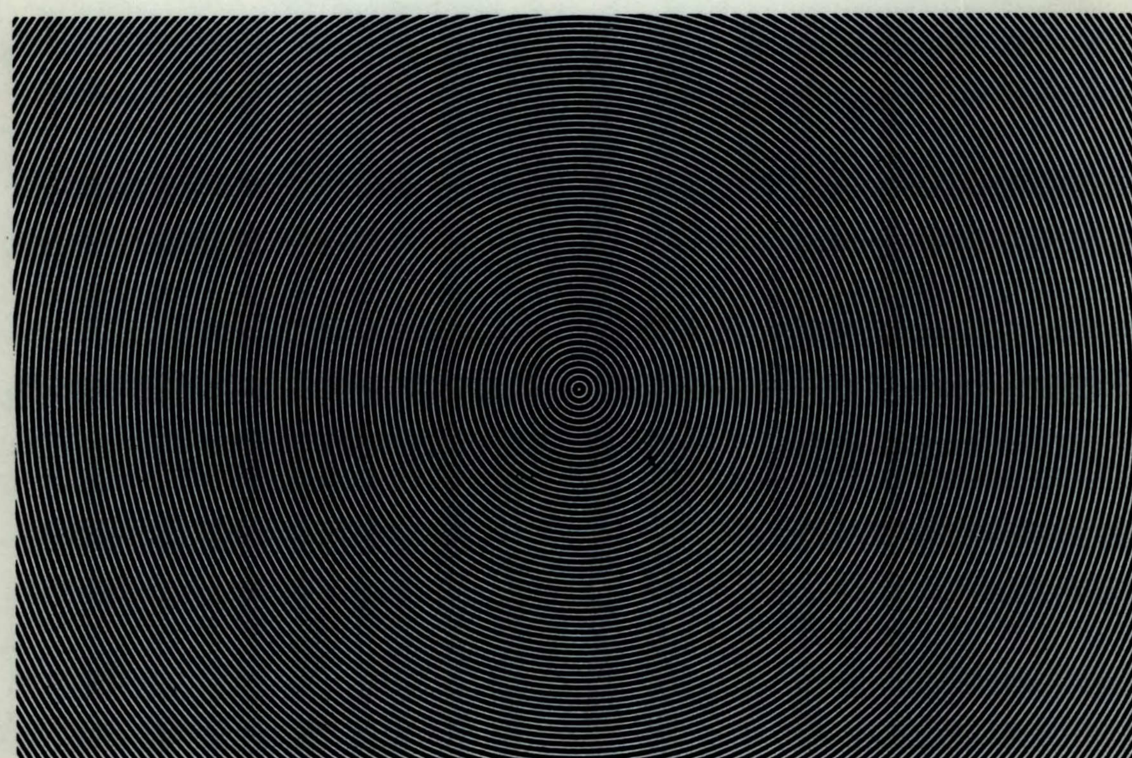
RADIO ADVISORY BOARD OF CANADA
CONSEIL CONSULTATIF CANADIEN DE LA RADIO

SPECTRUM 20/20

A SYMPOSIUM ON SPECTRUM USAGE: FUTURE DIRECTIONS IN CANADA

COLLOQUE SUR L'UTILISATION DU SPECTRE ORIENTATIONS FUTURES QUI SE DESSINENT AU CANADA



SYMPOSIUM PROCEEDINGS
LES ACTES DU COLLOQUE

MONTREAL, CANADA
MAY 12 AND 13, 1987

MONTRÉAL, CANADA
LES 12 ET 13 MAI 1987

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(1987: Montréal, Québec)

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SPECTRUM 20/20 IS JOINTLY SPONSORED BY THE DEPARTMENT OF COMMUNICATIONS AND THE RADIO ADVISORY BOARD OF CANADA

SPECTRUM 20/20 EST PARRAINÉ CONJOINTEMENT PAR LE MINISTÈRE DES COMMUNICATIONS ET LE CONSEIL CONSULTATIF CANADIEN DE LA RADIO

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SPECTRUM 20/20 Symposium Proceedings
Radio Advisory Board of Canada

SPECTRUM 20/20

The Radio Advisory Board of Canada (RABC) is pleased to announce the holding of a major symposium which will provide a unique opportunity for industry and government to express views on the future use of the radio spectrum in Canada. SPECTRUM 20/20 is jointly sponsored by the Department of Communications (DOC) and the RABC.

The Symposium, with the theme "Spectrum Usage - Future Directions in Canada," will bring together representatives of the manufacturing sector, regulatory bodies, radio service providers and users. These participants will express views on the future use of the radio spectrum based upon their knowledge of the new radio services and technologies which are likely to be available by the early part of the 21st century.

SPECTRUM 20/20

Le Conseil consultatif canadien de la radio (CCCR) est heureux d'annoncer la tenue d'un important colloque qui donnera à l'industrie et au gouvernement une occasion sans précédent d'exprimer leurs points de vue sur l'utilisation future du spectre des fréquences radioélectriques au Canada.

SPECTRUM 20/20 est parrainé conjointement par le ministère des Communications et le CCCR.

Ayant pour thème "L'utilisation du spectre - Orientations futures qui se dessinent au Canada", le colloque réunira des représentants des fabricants et des organismes de réglementation, ainsi que des exploitants et utilisateurs des services radio. Les participants exprimeront leurs points de vue sur l'utilisation future du spectre des fréquences radioélectriques d'après les connaissances qu'ils possèdent au sujet des nouveaux services et des technologies nouvelles qui seront vraisemblablement sur le marché dès le début du 21e siècle.

A NOTE ABOUT THE RABC

The RABC is a non-profit association of 24 organizations concerned with the use of the radio spectrum. These in turn represent the users of radio communications and related service providers, manufacturers and professional societies. The Board's purpose is to consult and advise the DOC on behalf of industry on the development, management and regulation of radio services in Canada.

NOTE SUR LE CCCR

Le CCCR est une association à but non lucratif composée de 24 organismes qui s'intéressent à l'utilisation du spectre des fréquences radioélectriques et qui représentent les utilisateurs des radiocommunications, les fournisseurs de services de radiocommunications, les fabricants et les associations professionnelles. Le but du Conseil est de consulter et de conseiller le MDC, au nom de l'industrie, au sujet du développement, de la gestion et de la réglementation des services radio du Canada.

SPECTRUM 20/20

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S.E. March	RABC/CCCR

PROGRAM

MONDAY May 11, 1987

1830 Registration

TUESDAY May 12, 1987

0700 Registration

0900 Opening Remarks by:

J.J. O'Shaughnessy
President, RABC

R.A. Gordon
ADM, Spectrum Management and Regional Operations
Department of Communications

0930 **SESSION I: NEW TECHNOLOGIES**

Chairman:
E.A. Welling
Vice-President, RABC

Papers:

I.1 SPECTRUM RELATED RESEARCH AT DOC
Dr. R.E. Barrington
Director General - Radar and Communications Technology
Communications Research Centre, DOC

I.2 THE IMPACT OF TECHNOLOGY ON FUTURE LAND MOBILE RADIO SPECTRUM REQUIREMENTS
Dr. J. Cohn
Vice-President of Technical Staff and Director of Research, and
Dr. M.D. Kotzin
Principal Staff Engineer
Motorola Inc.

I.3 IMPACT OF CURRENT AND DEVELOPING BROADCAST TECHNOLOGY ON RADIO FREQUENCY USAGE
B.D. Baldry
Assistant Vice-President - Engineering
Canadian Broadcasting Corporation

I.4 EVOLUTION OF SPACE COMMUNICATIONS TECHNOLOGY
G.A. Branchflower
Vice-President and General Manager, and
Dr. F.J.F. Osborne
Director-Advanced Systems
Spar Aerospace Ltd.

I.5 THE IMPACT OF TECHNOLOGY ON FIXED RADIO SERVICES
Dr. J. Elliott
Fellow Emeritus
Bell Northern Research

1230 Luncheon

Address by:
Dr. John Meisel
Professor of Political Studies
Queen's University, Kingston, Ontario

1430 SESSION II: NEW SERVICES

Chairman:
D.L. Garforth
1st Vice-President, RABC

Papers:

II.1 THE UNOFFICIAL WHITE PAPER ON DND SPECTRUM REQUIREMENTS TO THE MID TWENTY-FIRST CENTURY
LCol. G.J. Doucet
Director - Frequency Spectrum Management
Department of National Defence

II.2 MOBILE SERVICES IN THE YEAR 2000 AND BEYOND: PERSONAL THOUGHTS
P.W. Nurse
Director of Advanced Technology
Novatel Communications Ltd.

II.3 NEW BROADCAST SERVICES STUDIED WITHIN THE EUROPEAN BROADCASTING UNION (EBU)
D. Kopitz
Chief Engineer
European Broadcasting Union

II.4 SPECTRUM NEEDS FOR SATELLITE SERVICES BEYOND THE YEAR 2000
L.M. Rankin
Vice-President - Telecommunications Services
Telesat Canada

II.5 EVOLUTIONARY IMPACT OF NEW COMMUNICATIONS SERVICES ON FUTURE FIXED SERVICE SPECTRUM USE
D.A. Carruthers
Assistant Vice-President - Engineering
Bell Canada

1800 Reception

WEDNESDAY May 13, 1987

0900 **SESSION III: ROLE OF GOVERNMENT**

Chairman:
R.A. Gordon
ADM, Spectrum Management and Regional Operations
Department of Communications

Papers:

III.1 THE INTERNATIONAL DIMENSION IN SPECTRUM UTILIZATION
R.C. Kirby
Director, C.C.I.R., and
Dr. R.G. Struzak
Senior Counsellor, C.C.I.R.
International Telecommunication Union

III.2 CANADIAN DIMENSIONS OF SPECTRUM MANAGEMENT - NATIONAL POLICIES AND OBJECTIVES
R. Stursberg
ADM, Telecommunications & Technology
Department of Communications

III.3 RECENT U.S. SPECTRUM MANAGEMENT EXPERIENCE
Dr. T.P. Stanley
Chief Engineer, Office of Engineering and Technology
Federal Communications Commission

III.4 FUTURE TECHNICAL EVOLUTION OF NATIONAL SPECTRUM MANAGEMENT
S.N. Ahmed
Director General - Engineering Programs
Department of Communications

III.5 SPECTRUM MANAGEMENT - THE REGULATORY ENVIRONMENT
R.W. Jones
Director General - Radio Regulations
Department of Communications

1200 Luncheon

Address by:
The Honorable Flora MacDonald
Minister of Communications

1400 **SESSION IV: WRAP-UP**

Chairman:
K.T. Hepburn
Senior Assistant Deputy Minister
Department of Communications

Comments by conferees and Panel Discussion
with: E.A. Welling
D.L. Garforth
S.N. Ahmed
Dr. R.G. Struzak
Dr. T.P. Stanley

1530 Closing Remarks by:

R.A. Gordon
J.J. O'Shaughnessy

1600 Symposium Closes

PROGRAMME

Le lundi 11 mai 1987

1830 Inscription

Le mardi 12 mai 1987

0700 Inscription

0900 Discours d'ouverture prononcés par:

M. J.J. O'Shaughnessy
Président, CCCR

et

M. R.A. Gordon
Sous-ministre adjoint, Gestion du spectre
et opérations régionales, MDC

0930 **SÉANCE I: NOUVELLES TECHNOLOGIES**

Présidée par:

M. E.A. Welling
Vice-président, CCCR

Exposés:

I.1 RECHERCHES RELATIVES AU SPECTRE, EFFECTUÉES AU MDC

M. R.E. Barrington
Directeur général, Technologie du radar
et des télécommunications
Centre de recherche sur les communications, MDC

I.2 TECHNOLOGIES FUTURES A L'APPUI DES SERVICES MOBILES TERRESTRES

M. J. Cohn
Vice-président, Personnel technique et Directeur, Recherche
M. M.D. Kotzin
Ingénieur principal
Motorola Inc.

I.3 INCIDENCES DES TECHNOLOGIES ACTUELLES ET NOUVELLES
SUR L'UTILISATION DES FRÉQUENCES RADIOÉLECTRIQUES

M. B.D. Baldry
Vice-président adjoint, Ingénierie
Société Radio-Canada

I.4 ÉVOLUTION DE LA TECHNOLOGIE DES TÉLÉCOMMUNICATIONS SPATIALES

M. G.A. Branchflower, Vice-président et directeur général
M. F.J.F. Osborne, Directeur, Systèmes avancés
SPAR Aérospatiale Limitée

