis:

*In the case of an Experimental Digital Radio service operated by an existing AM or FM radio licensee, it would be a requirement that all programming on the Experimental Digital Radio service be a simulcast of the programming broadcast on the associated AM or FM radio undertaking, with the exception of up to two hours per week of separate programming. Separate programming on an Experimental Digital Radio undertaking would be subject to Part 1 of the Radio Regulations, 1986.

The Commission considers that this requirement would be consistent with the general principle that digital radio services should eventually replace, rather than supplement, existing AM and FM radio services, while ensuring that Experimental Digital Radio undertakings have sufficient flexibility to conduct useful market trials.

*In order to ensure that all licensees have fair and equitable access to digital channel capacity, each licensee would be restricted to the use of no more than 20% of the digital capacity of the 1.5âMHz channel specified for use by the geographic grouping of broadcasters to which the licensee belongs under the Department of Industry's allotment plan.

In addition to this restriction, the Commission would expect broadcasters to ensure that the main programming signal of the Experimental Digital Radio service is not noticeably degraded by the shifting of capacity from it to ancillary services.

Given that digital radio receivers will be capable of receiving both the main programming signal and the signals of any ancillary services provided, the Commission is concerned that the use of ancillary capacity for programming services could result in competition between main programming services and ancillary programming services. The Commission believes that this is an issue best considered in the context of its broad public process to determine a long-term policy approach for digital radio broadcasting.

For this reason, the Commission proposes that, during the short term, Experimental Digital Radio undertakings be prohibited from using the ancillary capacity of the spectrum allotted to them to provide a programming service. The Commission would not, however, have any objections to the use of ancillary capacity for experimental non-programming purposes.

*Each digital radio signal operated by an existing licensee would have to be broadcast from a single primary digital radio transmitter that is located so as to ensure that the resulting digital radio coverage area does not exceed the lesser of (a) the licensee's corresponding FM or daytime AM coverage area (that is, the 0.5 millivolt per metre coverage area for both AM and FM stations), or (b) the digital coverage area allotted to the licensee under the Department of Industry's spectrum allocation plan.

The Experimental Digital Radio Licence will specify the location of the single primary transmitter from which the digital radio signal must be broadcast. However, the use of "gap filler" transmitters to cover small unserved areas within the coverage area of the primary digital transmitter will not be restricted.

The Commission notes that, under the Department of Industry's allotment plan, the coverage areas of some digital radio services could be considerably greater than the coverage areas of their corresponding AM or FM radio stations. It acknowledges that a restriction such as that proposed above would thus constitute a limitation on the use of transmission facilities for Experimental Digital Radio services. Nevertheless, the Commission considers that such a restriction would be a reasonable measure to ensure that new Experimental Digital Radio services do not have an undue impact on competition in the radio industry in the short term.

*Experimental Digital Radio Licences would generally be issued for a term of three years. This would allow the Commission to establish and introduce a permanent licensing regime for digital radio undertakings following completion of the public process to determine a long-term approach for digital radio broadcasting.

*Experimental Digital Radio licensees would not be required to own and operate their own transmitters. This would provide flexibility for licensees and owners of digital radio transmission facilities to experiment with different kinds of ownership arrangements and structures in the short term.

*Experimental Digital Radio undertakings would not be subject to the Commission's long-standing policy that generally prohibits the common ownership of two undertakings of the same class serving the same market in the same language. Licensees would be permitted to operate one Experimental Digital Radio service for each existing conventional radio service they currently operate.

Call for comments

The Commission seeks comments on its proposed approach to the introduction of digital radio and, in particular, on the specific terms and conditions to which its proposed Experimental Digital Radio Licence should be subject. Comments must be submitted to the Secretary General, CRTC, Ottawa, K1A 0N2 by Monday, 17áJuly 1995. While receipt of submissions will not be acknowledged, all submissions will be considered by the Commission and will form part of the public record of the proceeding.

Allan J. Darling
Secretary General

DOC. #: AVI95-95

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Mr. Trenholm graduated with a B.A.Sc. in Electrical Engineering at the University of British Columbia in 1964.

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DRB Seminar, Ottawa, Ont., 27 October, 1995

Eureka 147 Emission Format

by

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Communications Research Centre
Centre de recherches sur les communications

Presentation Outline

1. DAB System Overview

2. Principles of COFDM

3. Modes of Operation

4. System Sensitivity to Non-linear Distortion (HPA)

5. System Sensitivity to Linear Distortion (Filtering)

6. Conclusions

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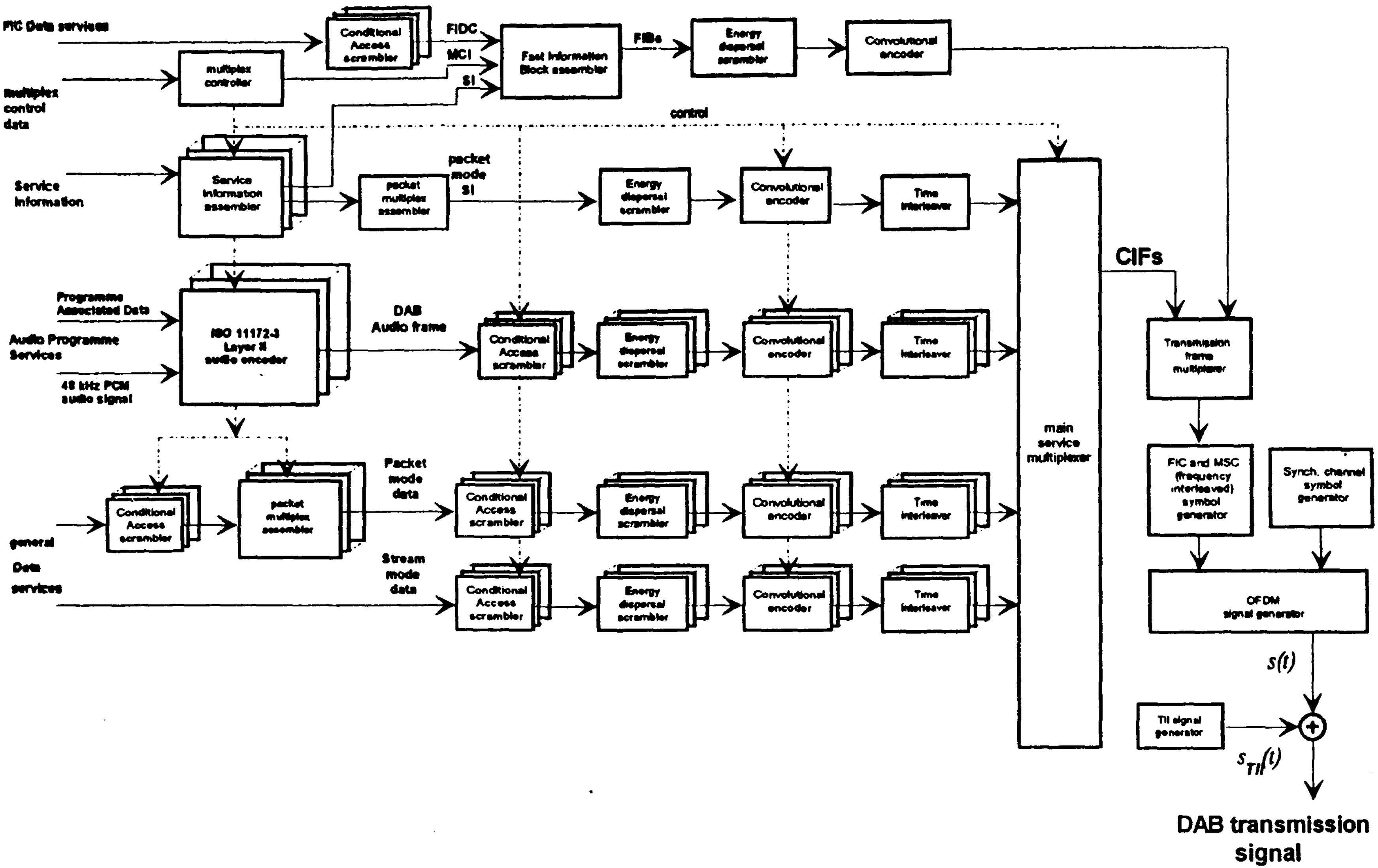

Figure 1: Conceptual DAB emission block diagram

Audio Services

- ISO/MPEG Layer II audio coding algorithm
- 48 or 24 kHz sampling rates (24 or 12 kHz audio BW)
- Mono, stereo and dual-channel
- Bit rates from 32 to 192 kbit/s per mono channel
- 224 or 192 kbit/s per stereo pair for near CD quality
- Coding based on masking characteristics of human ear

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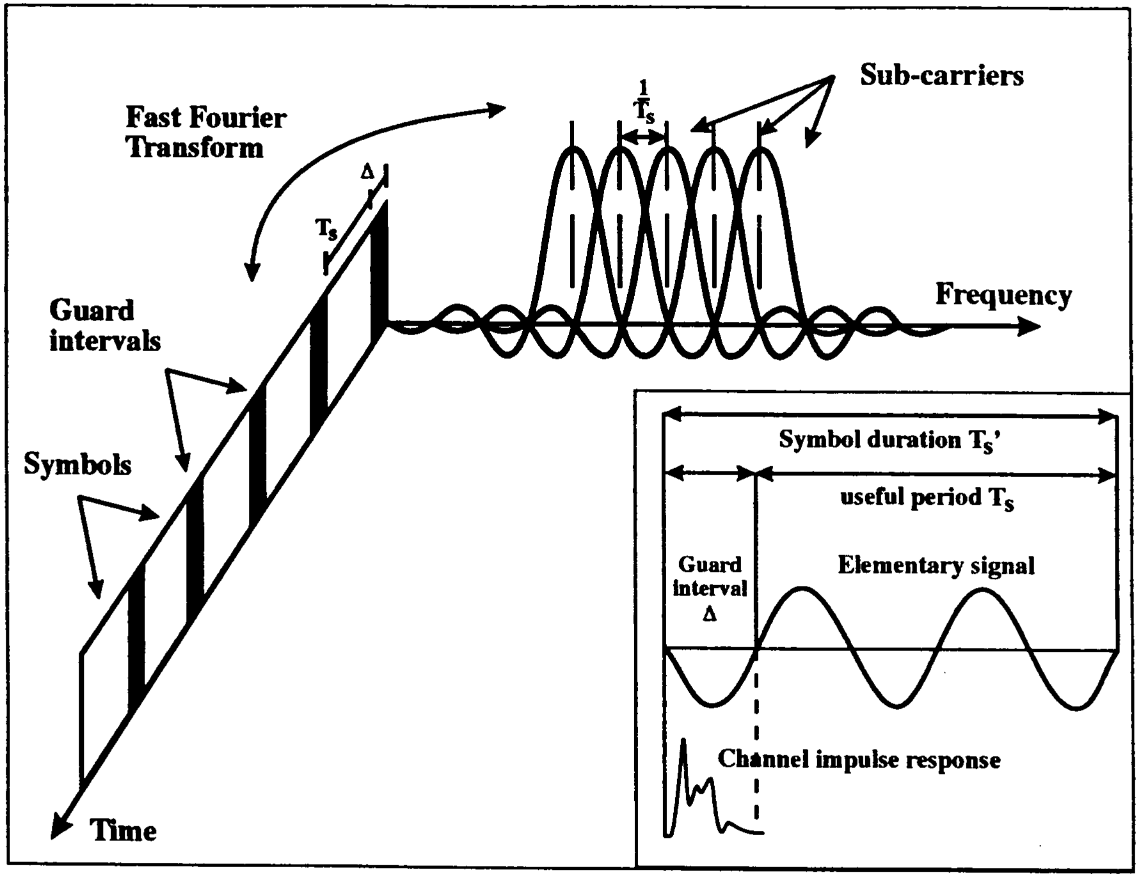
Data Services

- Programme Associated Data (PAD)
  - data incorporated in the compressed audio bit stream
  - used for information in sync with the sound programme
  - variable capacity (667 bit/s up to 65 kbit/s)
  - dynamic range control, programme labels, text & graphics,...

- Independent Data Services
  - transmitted independently or as part of the FIC
  - continuous bit stream or packet mode (N x 8 kbit/s)
  - paging, traffic information, GPS data, etc...

COFDM Basic Features

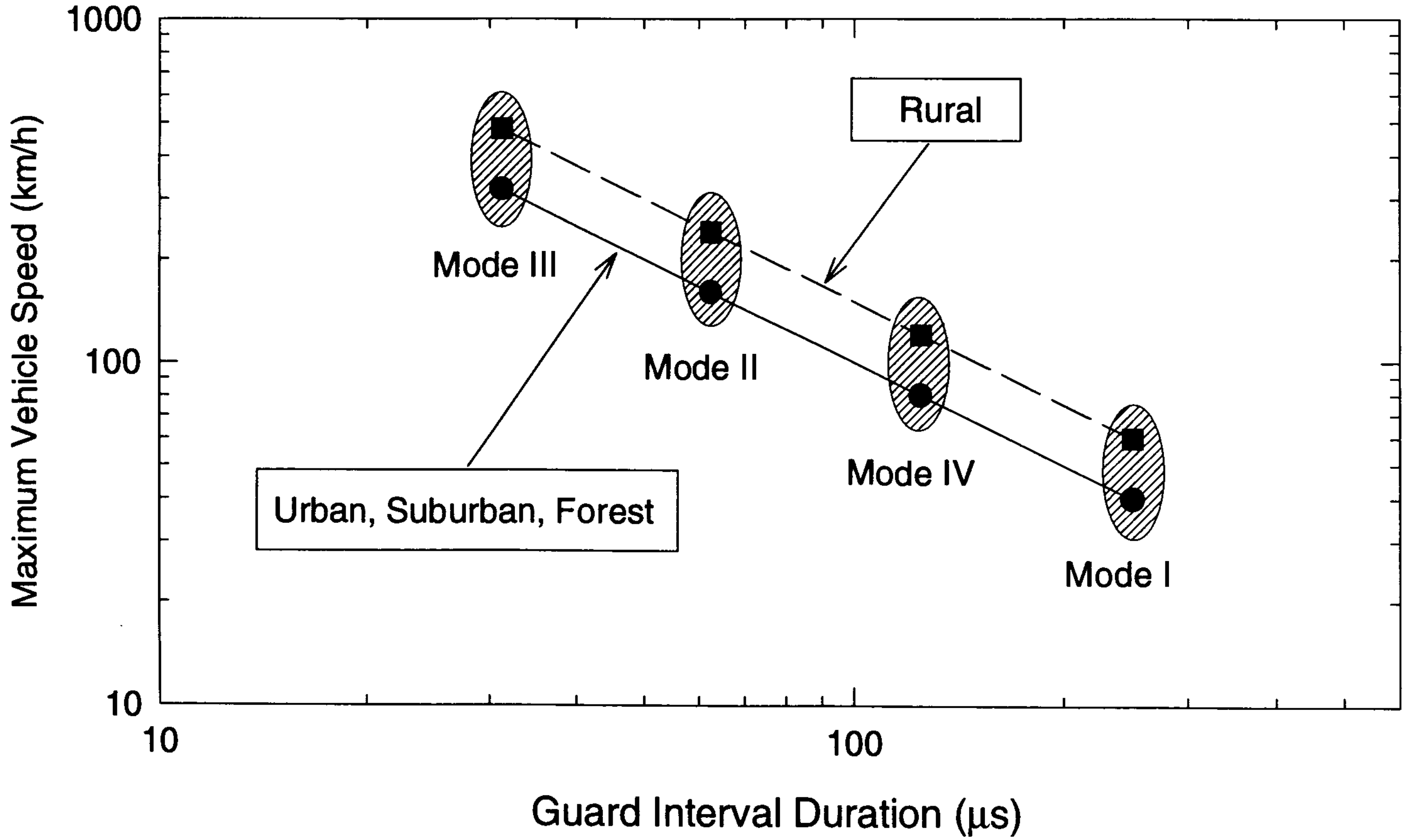
OFDM and guard interval to minimize ISI created by frequency selective fading



DAB Transmission Parameters for Each Transmission Mode

System Parameter	Transmission Mode			
	I	IV	II	III
Frame duration	96 ms	48 ms	24 ms	24 ms
Guard interval duration	246 μs	123 μs	62 μs	31 μs
Nominal maximum transmitter separation for SFN	96 km	48 km	24 km	12 km
Maximum vehicle speed (for reception at L-band)	40/60 km/h	80/120 km/h	160/240 km/h	320/480 km/h
Useful symbol duration	1 ms	500 μs	250 μs	125 μs
Total symbol duration	1246 μs	624 μs	312 μs	156 μs
Number of radiated carriers	1536	768	384	192

Maximum Vehicle Speed vs Guard Interval Duration for Different Transmission Modes at L-band Frequency



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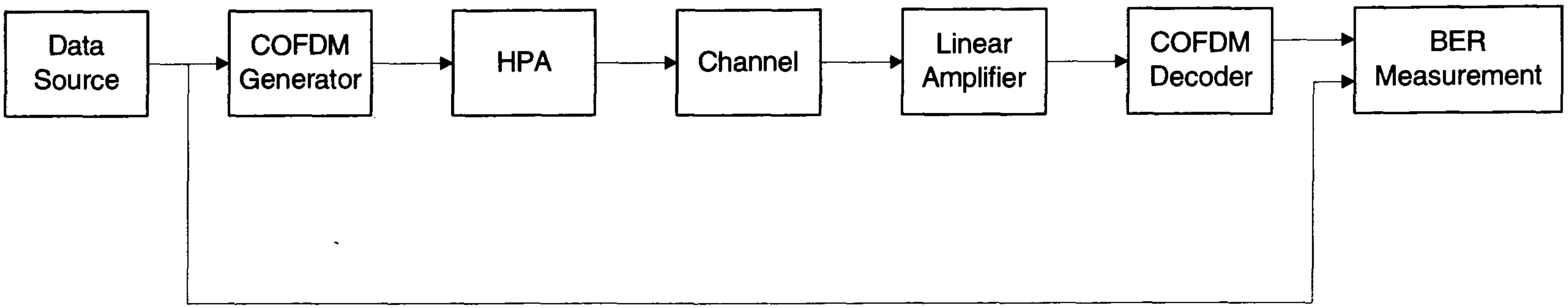
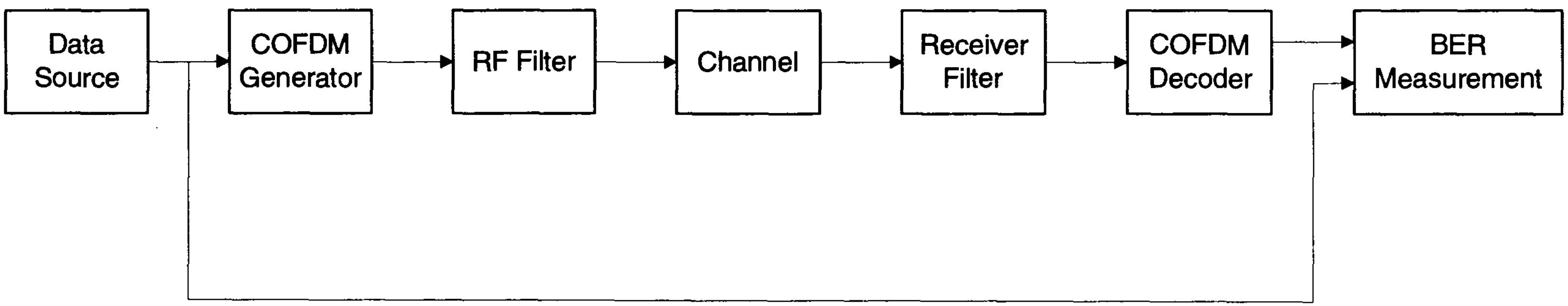
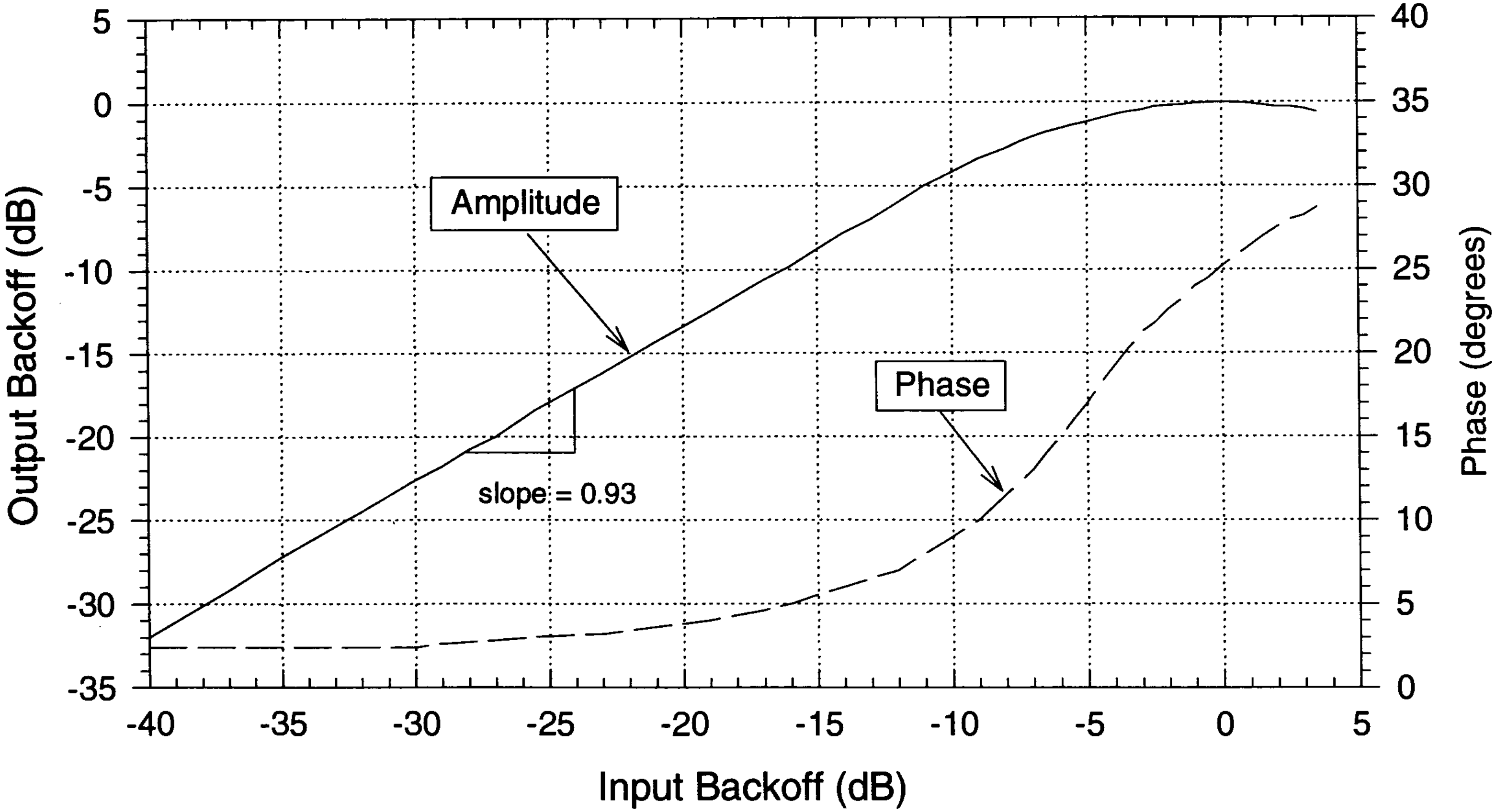
Simulation Model of COFDM System with HPA Non-Linear Distortion



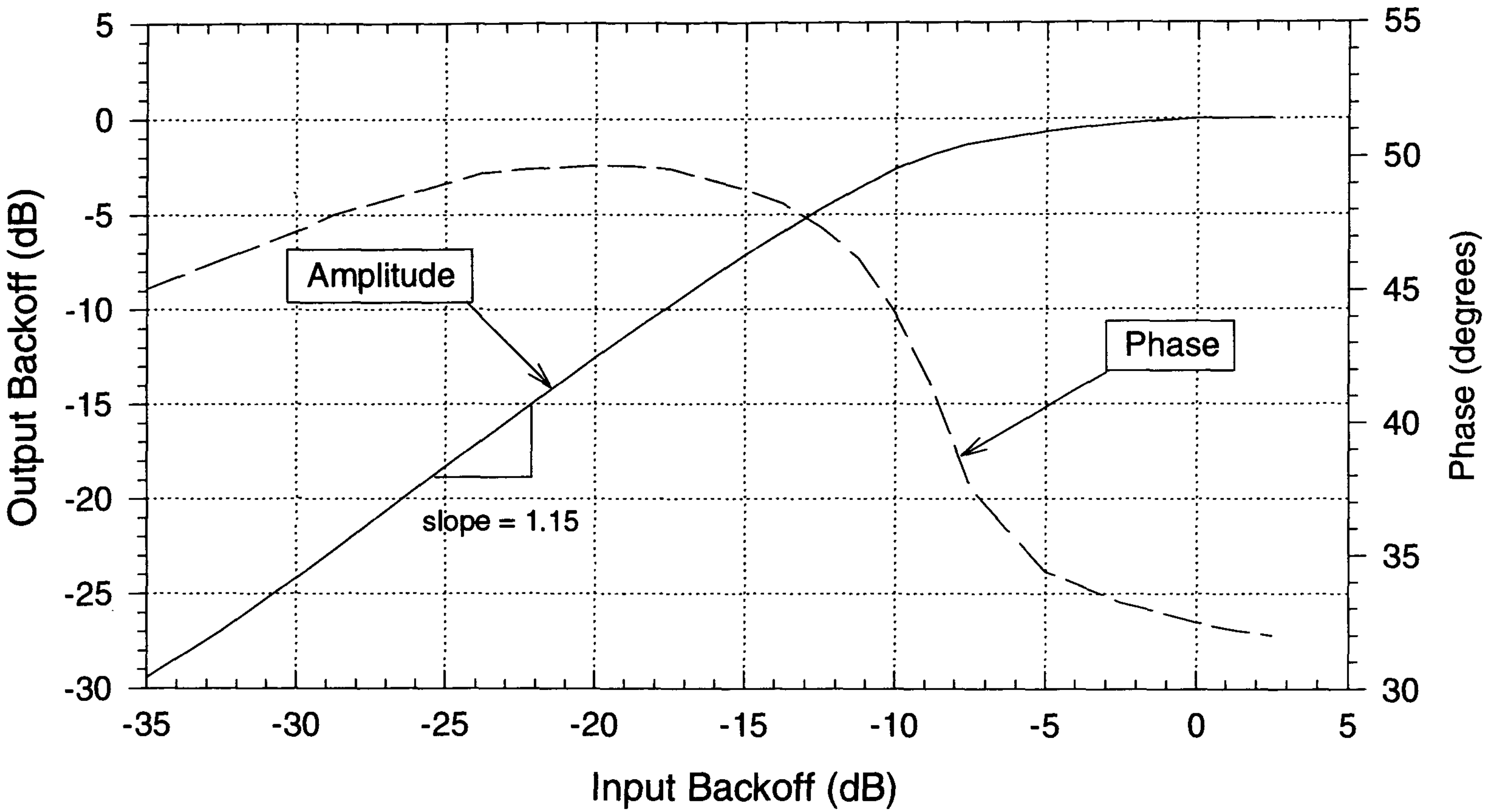
Simulation Model of COFDM System with RF Filter Linear Distortion