I.5 IMPACT DE LA TECHNOLOGIE SUR LES SERVICES FIXES DE RADIOCOMMUNICATIONS

M. J. Elliott
Membre honoraire
Bell Northern Research

1230 Déjeuner

Allocution proncée par:
M. John Meisel
Professeur d'études politiques
Université Queen's, Kingston (Ontario)

1430 **SÉANCE II: NOUVEAUX SERVICES**

Présidée par:

M. D.L. Garforth
Premier vice-président, CCCR

Exposés:

II.1 LIVRE BLANC NON OFFICIEL SUR LES BESOINS DU MDN EN FRÉQUENCES DU SPECTRE D'ICI LE MILIEU DU VINGT-ET-UNIÈME SIÈCLE

Lieutenant colonel G.J. Doucet
Directeur, Gestion du spectre des fréquences
Ministère de la Défense nationale

II.2 LES SERVICES MOBILES DE L'AN 2000 ET DES ANNÉES ULTÉRIEURES : RÉFLEXIONS PERSONNELLES

M. P.W. Nurse
Directeur, Technologie de pointe
Novatel Communications Ltd.

II.3 NOUVEAUX SERVICES DE RADIODIFFUSION ÉTUDIÉS PAR L'UNION EUROPÉENNE DE RADIODIFFUSION (UER)

M. D. Kopitz
Ingénieur en chef
Union européenne de radiodiffusion

II.4 BESOIN DE FRÉQUENCES LIÉS AUX SERVICES PAR SATELLITE DES ANNÉES 2000

Mme L.M. Rankin
Vice-présidente
Services des télécommunications
Télésat Canada

II.5 INCIDENCES DES NOUVEAUX SERVICES DE COMMUNICATIONS SUR L'ÉVOLUTION DE L'UTILISATION DU SPECTRE PAR LES SERVICES FIXES, DANS L'AVENIR

M. D.A. Carruthers
Vice-président adjoint
Service d'ingénierie
Bell Canada

1800 Réception

Le mercredi 13 mai 1987

0900 **SÉANCE III: ROLE DU GOUVERNEMENT**

Présidée par:

M. R.A. Gordon
Sous-ministre adjoint, Gestion du spectre et opérations régionales
Ministère des Communications

Exposés:

III.1 LA DIMENSION INTERNATIONALE DE L'UTILISATION DU SPECTRE

M. R.C. Kirby
Directeur, CCIR
M. R.G. Struzak
Conseiller principal
Union internationale des télécommunications

III.2 DIMENSIONS CANADIENNES DE LA GESTION DU SPECTRE - POLITIQUES ET OBJECTIFS NATIONAUX

M. R. Stursberg
Sous-ministre adjoint
Télécommunications et technologie
Ministère des Communications

III.3 RÉCENTE EXPÉRIENCE AMÉRICAINE EN GESTION DU SPECTRE

M. T.P. Stanley
Ingénieur en chef
Office of Engineering & Technology
Federal Communications Commission

III.4 L'ÉVOLUTION TECHNIQUE DE LA GESTION DU SPECTRE AU SEIN DE L'ÉTAT

M. S.N. Ahmed
Directeur général
Programmes techniques
Ministère des Communications

III.5 GESTION DU SPECTRE - RÉGIME DE RÉGLEMENTATION

M. R.W. Jones
Directeur général
Réglementation des radiocommunications
Ministère des Communications

1200 Déjeuner

Allocution principale prononcée par
L'honorable Flora MacDonald
Ministre des Communications

1400 **SÉANCE IV: CLOTURE**

Présidée par:

M. K.T. Hepburn
Sous-ministre adjoint principal
Ministère des Communications

Remarques des conférenciers et table ronde avec:

M. E.A. Welling
M. D.L. Garforth
M. S.N. Ahmed
M. R.G. Struzak
M. T.P. Stanley

1530 Discours de clôture prononcés par:

M. J.J. O'Shaughnessy
M. R.A. Gordon

1600 Fin du colloque

SPECTRUM RELATED RESEARCH AT DOC

by

R.E. Barrington
Communications Research Centre
Ottawa, Canada

ABSTRACT

A basic understanding of radio waves and their behaviour is essential, not only to the development of new radio technology and services, but also to the effective management of the radio spectrum. Since its creation, DOC has maintained a group of experts researching a variety of topics that are essential to this knowledge base. Three examples will illustrate the scope and relevance of this research to spectrum utilization.

A computer program has been developed to predict the effects of terrain, atmospheric refractivity, and diffraction on the behaviour of VHF and UHF radio systems. Although the terrain data base required is extensive, this program can employ a minicomputer, and is extremely useful, not only in the design of radio systems, but also for their licensing.

The advent of cordless telephones and proposals for radio based local area networks have raised questions about the propagation of radio waves both within and through office complexes. As yet, little definitive is known about such propagation, but in a co-operative program with industry, CRC researchers are developing important new knowledge about the design and regulatory issues posed by such applications.

Some CRC research is long range in nature, such as the stationary high altitude relay platform or SHARP project. In this work, the feasibility of using microwave energy transmitted from the ground to power a light-weight aircraft, circling continuously at altitudes of 20 km, has been studied. The potential applications and economics of such a low altitude "communications satellite" look interesting.

RECHERCHES RELATIVES AU SPECTRE, EFFECTUÉES AU MDC

par

R.E. Barrington
Centre de recherches sur les Communications
Ottawa (Canada)

RÉSUMÉ

Le souci de posséder une base de connaissances sur les ondes radioélectriques et leur comportement est une nécessité non seulement pour assurer le développement de nouvelles techniques et de nouveaux services de radiocommunications, mais également pour garantir la gestion efficace du spectre des fréquences radioélectriques. Depuis sa création, le MDC se soucie de conserver un groupe d'experts qui effectuent des recherches sur toute une gamme de sujets essentiels au maintien de cette base de connaissances. Les trois exemples évoqués dans les paragraphes qui suivent visent à illustrer la portée et la raison d'être de ces travaux de recherche au regard de l'utilisation du spectre.

Un programme informatique a été mis au point en vue de prévoir les incidences des accidents de terrain, de la réflectivité atmosphérique et de la diffraction sur le comportement des systèmes de radiocommunications VHF et UHF. Bien que la banque de données concernant les incidences des accidents de terrain soit de très grande envergure, ce programme peut être utilisé sur un mini-ordinateur et il est extrêmement utile non seulement pour la conception des systèmes radio mais également pour la délivrance des licences concernant lesdits systèmes.

L'entrée en scène des téléphones sans cordon et l'élaboration de projets de réseaux hertziens locaux ont fait naître des questions concernant la propagation des ondes radioélectriques tant à l'intérieur qu'à l'extérieur des immeubles à bureau. Jusqu'à présent, on possède bien peu de connaissances définitives au sujet de la propagation dans de telles conditions, mais dans le cadre d'un programme de coopération avec l'industrie, les chercheurs du CRC créent actuellement de nouvelles connaissances importantes à propos de la conception de telles applications et des questions de réglementation qu'elles soulèvent.

Certains travaux de recherche menés au CRC sont échelonnés sur une longue période. C'est le cas par exemple du projet de plate-forme relais fixe de haute altitude (SHARP). Les travaux effectués à ce propos ont eu pour objet d'étudier la possibilité d'utiliser des micro-ondes transmises à partir du sol pour alimenter en énergie un avion léger circulant sur orbite à des altitudes de 20 kilomètres. Les possibilités d'application d'un satellite de télécommunications d'aussi faible altitude et les retombées économiques d'un tel projet semblent intéressantes.

ORIGINAL : ANGLAIS

SPECTRUM RELATED RESEARCH AT DOC

by

R.E. Barrington
Department of Communications
Communications Research Centre
P.O. Box 11490, Station H
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Canada

Although radio waves were predicted and observed in the late nineteenth century, it was at the beginning of the twentieth century that Marconi successfully demonstrated their usefulness as a long-distance communications tool. To-day, after more than a century of research and development on the characteristics of radio waves, one can rightly ask what more is there to learn. In this regard, it is very interesting to look at a very common practice in the design or specification of many radio systems. The performance of antennas, amplifiers, detectors, transmitters, receivers, etc., are given to a fraction of a decibel but, when it comes to the over-all performance of a system or circuit, there is often as much as a 20 decibel margin introduced to take account of propagation uncertainty. In view of this, it is reasonable to conclude that there is still a great deal to be learned and applied in the field of radio wave research that will greatly enhance the use and value of the radio wave spectrum in the coming century.

Rather than try to present a broad comprehensive survey of the impact of radio wave research in the coming decades, I have decided to consider three rather different examples of what such research is contributing. The only common element in the three examples is that they are all projects that are currently underway at the Communications Research Centre of the Department of Communications. They do, however, give a varied picture of the challenges and opportunities that research and development on radio wave technology may present to the coming generations of spectrum planners and managers. In addition, since none of them deals with a specific service, I hope that they are distinct from what other participants in this session will present.

The first example involves essentially the use of computers to take into account in a relatively painless fashion the effects of antenna locations and patterns, terrain variations, atmospheric refractivity and diffraction in designing a radio system. There is nothing particularly novel in this technology; radio engineers have, over the decades, derived methods for taking all of these factors into account but, in many cases, they involved demanding and time consuming scaling and calculations to produce results. Several years ago at CRC, we decided to develop a computer program that would use the best methods for calculating the effects of these various physical phenomena, in the hope that it would provide a unique tool for use in Canadian environment.

The most difficult part of this undertaking was the question of how to incorporate into the program information on the contours of the Canadian land-mass. Ideally one would like to have information on the height above sea-level of every square foot of Canada. This, however, would require scaling 10^{14} points from topographic maps that, as yet, are not accurate enough to provide such information. Since the Canadian topographical maps have elevation contours every 25 ft. it was decided to use these maps and to determine the highest point in each quarter kilometre square block. Even at this greatly reduced scale, it would require the derivation of 40 million data points from our best topographic maps. A very good start on this enormous task has been made, as shown in Figure 1. The shaded areas of this map show the regions of the

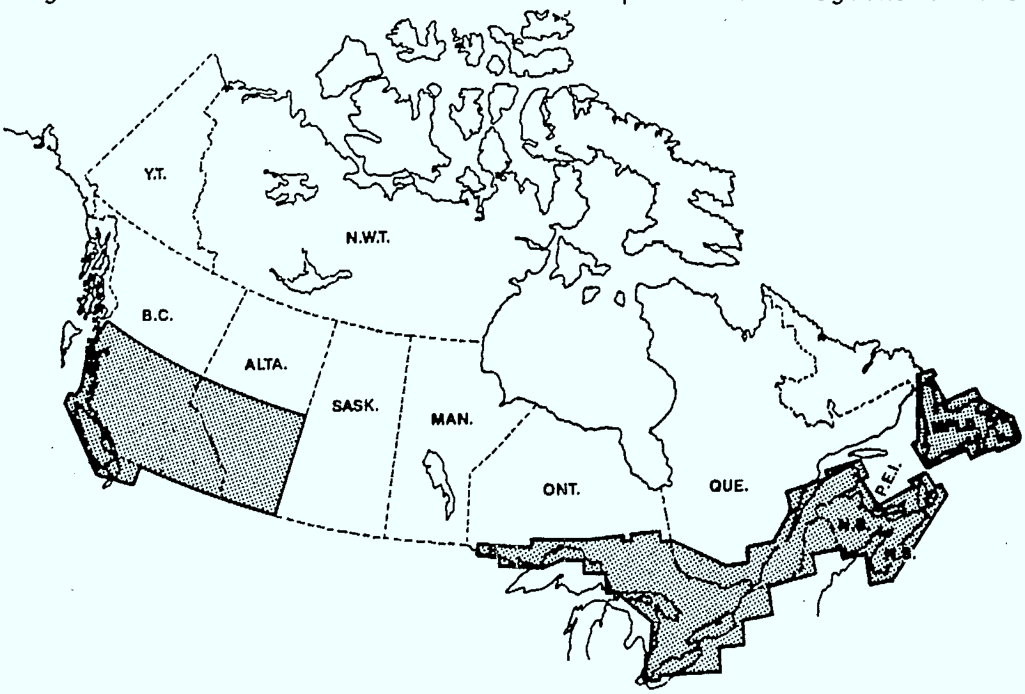


Fig.1- The shaded areas show the regions of Canada for which topographic data is incorporated in the propagation prediction program.

country for which the peak elevation in every quarter square kilometre have been tabulated. While this area is small compared to the country as a whole, it does include most of the populated regions for which there is appreciable relief to the landscape. The scaling of this information has required several person years of effort by members of the Department and other agencies.