AM-AM and AM-PM Characteristics of a TWTA



AM-AM and AM-PM Characteristics of a UHF SSPA



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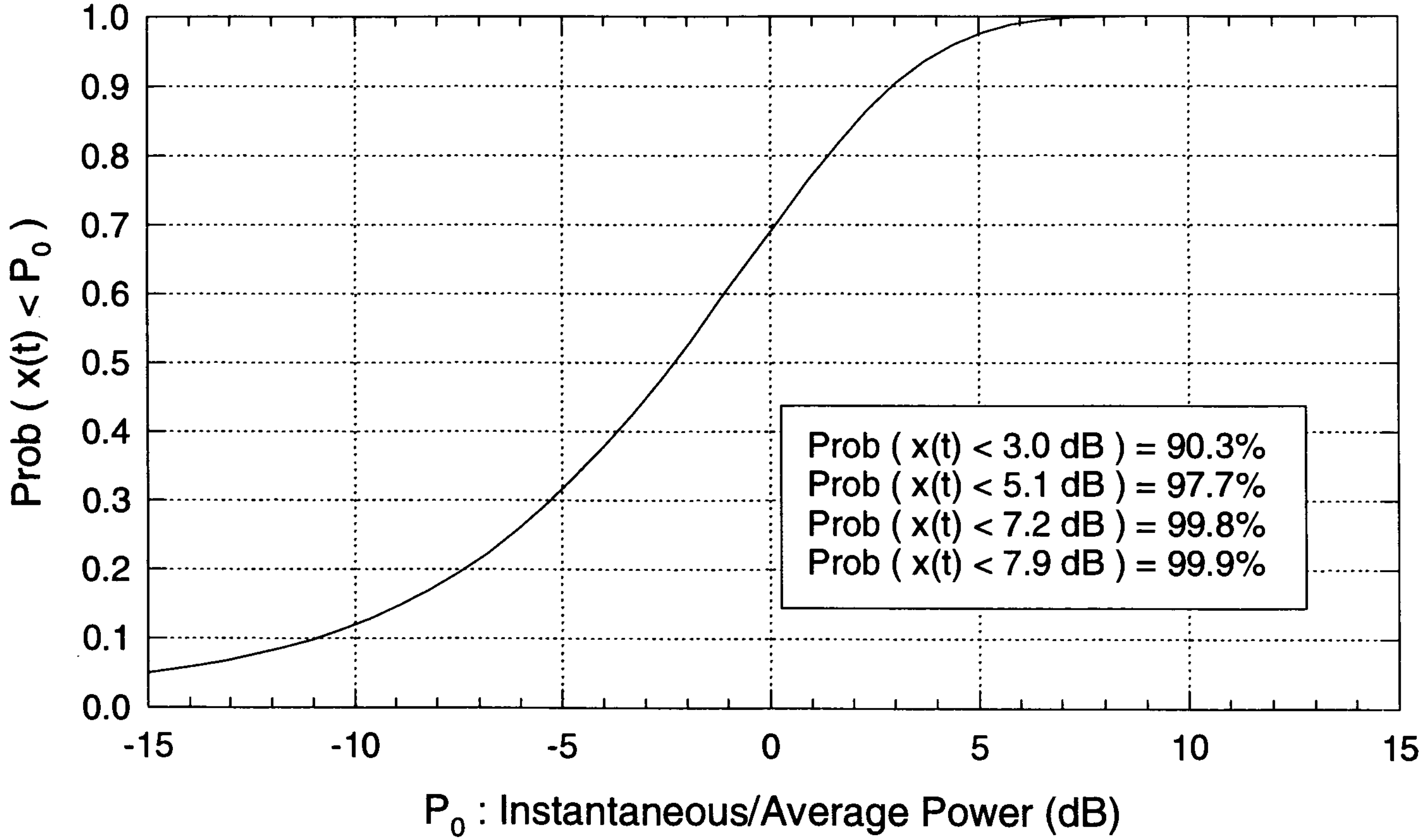
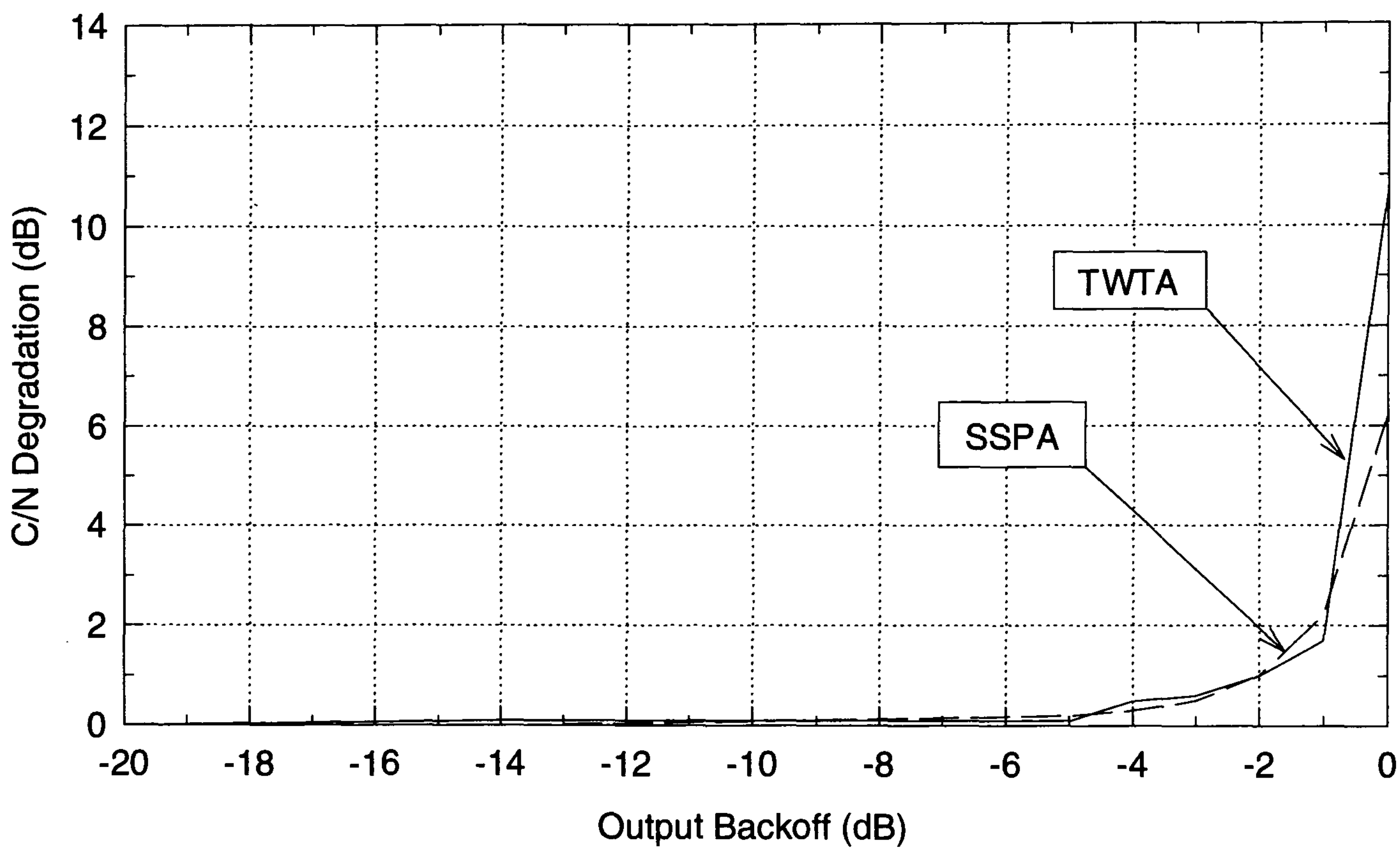
Cumulative Distribution Function of COFDM Signal



C/N Degradation vs OBO for different HPA's

(BER=10^{-4})



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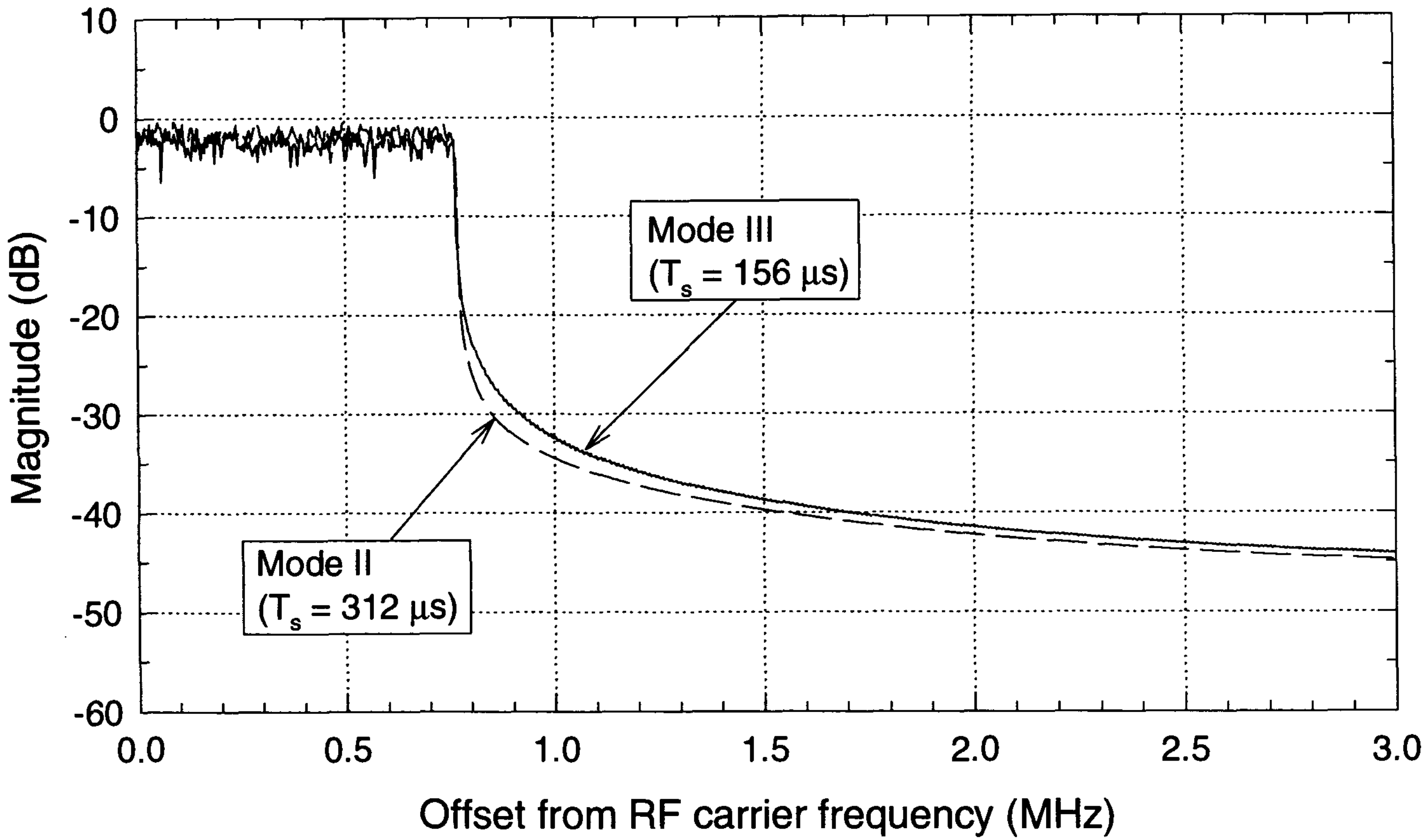
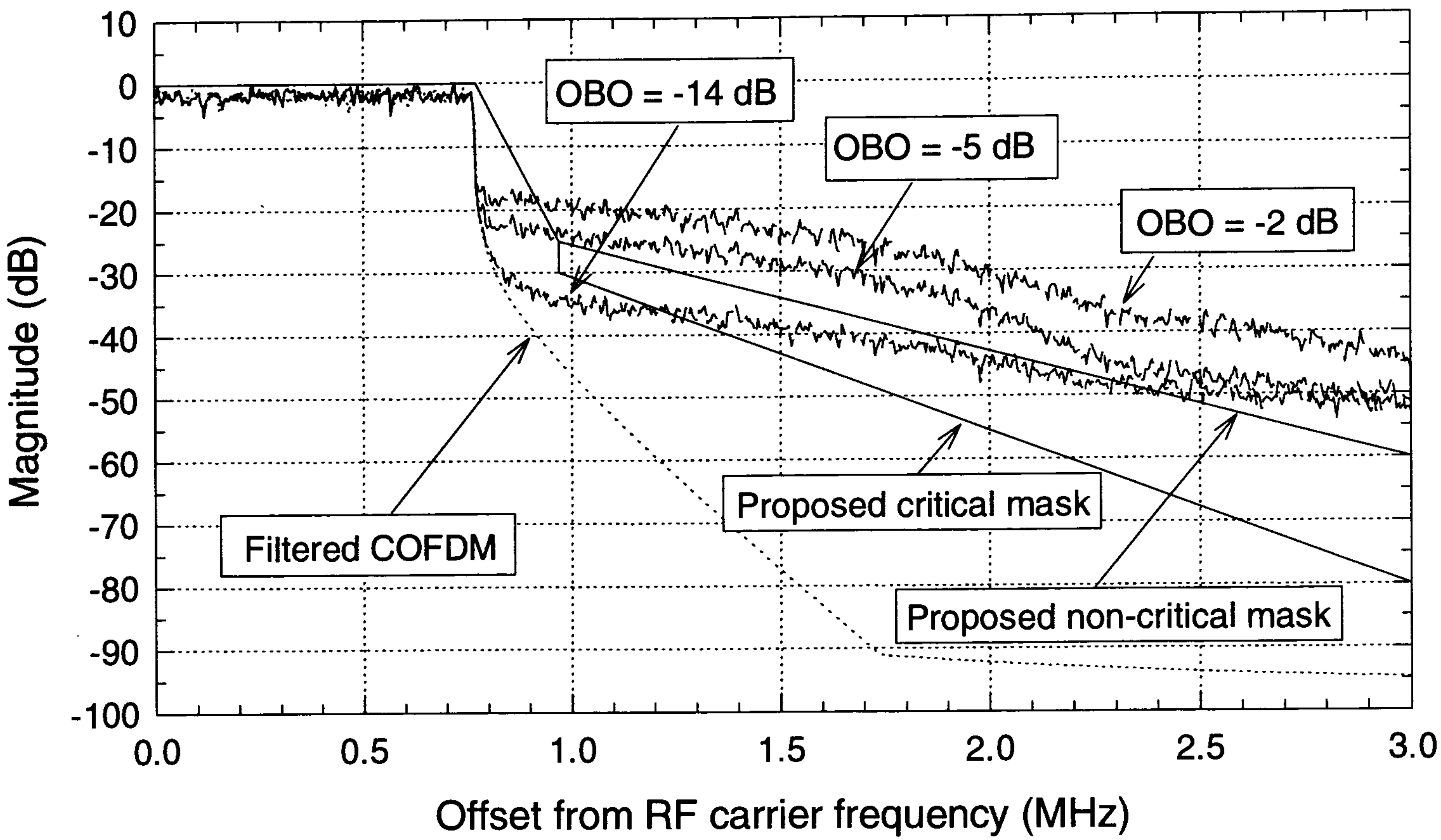
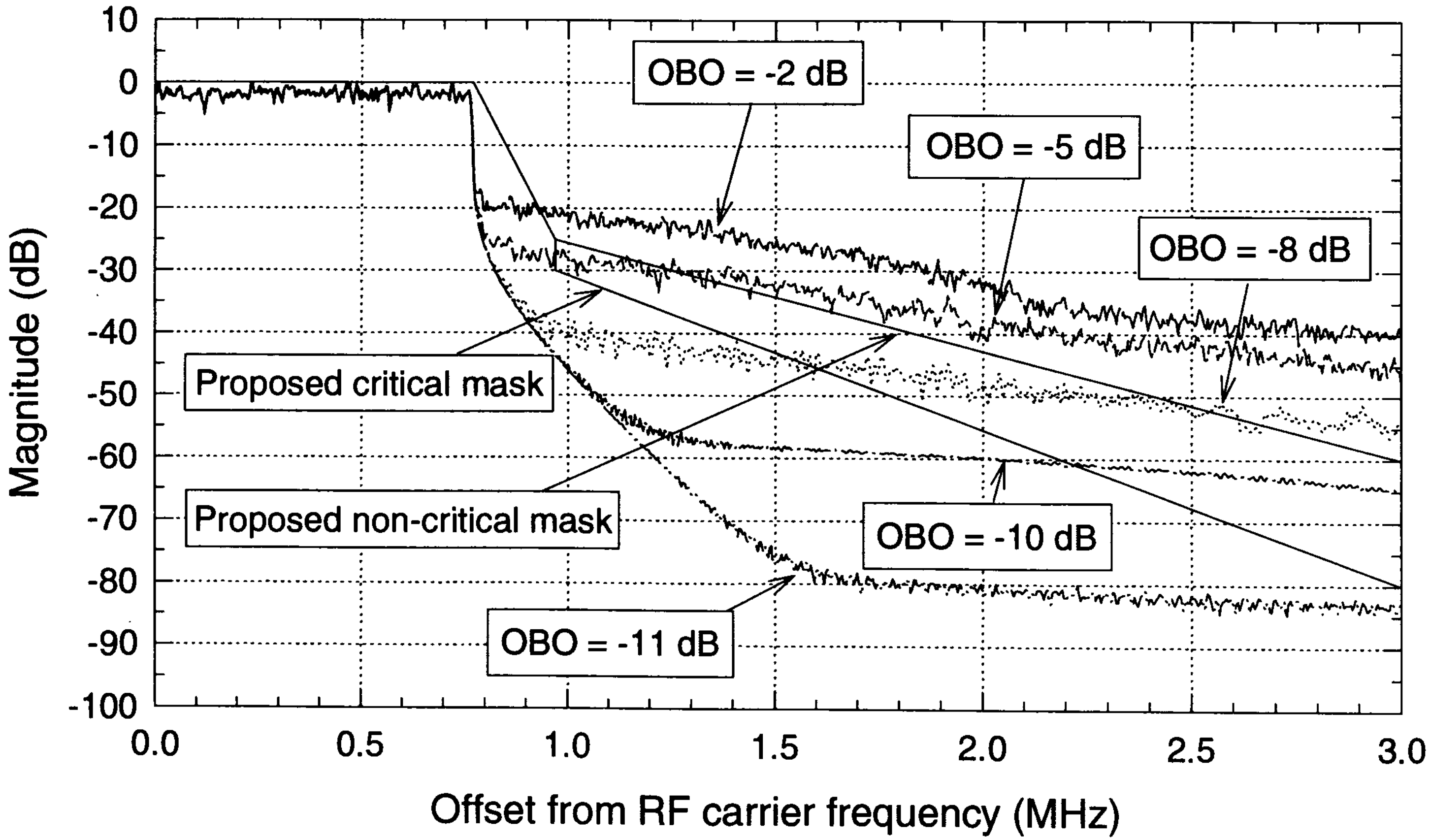
Single-Sided Power Spectra of COFDM Signals



Single-Sided Power Spectra of COFDM Signals (Mode II) at Output of a TWTA



Single-Sided Power Spectra of COFDM Signals (Mode II) at Output of a Clipper



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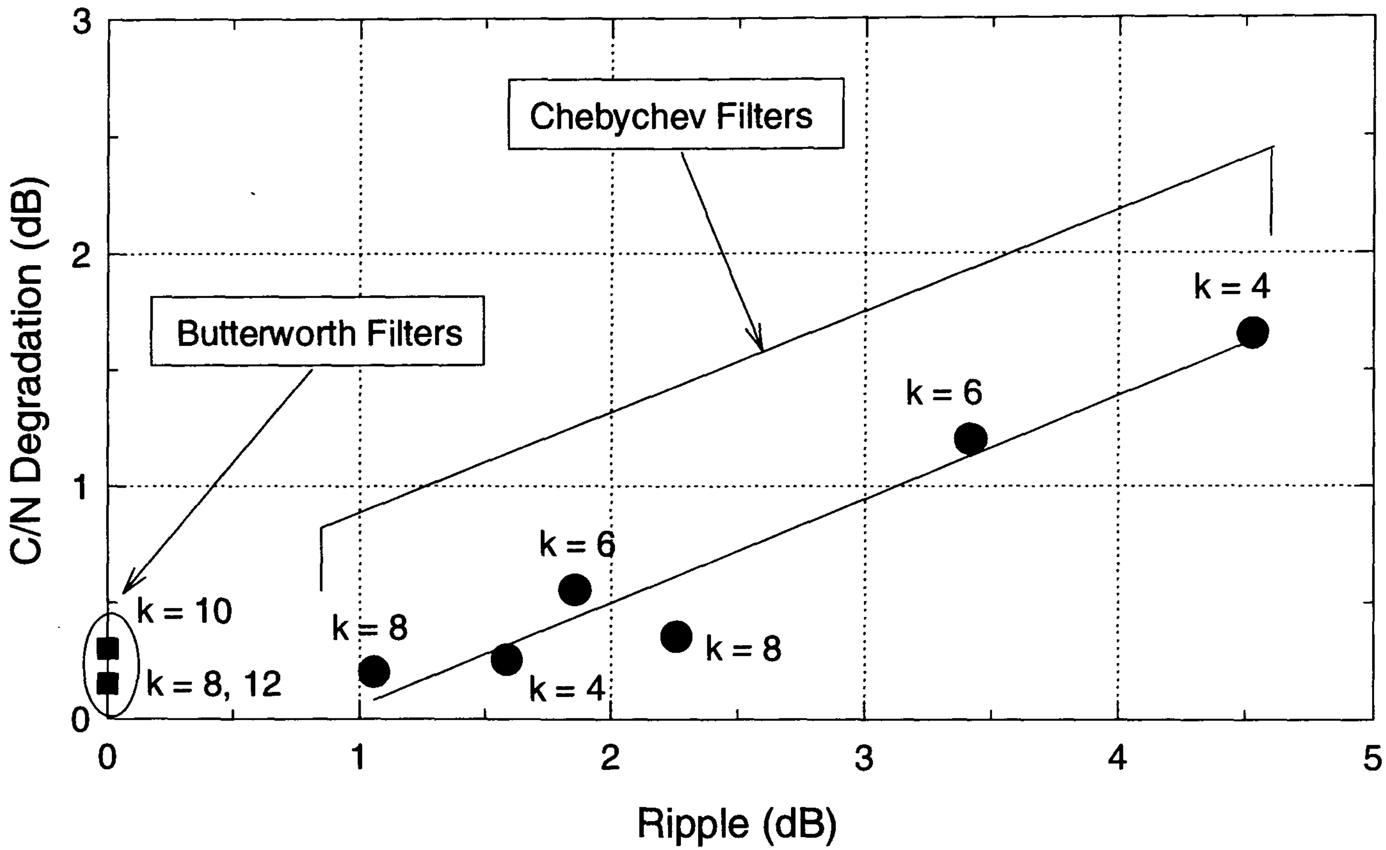
C/N Degradation vs Ripple for different Filters

(BER = 10^{-4})



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Conclusions

- **Modes of operation**
  - ⇒ Mode II and IV are both suitable for operation at L-band
  - ⇒ Mode II allows mobile reception at higher vehicle speeds
  - ⇒ Mode IV allows larger separation of on-channel transmitters.

Conclusions (cont'd)

- **HPA**
  - ⇒ Optimal OBO operating point ranges from -2 to -1 dB with regard to the intra-system performance point of view
  - ⇒ For OBO values of -5 dB or higher, there is little benefit in linearizing the amplifier transfer characteristics from the channel interference point of view.

- **RF Filter**
  - ⇒ The inclusion of a RF filter appears necessary
  - ⇒ Group delay causes little or no degradation in performance
  - ⇒ The loss due to RF filtering depends on the ripples (loss ≈ 0.5 dB when ripple equals to 2 dB)

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Minh Thien Le

Mr. Minh Thien Le received a master's degree in Systems and Computer Engineering from Carleton University, Ottawa. In 1992, he joined the Communications Research Centre as a research engineer in the Signal Processing and Psychoacoustics group of the Radio Broadcast Technologies Research Division.

His current research areas include channel coding and modulation techniques for digital radio broadcasting.

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Digital Radio Broadcasting
Service Multiplex and Network Configurations

by
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This paper examines the characteristics of the ITU-R System A (Eureka 147/DAB) data multiplex scheme and outlines the utilization options that are likely to be adopted by broadcasters as they implement terrestrial digital radio broadcasting (DRB). First of all, however, it may be useful to summarize the basics of Canada's DRB implementation strategy and roll-out plan.

As currently conceived, the broadcasters' strategic plan for DRB calls for the replacement of existing AM/FM coverage, within the limits recommended by the Task Force on the Introduction of Digital Radio[1]. An example of the service area that broadcasters would eventually want to duplicate is shown in Figure 1.

The Plan also says that broadcasters should utilize the L-Band DRB spectrum (1452-1492 MHz), allocated on a worldwide basis three years ago. Each DRB channel should be capable of accommodating at least five separate multiplexed audio programs, plus a variety of other data services. With respect to the latter, broadcasters believe that DRB must include new auxiliary data services, to ensure that there is a distinct "value-added" bonus available to listeners buying new digital receivers.

The roll-out plan that is currently envisaged calls upon broadcasters to provide off-air DRB signals well in advance of the availability of receivers at the consumer level. This will enable broadcasters to resolve any problems with their system designs during a time when there are few listeners. Moreover, making signals available is of paramount importance, if the public is to be convinced to buy new receivers.

The second part of the roll-out strategy says that DRB services should be provided first to the "core" area of each of the largest broadcast markets. This is basically the area within a 40 km radius of the centre of each market, corresponding to the coverage that can be achieved with a single, modestly-powered DRB transmitter. Coverage would then be expanded to the full service area over time, by adding additional re-broadcasting transmitters on each DRB channel. This is shown conceptually in Figure 2.

Studies have demonstrated that this scheme would enable stations in the top seven markets to cover initially at least 95% of the population within their Census Metropolitan Areas (CMA). Similarly, such core-service transmitters would cover anywhere from 67%-93% of the listeners now served by the largest FM stations in these markets. All this can be achieved at minimal capital cost - about $80,000 for each of five program services sharing a given transmitter.

If the core-service concept were to be applied over time to the top 100 markets in Canada (in descending order), the national DRB service availability growth curve for Canada would be as shown in Figure 3.

To turn now to the data multiplex, Figure 4 shows how a DRB channel might be divided among the various users. Using the System A configuration proposed for Canada, each DRB channel would have a total capacity of 2304 kilobits per second (kbit/s). This can be split into three parts ... those bits used for audio services, those used for data services, and those needed mainly for housekeeping. The latter bits, located in the Fast Information Channel (FIC), undergo relatively little processing can be accessed quickly by the receiver. They are needed in order to tell the receiver where to find the various components of each service that uses the channel. The FIC can also carry some low-rate data, not necessarily related to the program services.

The principal use of each broadcast channel will be for audio programming services. Each of these five audio sub-channels will also include a small associated data channel, containing "program-associated data" (PAD). This could include supplementary data about the audio content being carried at the moment.

The channel will also have capacity for one or more auxiliary data services that may or may not be connected with the program audio. This is the place where broadcasters might carry information previously transmitted via FM sub-carriers. There is no technical reason to assign a specific data capacity to each individual program service; however, this could be done if regulatory requirements so dictate.

Figure 5 shows the various bit-rate combinations that correspond to the audio modes that might be chosen by a broadcaster. Most FM stations would likely utilize the 192 kbit/s "Joint Stereo" mode. AM monophonic stations might choose the 96 kbit/s "Single Channel" option. These seem to present a good compromise between having a very high quality audio signal and allowing a reasonable data capacity in the channel for the replacement of sub-carrier signals now carried on FM.

To ensure that service reliability remains high, especially for moving receivers located in fringe service areas, each of the data or audio applications sharing a DRB channel will have to select a suitable "protection level" for its transmissions. For audio services, five protection levels are available for each of 14 different bit-rates, as shown in Figure 6[2]. If the highest level (P1) is used, the signal will be very reliable, but a greater number of bits will be used overall, leaving fewer for auxiliary data services. For data services, four possible protection rates (0.25, 0.375, 0.50, and 0.75) can be used.

The above information illustrates that there is a great deal of flexibility inherent in the multiplex of a DRB transmitter. However, all of the users of the multiplex must agree how to split the pie. Figures 7 and 8 show two possible options.

Figure 7 provides 192 kbit/s for the audio of each of five broadcasters sharing the channel, along with 32 kbit/s each for auxiliary data. In addition there is a "pool" data channel of 48 kbit/s for other uses.

Figure 8 shows an option where the broadcasters might decide to pool the whole auxiliary data capacity, so as to be able to offer a single, very high-capacity channel to a customer.

A very basic implementation configuration for a hypothetical broadcast installation is shown in Figure 9. Here each station originates its own digitized audio at its studios and sends this data over a 64-256 kbit/s link to a conveniently-located central multiplex location, where common auxiliary data might be added. After multiplexing all the data, it is then sent on a 1500 kbit/s link to the common transmitter location[3]. At this point, the channel coding, modulation, and amplification functions are performed and the signal is transmitted to the public. If more than one transmitter is needed to achieve the necessary coverage for the station, a split can be done at the multiplex site in order to feed a same-channel Single Frequency Network (SFN) location. This is shown in Figure 10.

Figure 11 shows a conceptual plan for a large on-channel re-broadcasting system. Here six SFN re-broadcasters are used to achieve the overall service requirements. Some of these SFNs include the use of low-power on-channel "gap-filler" transmitters, which are suitable for filling small coverage holes.

This description of the multiplex and networking arrangements that will likely be required by DRB broadcasters suggests that there are substantial opportunities for suppliers of both services and equipment. In addition to studio-to-multiplexer links, broadcasters may require extensive interconnection facilities to tie main transmitter sites to SFN locations. There are also opportunities for the development of small, inexpensive, gap-filler amplifier packages, including the necessary receive/transmit antennas.

Service providers, including satellite carriers, land-line carriers, and even TV broadcasters with extensive terrestrial microwave facilities, will all benefit from the interconnection requirements of the DRB broadcasters of the future.

Although the overall architecture of Canada's future DRB system will be considerably different from that used today for AM and FM services, the end results are expected to benefit broadcasters, suppliers, and especially the listening public.

ooOOOoo

ENDNOTES

1. The Task Force's coverage criteria say that a station's DRB service area should not exceed its AM/FM analog coverage and should be no greater than that of the largest class of FM station currently allocated to the community.

2. Six combinations out of a possible total of 70 are not supported, as shown in Figure 6.

3. In some installations (e.g. the CN tower in Toronto), it might prove more practical to multiplex the data at the transmitter location.

REFERENCES

[1] Joint Technical Committee on Advanced Broadcasting; ***Preliminary Cost Indications for the Implementation of DRB Transmission Facilities in Canada***; January 1995

[2] Joint Technical Committee on Advanced Broadcasting; ***Capacity and Flexibility of the DRB Channel Multiplex***; 1995

[3] Gerhauser, Heinz (Fraunhofer Institute Fur Integrierte); ***DAB - A First Step Toward Multimedia Broadcasting***; Paper presented at the ASBU Symposium on DAB, Tunis, November 1994

[4] Weck, Christfried (IRT); ***A Well-Chosen Concept of Source and Channel Coding & Modulation for DAB***; Paper presented at the ASBU Symposium on DAB, Tunis, November 1994

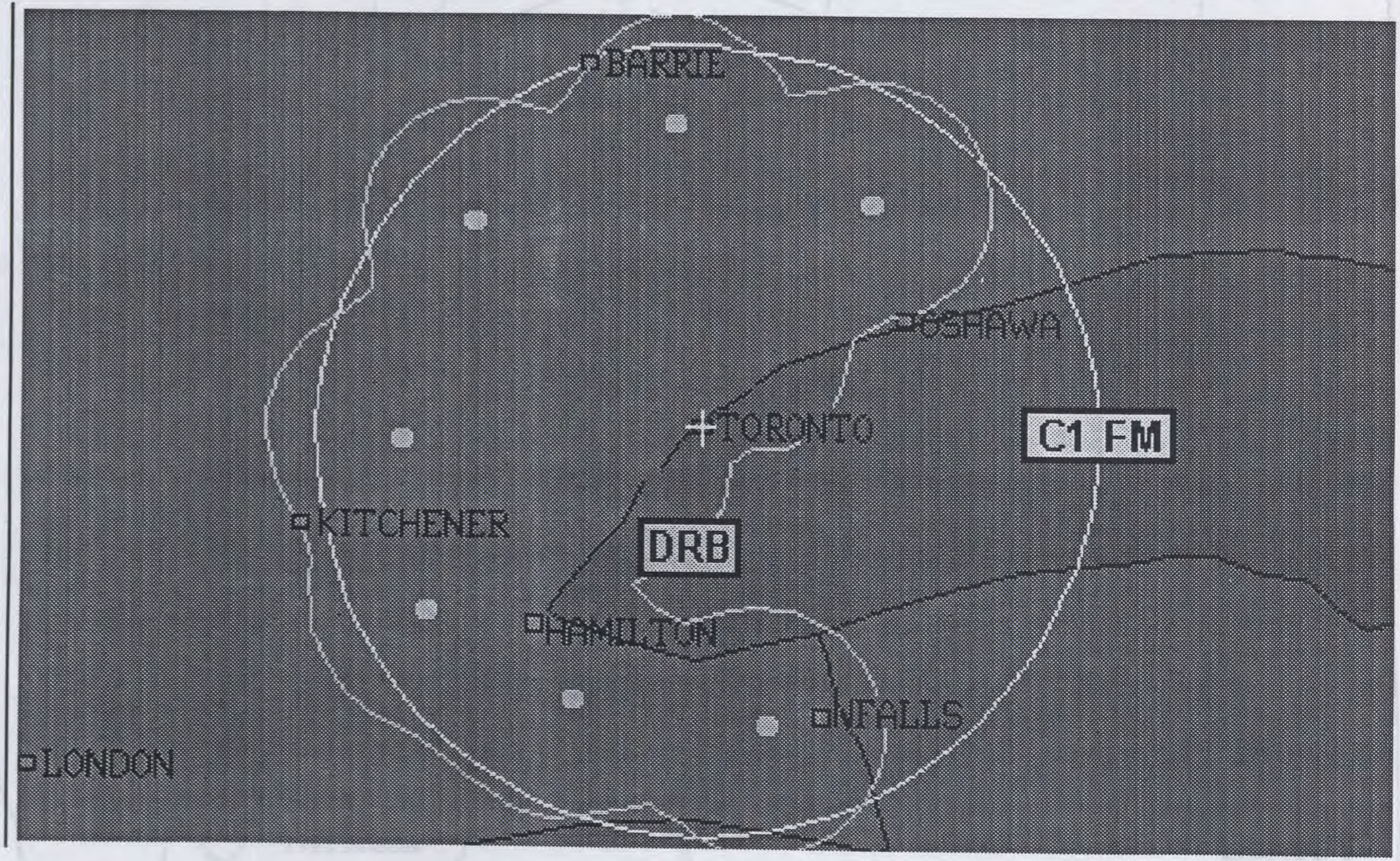
[5] Stacey, Lawson Associates Ltd. (in association with Nordicity Group Ltd.), ***Economic Impact of DAB on the Radio Industry***; Study prepared for the Ontario Ministry of Economic Development & Trade; June 1995

[6] Stacey, Wayne (Stacey, Lawson Associates Ltd); ***Assessment of Overall Radio Market coverage by Simple Core-Market DRB Transmitters***; Study prepared for the Joint Technical Committee on Advanced Broadcasting; June 1995

[7] Task Force on the Introduction of Digital Radio, Working Group I; ***Non-Technical Coverage and Service Area Issues***; August 1994

FIGURE 1.

EXAMPLE OF FULL DUPLICATE DRB COVERAGE - TORONTO



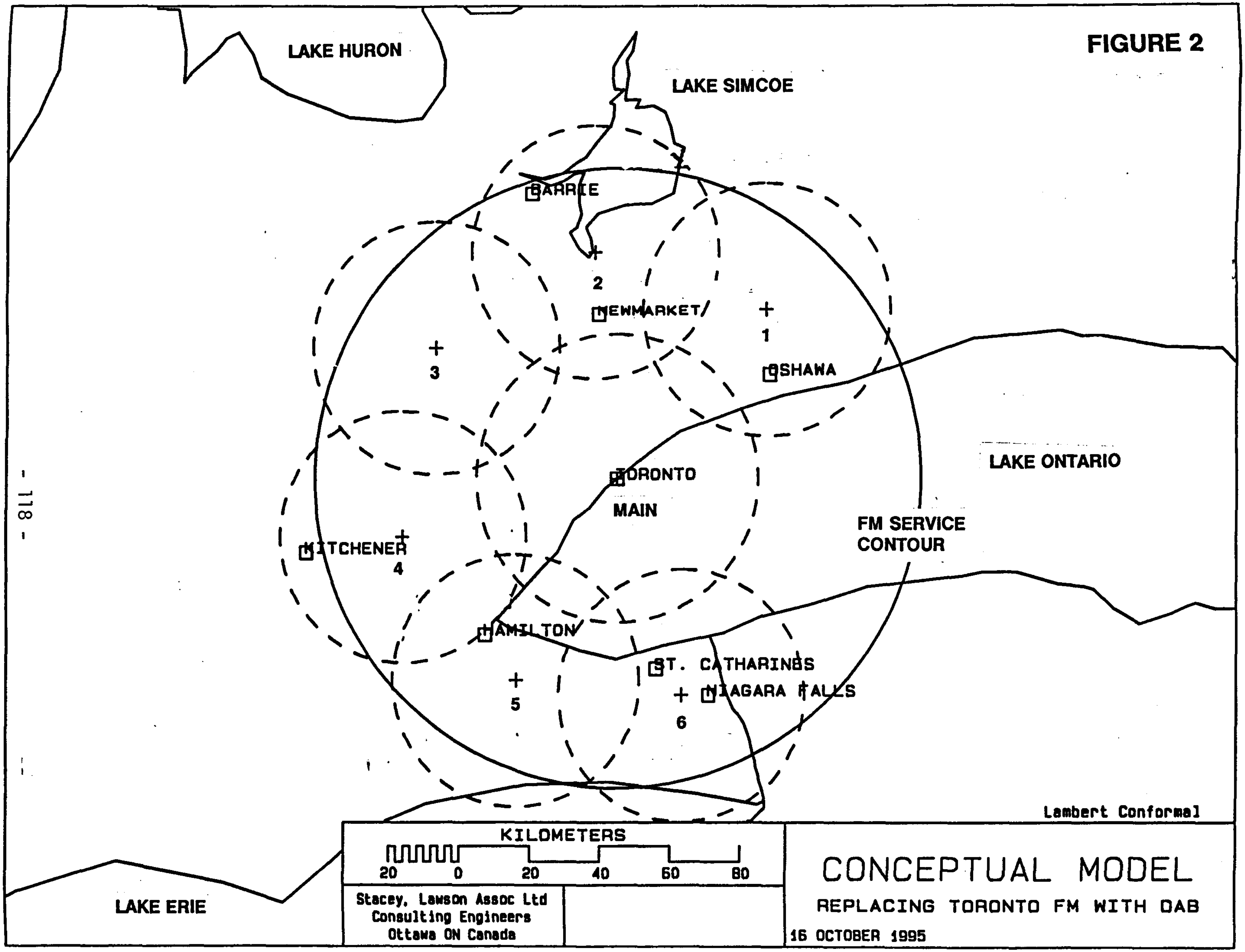


FIGURE 2
LAKE HURON
LAKE SIMCOE
BARRIE
2
NEWMARKET
1
3
OSHAWA
TORONTO
MAIN
LAKE ONTARIO
FM SERVICE
CONTOUR
KITCHENER
4
HAMILTON
ST. CATHARINES
NIAGARA FALLS
5
6
Lambert Conformal
KILOMETERS
20 0 20 40 60 80
LAKE ERIE
Stacey, Lawson Assoc Ltd
Consulting Engineers
Ottawa ON Canada
CONCEPTUAL MODEL
REPLACING TORONTO FM WITH DAB
16 OCTOBER 1995

FIGURE 3

DRB COVERAGE GROWTH, BY CMA

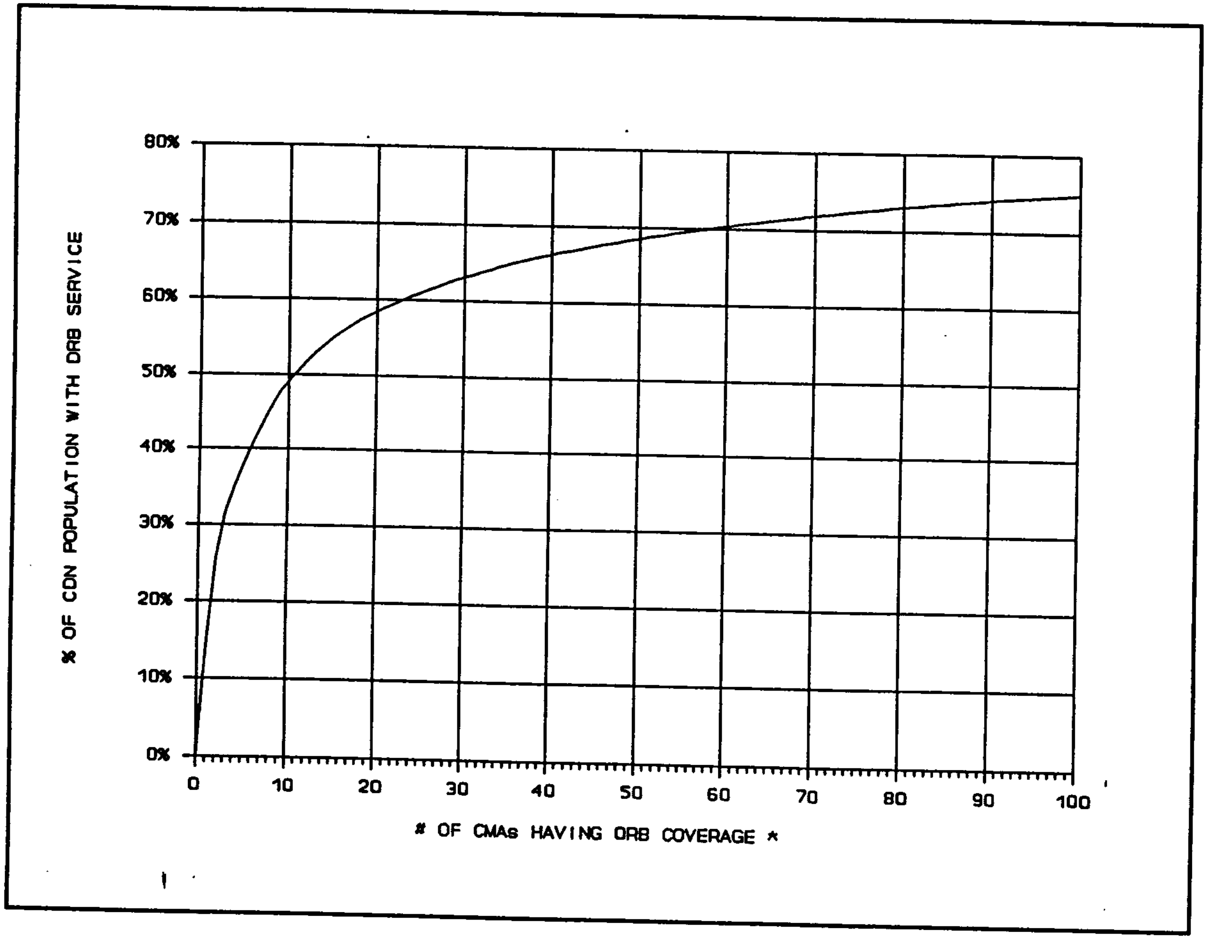


FIGURE 4

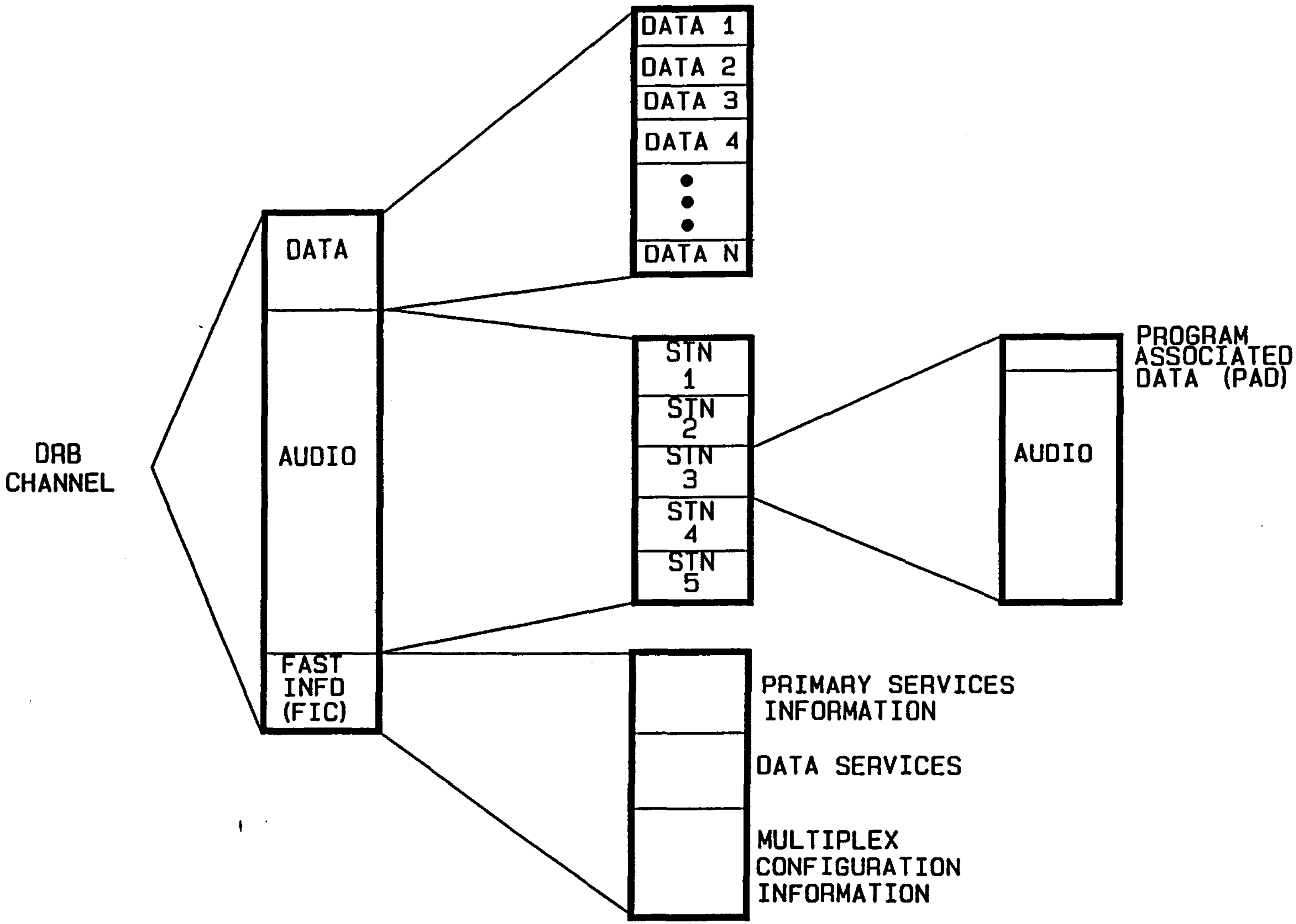

DRB
CHANNEL
DATA
AUDIO
FAST
INFO
(FIC)
DATA 1
DATA 2
DATA 3
DATA 4
DATA N
STN 1
STN 2
STN 3
STN 4
STN 5
PROGRAM
ASSOCIATED
DATA (PAD)
AUDIO
PRIMARY SERVICES
INFORMATION
DATA SERVICES
MULTIPLEX
CONFIGURATION
INFORMATION

FIGURE 5

EUREKA 147/DAB (ITU-R SYSTEM A)
AUDIO MODES AND BIT RATES APPLICABLE FOR DRB

Bit Rate (kbit/s)	AUDIO MODE			
	SINGLE CHANNEL	DUAL CHANNEL	STEREO	JOINT STEREO
32	X			
48	X			
56	X			
64	X	X	X	X
80	X			
96	X	X	X	X
112	X	X	X	X
128	X	X	X	X
160	X	X	X	X
192	X	X	X	X
224		X	X	X
256		X	X	X
320		X	X	X
384		X	X	X

FIGURE 6

EUREKA 147/DAB (ITU-R SYSTEM A)
PROTECTION LEVELS vs AUDIO BIT RATES

Bit Rate (kbps)	PROTECTION LEVEL				
	P1 (HIGHEST)	P2	P3	P4	P5 (LOWEST)
32, 48, 56, 64, 80, 96, 112, 128, 160 192, 224, 256 320, 384	Range 0.34 - 0.36	Range 0.40 - 0.43	Range 0.50 - 0.51	Range 0.57 - 0.62	Range 0.72 - 0.75

NUMBER OF BIT RATES: 14
NUMBER OF PROTECTION LEVELS: 5
COMBINATIONS NOT SUPPORTED: P1 @ 56, 112, 320 kbps
P2 & P4 @ 384 kbps
P3 @ 320 kbps

EXAMPLE 1

Parameter	Independent Stereo Audio Programs	Independent Auxiliary Data Channels	Joint Auxiliary Data Channels
No. of Services per transmitter	5	5	1
Data allotment for basic content (per channel)	192 kbits/sec	32 kbits/sec	48 kbits/sec
Data allotment for error correction (per channel)	185 kbits/sec P = 0.51	32 kbits/sec P = 0.50	48 kbits/sec P = 0.50
Total data allotment (per channel)	377 kbits/sec	64 kbits/sec	96 kbits/sec
Total data allotment (all channels)	1885 kbits/sec	320 kbits/sec	96 kbits/sec
Overall total data bits	2301 kbits/sec		

FIGURE 8

EXAMPLE 2

Parameter	Independent Stereo Audio Programs	Independent Auxiliary Data Channels	Joint Auxiliary Data Channels
No. of Services per transmitter	5	0	1
Data allotment for basic content (per channel)	192 kbits/sec	0 kbits/sec	192 kbits/sec
Data allotment for error correction (per channel)	185 kbits/sec P = 0.51	0 kbits/sec	192 kbits/sec P = 0.50
Total data allotment (per channel)	377 kbits/sec	0 kbits/sec	384 kbits/sec
Total data allotment (all channels)	1885 kbits/sec	0 kbits/sec	384 kbits/sec
Overall total data bits	2269 kbits/sec		

FIGURE 9

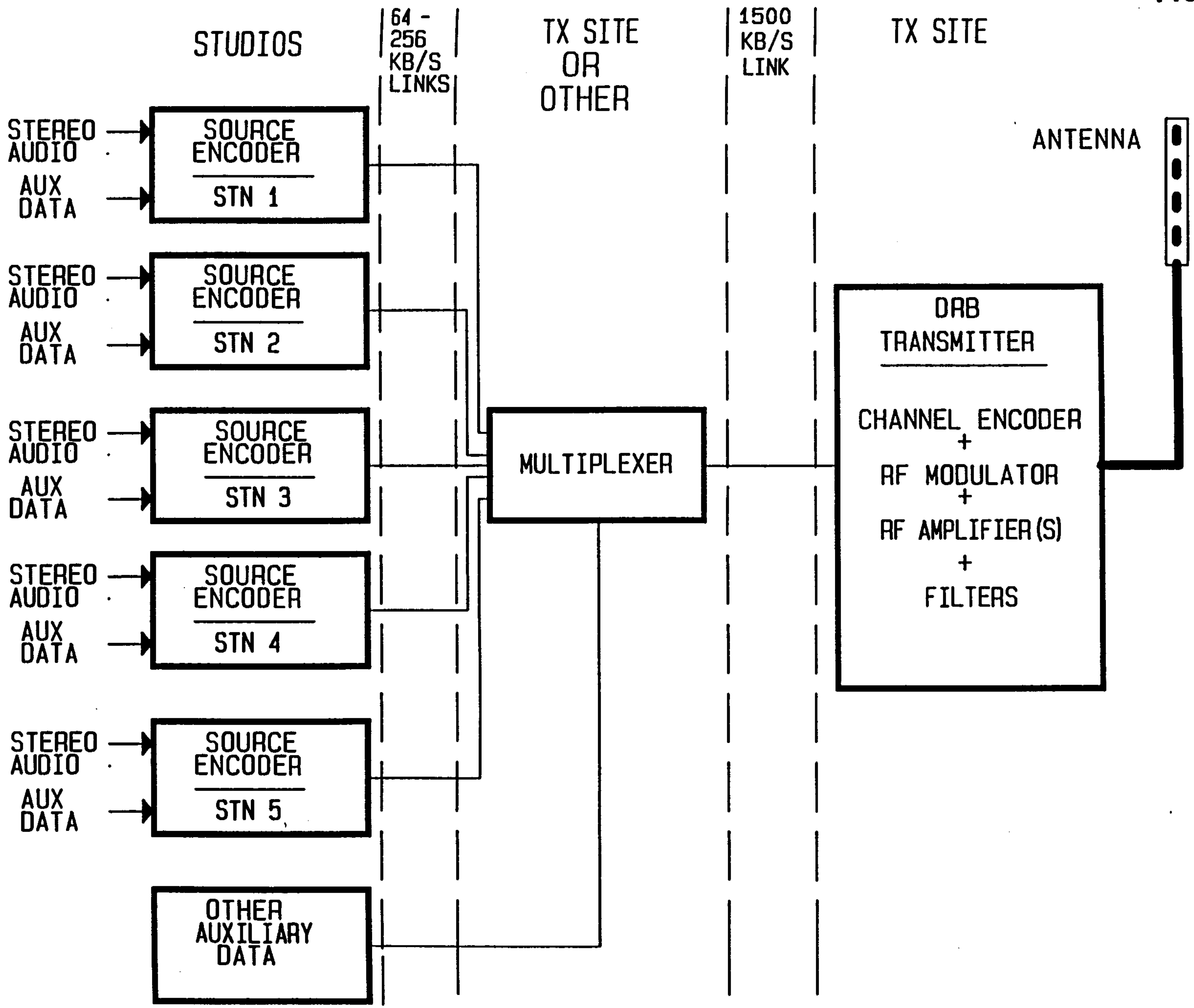
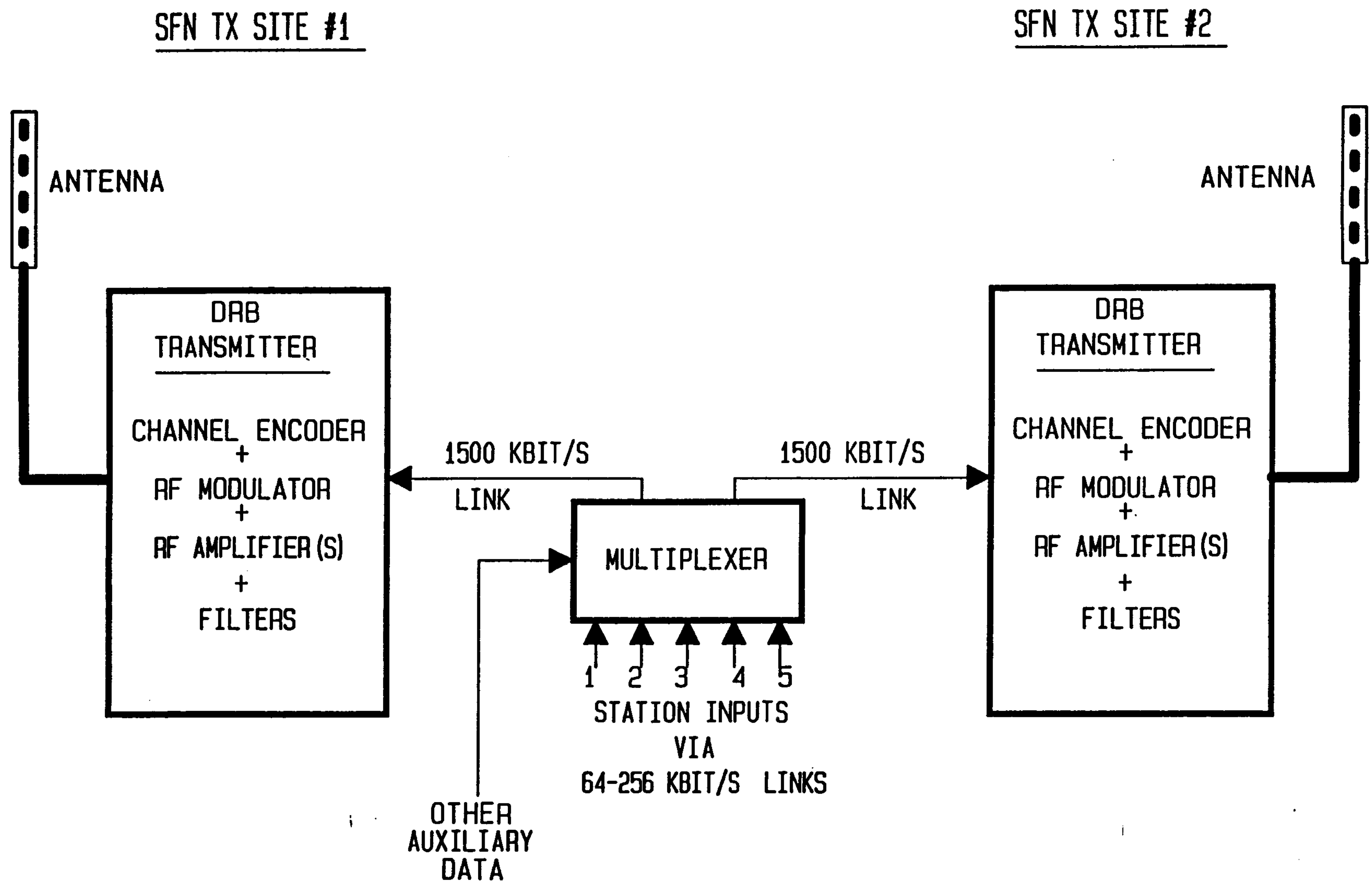
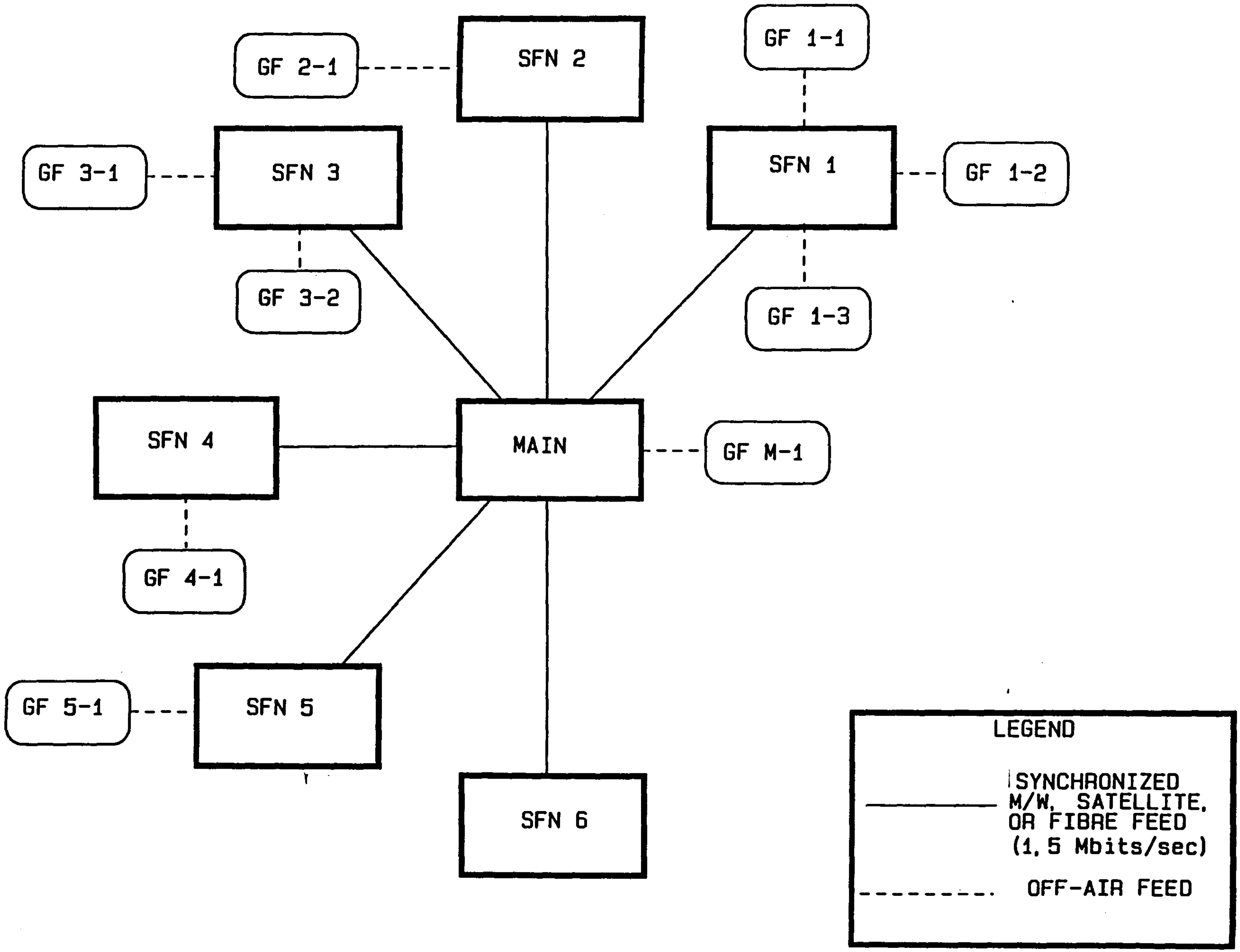

STUDIOS
64 - 256 KB/S LINKS
TX SITE OR OTHER
1500 KB/S LINK
TX SITE
STEREO AUDIO
AUX DATA
SOURCE ENCODER
STN 1
STEREO AUDIO
AUX DATA
SOURCE ENCODER
STN 2
STEREO AUDIO
AUX DATA
SOURCE ENCODER
STN 3
STEREO AUDIO
AUX DATA
SOURCE ENCODER
STN 4
STEREO AUDIO
AUX DATA
SOURCE ENCODER
STN 5
OTHER AUXILIARY DATA
MULTIPLEXER
ANTENNA
DRB TRANSMITTER
CHANNEL ENCODER
+
RF MODULATOR
+
RF AMPLIFIER(S)
+
FILTERS

FIGURE 10



SFN TX SITE #1
SFN TX SITE #2
ANTENNA
ANTENNA
DRB TRANSMITTER
CHANNEL ENCODER + RF MODULATOR + RF AMPLIFIER (S) + FILTERS
DRB TRANSMITTER
CHANNEL ENCODER + RF MODULATOR + RF AMPLIFIER (S) + FILTERS
1500 KBIT/S LINK
1500 KBIT/S LINK
MULTIPLEXER
1 2 3 4 5
STATION INPUTS VIA 64-256 KBIT/S LINKS
OTHER AUXILIARY DATA

FIGURE 11


GF 2-1
SFN 2
GF 1-1
GF 3-1
SFN 3
SFN 1
GF 1-2
GF 3-2
GF 1-3
SFN 4
MAIN
GF M-1
GF 4-1
GF 5-1
SFN 5
SFN 6
LEGEND
SYNCHRONIZED M/W, SATELLITE, OR FIBRE FEED (1.5 Mbits/sec)
OFF-AIR FEED

Wayne Stacey

Mr. Wayne Stacey holds a Science degree in Electrical Engineering. He has had extensive experience in broadcasting and telecommunications.