I will not describe the methods by which the atmospheric refractivity, the diffraction or diffusion of radio waves around hills and valleys and the effects of terrain types, i.e. water, marsh grasslands or bush are incorporated into the program. The methods for doing this have been carefully selected and tested and represent the best techniques currently available. The important thing is that, with this program, a transmitting antenna with a known power and radiating pattern can be located at any point in the scaled region and the signal strength at any other point and elevation calculated automatically. This is useful not only for designing point to point radio communications systems, but for determining the coverage area of a broadcast transmitter or a mobile radio base station.

While the program has many uses, a simple example may help in understanding its application. Figure 2 shows the

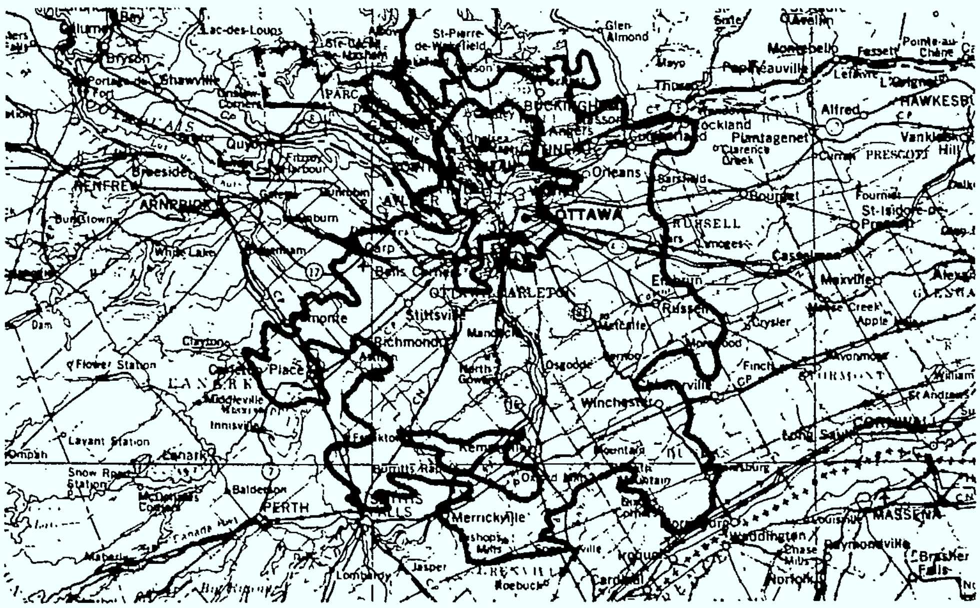


Fig.2- Map of the Ottawa region showing the calculated service contours for the CHRO channel 6 TV transmitter.

coverage contours for one of the Ottawa television transmitters CHRO located in the Gatineau hills to the north east of Ottawa. The irregularity of the coverage contours are due to the hills and valleys that encompass the transmitter and to a lesser degree the terrain features in the neighbourhood of the receiving location. This is an interesting example of how terrain can be used to help shape the coverage pattern of a TV station. No doubt such patterns are also of great interest to broadcasters when setting advertising rates.

In the early days of this project, it was based on the large mainframe computer at CRC. In this configuration, it has been used extensively by the Department, the RCMP and Alberta Government Telephones. The program and the data base are available through the access to information program and several users have acquired it and have it up and running on their own computational facilities. Depending somewhat on the computer involved, this can be a lengthy and demanding process. More recently the program has been rewritten for an IBM PC, and is available from Petrie Telecommunications as a turnkey system along with some systems support for about $8-10K. Thus, not only has the program and an extensive data base been developed, it is readily available at moderate cost to any major player in the communications business in Canada.

So much for the program and its capabilities; what does the existence of this technology mean for spectrum management and planning in coming decades. For those who have ever had to derive path profiles from topographic maps, it is an enormous time saver or to put it in the words of Jim Whitteker, who led the development work on the data-base, it is quite "addictive". Beyond saving time, it permits a much more accurate calculation of the coverage pattern of any transmit facility. This increased accuracy can reduce the cost and improve the effectiveness of wide area communications systems, such as are used by many agencies, e.g. police hydro cellular systems, delivery systems, etc. It also provides a useful tool for frequency co-ordination work and in the avoidance of interference. For broadcasters, it provides a much more accurate picture of their service area, and could be used to tailor the service areas of new transmitters to fill in gaps in coverage or to provide additional channels in certain areas. No doubt as time evolves, many other applications for this technology will emerge.

It is in the VHF and UHF bands of the spectrum that this program is most useful. In these bands the struggle for spectrum allocations are likely to be very severe during the next decade or two, since such frequencies have unique properties that make them particularly useful for mobile systems. For this reason, it will be important to use as much as possible of our knowledge of radio wave behaviour to increase the use of these crowded bands. The modern mini-computer and the program I have just described provide a vast amount of detailed knowledge and experience that, in the hands of a skillful operator, can contribute significantly to increasing the utility of these bands.

Before leaving this subject, I would like to say a little about how our propagation prediction program will change in the future. Work is still underway to expand the data base by scaling additional topographical maps for regions where there is a particular need. This activity has slowed somewhat from previous years, since the Department of Energy Mines and Resources has a major program underway to publish all topographical maps in digital format. In the not too distant future, this project will overtake the DOC effort and we will rely on EM&R to provide digital topographic data for all regions of the country with higher resolution than we have used. This EM&R initiative then will not only increase the area of Canada for which our program is available, but also for the region that are already covered, it will provide greater accuracy. It is expected that this EM&R project will be completed by the year 2000. At CRC we are still working on techniques to better predict the way in which radio waves diffuse or correctly speaking diffract around topographic obstacles with sharp edges. In addition, the Fortran 77 language in which the program is written is becoming obsolete and we will shortly rewrite it in a more modern language.

I have described this work in some detail because it is a prime example of how the marriage of research results and low cost computers are radically changing the techniques used for spectrum management and planning. Undoubtedly during the course of this conference, many other examples of the impact of the ubiquitous computer will be discussed.

Turning to a quite different subject, the increasing use of cordless telephones and the development of office equipment interconnected by radio rather than wires present new and interesting challenges to scientists, engineers and spectrum managers as well. The high costs and inflexibility of wiring office equipment into fixed locations coupled with the decreasing costs of radio equipment through the use of integrated circuit technology, makes the concept of radio interconnection attractive. In spite of its potential benefits, there is very little good information on the behaviour of radio waves within various types of buildings. Such information is essential for the development of effective local area networks using radio rather than wires. Beyond the purely technical issues of how best to deploy radio technology in offices, there are a number of interesting issues which must be faced by spectrum planners and regulators. Before outlining some of these issues, I would like to discuss some of the interesting results that are emerging from studies conducted at CRC and elsewhere on propagation within building.

The measurements that we have conducted at CRC and in other office complexes indicate that propagation within buildings does not lead to significantly higher losses than in free space. Walls and partitions, depending somewhat on their construction and location, lead to losses that may amount to several dB. The most interesting feature of the signals within buildings is that their strength changes rather slowly. They appear to have two components, a rather constant background level and variations super-imposed on this, due to the movement of people within the complex. It is also interesting that at least for the buildings that we have studied, there appears to be considerable leakage of signal between floors. There does not appear to be any significant limit to the data rates that can be used within buildings, at least for rates of the order of a megabit per second or so.

In a typical office radio link, operating at a data rate of 56 kilobits per second, a power of 10 to 20 millwatts would be adequate for a range of up to 30 meters. Due to the variability of the signal, it would probably be useful to incorporate error correction techniques to ensure the accuracy of the data. Such a link operating at a frequency of 900 MHz would be quite adequate for connecting a desk top terminal to a main frame computer or to a data base. So far, we had made most of our measurements at a frequency of 900 MHz with some at 1.7 GHz. These frequencies were chosen only because they are ones for which manufactures are currently developing systems. Undoubtedly, higher frequencies could be used for this type of application, but would probably involve somewhat faster fading and additional attenuation. The greatest impedement to the use of higher frequencies is the high cost of manufacturing equipment to use them. As monolithic microwave integrated circuit technology develops this disincentive will likely decrease and higher frequencies will be pressed into service.

Rather than providing further information on the technology and the studies that are currently underway at CRC. I would like to discuss the implications of these developments on spectrum usage. In my view, the policy that is adopted with respect to the licensing and regulation of office systems, will have a profound effect on the rapidity and extent to which this technology is developed and deployed. One reason for this is, that infra-red technology, as developed for the remote control of television sets and VCRs, offers a competing system that at least at the moment is free from regulatory restrictions. The data rates possible with the IR systems is substantially less that what is available with radio, and their ability to penetrate walls and floors is almost non-existant. The natural advantages of a radio link could readily be lost in the competition if the regulatory and licensing system was unduly cumbersome and experience.

One of the biggest questions that requires an answer, is whether these systems need to be licensed at all provided they operate below a given power level. The low power that is appropriate to many applications would argue against licensing of most systems. A much more difficult issue is the frequency band in which such systems should operate.

Ideally a frequency allocation devoted exclusively to this application is desirable. This would eliminate the possibility of external signals interfering with the communications links within an office complex. At the moment, we have a fairly good set of measurements for propagation within buildings at 900 MHz and 1.7GHz. As yet, we do not have much data on the penetration of such signals into an office complex.

If there is to be a frequency band devoted to office systems, the frequencies that are currently favoured by manufacturers for this application are those of the cellular radio systems. This makes a lot of sense from the manufacturing point of view, since the design of cellular-radio systems and office communications modems have a lot in common. Moreover, these frequencies lend themselves to the use of integrated circuit techniques in the manufacture of the hardware. However, what is attractive from a manufacturing point of view, is a nightmare for the spectrum planner, since these frequencies are in great demand by several user groups.

Beyond the question of licensing and frequency assignments for office systems, is the question of frequency management within an office complex. If it proves economically and operationally attractive to have office work stations connected together by radio, then a number of radio channels will be required even if the range of any given link is only a few metres. In a large office complex frequency re-use would certainly be possible, while frequency sharing would no doubt be a part of any large system. The number of channels and the data rates per channel that would be appropriate for a large office complex is not known at present. Such information is vital for proper spectrum planning for this type of radio service.

There is, of course, a school of thought that holds that wires will always be part of the office environment. Others would suggest that all services that can be provided via wires rather than radio, should be forced to do so. If these views prevail, then there will be no need for radio spectrum to support modern office operation. In my view, this issue is more likely to be resolved by economic considerations. If it is cost effective to connect office workstations together by radio rather than rewiring offices after every re-organization, then the pressure for spectrum allocations will be intense. In this regard, it should be noted that the costs of rewiring offices is rising rapidly, while the costs of radio modems is decreasing rapidly.