Mr. Stacey is a member of the CAB's Engineering and Technology Council, Industry Canada's Broadcast Technical Advisory Committee, and is vice-chairman of the Broadcasting Committee of the Radio Advisory Board of Canada. Since 1991, he has chaired the Digital Radio Coordinating Group of the Joint Technical Committee on Advanced Broadcasting.

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RF EQUIPMENT CONSIDERATIONS

Brian Sawyer, CBC

[SLIDE 1]

The Eureka-147 digital radio broadcasting system is remarkable in its inherent ability to assure an excellent quality of performance even in harsh radio frequency environments. This system, whose components are currently being standardized by several bodies, will allow mixed mode satellite-terrestrial broadcasting.

Unlike AM, FM and other proposed digital standards, which usually require the use of an isolated high-power transmitter per program, Eureka-147 permits both distributed emission on *Single Frequency Networks* (SFN) and the broadcasting of more than one program per channel, **[SLIDE 2]** resulting in better coverage and substantial power savings along with optimal spectrum usage. It is the robust *Coded Orthogonal Frequency Division Multiplexing* (COFDM) channel coding, which takes advantage of echo's, rather than suffering because of them, that renders all this possible.

[SLIDE 3] Eureka-147 represents, however, a considerable departure from traditional broadcast technology, with totally new parameters and requirements. Consequently, transmission system components need to be entirely re-designed. **[SLIDE 4]** To this point emphasis has been put on the design of coding and modulation equipment, but designers concerned with up-conversion, amplification and emission will also be faced with new challenges and opportunities.

Many Countries have officially adopted the L-band for DRB but Canada is considered the leader in the development of this band.

[SLIDE 5] As we can see, the immediate requirements for Canada, and many other Countries are: Up and down-conversion equipment, delay devices both for base-band as well as L-band, amplifiers operating at various power levels, high power band-pass filters that can meet the spectrum mask criteria while maintaining a low insertion loss, and antennas both active and passive.

[SLIDE 6] For those engineers concerned with the design of such new equipment, new challenges and opportunities are on the horizon....We must however, be innovative in our approach to the designs.

[SLIDE 7] The COFDM digital transmission technique, described in a number of papers, is basically composed of the OFDM modulation technique, augmented with an adaptable rate forward error coding resulting in a system that is so robust that reliable transmission of bit rates in the order of 1.2 Mb/s to mobile receivers is possible in a 1.5 MHz wide channel. However, as we will see, the COFDM modulation technique places new requirements on the design of transmission equipment, and in particular of RF power amplifiers.

OFDM combats urban and mobile transmission impairments by lengthening the symbol duration so that it becomes much longer than the extent of the multipath distortion profile. Consequently, inter-symbol interference (ISI) occurs only between adjacent symbols.

[SLIDE 8] To preserve the bit rate against the decreased baud transmission, information is distributed over a number of individual sub- or virtual carriers, modulated by some modulation method, such as QPSK, which are spaced such that they are orthogonal over a symbol period.

[SLIDE 9] These individual carriers can then be demodulated efficiently using a Fast Fourier Transform (FFT).

(Symbol alphabets are therefore very large. As an example, with Mode 2 DAB, there are 384 carriers and D-QPSK modulation = 2^2 *therefore in total we have* $2^{2 \times 384} = 2^{768}$ *states.)*

To eliminate the remaining ISI between adjacent symbols, each symbol is extended in time by repeating part of it during what is known as the guard time or guard interval. **[SLIDE 10]** At reception, the receiving window is set in the part of the symbol that is not affected by the multipath decay of the previous symbol.

[SLIDE 11] Since the COFDM system was designed to resist and even take advantage of multiple strong echoes of the signal within the guard interval, it invites the formation of a single frequency network (SFN). In SFN's, coverage of a given territory is achieved with distributed co-channel transmitters, rather than with a single large beacon-type transmitter as is usual with classical broadcast methods. Receivers in an SFN cannot distinguish the direct signal from other signals caused by multipath echos. This is an advantage with respect to channel degradation, which is approximately a function of distance to the power of 2. Random echos within the guard-interval reinforce the COFDM signal at the receiver. Thus SFN is far less sensitive, for an equivalent overall power, to signal decay due to distance than a traditional broadcast system.

Interestingly, single frequency networks were first proposed in the 1930's for AM broadcasting, for many of the same reasons as with digital radio broadcasting, including network power savings.

[SLIDE 12] Eureka-147 DAB broadcasting can be implemented in a number of bands ranging from VHF to S-band. **[SLIDE 13]** System parameters have been established for each of the bands. **[SLIDE 14]** As seen in an earlier slide, signals are distributed to the various cells within a local coverage area by various means. For synchronous operation of two or more transmitters, either fibre optic networking or microwave radio is used. In order to attain an optimized zone where signals from all active transmitters in the SFN arrive within the guard interval, appropriate delays are introduced into the system. It is important to note that optimization should take into account local terrain conditions. Two methods have been experimented with. The first permits time delay to be introduced at the 1.5 GHz level the second at the baseband level.

[SLIDE 15] The technology chosen for the on-channel delay unit is fibre optic based whereby a "lump" consisting of a small reel of fibre is introduced between a laser transmitter and receiver.

The laser is directly modulated by the 1.5 GHz fully modulated signal. Delays can be achieved in the range 0 to 200 uS. **[SLIDE 16]** The technology of choice for the synchronized stations is digital delay. The signal at the output of the FM microwave receiver is a true representation of the DRB modulator with the integrity of the frequency being intact due to the FM modulation used in the link. The center frequency of the fully modulated recovered DRB signal is 4 MHz. This is sampled at a clock rate of approximately 14 MHz and the digital representation is stored in memory. As defined by the service area, the signal is released from the buffer with the appropriate delay. This delay is adjustable from 0 to 1 mS in 10 uS increments. At the output the digital signal is converted to analog and output to an upconverter. Devices such as these have been tested and have proven viable both from a performance and cost perspective. **[SLIDE 17]** Gap fillers are often required in situation where terrain limits coverage, for instance, behind a mountain, in a deep valley or for providing coverage through long tunnels. These gap-fillers, being on-frequency, require special attention regarding the potential for feedback which can result in oscillation or at minimum, instability. What is required from the hardware perspective is; a highly directional receive antenna, for example a one metre parabolic antenna; a bandpass filter; a low noise pre-amplifier; a power amplifier and a transmitting antenna. In areas where the received signal may be problematic in terms of receive level, a mechanism to automatically control the overall gain of the system is required so as not to overload the power amplifier thereby creating intermod distortion. Typical power levels required for this type of application vary from 1 to 20 Watts of DRB power at the output of the HPA. **[SLIDE 18]** In the case of coverage extenders, the principle is the same but the power requirements would typically be higher requiring even more precautionary measures in the implementation. **[SLIDE 19]**

Researchers, including engineers from the public and private broadcast community, engineers from Industry Canada and scientists from the Communications Research Center, have been conducting L-band field experiments and theoretical studies under the management of the "Joint Technical Committee on Advanced Broadcasting" (JTCAB) using the resources of "Digital Radio Research Inc." (DRRI). **[SLIDE 20]** These experiments have shown that, in practice, an intermediate mode of operation between mode 1 and mode 2 appears to be feasible when used at L-band. (You might remember, we saw this mode listed in the slide describing the parameters for the different modes earlier). This mode of operation should improve the efficiency of L-band implementation in consideration of the number of sites required to provide a given coverage requirement. This is achieved in part by maintaining the added SFN network gain while being able to space transmitting stations at greater distances apart. This is possible as mode 1.5 provides double the guard interval time to that of Mode 2. The degrading effects of Doppler using mode 1.5 at L-band have been shown through field tests to be, in practical terms, only a problem at speeds in excess of the maximum speed limit in Canada. As DRB receivers are now capable of automatic mode sensing, at locations where this might be considered to be a problem, the transmit facility could be designed to operate in mode 2 where Doppler is much less of a problem. **[SLIDE 21]** Now we should look at other important system operating parameters as they specifically apply to the RF equipment described earlier. These include, but are not limited to; Phase noise, AM-PM conversion, generation of intermodulation products, and, in the case of an SFN operation, frequency stability. All of these parameters can be economically dealt with as long as the manufacturers take appropriate precautions in their equipment design. **[SLIDE 22]** I repeat what I said earlier..... we need to be innovative. Let me explain........

At L-Band it is relatively easy to achieve higher antenna gains and better coverage characteristics than in present broadcast systems. Electrical powers of only a few hundreds of Watts will be necessary, which is somewhat too low to justify the use of microwave power tubes (Klystrons and Triodes), but still much higher than what is usually required for communication systems. Today's semiconductor technology allows a maximum power output from an individual microwave transistor of the order of 20 to 30 W due to constraints on; die size and geometry; limits of cooling materials and impedance matching requirements. These limitations are so closely related to physical constraints that it is highly unlikely that considerably more powerful transistors will appear on the market in the near future. Existing designs of DAB power amplifiers try, in different ways, to combine the power of individual transistors to achieve the required power. Class A amplifiers, even though very linear, are wasteful of power, and are of little benefit in the presence of a high dynamic range signal such as exists with COFDM. They are also subject to AM/PM conversions, as are other amplifiers. On the other hand, Class AB amplifiers, usually built by biasing common emitter power transistors at their conduction threshold, are more efficient, but are somewhat less linear. Furthermore, present measurement and characterization methods used to evaluate the quality of amplifiers are not, in our opinion, adequate for the DAB environment. For example, the classical notions of third order intermodulation power and the two-tone test, with which amplifiers are presently being characterized are of little interest when they are fed with a random envelope input signal, as is the case in DAB. In fact, most manufacturers of amplifiers for experimental DAB stations, have dealt up to now with the aforementioned problem by operating the amplifiers well below saturation, without truly trying to understand the phenomena involved. Even then however, an appropriate compromise on drive back-off is hard to find as a low average input level causes cut-in distortion due to conduction thresholds and a high average input level causes spectrum spread distortion. Because of this, we believe it would be more appropriate to do a weighted average of the non-linear characteristics of an amplifier over the Probability Distribution Factor (PDF) of the input signal. Linearity, at least before amplifier saturation, can be improved in a number of manners that are becoming commonplace in other fields, such as cellular radio. These include feed-forward correction and predistortion. These techniques indirectly improve efficiency as they reduce the amount of back-off that is necessary to achieve the required distortion performance from a given amplifier. However, there are fundamental limits to what can be achieved with these methods . **[SLIDE 23]** It may be possible to reuse in the DRB field, techniques that are presently the realm of medium wave broadcasting. Work is under way in Canada to evaluate the best application of these techniques to digital audio broadcasting. One way to improve efficiency would be to use the *Doherty approach.* In this technique, the load is shared between two amplifiers that are biased and connected in such a way that one of the amplifiers carries most of the load at top efficiency, while the other contributes only on signal peaks. In L-band DRB, one could imagine a common-emitter class AB amplifier operated without back-off at top efficiency combined with a common-base pulse class C amplifier for the peaks. Another method is the *Chireix amplifier*. This technique employs two class C constant envelope amplifiers with each amplifier having a volt output of V_0, the combination of the two amplifiers permit the generation of any output voltages from zero to $2V_0$ volts with arbitrary phase. Other approaches might include RF feedback and envelope feedback. However, at this point in time, this is considered impractical at microwave frequencies with the present state of the art, because of the low gain of devices and stability problems brought about by narrow-band designs. As described, the construction of RF power amplifiers is a complex undertaking, which could benefit significantly from improved system design that address the following issues:

[SLIDE 24] ***Phase noise***. A COFDM signal is in fact the superposition of a great many individual carriers modulated by a low bit rate QPSK stream. Such low rate narrow band channels are sensitive to phase noise effects such as those generated by the local oscillator.

[SLIDE 25] ***Amplifier monitoring and leveling.*** Accurate measurement of RF quantities is particularly difficult when signals having a non-constant amplitude are present. The precision and the speed of the diode detectors measuring output voltage and power is therefore critical. Other methods for monitoring require investigation.

[SLIDE 26] ***Amplitude non-linearities***, ***AM-PM conversion***, and ***clipping*** introduce an intrinsic BER into the recovered OFDM signal. Non-linearities cause spectral expansion which complicates the achieving of spectral purity standards. Retransmitted COFDM signals will eventually become indecipherable because of accumulated errors brought about by AM-PM conversions. This is relevant in the case of analog distribution networks, satellite up- and down- links, and gap-fillers and coverage extenders.

[SLIDE 27] ***Filtering*** will modify the amplitude distribution. There is no simple method for predicting the effects of filtering on a given distribution function when it is modified by clipping.

As for our recommendations, since DAB is destined to be a widely disseminated broadcast system, we believe that performance and cost criteria can be achieved by equipment designers if appropriate consideration is given to the following:

[SLIDE 28] New approaches for power amplifier design have to be seriously considered in order to achieve higher power efficiency. Promising directions include employing techniques allowing reduction in back-off, techniques in splitting the signal between two or more amplifiers and methods to allow the placement of the amplifier as close as possible to the antenna. The operation of large networks with on-channel repeaters and possibly satellite links will involve careful analysis of overall system performance which will be dependent on phase noise, non-linear amplification effects and filtering both at intermediate and high power levels. And finally, whereas passive antenna technology at L-band frequencies has basically been mastered, serious consideration needs to be given to the development and deployment of antennas with integrated power amplifiers.

The EUREKA 147 design has reached a complexity such that the independent development of each single RF module is not optimal.

DRB L-Band Presentation
on
RF Equipment Considerations

The EU-147 DRB *system* is remarkable in its inherent ability to provide an excellent quality of performance even in a harsh radio frequency environment

Unlike other systems, which usually require the use of a single, often isolated, high-power transmitter per program, the EU-147 system permits:

- ***Distributed emission* on a Single Frequency Network (SFN)**

- **Broadcasting of *more than one* program per channel**

DRB L-Band Presentation
on
RF Equipment Considerations

Benefits:

- **better coverage**
- **substantial power savings**
- **along with optimal spectrum usage**

Why ?

It is rendered possible because of the robust Coded Orthogonal Frequency Division Multiplexing *(COFDM)* channel coding

and ....

because the design *exploits the echos* rather than suffering because of them.

DRB L-Band Presentation
on
RF Equipment Considerations

EU-147 represents however;

- **a considerable departure from traditional broadcast technology**

- **totally new parameters and requirements**

***Consequently*, transmission system components need to be entirely re-designed**

DRB L-Band Presentation
on
RF Equipment Considerations

<u>**To date :**</u>

Emphasis has been put on the design of the coding and modulation equipment

Many Countries have officially adopted L-band for DRB but *Canada is considered the leader* in the development of an implementation strategy which includes a joint cooperation with industry and government

DRB L-Band Presentation
on
RF Equipment Considerations

Immediate requirements :

- Up and down-conversion equipment
- Delay devices for base-band & L-band
- High, medium and low power amplification for a wide variety of transmission or re-transmission applications
- High power band-pass-filters
- Antennas, both active and passive

DRB L-Band Presentation
on
RF Equipment Considerations

For those engineers concerned with the design of such new equipment, new challenges and opportunities are on the horizon ......

.... if we are

innovative in the design approach

DRB L-Band Presentation
on
RF Equipment Considerations

EU -147 COFDM digital transmission technique

OFDM **modulation places new requirements on the design of transmission equipment, particularly for medium and high power *RF power amplifiers.***

OFDM combats urban and mobile transmission impairments by lengthening the symbol duration so that it becomes much longer than the extent of the multipath distortion profile. Consequently, inter-symbol interference (ISI) occurs only between adjacent symbols.

DRB L-Band Presentation
on
RF Equipment Considerations

EU -147 COFDM digital transmission technique (Continued...)

- To preserve the bit rate against the decreased baud transmission, information is distributed over a number of individual sub- or virtual carriers.
- These carriers are differentially quadrature phase shift keyed modulated (D-QPSK) and are spaced such that they are orthogonal over a symbol period

DRB L-Band Presentation
on
RF Equipment Considerations

EU -147 COFDM digital transmission technique (Continued...)

- Individual carriers can then be demodulated efficiently using a Fast Fourier Transform (FFT)

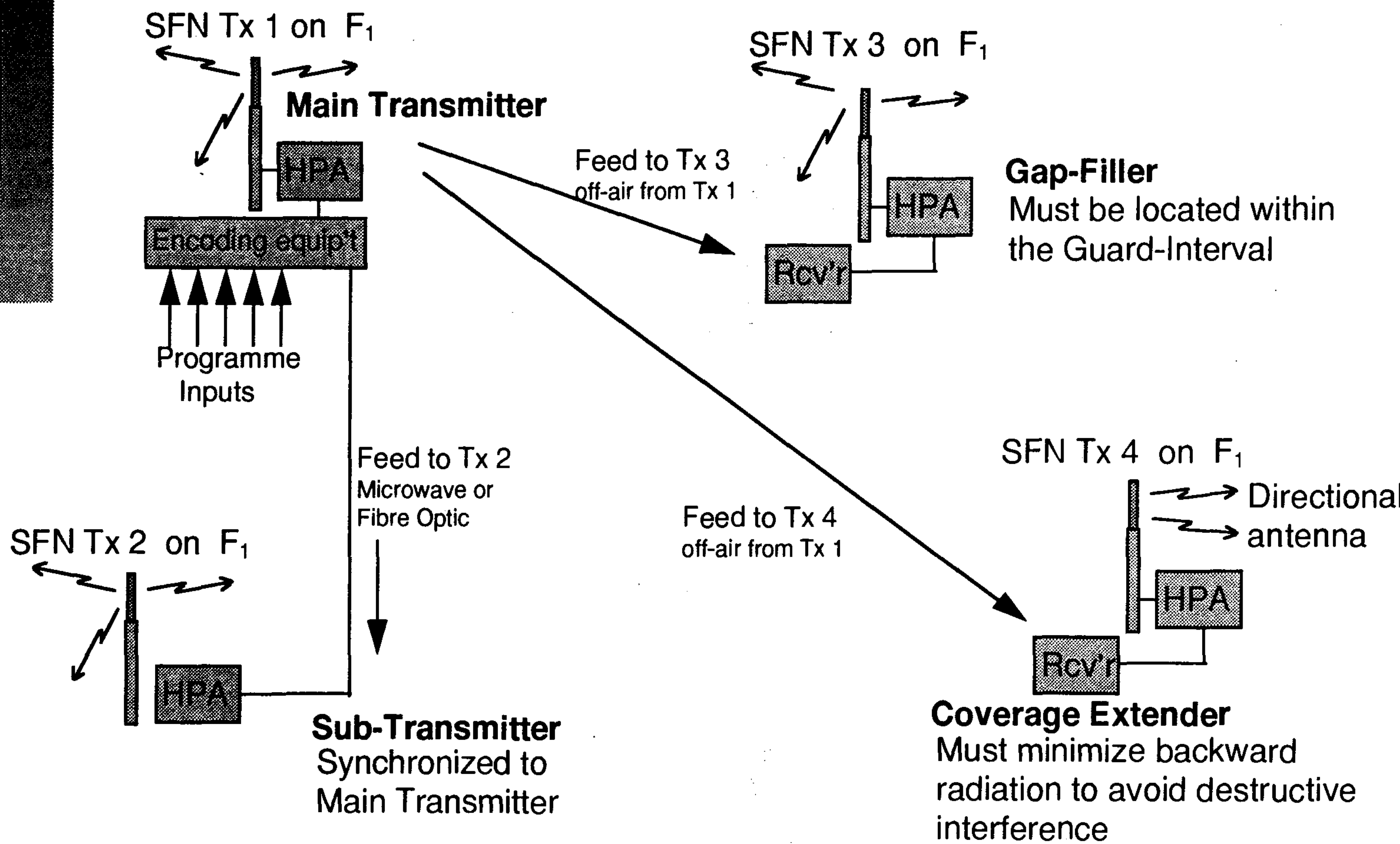
- To eliminate any remaining inter-symbol interference (ISI) between adjacent symbols, each symbol is extended in time by repeating part of it during what is known as the guard interval

DRB L-Band Presentation
on
RF Equipment Considerations

EU -147 COFDM digital transmission technique (Continued...)

- At reception, the receiving window is set in the part of the symbol that is not affected by the multipath decay of the previous symbol

DRB L-Band Presentation
on
RF Equipment Considerations



Typical SFN with Gap-Filler & Coverage Extender

DRB L-Band Presentation
on
RF Equipment Considerations

EU - 147 DRB broadcasting can be technically implemented in the 50 to 3,000 MHz frequency range. The following are being considered:

VHF	**47 - 68 MHz**
	174 - 230 MHz
	230 - 240 MHz
L - Band	**1,452 - 1,492 MHz**
S - Band	**2,310 - 2,360 MHz**
	2,535 - 2,655 MHz

DRB L-Band Presentation
on
RF Equipment Considerations

DRB System Parameters

Mode	# of Carriers	Useful Symbol Period	Guard Interval Time	Total Symbol Period	Symbols per Frame	Sub-Carrier spacing
1	1,536	1000 uS	246 uS	1,246 uS	76	1 kHz
1.5	768	500 uS	124 uS	624 uS	76	2 kHz
2	384	250 uS	62 uS	312 uS	76	4 kHz
3	192	125 uS	31 uS	156 uS	153	8 kHz

DRB L-Band Presentation
on
RF Equipment Considerations

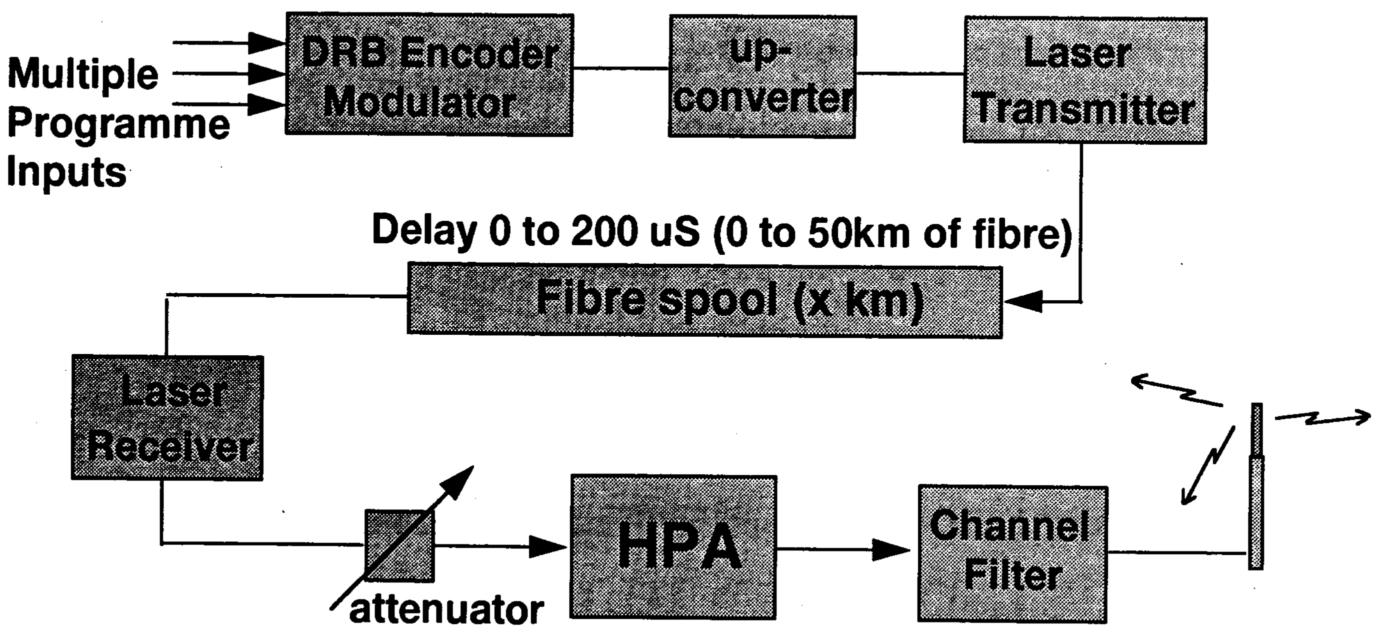
DRB Signal Distribution Mechanisms

within a

Local Coverage Area

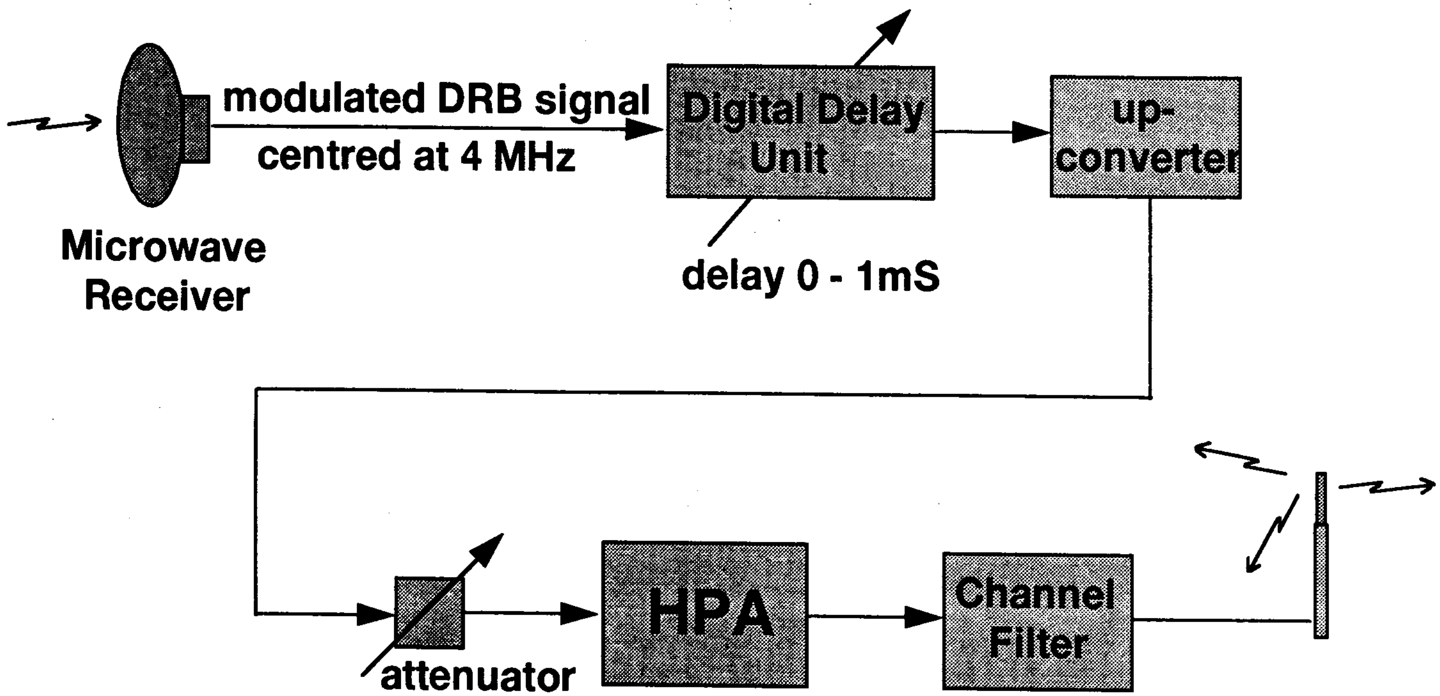
DRB L-Band Presentation
on
RF Equipment Considerations

Main DRB Transmitting Station



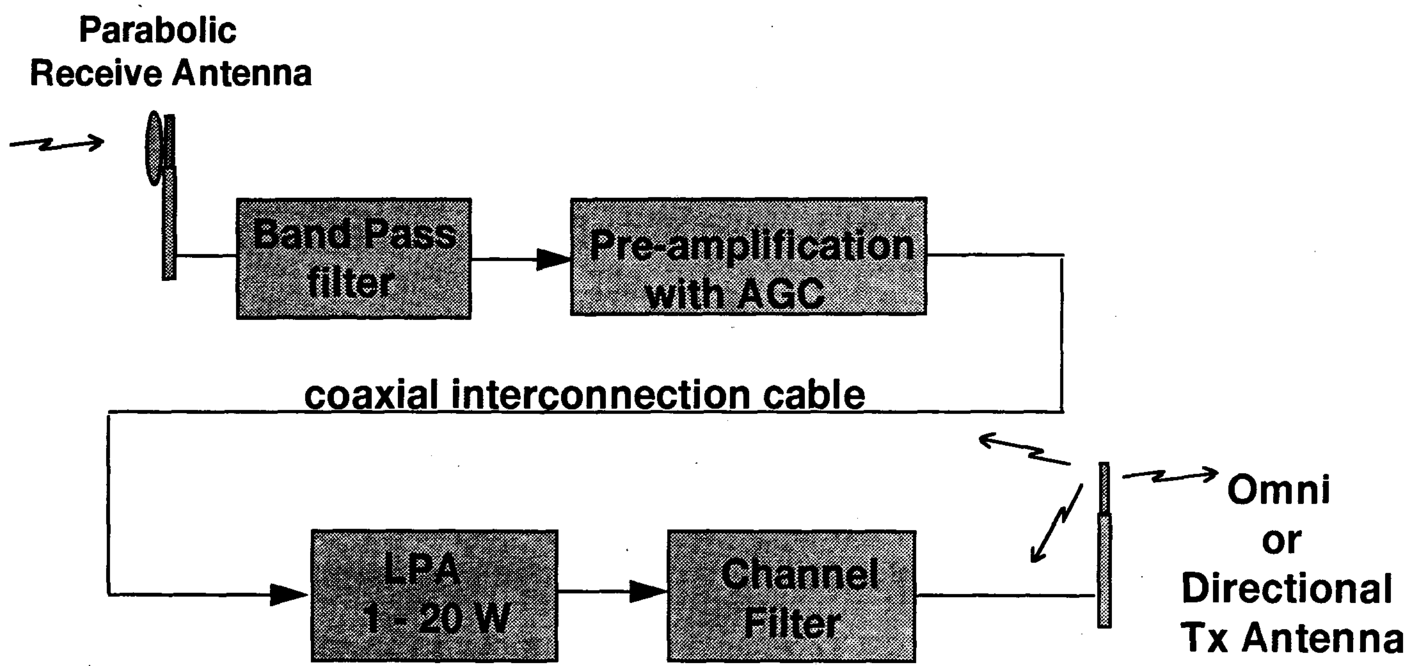
DRB L-Band Presentation
on
RF Equipment Considerations

Synchronized Transmitting Station



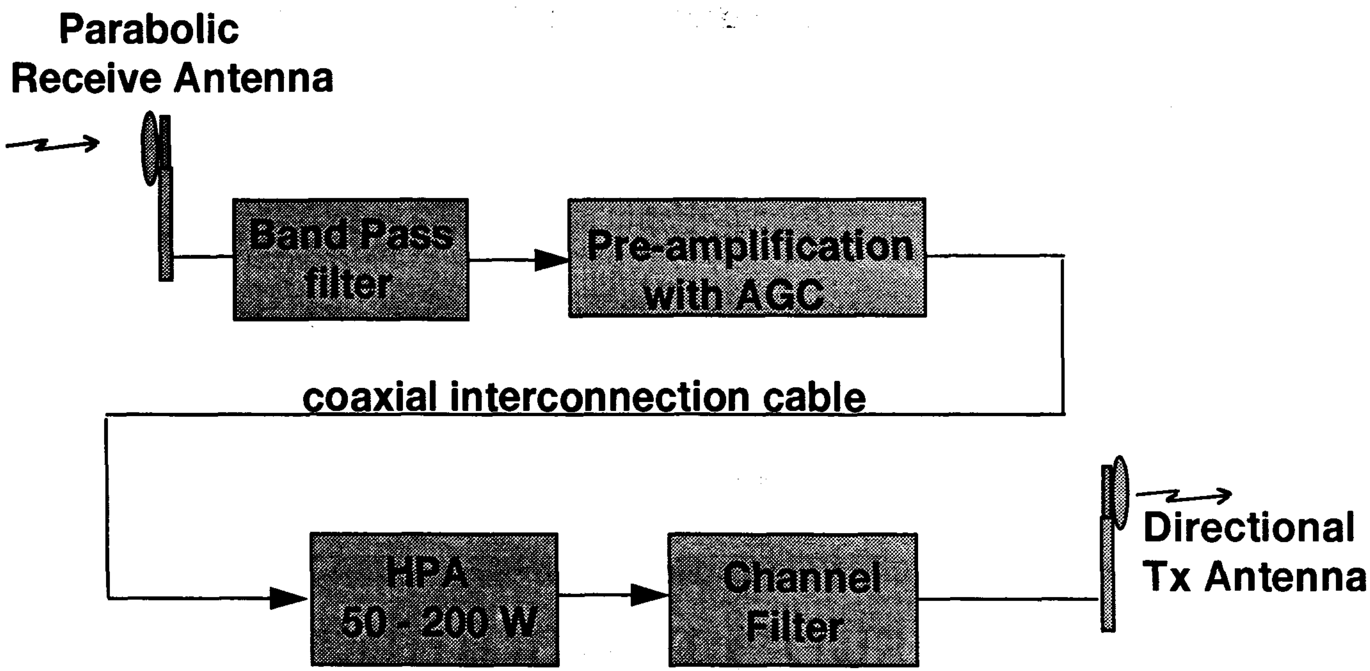
DRB L-Band Presentation
on
RF Equipment Considerations

TYPICAL GAP-FILLER



DRB L-Band Presentation
on
RF Equipment Considerations

TYPICAL COVERAGE EXTENDER



DRB L-Band Presentation
on
RF Equipment Considerations

Co-operation has been the key....

- Public Broadcaster
- Private Broadcaster
- Industry Canada
- Communications Research Centre

Steering Committees

- Joint Technical Committee on Advanced Broadcasting (JTCAB)
- Digital Radio Research Inc. (DRRI)

DRB L-Band Presentation
on
RF Equipment Considerations

1. **DRB in Mode 1.5 at L-band**

2. **Effects on System Performance by Doppler**

DRB L-Band Presentation
on
RF Equipment Considerations

Important Parameters to Consider in the Overall DRB System Design

- **Phase Noise**
- **AM to PM Conversion**
- **Non-Linearity (Generation of intermods)**
- **Frequency Stability for SFN operation (minimum requirement 10^{-9})**

DRB L-Band Presentation
on
RF Equipment Considerations

All of which are achieveable

.... if we are *innovative*

DRB L-Band Presentation
on
RF Equipment Considerations

Re examine old ideas

Adapt them to new solid state technology

DRB L-Band Presentation
on
RF Equipment Considerations

Phase noise

A COFDM signal is in fact the superposition of a great many individual carriers modulated by a low bit rate QPSK stream.

Such low rate narrow band channels are sensitive to phase noise effects such as those generated by the local oscillator.

DRB L-Band Presentation
on
RF Equipment Considerations

Amplifier monitoring and leveling

Accurate measurement of RF quantities is particularly difficult when signals having a non-constant amplitude are present. The precision and the speed of the diode detectors measuring output voltage and power is therefore critical.

Other methods for monitoring require investigation.

DRB L-Band Presentation
on
RF Equipment Considerations

Amplitude non-linearities, AM-PM conversion, and clipping introduce an intrinsic BER into the recovered OFDM signal.

Non-linearities cause spectral expansion which complicates the achieving of spectral purity standards. Retransmitted COFDM signals will eventually become indecipherable because of accumulated errors brought about by AM-PM conversions.

DRB L-Band Presentation
on
RF Equipment Considerations

Filtering will modify the amplitude distribution

There is no simple method for predicting the effects of filtering on a given distribution function when it is modified by clipping.

DRB L-Band Presentation
on
RF Equipment Considerations

New approaches for power amplifier design have to be seriously considered in order to achieve higher power efficiency.

Promising directions include employing techniques allowing reduction in back-off, techniques in splitting the signal between two or more amplifiers

Methods to allow the placement of the amplifier as close as possible to the antenna.

DRB L-Band Presentation
on
RF Equipment Considerations

Thank you for your attention

Questions ?

Brian Sawyer

Mr. Sawyer manages the group of engineers responsible for standards development for new technologies at the Corporate Engineering Headquarters of the CBC in Montreal.

He has spearheaded the equipment evaluation function for the Corporation and has been instrumental in the design of L-band facilities during the development phase of amplifier and frequency conversion equipment.

Presently, while employed by the CBC, Mr. Sawyer is working in cooperation with the Canadian government departments responsible for the development of new business opportunities. This work is coordinated through his participation with organizations such as Joint Technical Committee on Advanced Broadcasting, Digital Radio Research Inc. and the private broadcasters.

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CRC

Coverage Scenarios
and
Coverage Prediction

René Voyer
Radio Broadcast Systems
CRC

Communications Research Centre/Centre de recherches sur les communications

CRC

New Coverage Concepts

From "Single Transmitter" to "Distributed Emission"

- **COFDM**
- **Guard Interval: Constructive use of echoes**
- **Passive echoes, active echoes**
- **On-channel repeaters:**
  - *** Gap-fillers**
  - *** Coverage extenders**
  - *** Single Frequency Network (SFN)**

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Coverage Prediction Software

CRC-COV: Coverage synthesis and prediction

- **models the behavior of a DRB receiver**
- **single or multi-transmitter systems**
- **CCIR 370, Okumura, CRC-Predict**
- **runs on a PC**
- **user friendly interface**

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Coverage Scenarios

- **Single transmitter**
- **Distributed emission**
  - **Gap filler**
  - **Coverage extender**
  - **SFN**

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Coverage Scenarios

Case Study:

The National Capital Region

Ottawa and suburbs,
Hull, Aylmer, Gatineau,
highways, rural communities

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Coverage Scenarios

- *Single transmitter*
- **Distributed emission**
  - **Gap filler**
  - **Coverage extender**
  - **SFN**

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Coverage Scenarios

- **Single transmitter**
- **Distributed emission**
  - *Gap filler*
  - **Coverage extender**
  - **SFN**

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Coverage Scenarios

- **Single transmitter**
- **Distributed emission**
  - **Gap filler**
  - *Coverage extender*
  - **SFN**

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Coverage Scenarios

- **Single transmitter**
- **Distributed emission**
  - **Gap filler**
  - **Coverage extender**
  - *SFN*

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Summary

SCENARIO	Total HPA power (W)	Total ERP (W)
Single Transmitter	372	3600
Main + Gap Filler	372+41	3600+500
SFN	3x164	3x1000
Main + 3 Gap Fillers	2x164+98+38	3x1000+1200

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Summary

Scenario	ERP (W)	HPA (W)	Antenna Gain(dBd)	EHAAT (m)
Single	3600	200	16	330
Main+G.F.	3600+500	200+50	16+14	330+60
Main+G.F. + C.E.	3600+500 +1000	200+50 +50	16+14 +16	330+60 +70
SFN	3x1000	3x165	11	330+75 +75
Main+C.E.+ 2 G.F.	3x1000+1200	3x200+40+50	11+18+17	2x105+60+50

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Conclusion

- Eureka 147 (COFDM) works with echoes
- Active echoes with on-channel repeaters
- Distributed emission:
  - lower ERP's
  - high service reliability
  - coverage shaping
  - shorter reuse distances
  - spectrum efficiency
- CRC-COV prediction software

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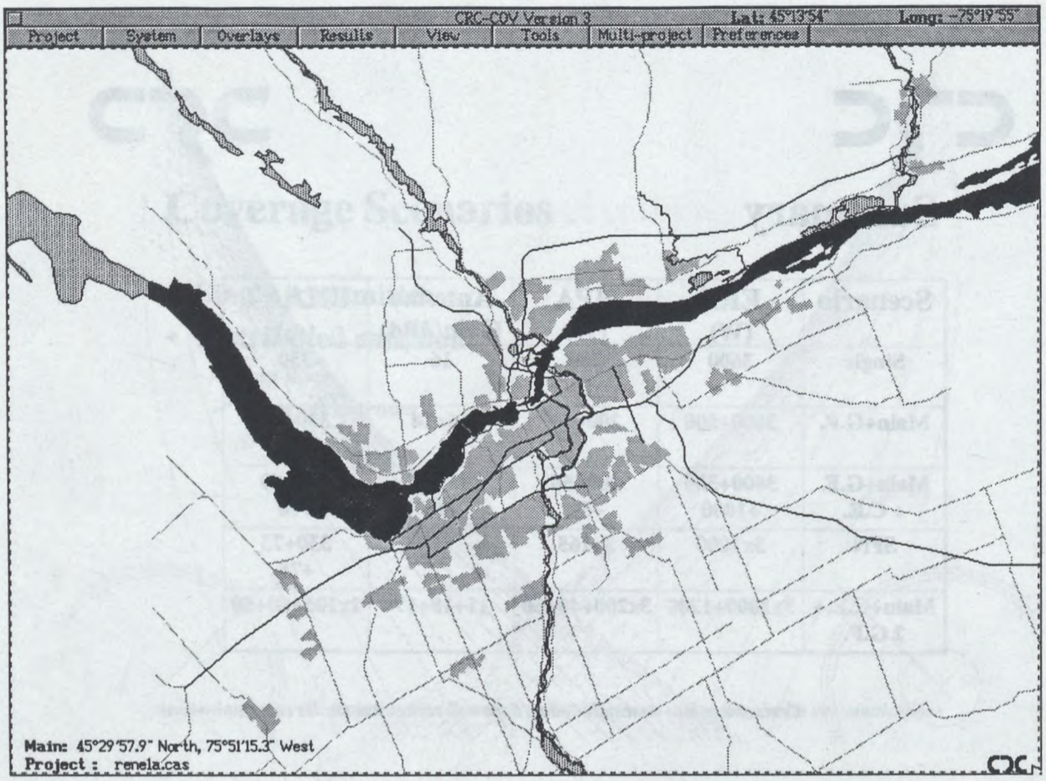

Figure 1 - National Capital Region, urban areas (shaded) and main roads

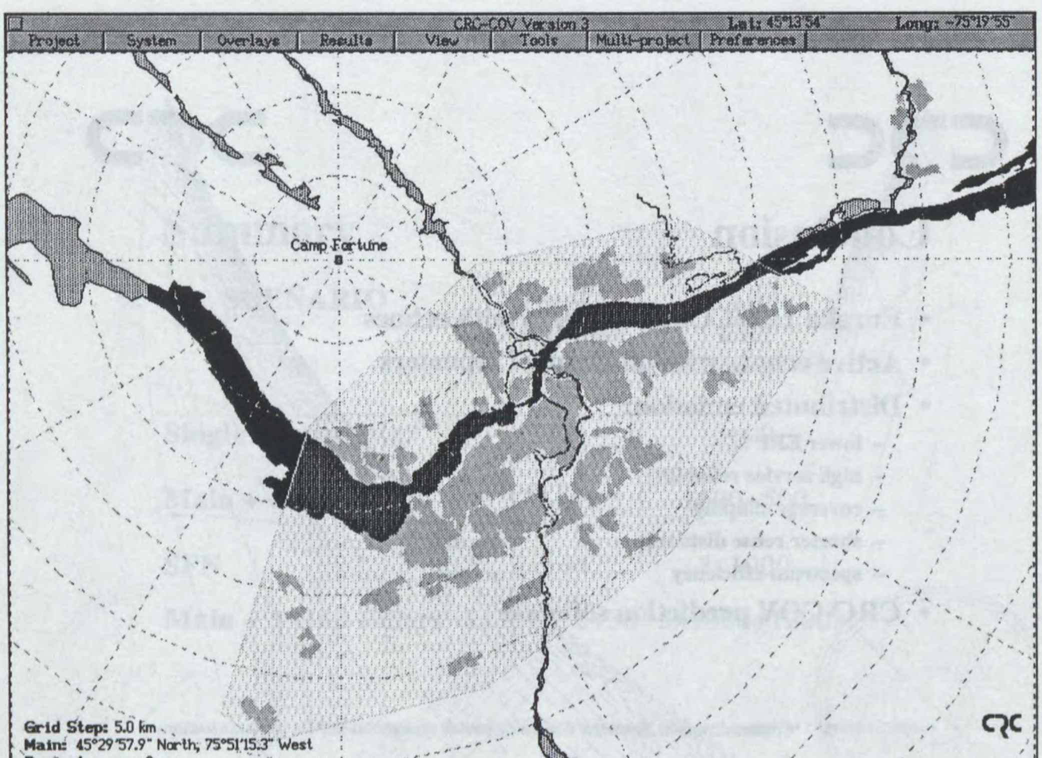

Figure 2 - Service polygon

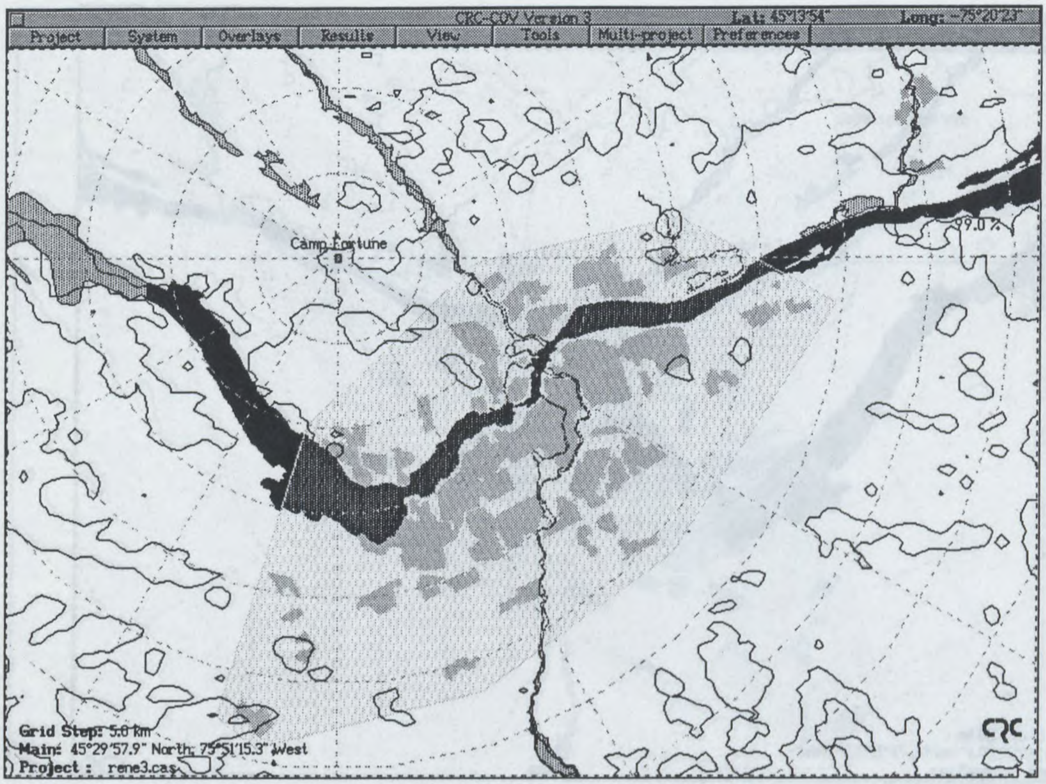

Figure 3 - Coverage (99% of locations) with single transmitter

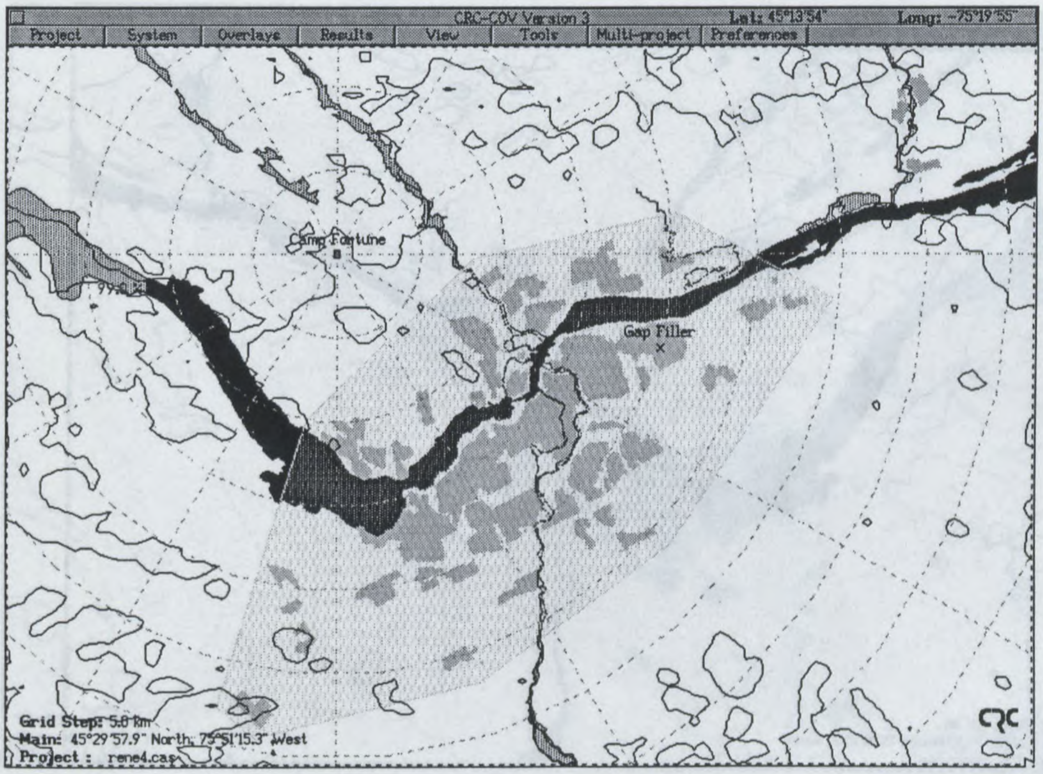

Figure 4 - Main transmitter with one gap filler

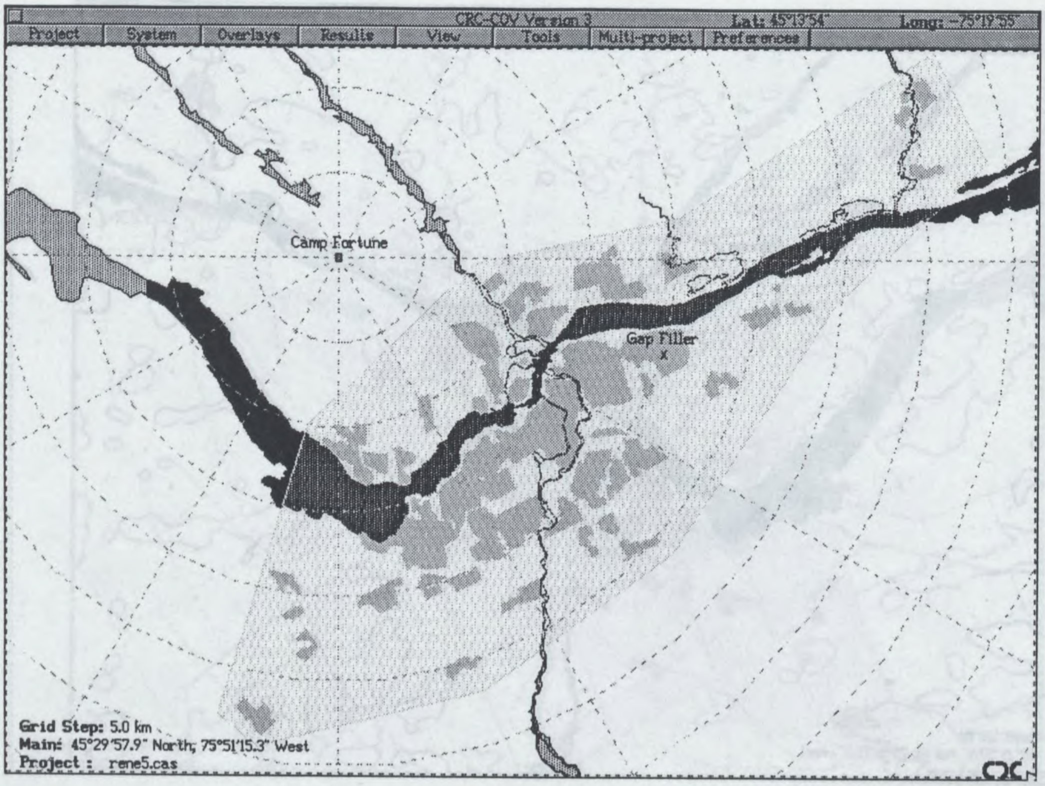

Figure 5 - Extended service polygon

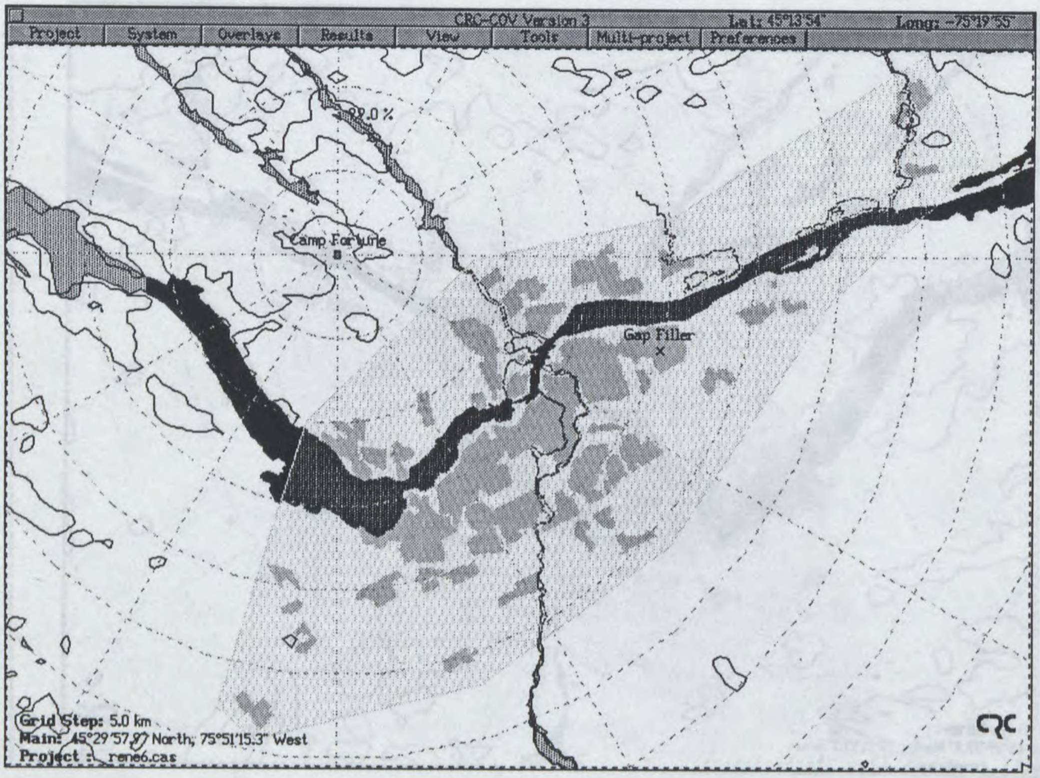

Figure 6 - Main transmitter with increased ERP

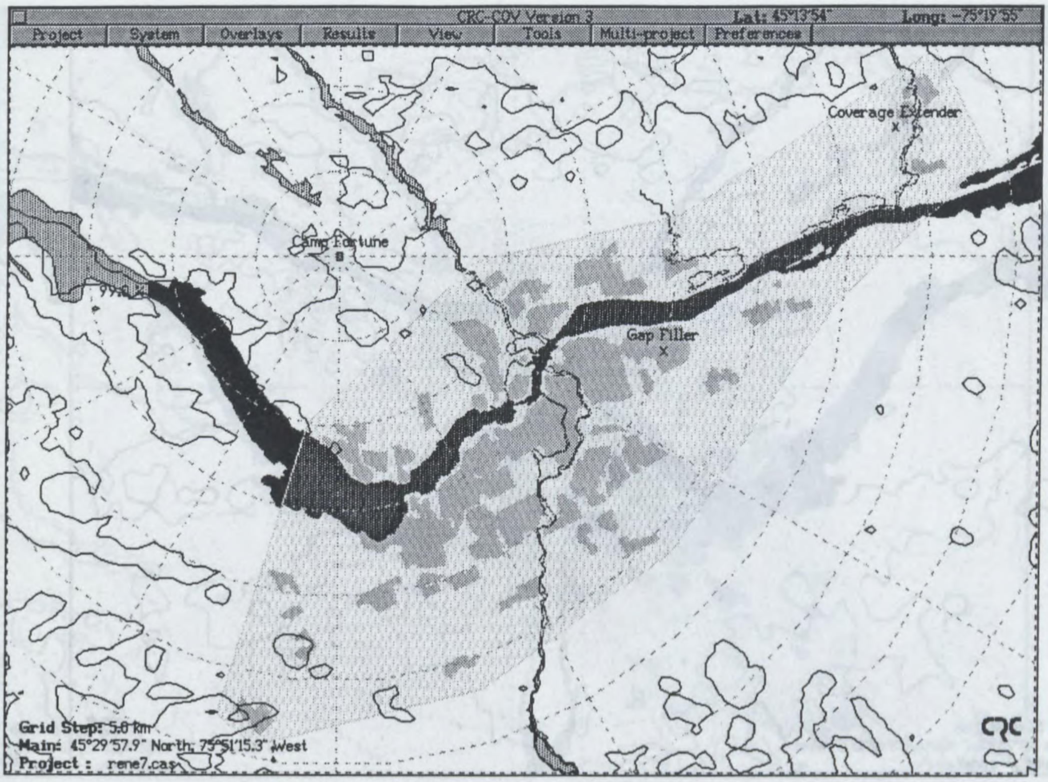

Figure 7 - Main transmitter with coverage extender

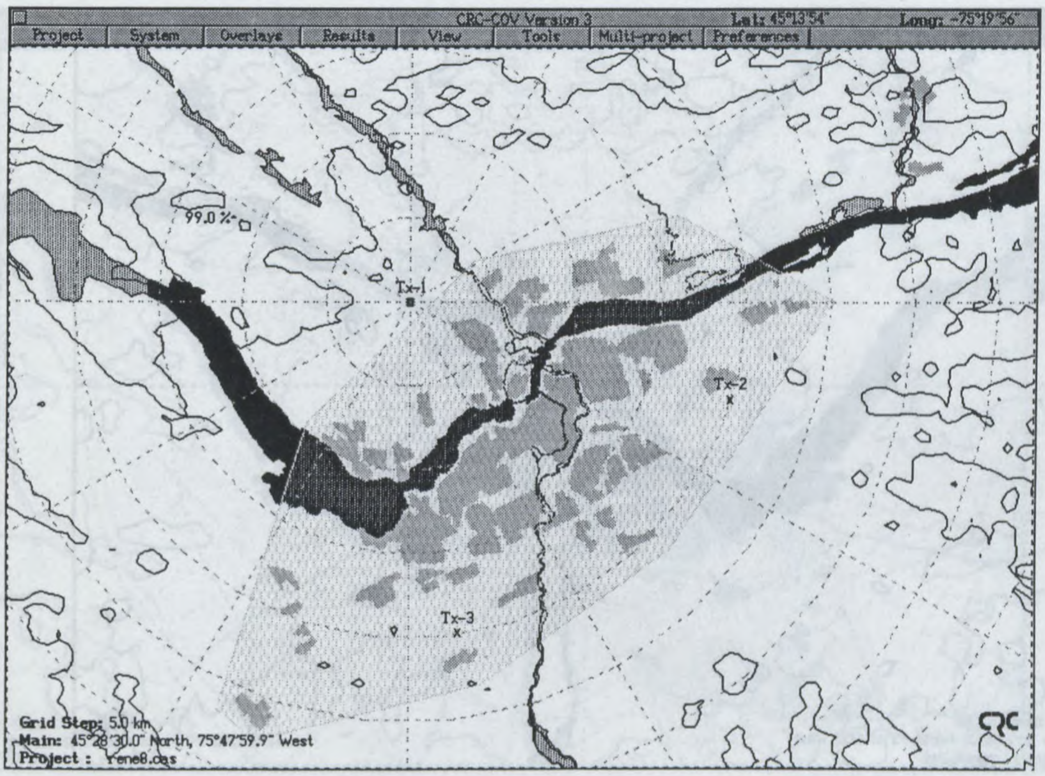

Figure 8 - Three transmitters single frequency network (SFN)