As a third example of some of the issues that new technology may pose for spectrum planners during the next decade, I would like to be somewhat more speculative than in the previous two cases. Since 1981 we have been exploring the technical feasability of a low altitude satellite that would remain at a fixed location above the earth's surface at altitudes of about 20 km. We have explored high altitude balloons semi-bouyant aircraft, light-weight aircraft, and rotary wing vehicles. From these studies, we concluded that the most promising vehicle is a light-weight aircraft much like the solar challenger that completed the first manned-flight across the English Channel using only solar power. For service as a low altitude satellite, the aircraft would be unmanned and equipped with solar cells on its upper surfaces so that it could be flown unto station and maintained there during daylight hours using solar power. During darkness microwave power would be beamed from the ground, captured by rectennae mounted on the lower side of the aircraft, and the output DC power used to drive the electric motor of the aircraft. The beam would track the aircraft as it circled in tight 1 km diameter circles above the microwave power source at a height of 20 km. Figure 3 is a diagram of the configuration that is envisaged, and we have named this the SHARP system, meaning Stationary High Altitude Relay Platform.

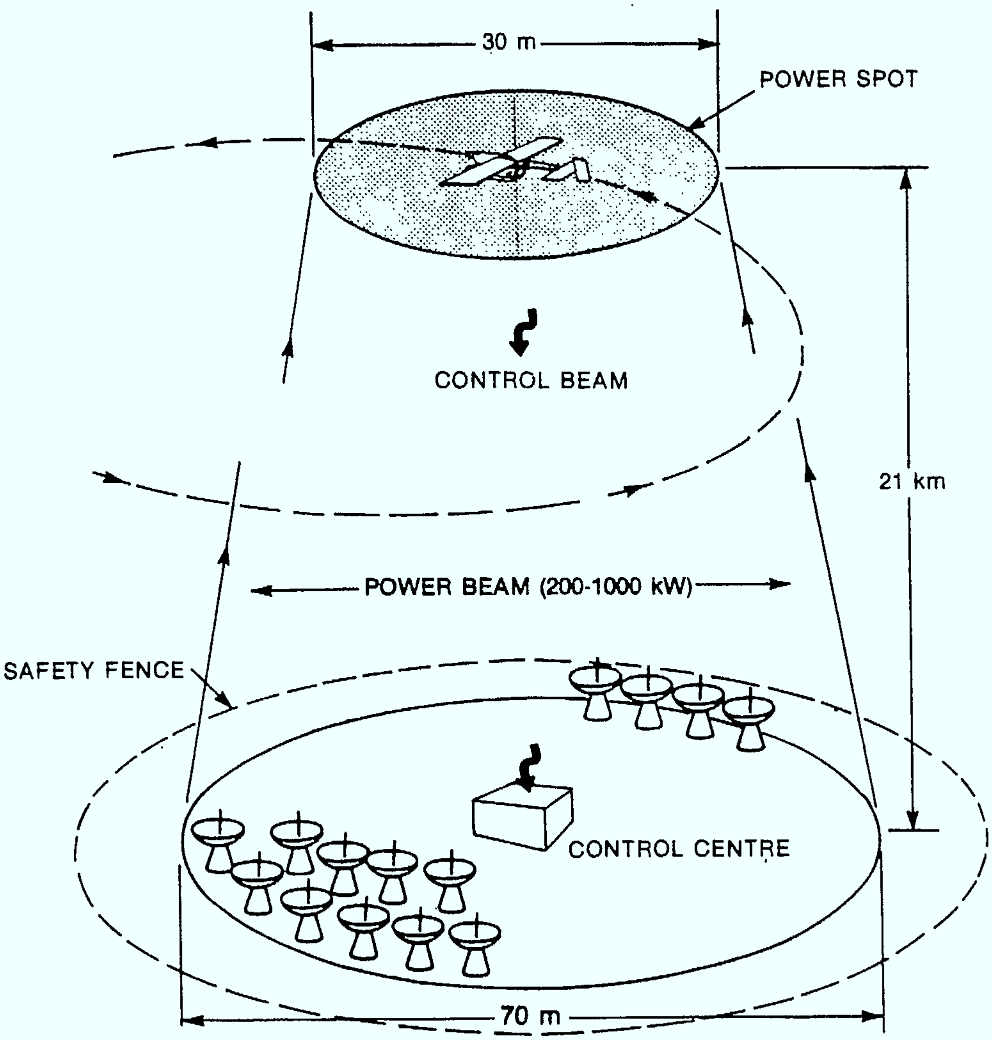
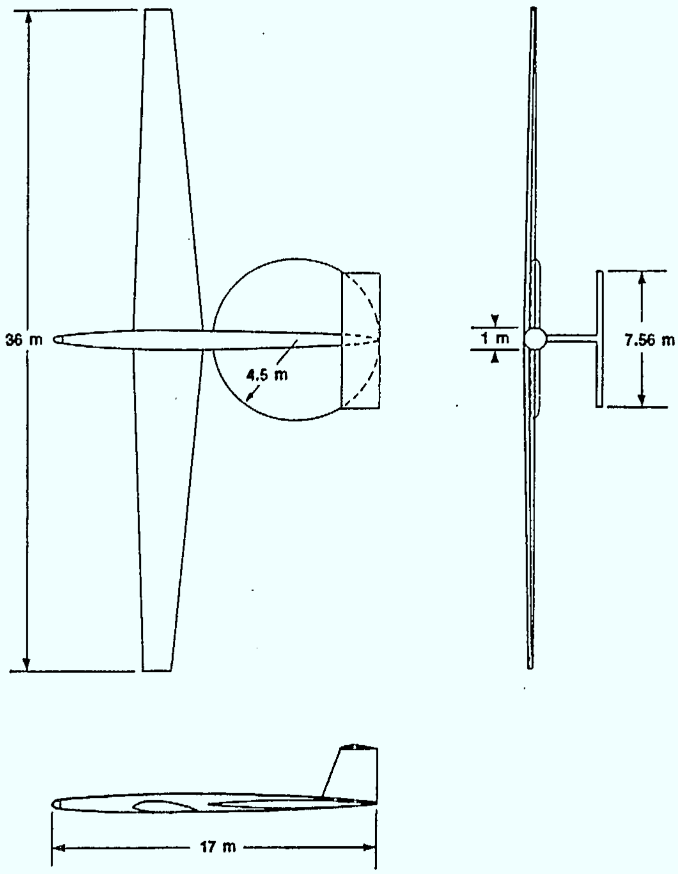


Fig.3- Configuration drawing of the SHARP system.

With such technology, it is possible to sustain a payload of about 100 kg and with a power consumption of up to 5 kilowatts for periods of several months. During the 1984/85 fiscal year, an extensive study of this system was carried out at CRC and judged to be feasible. More recently the Lockheed Georgia Co., carried out a study of this technology for NASA with some input from our CRC studies and reached the same conclusion that we had. From the Canadian studies, we concluded that the most efficient aircraft configuration for this application is as shown in Figure 4. This aircraft is



ASPECT RATIO	14
WEIGHT	1260 lb
NORMAL OPERATING SPEED	162 ft/sec (49.5 m/s)
POWER FLUX DENSITY	216 w/m^2
PAYLOAD / AVIONICS	100 kg/2 kw

ISIS AIRPLANE

Fig.4- Configuration and dimension of the operational SHARP aircraft.

essentially a very efficient sailplane with some power collecting units mounted on the central portions of the wings, but with the bulk of the power collected on a large non-lifting disk mounted near the centre of the fusilage. More recent studies suggest that an even more efficient design would have a canard mounted in front of the main wing and a smaller stabilizer assembly in the rear.

Such a platform maintained for months at a time at an altitude of about 20 km could provide broadcasting or radio relay services over a wide area. Line-of-sight path lengths from a fixed or mobile receiver to the SHARP aircraft would range from 20 km to 300 km corresponding to elevation angles from 90° down to 3° above the horizon. By comparison, ground satellite path lengths are about 30,000 km. Therefore free space path losses at maximum range for SHARP would be at least 40 db less than those for satellite transmission ones. Of course there is a price to be paid for this advantage, since the service area of SHARP has a diametre of around 600 kilometres rather than an entire hemisphere as in the case of a satellite.

The low altitude satellite or SHARP system that I have outlined has a wide variety of potential applications. It offers a very interesting large cell capability which could be used to extend current cellular technology into the rural and less populated regions of the country on an economic basis. It could even provide basic telephone service to remote locations. Wide area paging services or regional FM broadcasting are entirely feasible. Using frequencies above 10GHz, SHARP could be a useful vehicle for providing a multi-channel high definition TV service or to provide the thirty odd channels of cable TV to which city dwellers have become accustomed in rural regions of the country that cannot be served economically by conventional cable systems.

Nor are the possible applications confined to the communications' field. Such a low altitude satellite would be very effective for various forms of surveillance. The study by Lockheed-Georgia to which I alluded earlier was aimed at using this technology for monitoring carbon dioxide and other atmospheric constituents at altitude of 20 km. Such measurements are essential to the understanding and control of pollutants on a continental scale. Studies have shown that the aircraft I have described could carry a light weight powerful, high resolution radar. Such a facility would be extremely well suited for coastal surveillance and monitoring of fishing activities in our coastal waters.

It could also be the basis of a much more effective North Warning System than is provided by the present ground based radars.

So much for the SHARP technology and its potential applications. I hope that I have said enough to convince you that the technology is feasible, and that there are many important applications for it. As yet, there are no operational systems to point to, but the introduction and use of this technology will have a very significant impact on spectrum usage in the next century and it is important to plan for this development now. While there are several important spectrum usage issues presented by SHARP, I would like to concentrate on three of them.

The concept of power transmission using radio waves has a long history, going back almost one hundred years to Heinrich Hertz and the very beginnings of radio in 1888. But it is only in the past decade that major technical barriers were reduced to a level such that it could be considered as a practical proposition. Studies concerned with assessing the feasibility of the Solar Power Satellite confirmed the feasibility of power transmission by radio and indicated that 2.45 GHz, a frequency in the Industrial Scientific and Medical band, was very useful for this application, not only because high power sources are available, but also propagation factors are favourable. It is this frequency that we have used at CRC for our experiments on microwave-power transmission to aircraft and this is also the frequency used in microwave ovens.

One of the features of equipment used in the ISM band is, that it usually employs high power devices and these tend to radiate at harmonics of their operating frequencies and it is often difficult and expensive to surpress these harmonics. This situation is particularly true in the case of microwave -power transmission by radio. Unfortunately the well known physical fact that that high power device are non linear seems, to date, to have been overlooked by spectrum planners, since the ISM bands are located at 2.4-2.5GHz, 5.725-5.875GHz and 24.0-24.25GHz rather than at harmonics of each other. If microwave-power transmission were to become widespread, the choice of frequencies for ISM application could become a very contentious area of spectrum usage in future decades due to this oversight.

SHARP appears to be a very attractive way to add a very large cell with a diameter of about 600 km to existing cellular systems. A cell of this dimension is not attainable with ground based transmitters, but would be highly useful in extending cellular coverage into regions of low customer density at a reasonable cost. While such an addition would be very desirable from the customer point of view and quite feasible from a technical point of view, it would create some interesting dilemnas for spectrum planners.

Cellular-radio is viewed as a land-mobile service and hence uses frequencies in the land-mobile band if they can be found. But what frequencies are appropriate for a SHARP cell? Presumably the aircraft should use the aeronautical mobile band, since it involves an aircraft, or should it use a frequency in the land-mobile satellite service, since SHARP can be viewed as a low altitude satellite. Similarly one could argue as to whether SHARP is a fixed or mobile platform since, while it remains in the vicinity of a fixed point on the earth's surface, it actually moves in small circles about this point. These questions serve to point out that SHARP is an interesting hybrid system that does not appear to fit comfortably into the currently identified radio services. However, if it proves economic and useful, it is a technology that must be incorporated into the radio regulations.

SHARP also appears to be a very interesting mechanism for delivering high definition TV or interactive TV and a multiplicity of television channels to customers not currently served by cable systems. It is thus a very promising vehicle for reducing the disparity in the quality of broadcasting and cable services available to rural regions of the country. However, this will only be possible if considerable spectrum bandwidth is available to such systems at frequencies about 10 GHz. If SHARP is viewed as a satellite, it could use frequencies assigned to the broadcasting satellite service. If it is viewed as an aeronautical service, then current spectrum allocations would preclude this application.