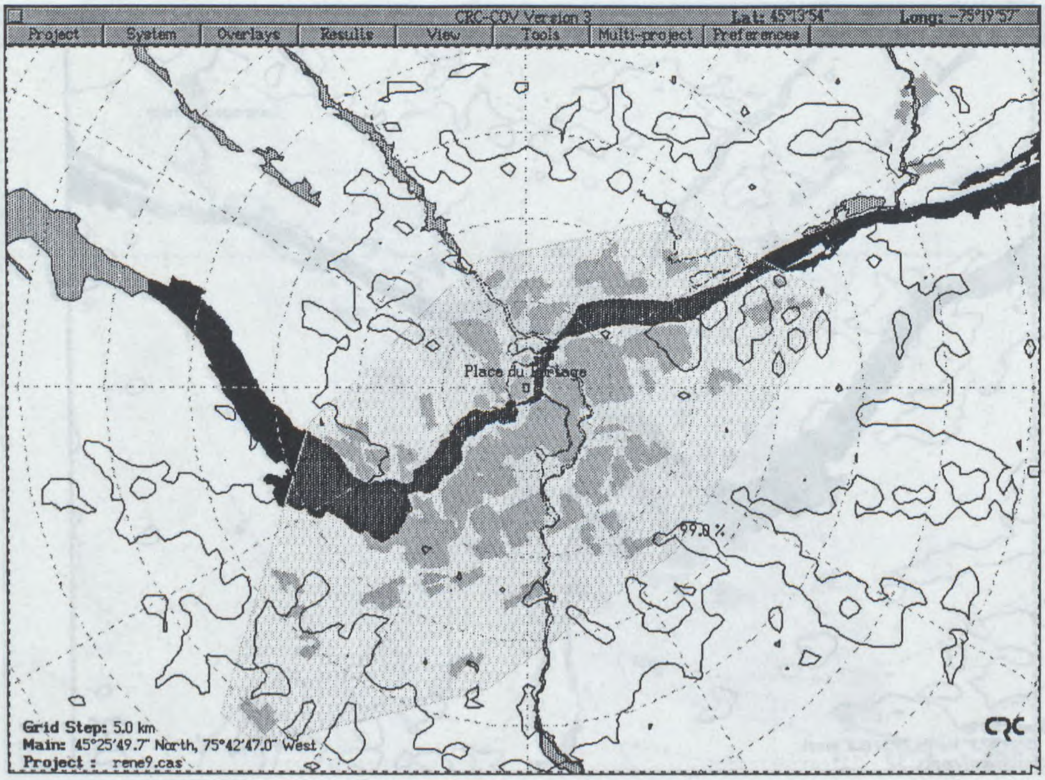

Figure 9 - Main transmitter at Place du Portage

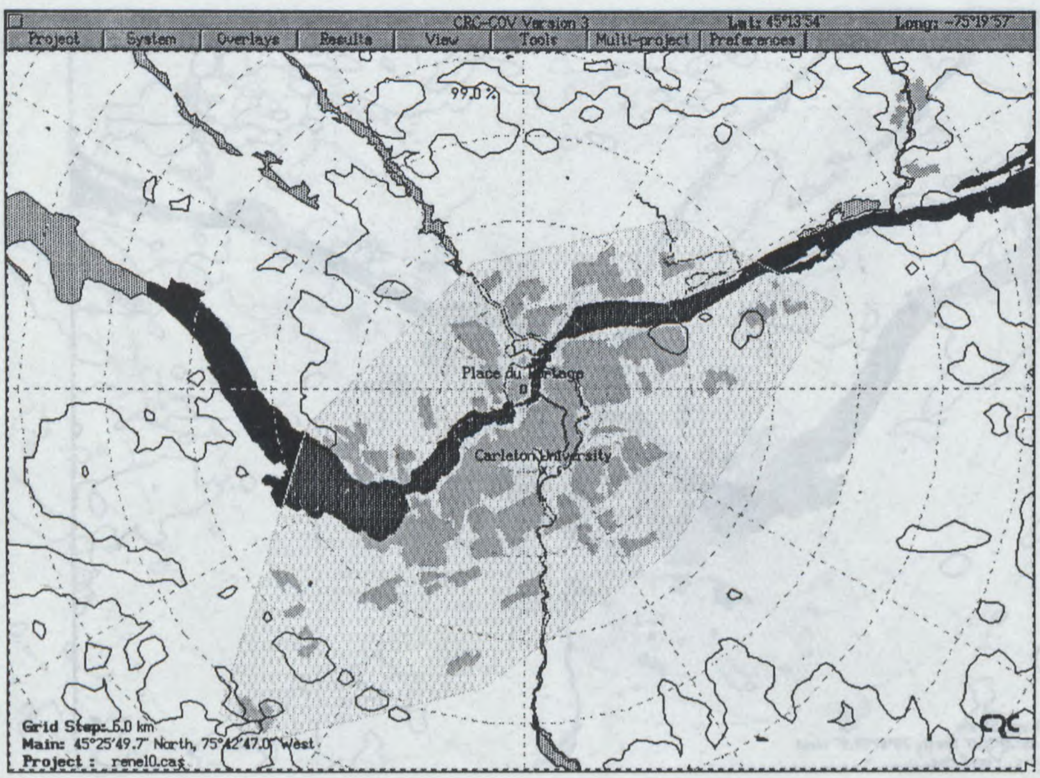

Figure 10 - Main transmitter and coverage extender

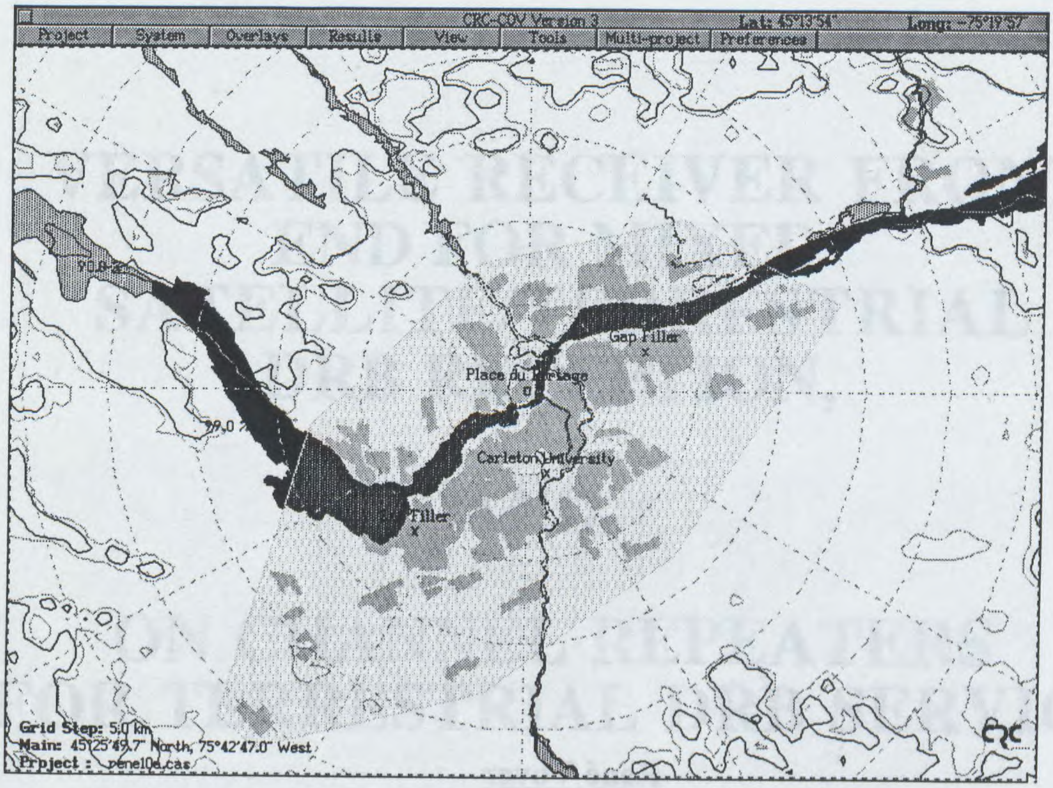

Figure 11 - Coverage with main transmitter, coverage extender and two gap fillers

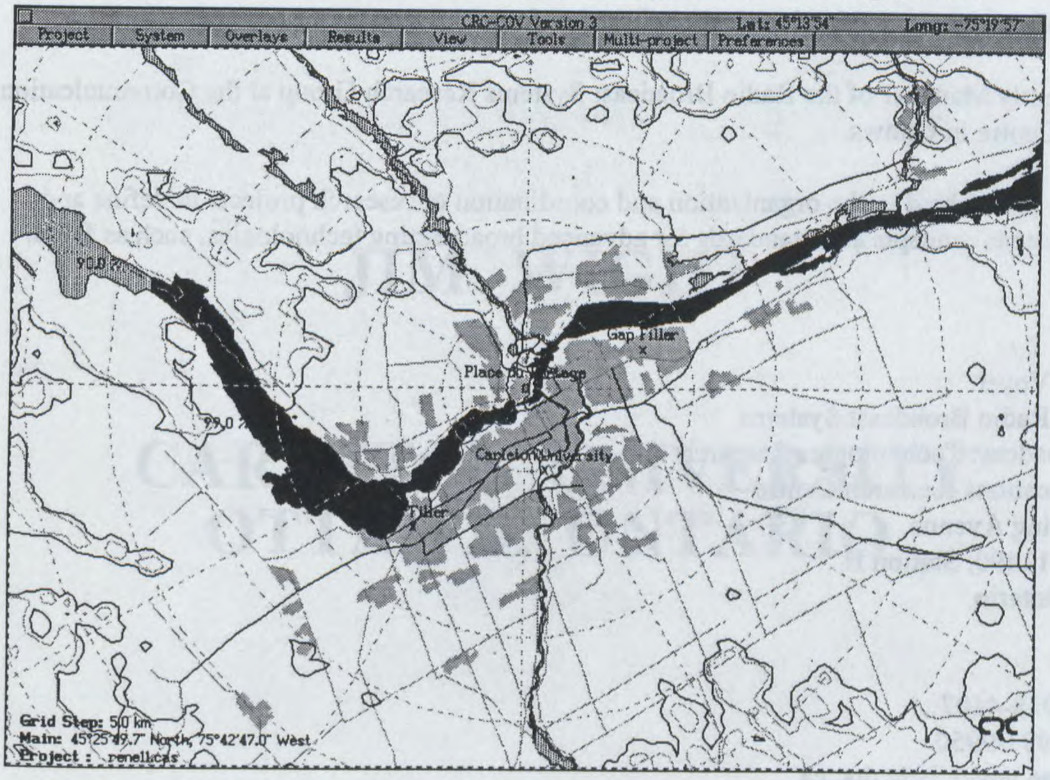

Figure 12 - Coverage of the distributed emission system

René Voyer

Mr. René Voyer graduated in electrical engineering from Université de Sherbrooke in 1976.

He is currently Manager of the Radio Broadcast Systems Research Group at the Communications Research Centre in Ottawa.

Mr. Voyer is involved in the organization and coordination of research projects to define and develop system concepts and standards for advanced broadcasting technologies, such as DRB.

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VERSATILE RECEIVER FRONT END FOR MIXED SATELLITE/TERRESTRIAL DRB RECEPTION,

AND

ON CHANNEL REPEATERS FOR TERRESTRIAL DRB SERVICE

JIM WIGHT

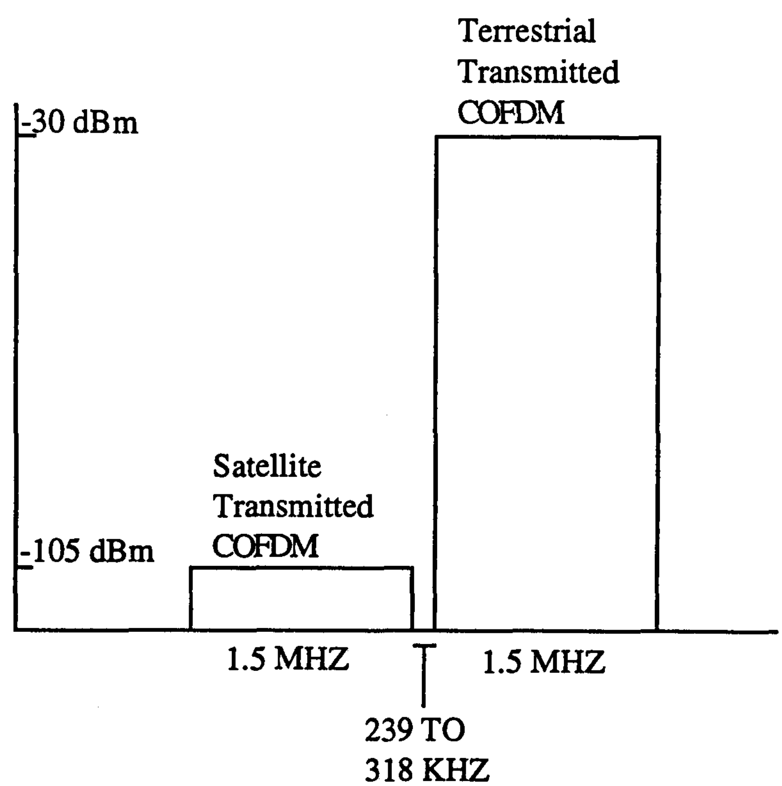
CARLETON UNIVERSITY
OTTAWA, ONTARIO

VERSATILE RECEIVER FRONT END FOR MIXED SATELLITE/TERRESTRIAL DRB RECEPTION

OUTLINE

- **COFDM Signal Structure**
- **Satellite and Terrestrial Reception**
- **Constraints and Design Issues**
- **Receiver Architecture**
- **Performance Simulation and Measurements**

SATELLITE AND TERRESTRIAL RECEPTION



- **High AGC Requirement**

- **Severe Adjacent Channel Rejection Requirement**

CONSTRAINTS

- **Desire To Have A Highly Selective Filter As The First Element To Remove Strong Adjacent Channel Interference Is Compromised By The Need To Establish Good NF**

- **Desire To Have The Low Noise Amplifier As The First Element Is Compromised By The Need To Avoid Compression Due To The Presence Of The Strong Terrestrial Signal**

DESIGN ISSUES

- Dual Strips Are Provided To Accommodate Spatial Diversity (Identical Vertical Pol Antennas) For Terrestrial Reception Only,

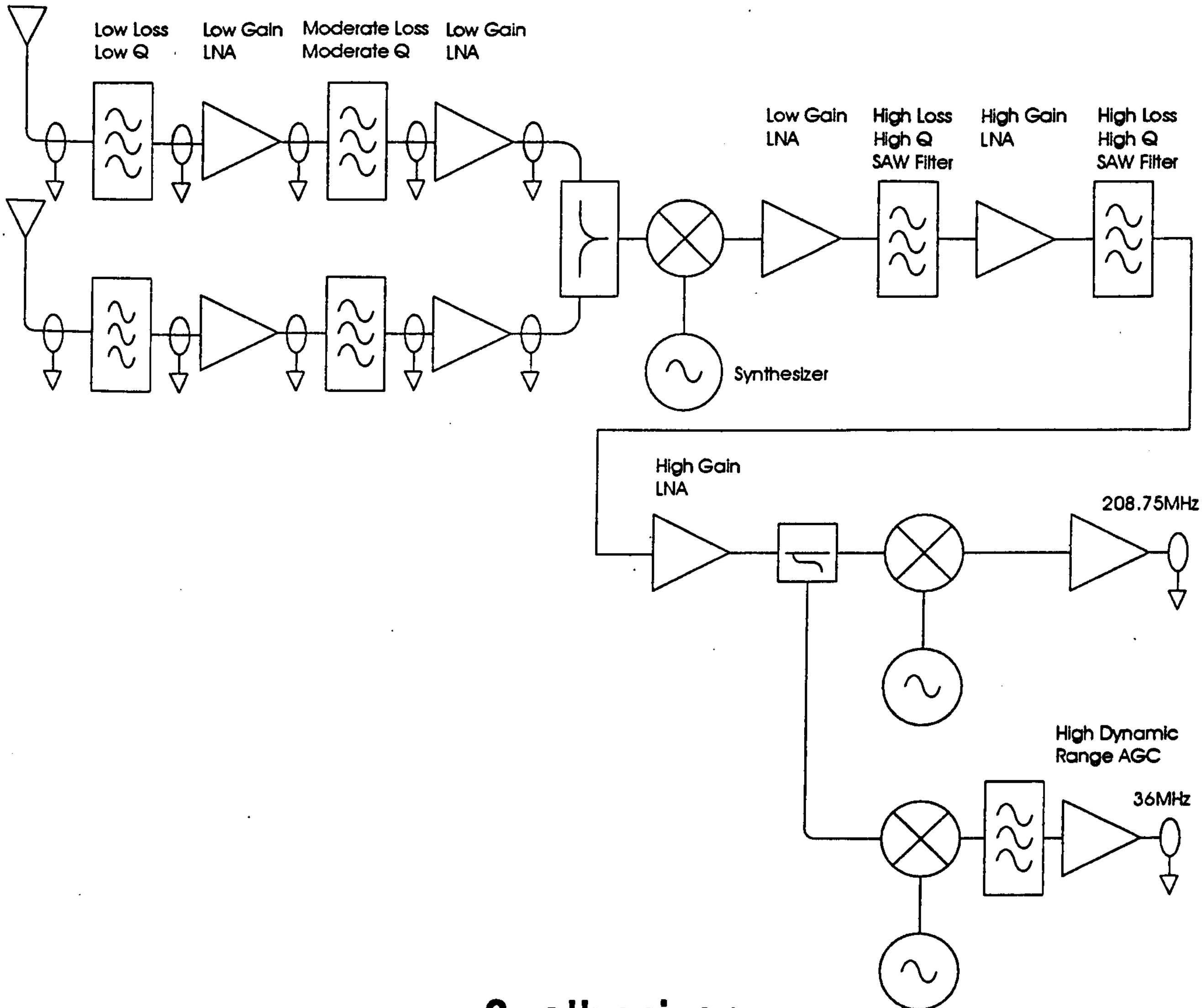
  Or

  To Accommodate Switched Satellite/ Terrestrial Reception (One Circular Pol, One Vertical Pol Antenna) For Mixed Service

- DRB Signal Block Selection Is Achieved After Down Conversion With The Use Of Cascaded Fixed Frequency, SAW Filters, And A Frequency Synthesized LO

- The Large Dynamic Range Between Satellite And Terrestrial Signals Is Removed With AGC After All Adjacent Channels Have Been Attenuated To 43 dB Below The Desired Signal Block

Down Converter



Synthesizer

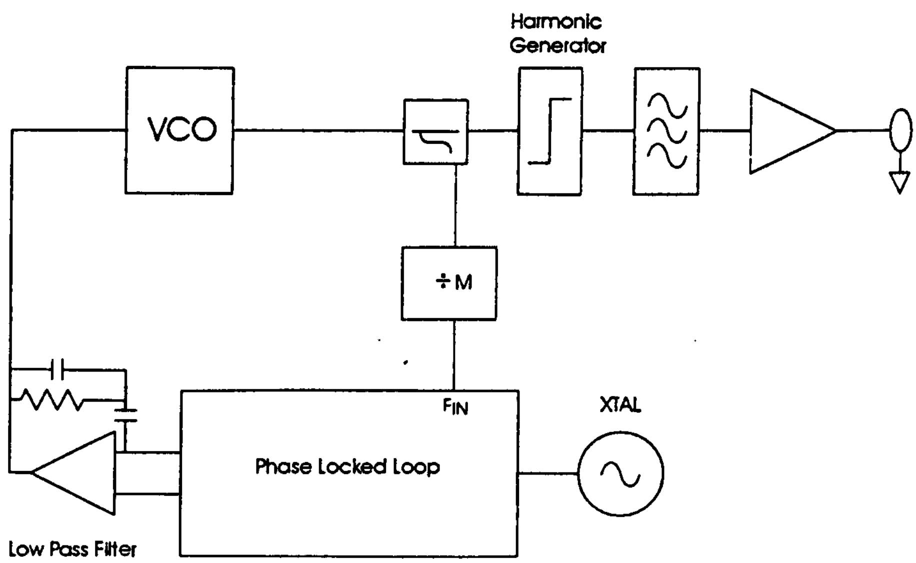


FIGURE 1: RECEIVER FRONT END ARCHITECTURE

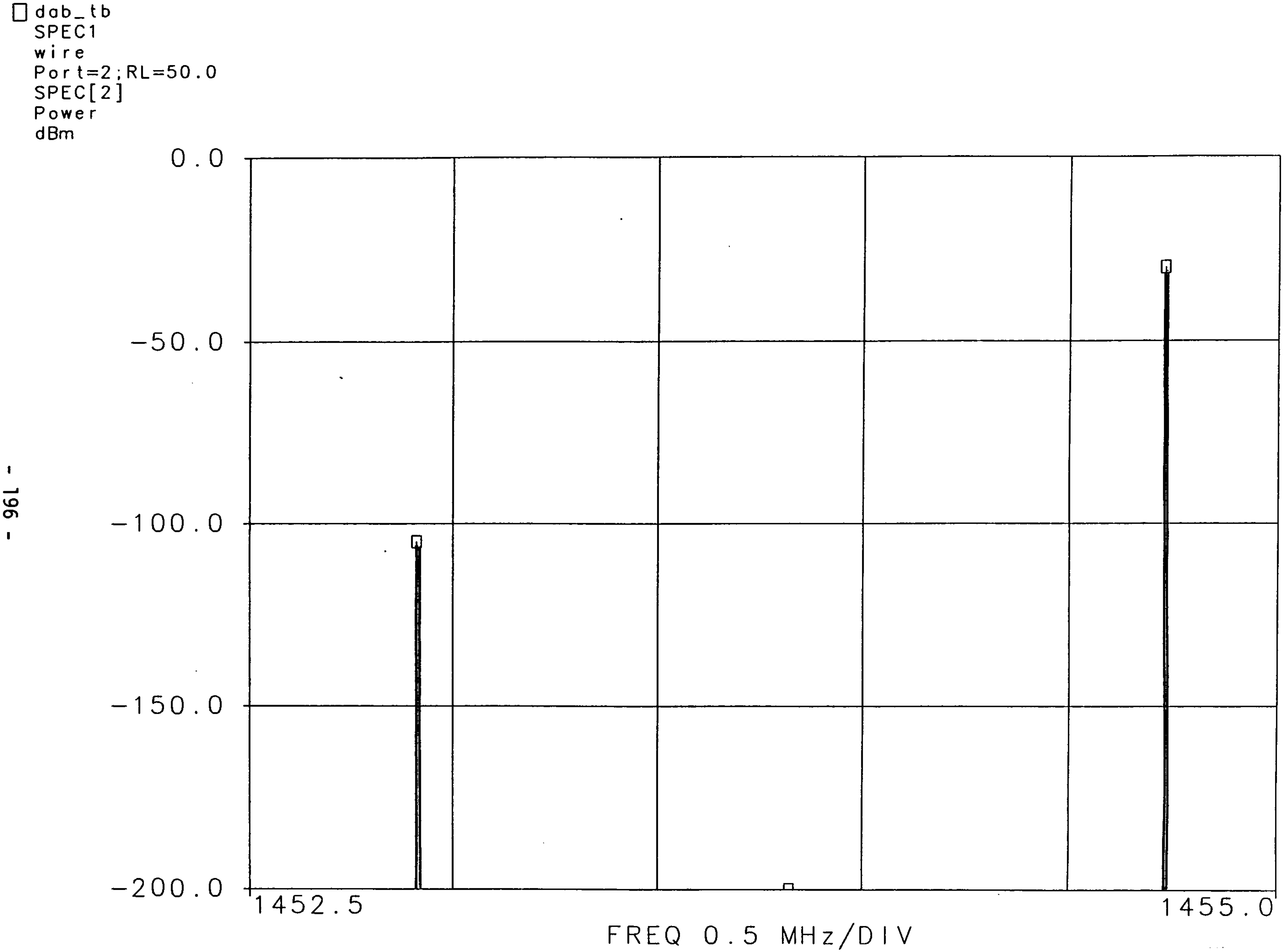


FIGURE 3: OMNISYS SIMULATED DRB RECEIVER INPUT

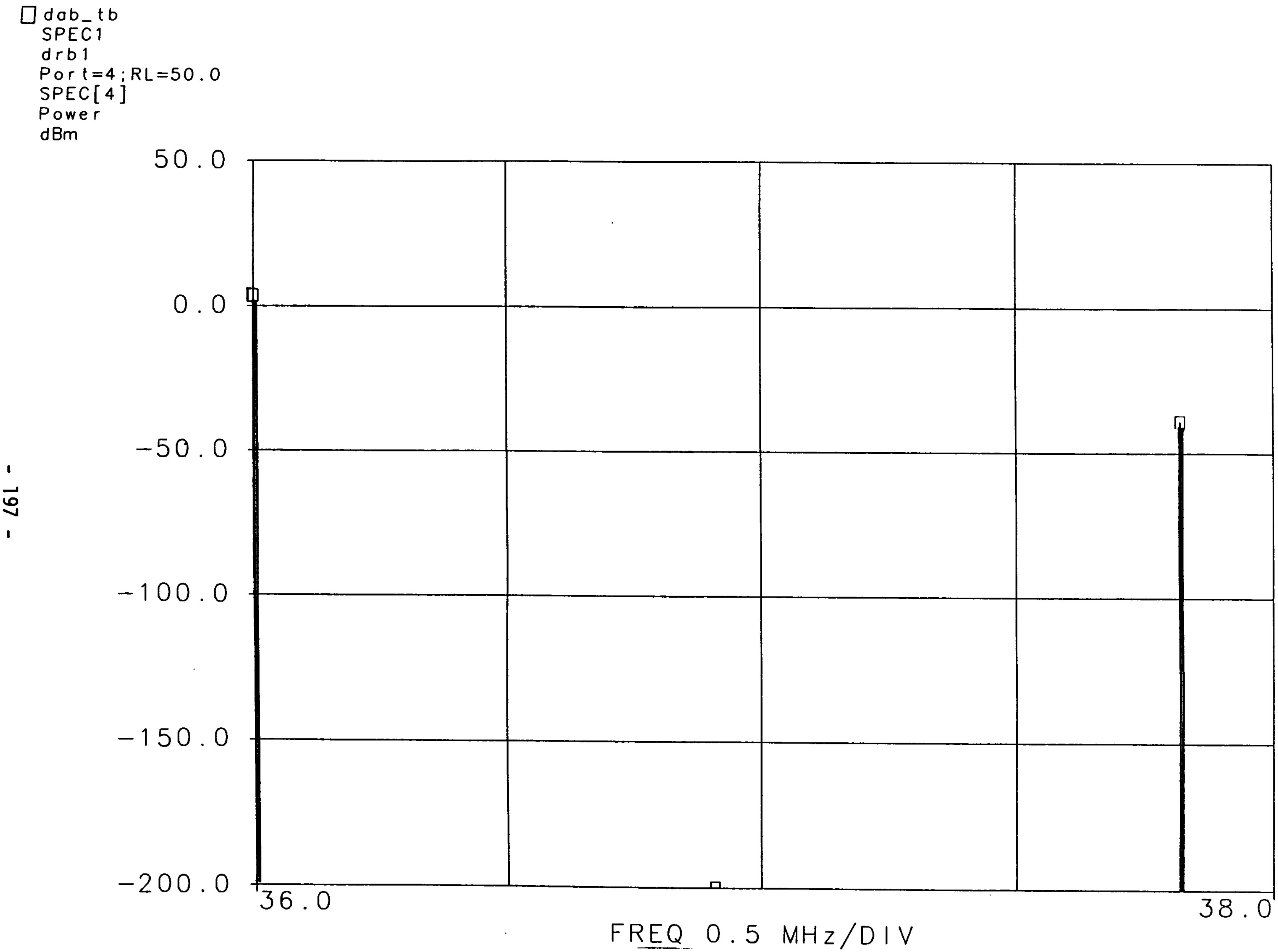


FIGURE 4: OMNISYS SIMULATED DRB RECEIVER OUTPUT

ON CHANNEL REPEATERS
FOR TERRESTRIAL DRB SERVICE

OUTLINE

- APPLICATIONS

- ENVIRONMENTAL CLASSIFICATION

- SYSTEM ATTRIBUTES

- ENVIRONMENT/SYSTEM ATTRIBUTE MATRIX

- STRAW MAN ON-CHANNEL REPEATERS

4.0 ENVIRONMENT CLASSIFICATION

Stable Channel	< 1 dB Variation Vertical Polarization
Unstable Channel	< 6 dB Variation in 1 Sec Any Polarization
Low Input Power Density	$> 55\ dB\mu V/m^2 = -60\ dBm/m^2$
Medium Input Power Density	$>-30\ dBm/m^2$
Low Output Power	< 100 W ERP (for 18 dB Gain Antenna)
Medium Output Power	< 1 KW ERP (for 18 dB Gain Antenna)
Strong Output Power	< 5 KW ERP (for 15 dB Gain Antenna)
Medium Amplifier Gain	< 80 dB
High Amplifier Gain	< 115 dB
Uncontrolled Echoes from Repeater	>-90 dB
On Channel Interference	-20 dBc < I < +20 dBc
Adjacent Channel Interference	C/I > -35 dB for 99%
Amplitude Spikes in Symbol	< 20 dBc One Every Symbol (TBD)
Tx Emission Mask	<-56 dBc for Offset >838.5 KHz <-103 dBc for Offset >1985 KHz (see Section 3 for interpretation)
Group Delay Distortion	< 5 μsec

5.0 SYSTEM ATTRIBUTES

Full Band

Heterodyned Single Channel

Heterodyned Selective Channel

- -

Fixed Tx/Rx Polarization

Switched Tx/Rx Polarization

Tracking Tx/Rx Polarization

- -

Rx Antenna Beamwidth

Rx Antenna Null Placement

Echo Canceling with SS Test Sequence

- -

Filtering

AGC

Limiter

Tx Backoff

ENVIRONMENT / SYSTEM ATTRIBUTE MATRIX

	Full Band	Heterodyned Single Channel	Heterodyned Selective Channel	Fixed Tx/Rx Polarization	Switched Tx/Rx Polarization	Tracking Tx/Rx Polarization	Rx Antenna Beamwidth	Rx Antenna Null Placement	Echo Canceling with SS Test Sequence	Filtering	AGC	Limiter	Tx Backoff
Stable Channel	✓	✓	✓	✓									
Unstable Channel		✓	✓		✓	✓					✓		
Low Input Power Density		✓	✓							✓			
Medium Input Power Density	✓	✓	✓										
Low Output Power	✓	✓	✓										✓
Medium Output Power		✓	✓										✓
Strong Output Power		✓	✓										✓
Medium Amplifier Gain	✓	✓	✓	✓	✓	✓							
High Amplifier Gain		✓	✓	✓	✓	✓		✓	✓				
Uncontrolled Echoes from Repeater						✓		✓	✓				
On Channel Interference							✓	✓					
Adjacent Channel Interference		✓	✓				✓	✓		✓			
Amplitude Spikes in Symbol												✓	
Tx Emission Mask										✓			✓
Group Delay Distortion										✓			✓

7.0 STRAW MAN ON-CHANNEL REPEATERS

Straw man #1

Environment

- Stable Channel
- Medium Input Power Density
- Low Output Power
- Medium Gain
- Uncontrolled Echoes

Attributes

- Full Band
- Fixed Tx/Rx Polarization
- Rx Antenna Null Placement
- Tx Backoff

Straw man #2

Environment

- Unstable Channel
- Low Input Power
- Medium Output Power
- Medium Gain
- Uncontrolled Echoes
- Amplitude Spikes in Symbol

Attributes

- Heterodyned Single Channel
- Switched Tx/Rx Polarization
- Rx Antenna Null Placement
- Filtering
- AGC
- Limiter
- Tx Backoff

8.0 STRAW MAN / APPLICATION MATRIX

Straw man #1	Shadowing Gap Filler Intra SFN Interference
Straw man #2	Shadowing Gap Filler Intra SFN Interference Cell Detachment Coverage Extension Coverage Shaping
Straw man #3	Intra SFN Interference Cell Detachment Coverage Extension

REPEATER ELECTRONICS SPECIFICATION
FOR
DRB ON-CHANNEL REPEATERS
(revision 2)

	Strawman #1	Strawman #2	Strawman #3
RF Band	1452 to 1492 MHz	1452 to 1492 MHz	1452 to 1492 MHz
Input Power	-30 dBm	-60 dBm	-60 dBm
Input Filtering	full RF band	full RF band	full RF band
Input Filter Selectivity	-3 dB at 1452.159 and 1491.841 MHz -20 dB at TBD and TBD MHz	-3 dB at 1452.159 and 1491.841 MHz -20 dB at TBD and TBD MHz	-3 dB at 1452.159 and 1491.841 MHz -20 dB at TBD and TBD MHz
Receiver NF	TBD dB	2 dB	2 dB
Output Power	30 dBm	40 dBm	50 dBm
Single Channel Emission Mask	-30 dB at 838.5 KHz offset (from center of channel)	-56 dB at 838.5 KHz offset -103 dB at 1985 KHz offset	-56 dB at 838.5 KHz offset -103 dB at 1985 KHz offset
Output Filtering	full RF band	full RF band	full RF band
IF Band	NA	140±0.767 MHz	140±0.767 MHz
IF Filtering	NA	single channel	single channel

LO Freq	NA	fixed	synthesized f=1312.926 + n(1.734) MHz n=0,1....22
Freq Stability	NA	3.0×10^{-7}	3.0×10^{-7}
AGC	NA	20 dB	20 dB
AGC Settling Time	NA	10 msec	10 msec
AGC Accuracy	NA	±1 dB	±1 dB
Limiter	NA	4±1 dB above mean power	4±1 dB above mean power
Antenna Pol Control	NA	switched	tracking
Echo Canceller	NA	NA	SS test sequence

STRAWMAN 1
Initial specs.