My purpose here is not to provide answers to the questions that have been raised. Rather, I have talked in some detail about SHARP to show that there are still new technologies emerging from the laboratories that have the potential to significantly alter the current and planned usage of the radio spectrum. Experience has shown that mature technologies with agreed allocations of spectrum are very difficult to displace with newer ideas. However, I feel that the greatest challenge to spectrum usage in the years that lie ahead is to cope gracefully and effectively with the decline of older technologies and the growth and development of new ones.

THE IMPACT OF TECHNOLOGY ON FUTURE LAND MOBILE RADIO SPECTRUM REQUIREMENTS

by

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ABSTRACT

One major driving force which is creating the need for advanced technologies for land mobile services is the limited availability of spectrum to handle the increasing number of users and the increasing volume of both voice and data communications by those users.

The technology advances which are being made, are being built on the foundation of digital integrated circuits and their continuing exponential increase in capabilities. The digital signal processing which the digital I.C. technology makes possible, will provide and increasingly complex array of modulation, coding, and system organization to increase spectrum efficiency.

The potential technology candidates for future use will be identified and their characteristics, strengths and weaknesses highlighted. The trade-offs such as communication throughput versus system range, as well as the impact of various constraints such as cost and power drain will also be referenced.

TECHNOLOGIES FUTURES A L'APPUI DES SERVICES MOBILES TERRESTRES

par

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RÉSUMÉ

L'un des grands facteurs qui sous-tendent la nécessité d'utiliser les technologies de pointe en faveur des services mobiles terrestres est le peu de fréquences disponibles pour répondre aux besoins du nombre croissant d'usagers et pour traiter le volume de plus en plus fort du trafic de transmission de la voix et des données, acheminé par ces usagers.

Les progrès technologiques qui sont réalisés actuellement ont pour assises les circuits numériques intégrés et l'accroissement exponentiel constant de leur capacité. Le traitement des signaux numériques rendu possible par la technologie des circuits intégrés fournira une gamme de plus en plus complexe de techniques de modulation, de codage et d'organisation de systèmes qui amélioreront l'efficacité de l'utilisation du spectre.

Les technologies qui pourront être utilisée à l'avenir seront identifiées et l'on fera ressortir leurs caractéristiques, leurs points forts et leurs points faibles. On traitera également des avantages et inconvénients de ces technologies, par exemple le débit en regard de la portée du système, ainsi que les répercussions de diverses contraintes qui y sont inhérentes, par exemple le coût en regard de la consommation d'énergie.

ORIGINAL : ANGLAIS

THE IMPACT OF TECHNOLOGY ON FUTURE LAND MOBILE RADIO SPECTRUM REQUIREMENTS

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SUMMARY

Technologies needed to provide more efficient use of land mobile spectrum continue to evolve. The rate of evolution of the basic technologies, however, has not been rapid enough to meet the increasing demand for communication capacity. Consequently, the solution will require both additional spectrum allocation as well as more efficient spectrum utilization. The future solution will mandate improvements in the core technologies of voice compression, data transmission, and system architectures.

INTRODUCTION

Since its introduction in the 1940's, the history of land mobile radio has been one of rapidly increasing usage, requiring more communication capacity. This growth in demand has been met by a combination of technology, providing improved spectrum efficiency, along with additional spectrum allocations.

It is the purpose of this paper to examine the fundamental trends in technology that will be utilized in making future contributions to this process of improving spectrum efficiency.

Increasing Demand for Land Mobile Communications

A representative spectrum demand growth curve for a major metropolitan area is shown in Figure 1. The driving force creating this demand, and the consequent spectrum shortages, is the increasing use of land mobile radio for purposes of both safety and efficiency. The area of safety includes police, fire, emergency medical services, and public utilities among many others. The impact on the economic efficiency of almost every kind and size of business has made land mobile radio a universal and standard operating tool.

It is important to note that not only is the demand for channel capacity increasing with time but it is doing so at an increasing rate. Market studies carried out by Motorola, including projections to the year 2000, and those developed by the U.S. Federal Communications Commission are in agreement both in terms of the historical trends and the future projections. Historically, these projections are consistently on the conservative side. Thus the spectrum problem is indeed a real one, one that requires effective long range planning. It is hoped that the technology trends to be discussed in this paper will contribute some perspective to that long range planning.

In considering this projected demand curve, it is important to note what it does include namely data and voice communication; and what it does not include namely mobile telephone service spectrum needs. Both of these subjects are discussed below.

Also, the demand curve does not include new services, whether they be voice or data, which are outside the current range of services utilized by the land mobile users. These new and as yet unidentified services will add further to the demand curve.

Land Mobile Data Communications

While data traffic today is small compared to voice communication, it is increasing rapidly. Data applications include computer inquiry, messaging, status reporting, and automatic vehicle location systems. Data traffic is considerably more concise and efficient than voice traffic and further benefits from not requiring continuous real time access to the channel. In some cases, the use of data has reduced the overall channel capacity demand where it has been used to substitute for a voice function. However, field experience has proven the value and ease of data communication, causing very rapid growth. As a result, the overall impact of data communications has been to increase rather than diminish the communications load.

Mobile Telephone

Mobile radio telephone systems, including cellular, have a set of parameters that are unique to that service. There is separate spectrum allocated for that use and a separate set of system technologies developed to be optimum for that application. The differences in mobile telephone service from land mobile services are well known and will only be briefly referenced here. A primary difference derives from the fact that mobile telephone is basically a one-to-one communication, while land mobile radio frequently involves a group of users who communicate among themselves. The mobile telephone system is inherently a large scale standardized system which meets the needs of the general public and is therefore not tailored to the unique requirements of land mobile radio users. The unique requirements may include coverage areas, be they in-building or areas not covered by the radio telephone system. Also, in the past, there have been a number of data features including encryption, automatic status monitoring, automatic vehicle location, and the ability for units to talk directly to each other bypassing the central control. In the future we can expect other specialized requirements to be available for land mobile radio which do not fit into the system approach used for the very large mobile telephone systems.

Past Spectrum Efficiency Experience

The introduction of spectrum efficient communications technology has been ongoing for decades based on advances in those components which provide frequency stability and selectivity as well as system architectural advancements. In the '50s, the land mobile channels were reduced from 120 kHz to 60 kHz. This trend has continued to the 12.5 kHz spaced channels recently authorized at 900 MHz. The ability to continue this straightforward narrowbanding practice is limited, however, by excessive splatter generation as shown in Figure 2. Even with 12.5 kHz channels, there is an impact on system organization - the utilization of contiguous channel assignments is required to minimize performance degradation arising from the increased level of adjacent channel splatter.

Improvements in channel loading by way of evolving system organization has also been occurring. The transition from single user maintained systems, to community repeaters, and finally to trunking systems in the '70s has brought not only more efficient spectrum usage but, especially in the case of trunking, easier and more rapid access to the channel as well as numerous features.

At the same time as systems have become more centralized, there has also been an important trend in the opposite direction. Local, on-site communication capability has become prevalent, both the permanent in-building or on-campus variety, as well as the transient versions used by construction and maintenance, in addition to police, fire and other public safety users. These low power systems have permitted reuse of the same channels in a metropolitan area.

RELEVANT TECHNOLOGIES

The future impact on land mobile spectrum efficiency arises from three primary facets of technology; first, by a consideration of the amount of information needed to be transmitted; second, by the channel modulation scheme used to encode this information on a channel; and third, by system architecture and organization. Each of these is discussed in more detail below.

Speech Coding

Speech processing allows reduction in the redundancy of the speech waveform. However, the bandwidth expansion which occurs when converting the analog voice waveform to a digital signal using today's coding rates and modulation capabilities has not yet reached the breakeven point in spectrum efficiency compared to analog modulation. Various digital speech coders have already been commercially marketed for land mobile and cellular use mainly for high security encryption. The audio quality produced has often been reduced compared to uncoded analog FM - to a level that is not considered acceptable for general land mobile use.

Figure 3 shows the trends in digital voice compression technology. The top line represents the speech bit rate reduction experience for high or "toll" quality speech as used over telephone networks.

The lower line shows estimated rates necessary for "communications" quality coders. These coders produce slightly degraded but generally useful speech for land mobile applications such as dispatch. Due to the lack of commercial systems employing this type of coder, precise trending is difficult but it is generally agreed that the trend line parallels the toll quality curve at approximately the level shown. Some digital encryption techniques are included on the chart for reference.

Continued reduction of the speech coder bit rate will be progressively more difficult. Further developments will depend heavily on the availability of digital signal processing IC's. Also, as redundancy is removed from the speech signal, invariably so does robustness to channel errors. In land mobile radio, error floors due to fading are the norm. Thus, only with specialized fading reduction techniques such as diversity, will the reduced bit rate be of value. Progress in speech coding might also be made more difficult by acoustical performance of the input/output transducers and the presence of environmental noise. These perturbations are often worsened using low bit rate coding techniques.

Channel Modulation

Considerable research has addressed the ability to transmit high rate data or digitized speech information on faded radio channels. It is important to note that a mobile unit driving through a city environment encounters multiple reflections of the transmitted signal, i.e. the faded radio channel. As a result, there are serious limitations to the data rates achievable compared to those in stationary point-to-point communications.

Figure 4 shows some representative digital systems that have been marketed or proposed on 25 kHz spaced channels (some normalized for acceptable splatter performance). The 12 kbps system for encrypted speech is quite old yet represents a simple and effective approach to provide acceptable performance at a reasonably high data rate. More recent research results indicate that constant envelope signaling rates may extend to 25 kbps using considerably more complex multilevel, partial response, and channel coding techniques. These implementations require significantly improved DSP hardware than found in current systems. Systems using amplitude modulation of the carrier may achieve higher limits yet. In any case, over the next 20 years, the rate of improvement in modulation rates from those currently achievable are projected to be relatively modest.

Impact of Voice Compression and Data Transmission Techniques

The general direction of communication worldwide toward totally digital formats is very clear. The rapid growth and evolution toward ISDN standards in the telephone network and elsewhere is indicative of this direction. It is apparent that land mobile will follow this trend.

The key question is when will the future trends in voice compression and data transmission impact on spectrum efficiency. We have used the technology trends discussed previously as an input in developing the spectrum efficiency trend shown in Figure 5. That figure is a plot of the mobiles per kHz that we anticipate will be necessary to achieve to the year 2000.

Since the use of mobiles per kHz is perhaps an unfamiliar measure of spectrum efficiency, an explanation is warranted. The starting point of 2 mobiles per kHz shown for 1982 is based on a loading standard of 100 mobiles per channel with the channel consisting of two 25 kHz segments for the two-way conversation. Thus the 100 mobiles in a 50 kHz total channel bandwidth results in the 2 mobiles per kHz figure. The various dates for improvement from the 2 mobiles per kHz to 10 mobiles per kHz is shown in that figure. Note that this corresponds to an improvement in equivalent channel spacing, going from 25 kHz in 1982 to 5 kHz by the year 2000.

In order to achieve this projected increase in spectrum efficiency, it will be necessary to accelerate the trends in voice compression and in data transmission rates beyond those discussed in the previous sections. Much research and development effort is being expended to achieve the needed accelerated progress.

System Architecture and Organization

This subject involves the system's physical configuration and capability and how the available channels are allocated and utilized. The next major architectural enhancement that is likely to increase spectrum efficiency will be to incorporate the geographic frequency reuse of the decentralized systems into highly centralized trunking systems. This, of course, is what is done in cellular systems but will have to be modified to take into account the unique requirements of land mobile users.

There are significant economic barriers associated with geographically distributed infrastructures which can deal effectively with the great diversity of systems, functions, and features utilized in land mobile radio. As a result, only a portion of the communication load will be handled in these frequency reuse systems. Further, the use of these systems will probably be limited to the largest of the metropolitan areas, where the spectrum needs are most pressing, and the user base is large enough to find large groups sharing common needs. Such systems are anticipated to become practical in the late 1990's and will be helpful in reaching the 10 mobiles per kHz goal by the year 2000.

CONCLUSION

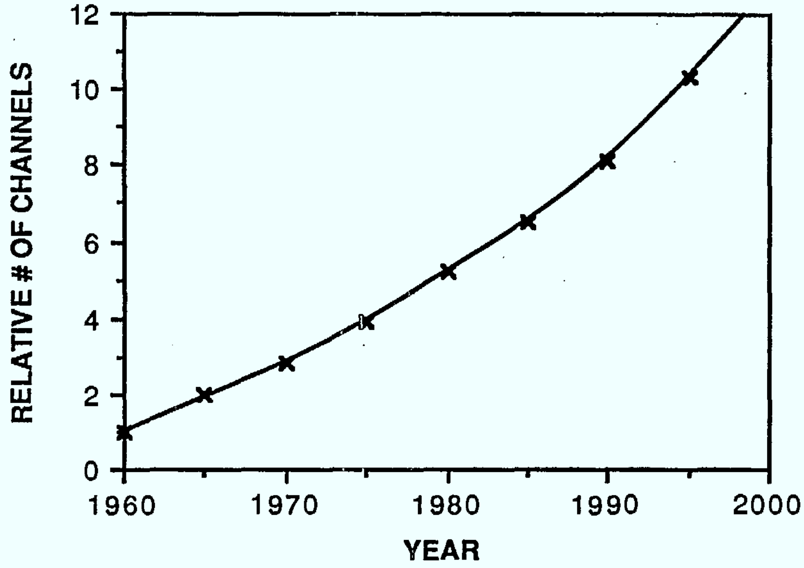
Technology has in the past and will continue in the future to make significant improvements in spectrum efficiency. However, it is clear that technology alone cannot provide the capacity to meet the increasing need for land mobile communications.

The time needed to achieve the necessary technical advances is large. For industry to participate and provide the requisite resources for these R&D efforts, it is necessary that the spectrum in which these technology advances will be used, is known and the allocation uncertainties have been removed.

The problems (or opportunities) which are posed by the expanding use of land mobile radio is a challenge to the regulatory process as well as to the technical community.

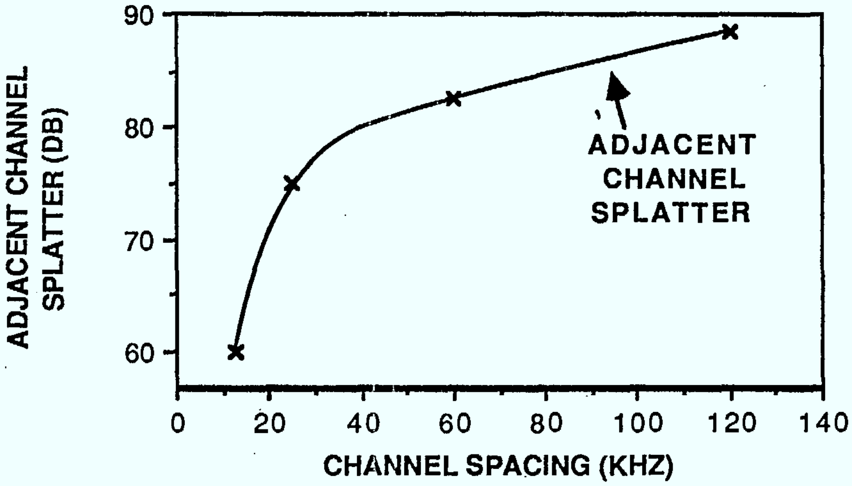
SPECTRUM DEMAND TREND

FIGURE 1



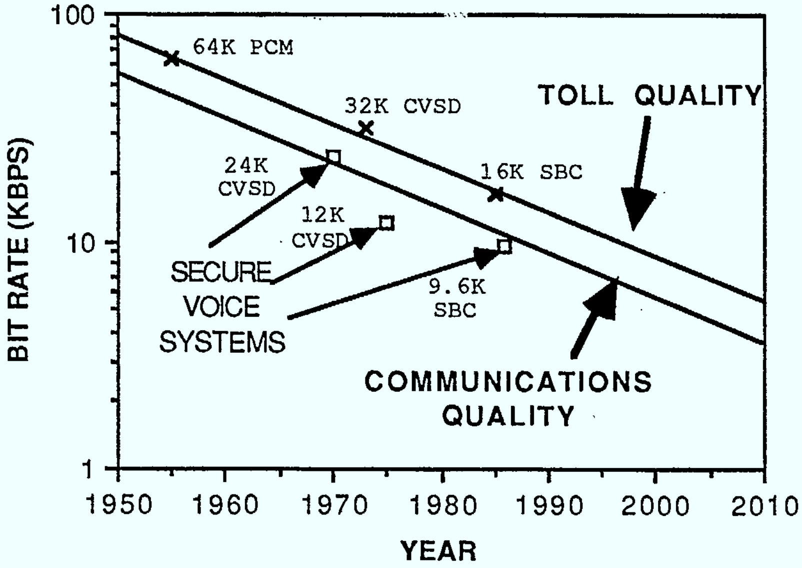
SPLATTER VS CHANNEL SPACING

FIGURE 2



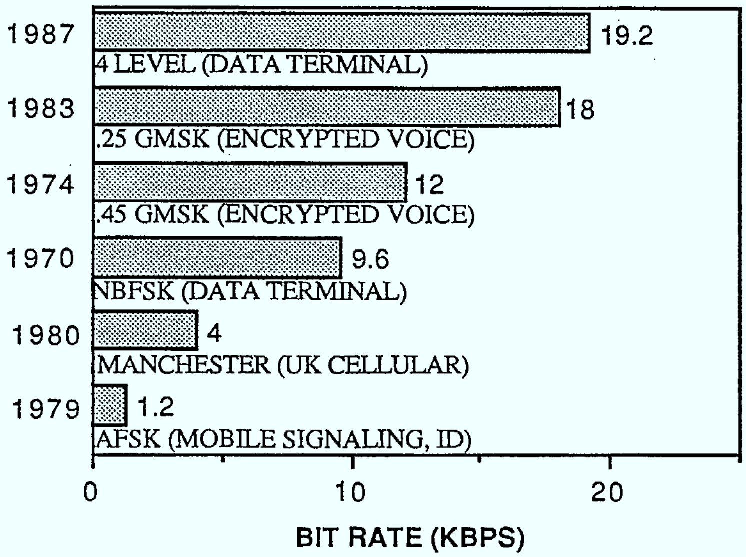
VOICE COMPRESSION TRENDS

FIGURE 3

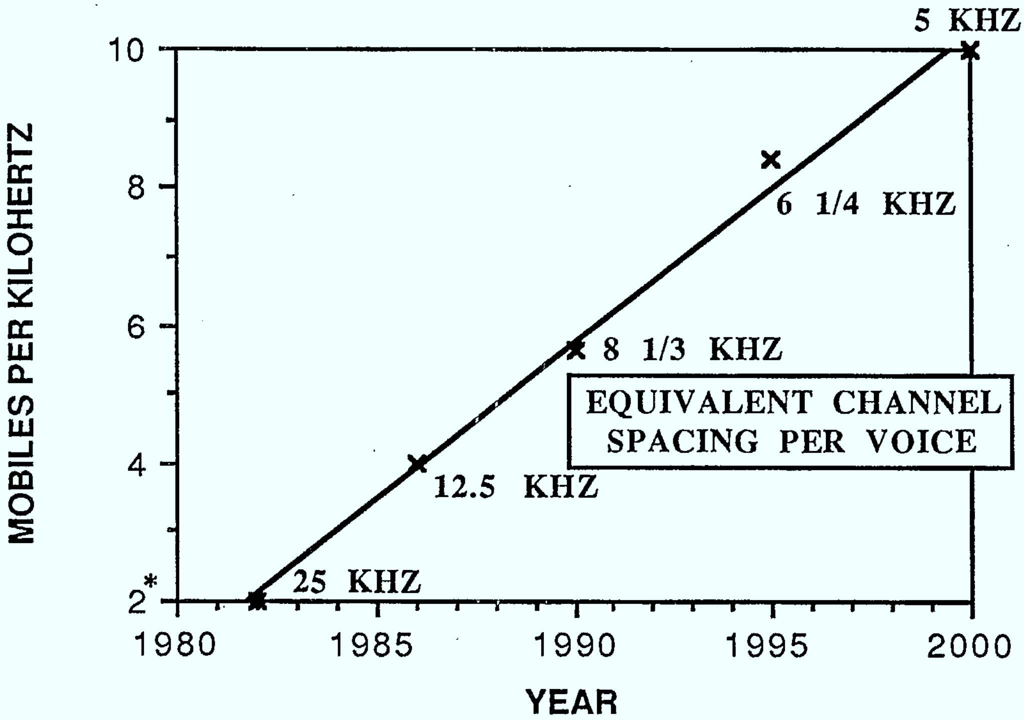


DIGITAL THROUGHPUT (25 KHZ SPACED SYSTEMS)

FIGURE 4



TREND IN MOBILES PER KHZ
FIGURE 5



* EXAMPLE: 1982
# MOBILES = 100, KHZ = 25 X 2 = 50

IMPACT OF CURRENT AND DEVELOPING BROADCAST TECHNOLOGY ON RADIO FREQUENCY USAGE

by

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ABSTRACT

This paper will outline first the current use of spectrum by broadcasting enterprises in the delivery of programme services to the consumer and in internal uses for reasons of programme collection, distribution, communications, etc.

The technologies which are used in programme delivery will be reviewed with particular reference to modulation systems and receiving apparatus, and with consideration given to their adequacy for maintaining their current service roles from viewpoints of:

- deteriorating electromagnetic environment;
- spectrum allocation limiting service development.

Possible directions of development of broadcast delivery technology needed to support new and/or enhanced services will be addressed, with reference also to the impact on spectrum considerations of the possible inclusion in receivers of advanced signal processing, and the availability of alternative technologies for delivering signals to consumers.

Brief conclusions will be drawn as to which provision in frequency planning should be examined in order to support broadcast service development in the future.

INCIDENCES DES TECHNOLOGIES ACTUELLES ET NOUVELLES SUR L'UTILISATION DES FRÉQUENCES RADIOÉLECTRIQUES

par

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RÉSUMÉ

Le présent exposé décrit principalement l'utilisation actuelle du spectre des fréquences radioélectriques par les entreprises de radiodiffusion dans le cadre de leurs services aux consommateurs et de leur gestion interne liée à la collecte, la distribution et la transmission des programmes.

Les technologies qui interviennent dans la distribution des programmes sont passées en revue, l'accent étant particulièrement mis sur les systèmes de modulation et les installations de réception, ainsi que sur leur capacité à répondre à leur vocation de service et ce, sous le double angle suivant:

- détérioration de l'environnement électromagnétique;
- développement des services limitant l'attribution du spectre.

Les orientations possibles du développement des technologies de radiodiffusion nécessaires à la gestion des services nouveaux et améliorés seront abordées, en relation également avec les retombées sur le spectre liées à l'inclusion éventuelle dans les récepteurs du traitement de signal évolué, et l'avènement de nouvelles technologies d'acheminement du signal aux consommateurs.

De brèves conclusions seront tirées quant aux dispositions à examiner en matière de planification des fréquences, dans le but de promouvoir l'essor futur des services de radiodiffusion.

ORIGINAL : ANGLAIS

IMPACT OF CURRENT AND DEVELOPING BROADCAST TECHNOLOGY ON RADIO FREQUENCY USAGE

by

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SUMMARY

The use made by broadcasters of the radio frequency spectrum is described, and an assessment is made of the performance of radio and TV services. Some suggestions are made of areas of technology which could enhance todays system performance, as well as an assessment of where no enhancement seems possible. Comments are given of the technological developments needed to realise direct radio broadcast by satellite, and improved definition TV systems.

The business of broadcasting has been inextricably linked to technology developments throughout its history. It has capitalized on developments in both transmitting and receiving technology and systems that have successively opened up spectrum bands ranging from medium wave up to SHF bands. It is equally dependent for its continued growth on the technology developments that will open up new spectra for new service offerings, as well as those which will contribute to more effective utilisation of the existing bands.

Each advance of technology in the past has provided opportunity for growth. Each successive demand for new or expanded service, or improved quality had to respect compatibility of the existing receiver base in the hands of the public, and this has caused broadcasters to employ technology that makes the existing services perform better - enhanced quality or new services - as well as moving to new spectrum. An example of the former is the introduction of color signals to monochrome TV, all transmitted inside the same bandwidths established in 1941. That is still the case today, when ancillary services in the Vertical Blanking interval, an additional sound channel to carry stereo sound, and in some manifestations, a subsidiary audio channel have also been added.