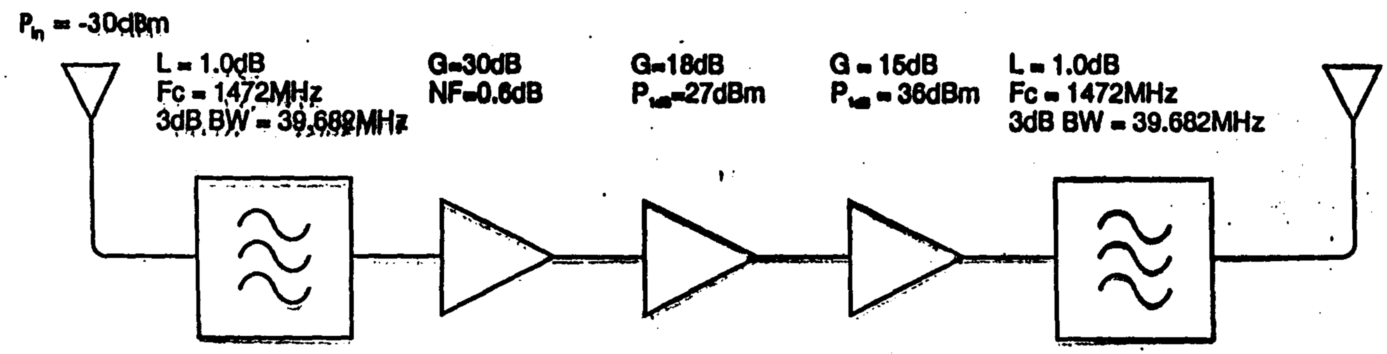


FIGURE 1 STRAWMAN 1 BLOCK DIAGRAM

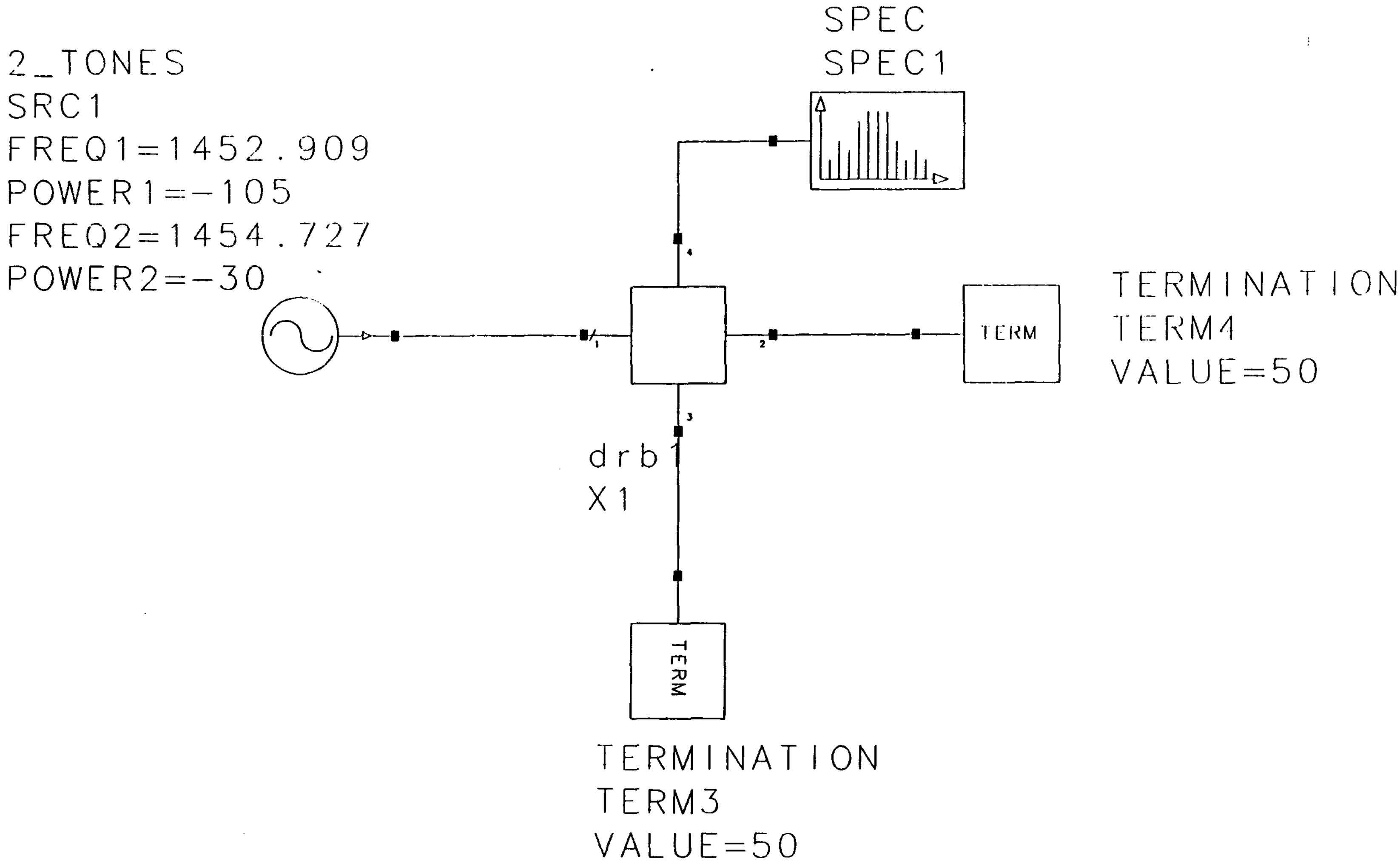
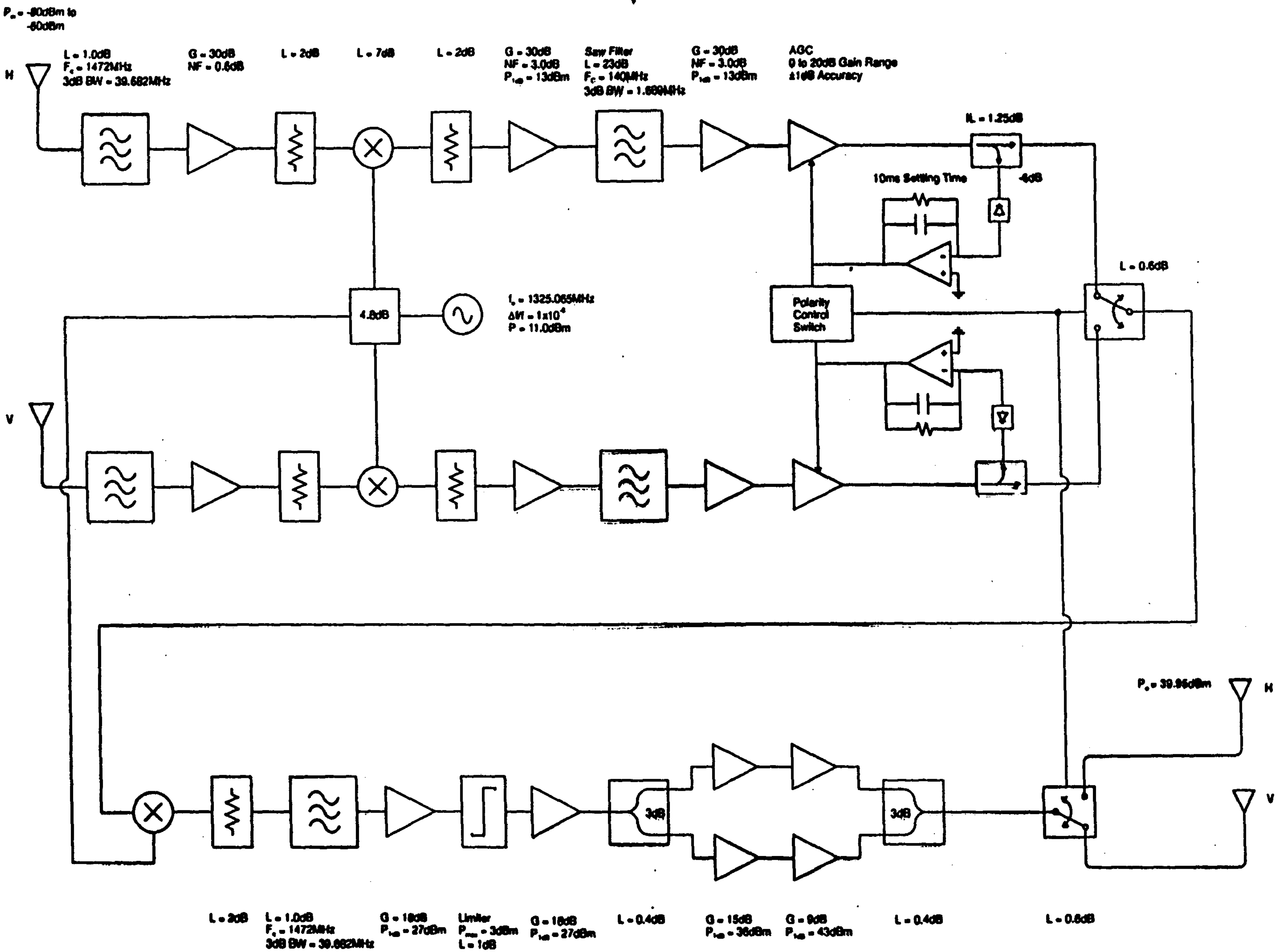


FIGURE 2: OMNISYS SIGNAL MEASUREMENT TEST BENCH

STRAWMAN 2
Initial Specs.



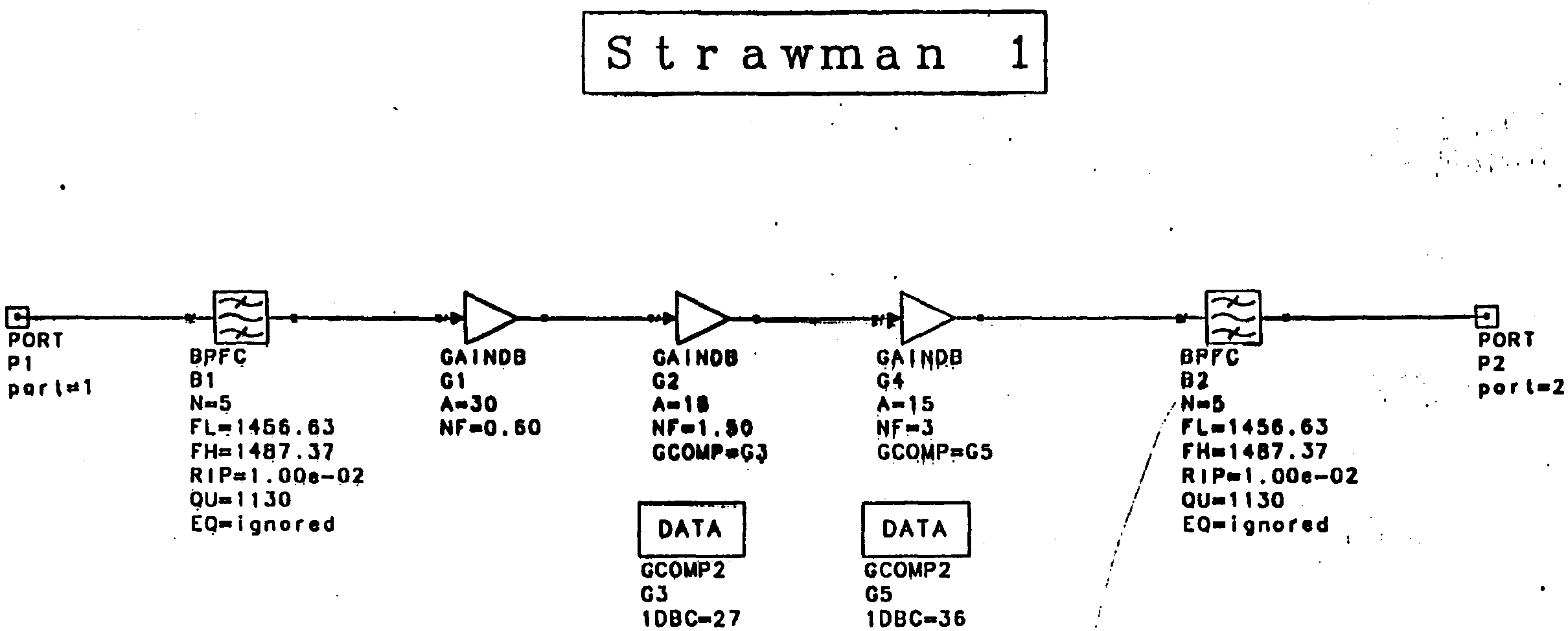


FIGURE 7 OMNISYS GENERATED BLOCK DIAGRAM OF STRAWMAN 1

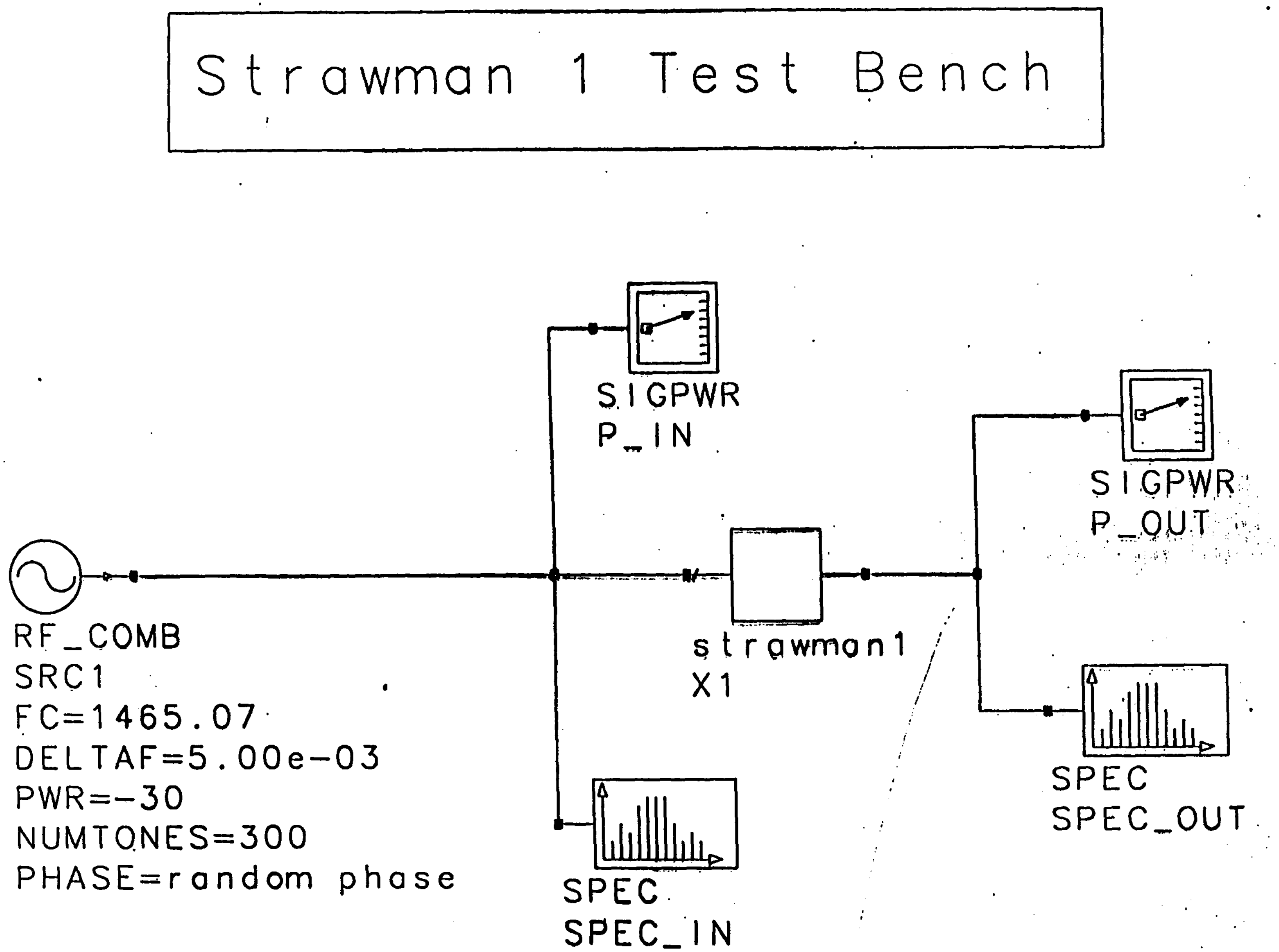


FIGURE 6 INPUT TO THE OMNISYS SIMULATED ON-CHANNEL REPEATER

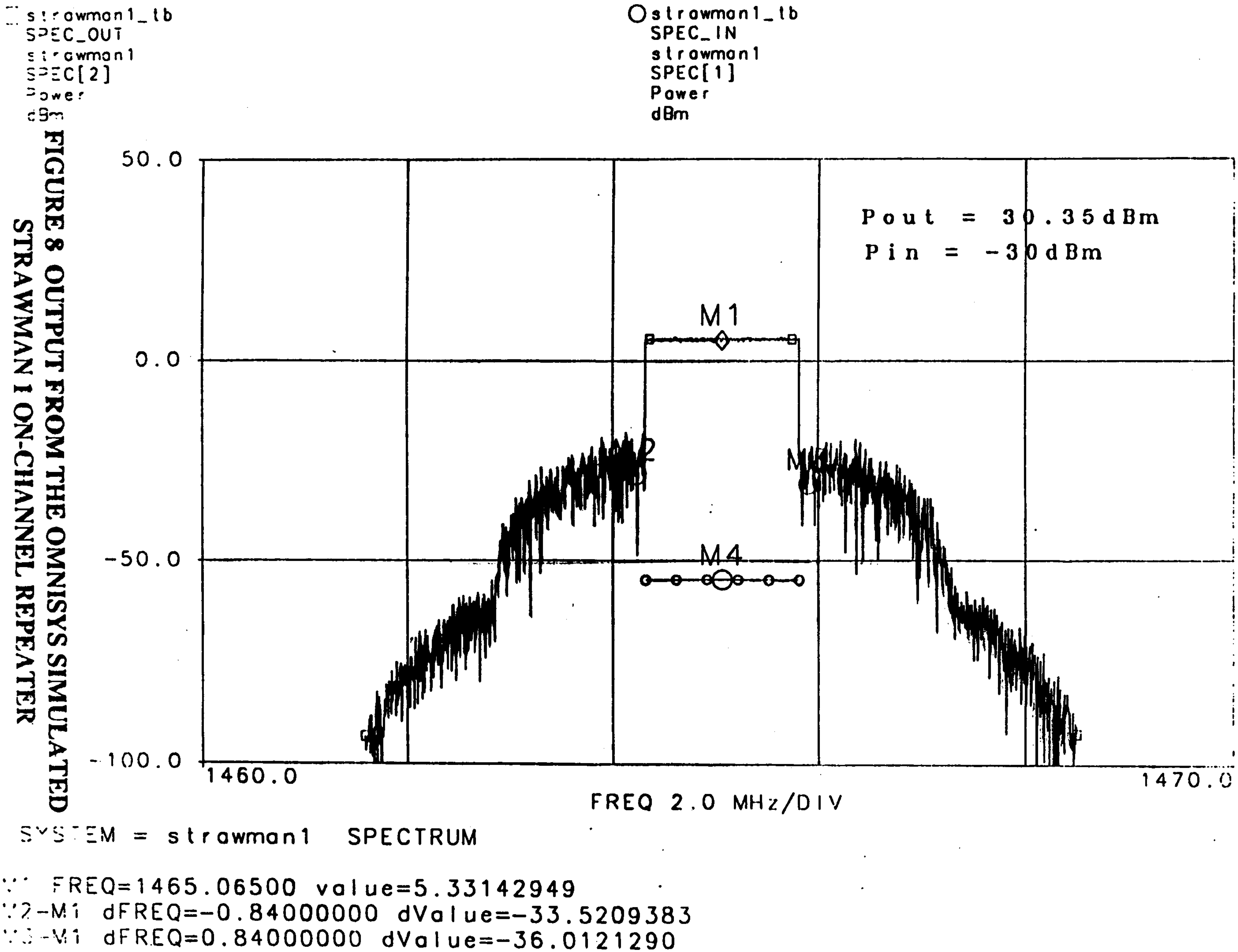


FIGURE 8 OUTPUT FROM THE OMNISYS SIMULATED STRAWMAN 1 ON-CHANNEL REPEATER

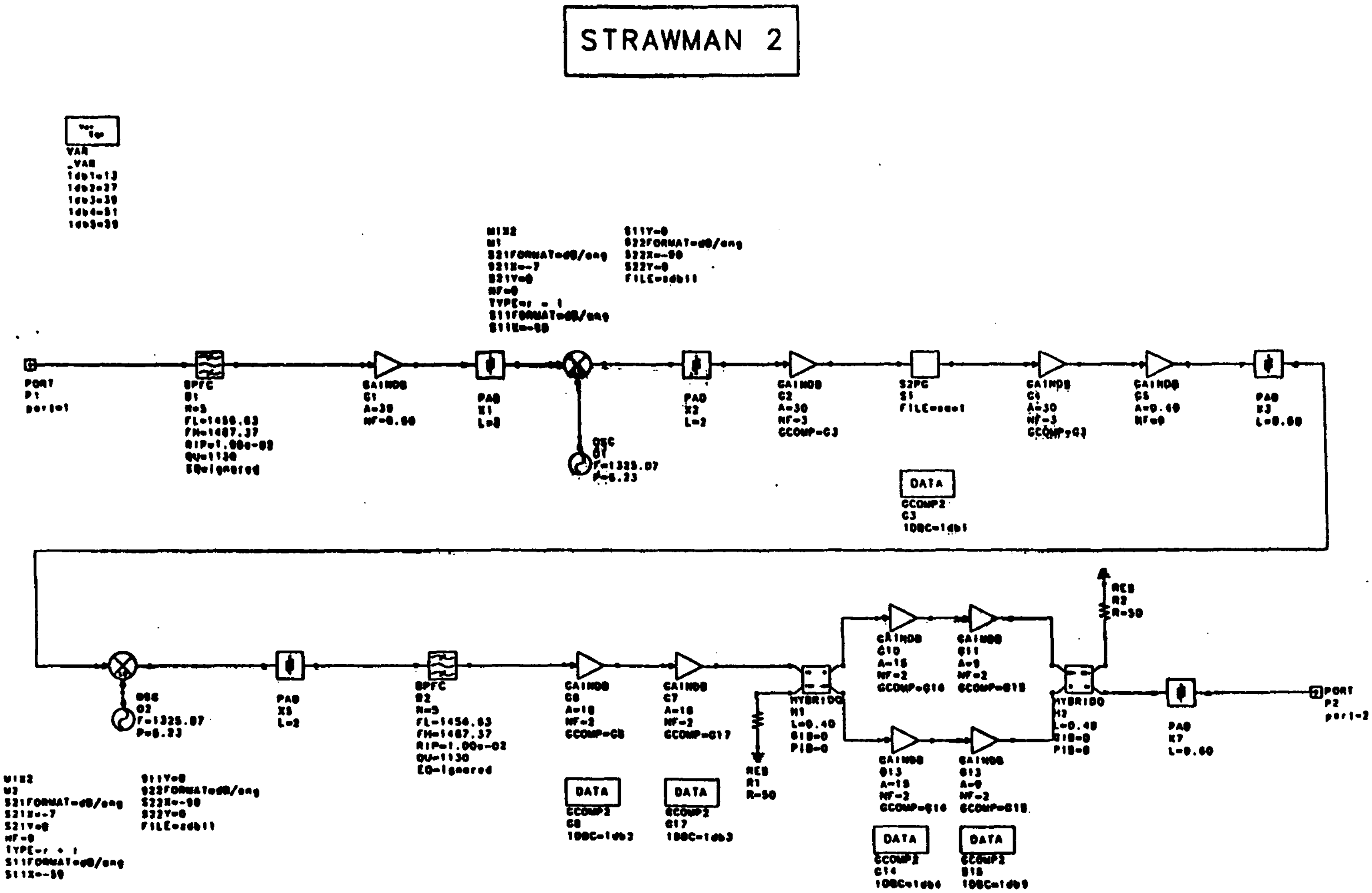
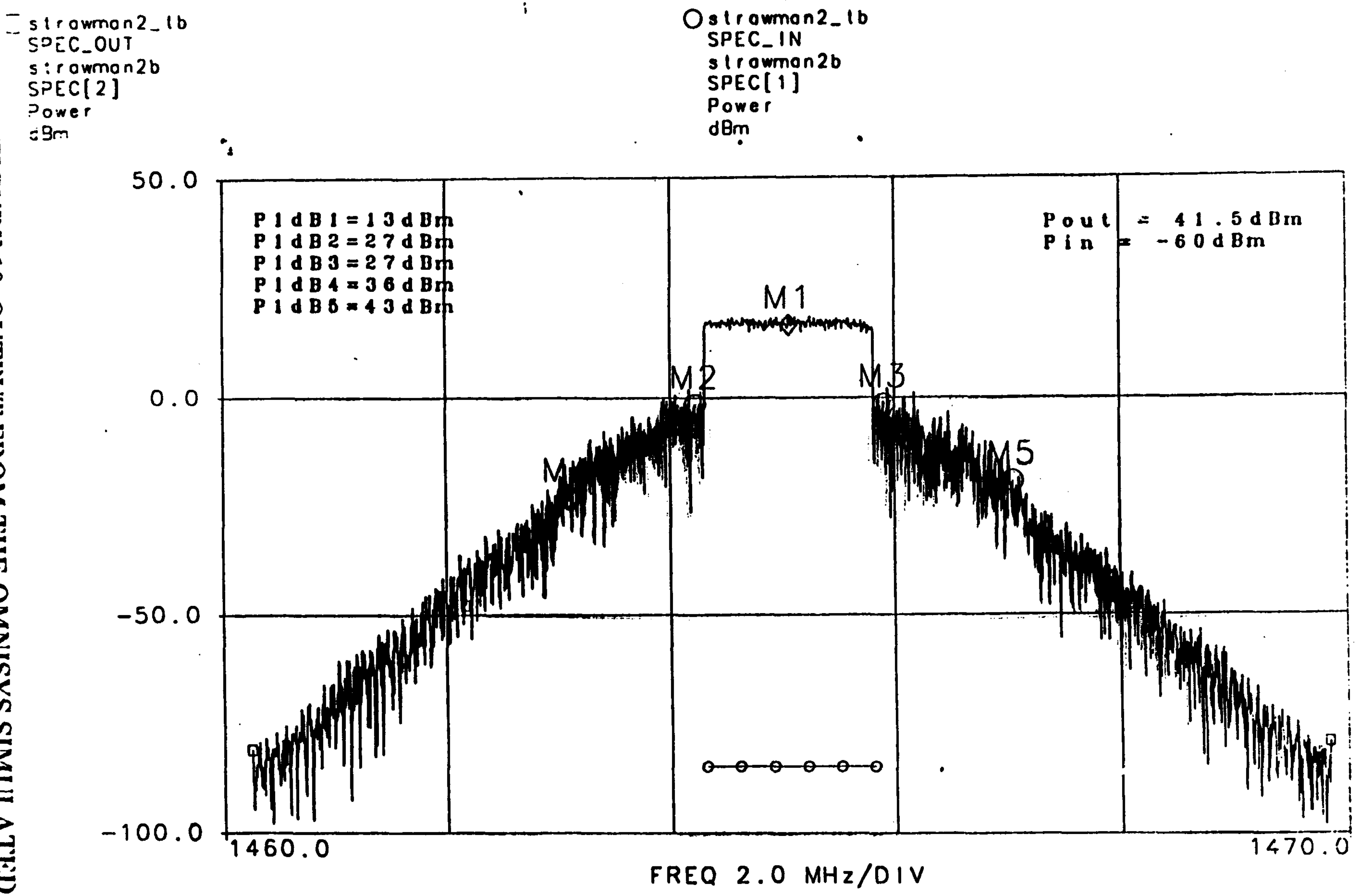