The use of 6/4 GHz satellite systems for point-to-point and multipoint distribution is an example of the use of new spectrum.

Canadian broadcasters are allocated discreet portions of the radio spectrum from the low end - about 500 kHz, up to the highest in the 86 GHz region. While this is an impressive range, bands allocated for exploitation by broadcasters represents only a total of 448 MHz, or about 0.11% of the available radio spectrum, excluding satellite allocations.

How well does this array of spectrum usage fit the expectations of today and the potential of the next twenty years?

A broadcaster delivers a program to the public which, we hope, will find it enjoyable to listen to and/or to watch. One important part of this enjoyment is, of course, programme content and values, but those are not our concern here today. The one which does concern us, and will continue to motivate our actions as engineers, is to at least preserve and indeed to enhance the illusionary experience which is Radio and TV. We cannot accept and institutionalise, via regulation or standard technical limitations which infringe on the consciousness of our public, and impair their feeling of enjoyment. An indispensable element of the chain as far as the broadcaster is concerned is, and will remain so, the path between the point of origin and the point of reception.

Three criteria can be stated to be driving us today:

The need for more services.
The need for enhanced quality.
The need to prevent existing quality from deteriorating.

What potential do these criteria have to drive demands on spectrum and spectrum allocation?

One of the earliest bands in use for broadcast services is the medium-wave band, extending from 525 kHz to 1605 kHz, and offering a total of 108 10 kHz channels. In Canada, some 755 transmitters operate in these channels, providing local, regional and national service. From the propagation viewpoint the band does well, but there are serious problems as to its suitability for the intended service to the end of the century. It is unfortunate that the amplitude modulation system used - the only technology we knew how to make in those day - is also the one which is most subject to the type of noise interference which our 1980's towns and cities generate. The propagation characteristic of this band, attractive in itself, works to severe disadvantage in generating distant station interference, so much so that the night-time interference is the determining factor in establishing a station's coverage. The signal itself is absorbed by tall buildings, interfered with by man made noise, and also by distant stations interference - a harsh electromagnetic environment that would call for the most careful receiver design to mitigate. Unfortunately AM receiver design has gone the other way, both from RF and from audio quality considerations.

It is a fact that the AM listening public is in decline in the major markets of Canada and the USA. Both broadcasters and receiver manufacturers must share this responsibility - the magazine 'Electronics' has said "quality of receivers has hit a all-time low: poor workmanship, poor tone fidelity, low prices ..." That is a quote from 1931. In March 1987, 'Broadcast Engineering' remarks that the average AM receiver frequency response is less than 3 kHz - about the same as the telephone, and comments that this has been necessary due to uncontrolled pre-emphasis in adjacent channel stations.

Radio broadcasting also makes use of the FM modulation system using Band II. This is a good technology taken overall, with the quality potential to respond to forseeable service demands. Its major problem, however, is there is not enough of it to go around, at least in areas of dense population. One study of projected requirements as of 1986 shows a lack of 69 channels in major Canadian cities, with no prospect of being able to satisfy this demand. The total channels available between 88 MHz and 108 MHz is 100, each of 200 KHz bandwidth. Currently there are 738 FM stations radiating, with a projected demand for 1,245 more.

The next portion of the RF Spectrum used by broadcasters for long distance broadcasting, but also in some countries for national programming, is the short wave band 2.3 MHz to 26.1 MHz using amplitude modulation, DSB. It is generally listened to on quite sophisticated receivers, but it has long been apparent that this band is overcrowded, causing interference from other stations, and that it is subject to atmospheric effects such as fading, etc. A major change in modulation and receivers is needed to resolve overcrowding and a recent HF WARC has set as an objective the total conversion to SSB operations in about twenty years time. A doubling of channel capacity will result.

Television is spread over four portions of the spectrum, namely:

Low band VHF : 54 to 88 MHz

High band VHF: 174 to 216 MHz

Low UHF : 470 to 608 MHz

Upper UHF : 614 to 806 MHz

All systems in North America use the N.T.S.C. base-band signal, and use double-side-band modulation incorporating vestigial side-band filtering, occupying a bandwidth of 6 MHz. Channel availability in the VHF band is extremely scarce, and is non existent in many parts of Canada. This has led to expansion into the UHF bands. Being much higher in frequency, the UHF propagation characteristics require much larger transmitter power, and/or several transmitters, to match the coverage offered by VHF transmission. This can make a large difference in the profitability of a particular broadcasting enterprise because of the cost of acquiring and operating multiple sites, with consequent impact on capital and operating costs.

Moving higher in the spectrum, small slots are assigned to the broadcaster at 450 and 960 MHz for radio - studio transmitter links (STL) and television STL's occupy slots at 6 MHz. The ENG (Electronic News Gathering) equipment uses microwave links in the 7 and 13 GHz bands.

Finally, at the upper end of the spectrum the broadcaster utilises the satellite frequencies in the 6/4 and 14/12 GHz for distribution of the network signals, and direct reception at television and radio transmitter sites for subsequent terrestrial broadcast.

Common threads in this very rapid overview are:

- generally, there is insufficient spectrum

- the electromagnetic environment has deteriorated as more stations have been built, and as more noise sources are apparent.

- the technology in use is not necessarily the best or the most efficient, but follows closely the evolution of the technology itself.

What is in store for us in the emerging technology which can be applied to maintain the existing services and accomodate foreseen developments?

In the case of sound broadcasting on Medium Waves perhaps the most serious impairment, and the one which in effect determines the service limit, is night time interference from co-channel and adjacent channel stations. Areas of technology development that may help here are:

- MW antenna developments that reduce sky-wave. These would improve both co-channel and adjacent channel interference.
- General adoption of a standard pre-emphasis curve by the broadcaster to reduce, and even eliminate, out-of-band radiation - known as splatter. This would require the adoption of a standard reciprocal curve by receiver manufacturers to preserve fidelity.
- More general use of synchronous detection to improve selectivity and signal/noise in the presence of low signal levels. This could help with the problem of signal absorption by large buildings.
- Better audio performance in the receiver.

To this, others might add the technology of stereophonic A.M., and will argue that this is fundamental to the survival of AM broadcasting in the MW band over the next 10 years.

The extension of the AM band from 1605 KHz to 1705 KHz is not thought to be of significant effect in improving the position of AM services, although more capacity for local stations has been added.

Without some effective action toward stabilising and reversing the decline of popularity of AM, the prospect has to be contemplated of increasing pressure to permit simulcasting, with fully nested service areas, and the consequent demand for frequencies in other spectral areas.

With reference to FM receiver technology a joint report by Sandy Day and Peter Cahn, (well known and respected broadcast consultants), published in 1978, commented on FM receiver performance and its relevance to the FM allotment criteria. The performance of 22 receivers was analyzed in the context of the protection requirements for FM allocations, e.g. sensitivity, selectivity, signal to noise ratio, etc. The report concluded that it is doubtful that any amount of juggling with the allocation parameters such as channel spacing, ERP, EHAAT, could produce an improved solution. Therefore, it seems that unless a dramatic improvement in receiver performance is achieved, nothing can allievate the present spacing and allottment problem in the FM band.

If this conclusion is valid it is not feasible that the already apparent demands can be met inside the existing allocations, and one must look to new technologies to open up new spectrum. One such technology is direct broadcasting of radio services by satellite. This is already being studied in various parts of the world, with work going forward on possible modulations schemes, channelisation, and receiver antennas which are suitable for installation and reception in moving vehicles.

Turning now to the television services, the prospect before broadcasters as the end of the ninth decade of the twentieth century nears is one of growing interest in higher quality television pictures and accompanying sound. New sources of TV pictures in the home, other than those provided by the broadcaster over the air, provide a comparison between our quality of service and that available off-tape or off-satellite. The existing spectrum per channel is used quite effectively to carry light and dark, color hue and intensity, spatial and temporal synchronisation, sound and ancilliary signals such as services for the hard of hearing.

The quality delivered for relatively small-screen sets is acceptable, and indeed is not yet at its perfected limit. Neither, in general, is the service spectrum limited in Canada if all the UHF channels are fully utilised, leaving aside the very real concern of the cost of implementing UHF coverage. As in the case of radio receivers, UHF reception may benefit from incorporation in the TV set of ghost cancellation, and improvements in R.F./I.F. selectivity.

Recent work has shown that the use of two-dimensional pre-filtering of the color television elements, prior to encoding, can eliminate many of the defects of the todays implementation of the NTSC color-TV system, such as cross-color and cross-luminance. This technology, implemented by active filters, continues to improve the delivered signal quality, within the limits of the existing line scan and color coding system. One must conclude that NTSC color service will be with us to the end of the century, and that the spectra currently allocated to it will still be required.

But there are new prospects in view, a TV service with higher resolution, capable of being viewed on bigger screens with acceptable quality, and with better sound than we know today. It is for the services session to consider how such services are to be implemented, and for me to relate this technology to the spectrum concerns. Four technologies suggest themselves, two of which respect the broadcaster's mandate, namely Direct Broadcast Satellites and over-the-air transmission.

Before considering the specific technology, mention should be made of the two views of the development of higher definition TV systems - that it must evolve from, and maintain compatability at the receiver (with an adaptor) with existing national TV emission standards; or that it should be a revolutionary service, with no compatibility, but convertible by the broadcaster to existing standards.

Whichever way they come, HDTV signals are technically attractive in the 20-23 GHz range, and will require development of every part of the delivery mechanism technology to realise. There is a concerted movement among world broadcasters to obtain a world-wide allocation in the 23 GHz range for this type of service.

The practicality of transmission in the U.H.F. spectrum has recently been demonstrated in the United States, using two adjacent channels in the top end of the U.H.F. spectrum. Should over the air broadcast HDTV services be planned, technological developments in bandwidth reduction will need to be progressed, but the potential to achieve reductions down to the 6 MHz channel width of the existing UHF channels with satisfactory motion portrayal is not very high. Some early thoughts suggest a 9 MHz bandwidth may be satisfactory, with baseband signal processing, such as elimination of line sync pulses, and removal of blanking, to allow the 9 MHz to be radiated in 6 MHz channels without undue interference to adjacent channels.

The base-band requirements of HDTV systems likely to be acceptable for production and display is large indeed - about 40 MHz or a bit rate of about 600 Mbit/second for digital transmission. Even at 23 GHz this amount of bandwidth is not an attractive proposition.

Currently, technology is therefore being applied to bandwidth reduction techniques to fit the signal through the somewhat narrow pipe of the available transmission media.

While considerable interest - and indeed planning - is evident for a 12 GHz HDTV system, the maximum baseband that could be transmitted in a standard WARC channel is about 10 MHz, or 50 Mbits/second, requiring large compression ratios to be achieved, and hence sophisticated receivers. This explains the attraction of a new frequency band, which will require new receivers, but which will permit wider bandwidths per channel to be used.

The successful launching, therefore, of improved definition TV systems, evolutionary or revolutionary, requires sophisticated pre-processing and modulation techniques which will in turn require the design of TV receiver components not common today.

To promote the growth of such technology the studies now under-way must result in the maximum commonality of systems and unique standards. This is essential for a replacement technology such as HDTV to launch into a world-wide developed market, where it will be costly enough. Surely no country can afford to develop in isolation a system which is inherently non-standard.

CONCLUSION

The areas of broadcasters' interests covered in this paper are, I believe, the more important ones. Technology developments are today being applied to offer tomorrow's improved quality and new services. Continued pressure will be evident on new spectrum allocations as technology developments make new services feasible, and foresight will be needed to not unduly limit their potential due to inappropriate or limited allocations. Technology has also the capability to improve the performance of existing services inside existing allocations, but compatibility considerations with existing broadcaster and consumer equipment populations will be of prime importance, potentially limiting the degree to which the benefits could be achieved.