FIGURE 9 OMNISYS GENERATED BLOCK DIAGRAM OF STRAWMAN 2



SYSTEM = strawman2b SPECTRUM

M1 FREQ=1465.06500 value=16.4113848
M2-M1 dFREQ=-0.84000000 dValue=-18.1719508
M3-M1 dFREQ=0.84000000 dValue=-17.9463563

FIGURE 10 OUTPUT FROM THE OMNISYS SIMULATED [illegible] CHANNEL REPEATER

□ strawman2_lb
SPEC_OUT
strawman2b
SPEC[2]
Power
dBm

○ strawman2_lb
SPEC_IN
strawman2b
SPEC[1]
Power
dBm

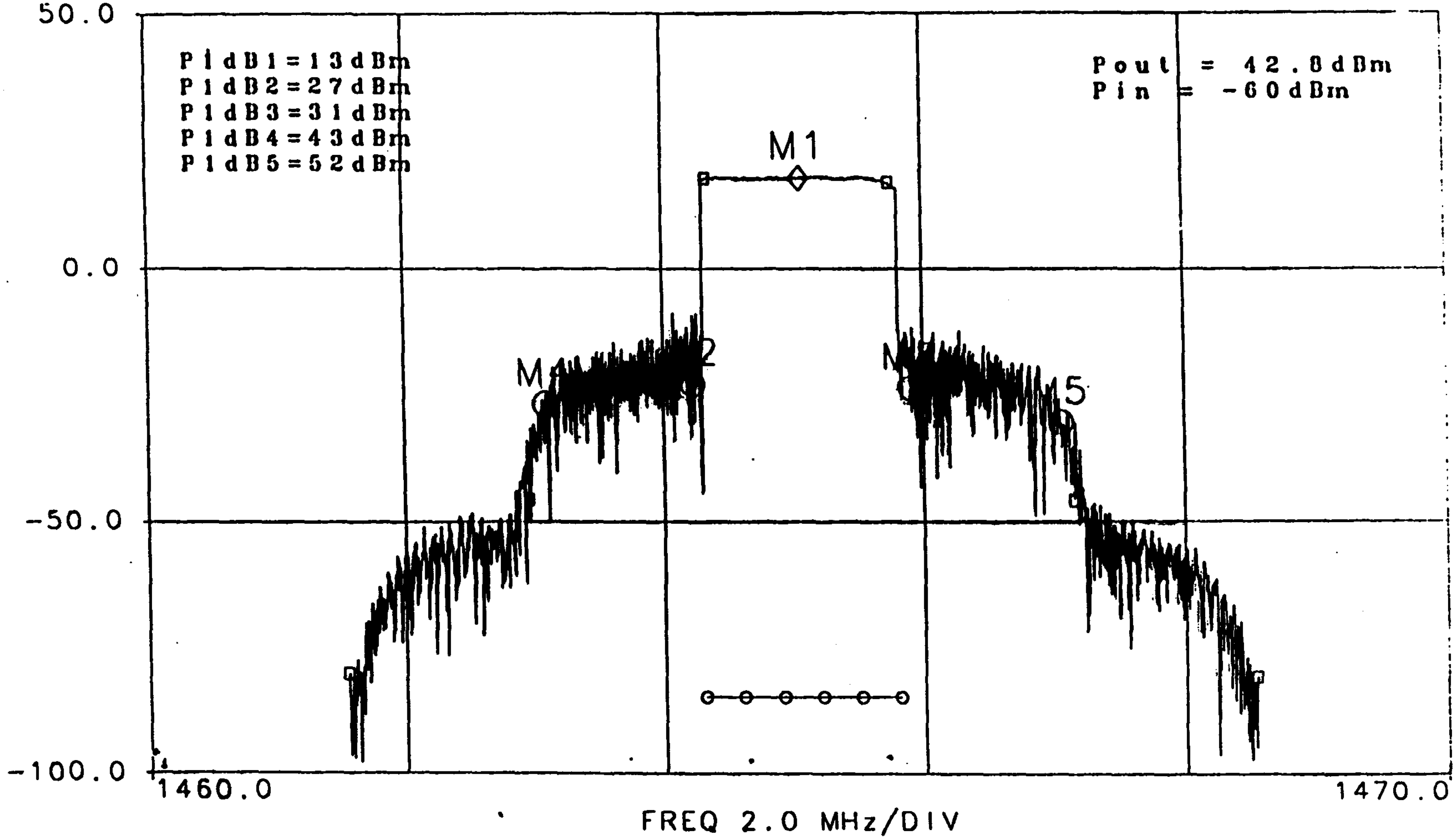


FIGURE 11 OUTPUT FROM STRAWMAN 2 WITH INCREASED 1 DB COMPRESSION POINTS FOR THE LAST 3 AMPLIFIERS

SYSTEM = strawman2b SPECTRUM

M1 FREQ=1465.06500 value=18.1047232
M2-M1 dFREQ=-0.84000000 dValue=-41.1482174
FREQ=0.84000000 dValue=-41.9485449

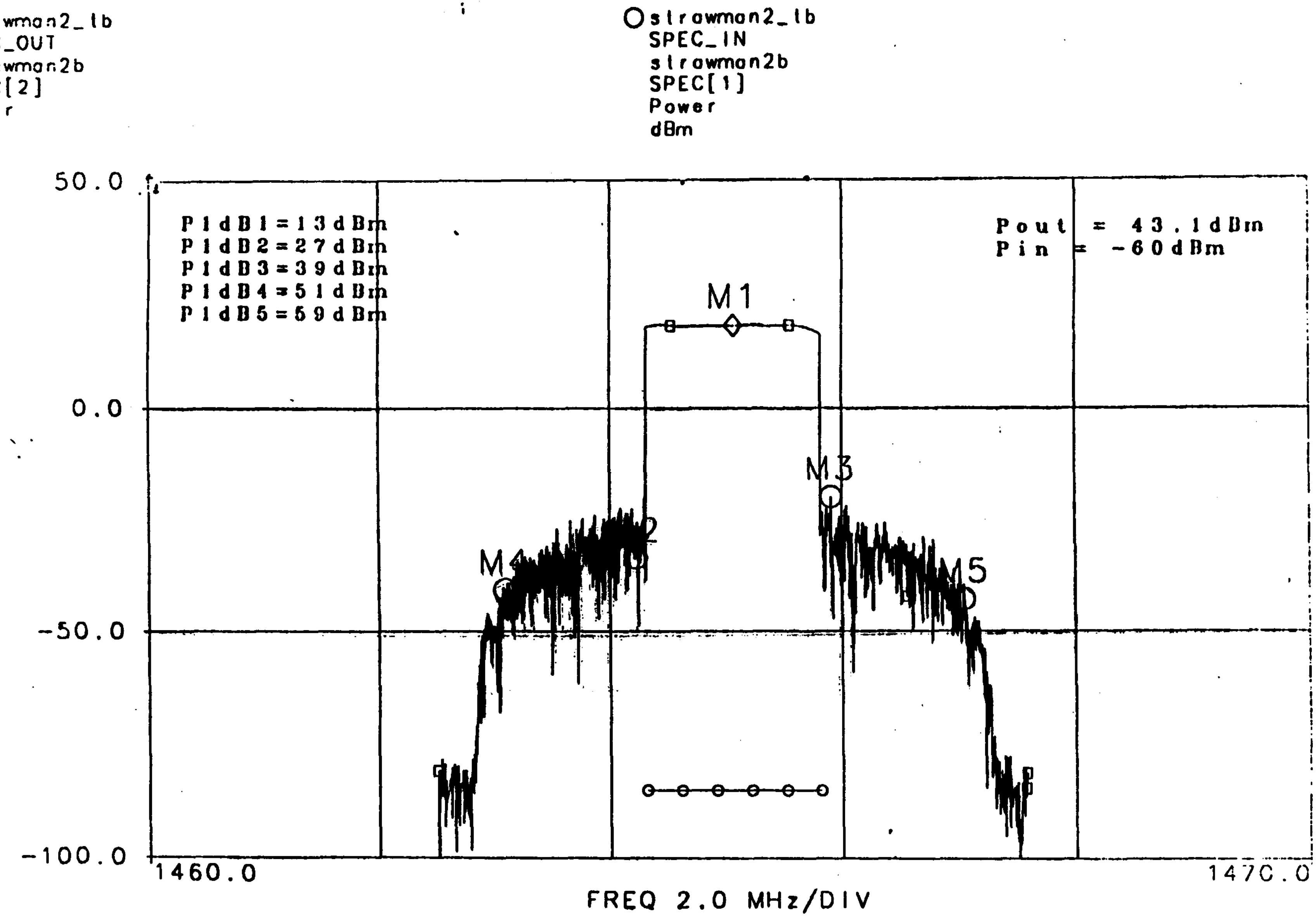


FIGURE 12 OUTPUT FROM STRAWMAN 2 WITH INCREASED 1 DB COMPRESSION POINTS FOR THE LAST 3 AMPLIFIERS

SYSTEM = strawman2b SPECTRUM

M1 FREQ=1465.06500 value=18.3927281
M2-M1 dFREQ=-0.84000000 dValue=-51.8596379
M3-M1 dFREQ=0.84000000 dValue=-38.3480981
M4-M1 dFREQ=-1.98500000 dValue=-58.9425843

Jim Wight

Dr. Jim Wight received the B.Sc. degree in 1972 from the University of Calgary, and the M. Eng and Ph. D. degrees in 1973 and 1976, respectively, from Carleton University, Ottawa.

He is Professor and Chairman of the Department of Electronics, Carleton University. His current research interests focus on microstrip patch antennas and arrays, and monolithic microwave integrated circuits. He has acted for 14 years as consultant to CAL Corp., SPAR Aerospace and Vistar and has conducted many joint research programs with the Communications Research Centre, Ottawa over the past 20 years.

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DRB Seminar, Ottawa, Ont., 27 October, 1995

DRB Testbed Activities at CRC

by

Barry McLarnon
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Ottawa, Ontario

CRC Communications Research Centre
Centre de recherches sur les communications

Presentation Outline

1. Introduction

2. Elements of the DRB Testbed

3. Measurement Capabilities

4. Sample Results

5. Conclusions

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Introduction: Purpose of the Testbed

Support In-house Research:

- characterization of DRB hardware and transmission channels for simulation and modeling
- verification of simulation results
- investigation of optimal DRB parameters

Assist Canadian industry in product development

- test and characterize new hardware under realistic conditions

- test interoperability of DRB hardware

- provide advice and recommendations on product improvements

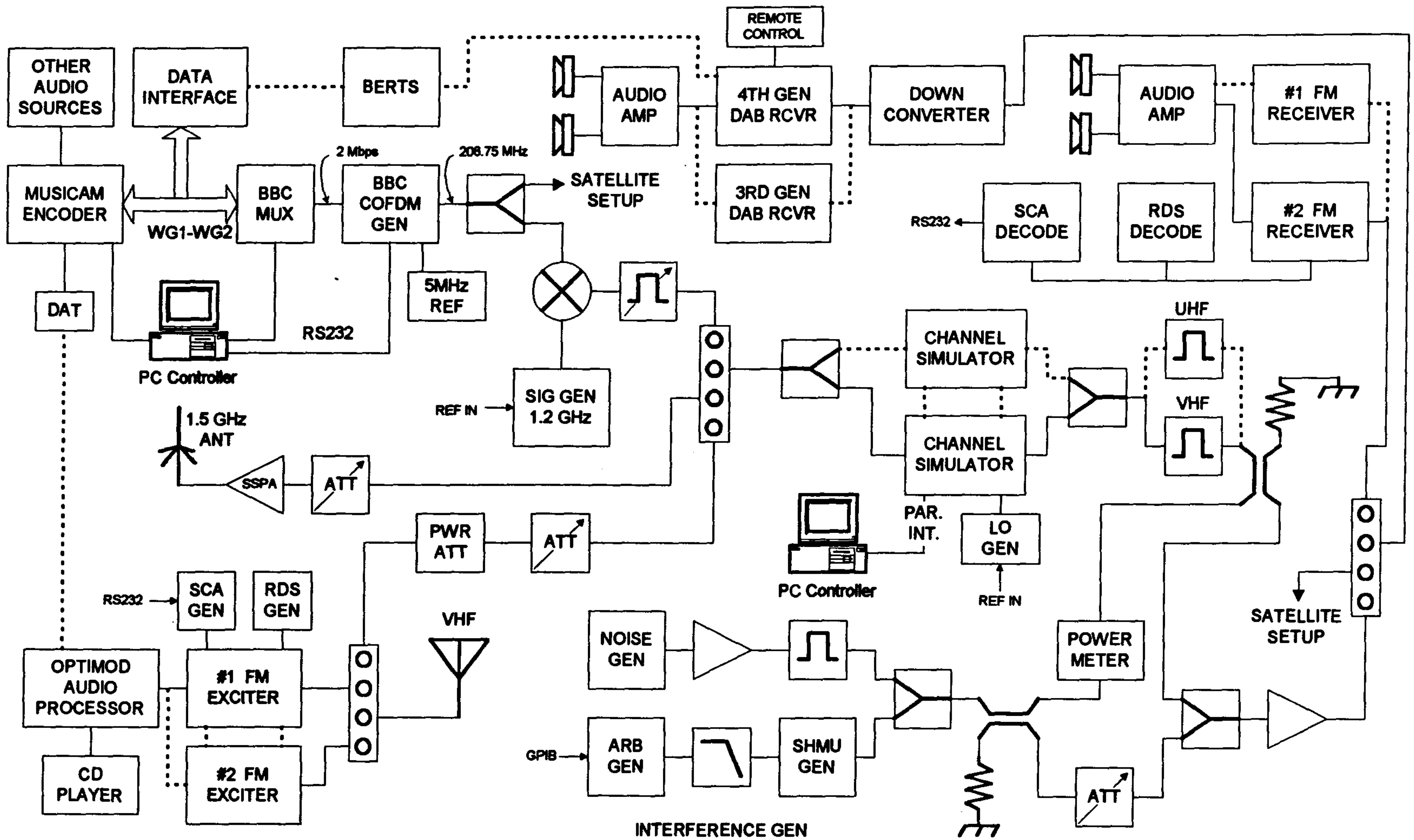
Basic Testbed Elements:

- Digital audio and data sources
- Audio source coder
- Multiplexer
- Channel coder and COFDM modulator
- VHF ⇨ L-band up-converter
- Channel simulator
- L-band ⇨ VHF down-converter
- DRB receivers

Associated Elements:

- Test equipment
- Power amplifier
- Tower and transmitting antenna
- Mobile test vans
- FM broadcast testbed
- Services of other DRB groups (e.g., system modelling, subjective audio testing)

DRB Laboratory Testbed Block Diagram



- 224 -

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Test equipment:

- Spectrum analyzers and synthesized signal generators
- Arbitrary Waveform Generator
- Rubidium frequency standards
- Mobile channel simulator
- BER test set
- Miscellaneous RF: power meters, loads, attenuators, directional couplers, tunable filters, noise sources
- High-speed data acquisition system
- Other equipment available on-site (e.g., network analyzers, environmental test facilities)

Measurement Capabilities:

- RF amplifier power gain and AM⇨PM characteristics
- Intermodulation Distortion
- Amplifier noise figure and oscillator phase noise
- Bit Error Rate
- Subjective audio impairments
- Co-channel/adjacent channel interference
- Mobile channel characteristics

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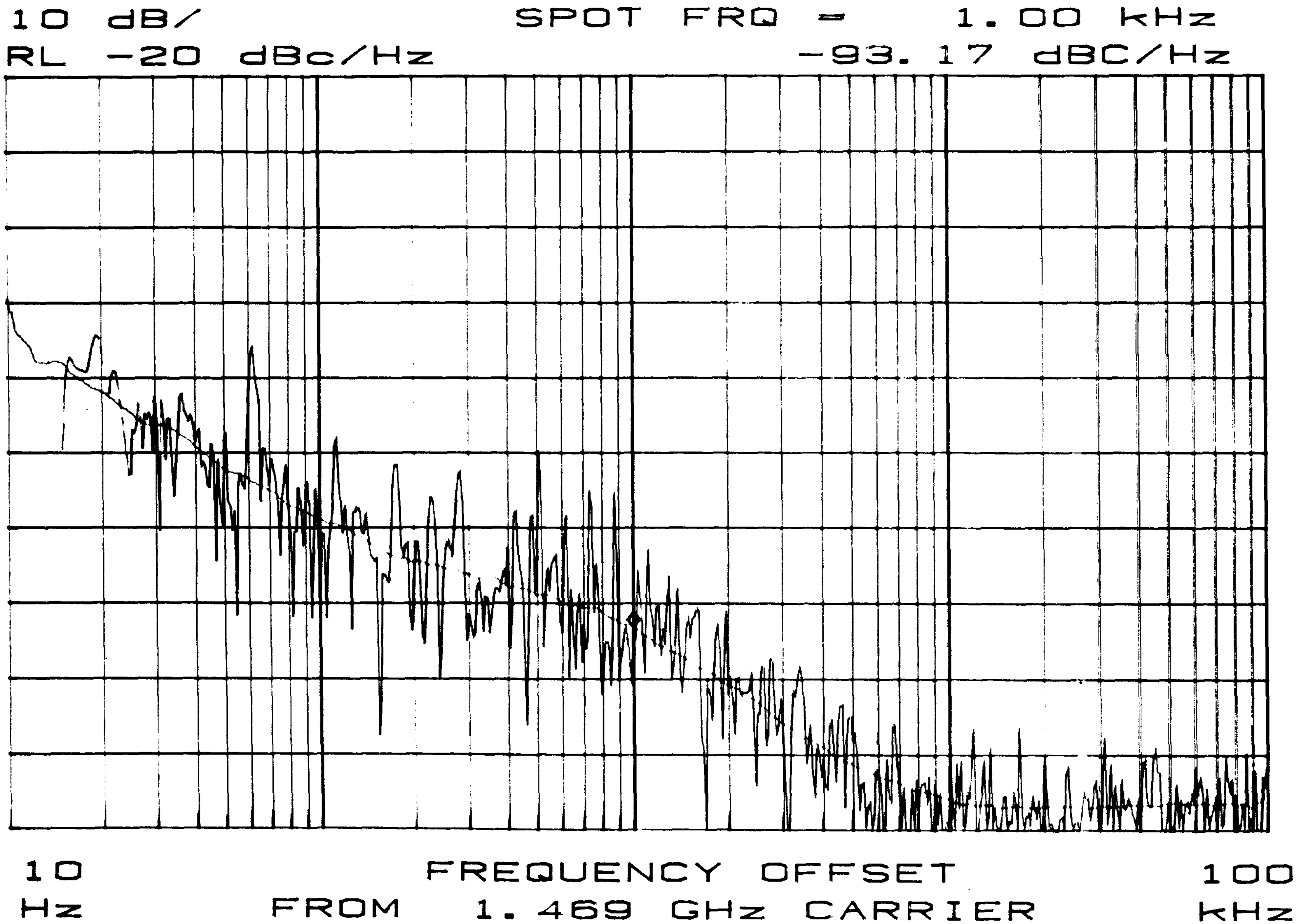
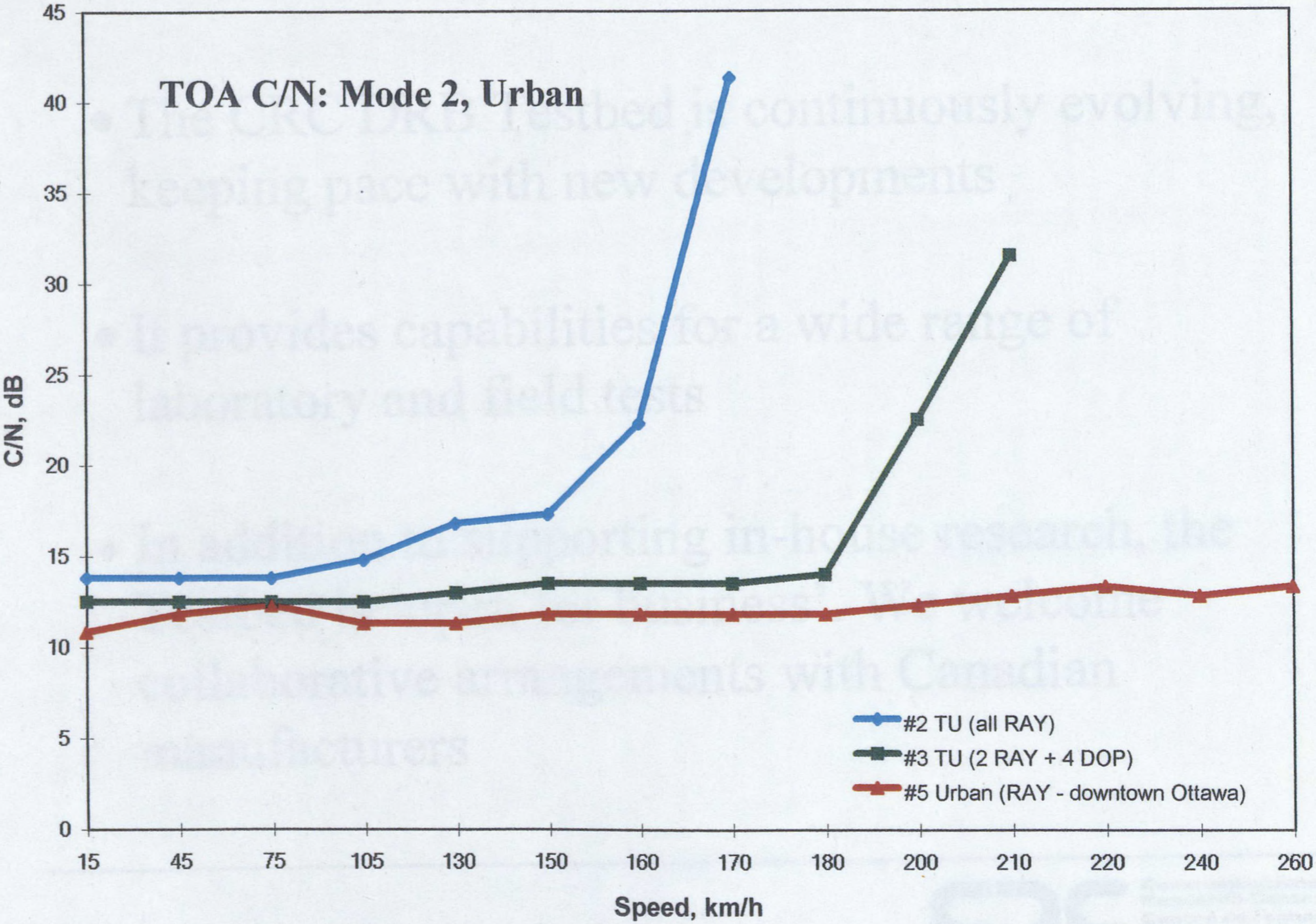

10 dB/
SPOT FRQ = 1.00 kHz
RL -20 dBc/Hz
-93.17 dBC/Hz
10 Hz
FREQUENCY OFFSET
FROM 1.469 GHz CARRIER
100 kHz


TOA C/N: Mode 2, Urban
C/N, dB
45
40
35
30
25
20
15
10
5
0
15
45
75
105
130
150
160
170
180
200
210
220
240
260
Speed, km/h
#2 TU (all RAY)
#3 TU (2 RAY + 4 DOP)
#5 Urban (RAY - downtown Ottawa)

Conclusions

- The CRC DRB Testbed is continuously evolving, keeping pace with new developments

- It provides capabilities for a wide range of laboratory and field tests

- In addition to supporting in-house research, the Testbed is 'open for business'. We welcome collaborative arrangements with Canadian manufacturers

Barry McLarnon

Mr. McLarnon holds a B.Sc. degree in physics and M.Sc. degree in electrical engineering, both from the University of Alberta in Edmonton.

Since 1993 he has been the Manager of the Transmission group in the Radio Broadcast Technologies Research Division at CRC where he has been involved in the measurement of broadcast channel characteristics, performance measurement of digital broadcast transmission equipment, as well as the study of enhancements to existing analog broadcast systems.

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Closing remarks by the Session Chairman

Today, we are on the verge of a revolution in radio broadcasting and the medium and long term repercussions of this DRB implementation are probably under-estimated.

Since the first demonstration of the Eureka 147 DAB technology in Canada during the summer of 1990, we have gone a long way in testing, demonstrating and even improving the technology. Through these activities, we, in Canada, have acquired a good 5 years of experience in the technology and its implementation in the field. The degree to which Canadian manufacturers are likely to profit from the introduction of DRB depends very much on whether they will be able to take advantage of the technological advance that was gained through these 5 years of investigation.

From the discussions that we just heard, I would like to highlights the following points:

- It is safe to say that DRB will happen and, beyond bringing improved audio broadcasting services, a plethora of new services will develop from its sizeable data transmission capability.

- The broadcasters in Canada are keen in starting with this new technology. They are very interested in exploiting the future businesses possible from the datacasting services that can develop with DRB.

- There is a special interest to develop a PC-board version of the DRB receiver for use in Personal Computers. This is increasingly attractive, on one hand looking at the increasing penetration of the PC's into homes and on the other hand looking at the ease in interfacing and controlling these new data services with the PC's.

- The use of fiber optic technology to build delay lines required to control the timing of the SFN, coverage extenders and gap-fillers seem to be promising. There is a potential sizeable market for such delay lines.

- There are still some specific equipment missing that the Canadian manufacturers may want to address.

While Canada may have to resign itself to not being a principal player in the high-volume manufacture of digital radio receivers, there should nevertheless be good opportunities in niche products. One product line in which Canada can certainly participate is digital broadcast transmitters. Also, new products that will likely be required include specialized transmitters, such as gap fillers, coverage extenders and gap-fillers. There might also be other opportunities that may develop in time.

With the 5 years of experience that we have acquired in the field of DRB and in the use of the 1.5 GHz band, expertise is available in Canada. Furthermore, as we heard in the last presentation, there is a DRB testbed being developed at CRC on which new equipment could be tested and qualified.

Industry Canada is prepared to provide a broad view at the DRB manufacturing opportunities and help in forming possible manufacturers alliances in the field of DRB equipment development. CRC can provide the technical expertise and transfer the knowledge that it has accumulated over these 5 years of working in this field.

We hope that this seminar has proven to be useful and instructive. We should not consider this seminar the end of the road but rather as part of a continuum to get the Canadian Manufacturers involved in this exciting and promising technology.

I would now like to thank all the **speakers** for their very interesting and enlightening presentations, and the **exhibitors** for participating and showing that the Canadian industry has already a head start in this field.

I would also like to thank the members of the organizing committee, **R. Douville** from CRC, **David Spendlove**, retired from Industry Canada, **Debbie Kemp** from the CRC Corporate group and **Royce Trenholm** from Industry Canada.

I would also like to thank the CAB for the support in mailing the Seminar announcements along with their CAB convention documentation.

Finally, I would like to thank the two **coordinators** of this event: **Debbie Kemp** from the CRC Corporate group and **Nelly Yates-Lawson** from the DRB Division at CRC, and also all the staff of the DRB Division at CRC for setting up the CRC booth and helping making sure that this seminar go smoothly.

Thank you for your attention!

Exhibits

A number of exhibits were presented in the room adjacent to the session room. The coffee break and the reception held at the end of the day took place in this area so that participants could take advantage of these exhibits during break periods.

We were pleased to have three Canadian companies exhibiting new RF amplification hardware developed for DRB operation at 1.5 GHz. These companies were:

G&A Telecom

This company demonstrated an innovative design of "Power Panels" which allow integration of 50 W 1.5 GHz RF amplifiers and phased array antenna into common panels. This was claimed to be well suited for DRB applications, especially for coverage extenders and gap fillers.

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President
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Montreal, PQ H2T 2S6
Tel: 514-282-6426 Fax: 514-879-3434

Unique systems

This company demonstrated some technology which allow them to manufacture 100W and 200W 1.5 GHz RF amplifiers for the DRB market.

Contact: Alex Dolgonos
Chief Executive Officer
Unique Systems Inc.
55 Torbay Road, Unit 14
Markham, ON L3R 1G7
Tel: 905-474-0091 Fax: 905-474-1563

Wavesat

This company demonstrated technologies that they developed in the field of microwave amplification in the range of 1.5 GHz suited for the DRB RF amplifier market. This company had already built a 100W RF amplifier which was in use to transmit the DRB signal over the air in Ottawa at the time of the seminar.

Contact: Raffi Antepyan
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5607 St François
Montreal, PQ H4S1W6
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CRC also presented a number of display elements related to the field of DRB such as a complete DRB testbed and related hardware as well as DRB coverage software and audio quality assessment tools used in our tests of the American DAR systems under contract for EIA.

There was also, demonstrated, a DRB receiver tuned to the Ottawa DRB Station in operation at the time of the seminar.

Finally, in conjunction with the CRC exhibit, a representative of the **ITIS** corporation from France was available to discuss and describe their latest generation of equipment. ITIS is one of the main suppliers of Eureka 147 DAB encoding equipment.

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DATE DUE
DATE DE RETOUR