EVOLUTION OF SPACE COMMUNICATIONS TECHNOLOGY

by

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Abstract

Although space exploration and applications have been a strong driver of technology, often to its limits, economics and competitive pressures have dictated a large measure of conservatism in commercial space communications. Thus the trend has been towards utilization of lower risk solutions rather than attempting higher risk potentially higher performance alternatives. The result has been the evolution of the extremely reliable cost-effective systems of today.

The early eighties have seen the transition of space systems based on enabling technology working into a large potential market with some regulatory constraints, into a situation of short term capability oversupply with pressures for deregulation of old and exploration of new markets. This has come about primarily through changes of operations e.g. narrower slot spacings and the presence of more spacecraft albeit with some evolution of the requisite technology.

The need to address new market niches has led to improvements in system flexibility and particularly in ability to serve smaller volume systems. Most recently the introduction and rapidly developing oversupply of fiber optics in the trunking markets has accentuated the strengths and weaknesses in current space communications technologies and accelerated these trends towards more specialized markets.

SOMMAIRE

Bien que l'exploration de l'espace et les applications spatiales aient été une force motrice de la technologie, la poussant souvent jusqu'au bout de ses limites, les pressions économiques et concurrentielles ont imposé une grande mesure de conservatisme dans le domaine des communications spatiales commerciales. Ainsi, la tendance penchait vers l'utilisation de solutions à faible risque plutôt que d'essayer des alternatives ayant un potentiel de haute performance mais comportant un risque élevé. Le résultat a été la mise au point des systèmes actuels très fiables et à des coûts optimalisés.

On a vu, au début des années 80, la transition des systèmes spatiaux basés sur une conception qui permettait à la technologie de fonctionner dans un marché au potentiel élevé mais comportant certaines contraintes régulatrices, à une situation qui permet un excédent de provision à court terme et où des pressions sont exercées pour une déréglementation des anciens marchés et l'exploration de nouveaux. Cette transition s'est produite surtout suite aux changements dans les opérations, par exemple des espacements de bande plus étroits et la présence d'un plus grand nombre de satellites, quoiqu'avec une certaine évolution de la technologie requise.

Le besoin d'attaquer de nouveaux créneaux de marché a entraîné une amélioration de la flexibilité des systèmes et en particulier de la capacité à desservir des systèmes au volume plus faible. Plus récemment, l'introduction de fibres optiques, et leur provision évoluant rapidement sur les marchés de trafic interurbain, a fait ressortir les points forts et les points faibles des technologies actuelles reliées aux communications spatiales et a accéléré ces tendances vers des marchés plus spécialisés.

Introduction

It is perhaps appropriate initially to point out that although technological evolution as it pertains to space communications and the resulting impact on the frequency spectrum utilization is the subject of this paper, it is fundamental that it is the combination of the regulatory environment, the market needs and the available technology which determines the systems implemented. Thus we may consider a triangle in which the sides are the three general topics of this conference, and the extent of any one side, or at least its utilization/realization, is effectively constrained by the sum of the other two.
Space communications is a fairly new transmission medium, it being only 25 years since the Telestar and Relay initiation of international services and only 15 since Anik A provided the first geosynchronous domestic services. Thus space communications has largely evolved from other media with their associated technologies and accordingly has been significantly constrained by their associated markets and regulations as will be indicated. It may be noted that this inheritance in addition to the regulatory aspects also often includes the associated standards and design guidelines even where they are not required by compatibility constraints.

Space communications in common with other communications systems is based on long term revenue returns and consequently operational systems tend to be implemented by the most conservative use of technology which fulfills the mission (market) requirements. It is this combination of very high risk technology in lowest possible risk long life design and realizations which characterize the business. For example, there is typically a period of several years in which a concept or technological advance is brought to a state of "space qualification" or acceptability for application in an operational system. This is followed by a period of about three years while a spacecraft incorporating the advance is designed and built. It is common practice to design for 10 or more years of operational lifetime after several years of ground or on-orbit storage. This operational period is presently considered a reasonable trade-off between the spacecraft's ability to maintain station earning revenue and its technological obsolescence. With no facility for repair or refurbishment of geo-synchronous satellites projected for at least some time, it is apparent that the laboratory advances of today are motivated by and hopefully applicable to service and regulatory environments well beyond the year 2000 perhaps to 2010.

One major factor which must be considered in forecasting the technological trends, and that is the growth in communications traffic. For many years there has been an exponential growth, with anticipation of continuing at the same rate well into the next century. There is now considerable evidence that the growth has been responding to unfulfilled needs in capacity whereas future high rates of growth will be a result of introduction of new services. At the same time erosion of present space communications service markets by other technologies is now and will continue to occur. The general trend anticipated is that of a continual rationalization of space communications and it is this that the space technologies must support.

For those more conversant with other communications systems it may be pertinent to indicate a few distinct characteristics of space systems. A principal feature is that there are commonly a large number of signal sources operating in a common frequency band available to the earth portion of the system. Since the signals are at the same frequency, the earth station uses spatial discrimination to select the desired source. Thus the earth station operates its antenna on "boresite" and has stringent requirements on side lobe performance for both up and down link transmissions. The space segment is usually required to illuminate a region of the earth and thus is not operating on boresite and in fact the design is usually based on a highly shaped beam with a flat top and steep skirts to maximize availability of r.f. power over the desired area.

Space Technology Origins

Space communications originated as point to point wide band services basically in the context of trans-Atlantic relay. Thus the technology was based on the bandwidth of then current multichannel telephony optimized for a minimum number of ground stations and a global coverage footprint. The terrestrial relay systems provided the C Band (6/4 GHz) hardware but the sharing of the band meant flux limitations and coordination of sites of both the terrestrial relay stations and the earth stations for the space system. The former had to be aligned so as to avoid propagating towards the equatorial orbit, while the earth stations were moved outside major cities to electrically quiet sites and the communications backhauled to the switching centers so as to avoid the high concentrations of terrestrial microwave signals.

The limitations imposed by the shared band were not critical in the first decade of space communications because the service was basically international and the users were accustomed to "gateway operations". In the late sixties and early seventies, the extension of space technologies to the domestic communications needs met several problems. Basically using the same travelling wave amplifiers as the international systems, the limited coverage needed increased the ground flux density, which allowed the use of smaller earth stations as was required for multiple station systems. However the initial concepts still required the sites to be in quiet areas, with the signals backhauled to principal network nodes or switching centers.

In contrast to the international systems which were optimized for point to point multichannel telephony, the first domestic systems were required to handle effectively (but not optimally) television distribution, multiple carrier telephony for thin route, as well as heavy route trunking. The relative importance given in design was a function of the anticipated market responses and/or political attractiveness. Of course to coordinate with other systems it was desirable to use the same frequency plans, and to provide the full flexibility inherent in the system, all channels were made equally capable. Thus the earliest choices were in the direction of uniformity in and between systems and to a large extent the space system standards are directly traceable to those of the shared terrestrial band.

The recognition that the earth station costs coupled where applicable with those of the terrestrial backhaul were dominating the system costs led to the experimentation with the Ku Band (14/12 GHz). The higher frequency maintained the needed directivity for the desired smaller earth stations, while the higher flux available in the space dedicated band provided the necessary signal levels even after allowing margin for the more severe rain attenuation characteristic of the band. This band must still be considered in the early stages of development but is likely to be central to the new technologies under discussion.

<u>Technology Trust</u>

In the discussion which follows, the emphasis will be in the major advances which permit or substantially enhance the space communications services rather than those which have marginal impact. However it must be remembered that several small advances may culminate in a cost or performance advantage over competing systems and thus be of market significance. Also the emphasis will be on the space segment although in the domestic systems the earth segment economics will continue to dominate the system costs. The emphasis chosen will be justified by the background of the authors and the belief that the major trend of the future will be the transition of the spacecraft communications subsystem from a "bent pipe" to a complex switching and routing center, a "switch-board" in the sky. This direction of space segment evolution is driven by the fact that the spacecraft has several limitations in resources notably power, weight and bandwidth. The contentional satellite operates effectively in a broadcast mode and tends to be less efficient in point-to-point distribution because of the wasted coverage i.e. power. The switchboard satellite is based on illuminating only the region of the terminals designated in the transmission. The onboard technologies are based on a very high degree of integration, baseband or r.f. switching, and in most configurations digital signals and often regenerative transponders. At this level of complexity it is also feasible to incorporate compensation for rain attenuation i.e. power control.

It is clear that satellites are likely to remain a major factor in broadcast services of any type. It also appears likely that satellites will remain a part of point to point telephony and data services, either because of their flexibility to reallocate resources, their ability to provide rapid restoration in the event of natural or manmade disasters or the inability of other systems to economically connect two points. It may be that fiber optics will take over the role of terrestrial microwave rather than that of space systems.

The space systems may be expected to shift their emphasis to the other natural market for services, namely terrestrial, maritime and aeronautical mobile systems.

C Band Allocation

This band will continue to be the band of choice where propagation is the determining factor. The extended frequency allocations have not been exploited as of now because of differing assignments in the different regions, again emphasizing the problems of shared/coordinated band assignments. This has inhibited manufacturers looking for maximum sales of a given product configuration.. The trend would seem to be towards at least a degree of dedication of band segments to specific service which improves efficiency and coordination at the cost of flexibility. However its characteristics will ensure the band is widely used both internationally and in domestic systems. The present spacing of two degrees of orbital arc in ITU Region 2 seems to be a reasonable limit based on the interference susceptibility of some advanced systems.

Ku Band Allocation

The dedication of the band to space with the higher allowable flux coupled with the higher directivity of antennas per foot of diameter makes the Ku band attractive and is balanced only by the rain attenuation. The earlier hardware availability and cost implications have been largely overcome and it appears that the proliferation of systems may bring equipment costs below those of C Band. This appears to be the developing band of choice for business and small user services, notwithstanding the V-Sat successes in C Band. It is of course the band for full and quasi Direct Broadcast Services. As in C Band, the extended assignments have introduced some design difficulties particularly in wide band receivers, but these will be overcome when the market requires it. In this band the dedication of separate segments to specific services has begun and may be expected to expand through either regulation or convention.

Ka Band Allocation

This band is largely unexploited, but offers a dedicated band with very high potential to use antenna directivity as a design feature. Lower directivity systems based on reduced antenna diameters will suffer from a lack of receiving area, while the propagation properties will demand increased rainfall margins. The present oversupply of capacity in lower frequency bands will inhibit the move to this band despite the growing worldwide experimental work.

Other Band Allocations

The bands at 60 GHz are likely to be used for intersatellite links as could the optical frequencies. The thrust here is intersystem and/or intrasystem interconnectivity for flexibility, lower cost and reduced propagation delays in multi-satellite hops. This does not seem to be likely to be extensive in the time frame of interest.

The UHF/L band allocations have been a contentious issue in the past year largely because of the emergence of mobile communications as a major space market. The proposed sharing and the minimal frequency allocation are likely to cause future problems as such systems become prevalent. The difficulties arise from the lack of directivity readily achieved from a conformal type antenna on a moving platform, which limits the earth segment's ability to discriminate between sources in view.

Conclusion

In the major space communications assignments in the C and Ku Bands, technological advances do not appear to be a significant factor affecting the spectrum regulations or utilization. The specific services provided by space communications are likely to change with a greater emphasis on the areas of broadcast, remote telephony and thin route high flexibility services. The variety of services may make it desirable to designate by regulation or convention sub-bands for specific services. The shared nature of the C Band assignment will continue to require intelligent co-ordination and regulation.

In the narrower band, low frequency assignments such as the aeronautical and land mobile bands, the evolving technology and market requirements for new services coupled with the shared nature of both the market and band assignments, are likely to result in requirements for regulator action.

THE IMPACT OF TECHNOLOGY ON FIXED RADIO SERVICES

by

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ABSTRACT

Pushed by advances in technology and pulled by market demand, a wide variety of voice, data, image and multi-media services have begun to spread throughout the business and residential marketplaces. The driving force behind the technology push is progress in semiconductor technology. Market pull is based on value and functionality: increasingly this translates into "bandwidth on demand".

This paper examines some possible impacts of technology evolution, and product and service innovation, on the demand for spectrum for "fixed radio services".

IMPACT DE LA TECHNOLOGIE SUR LES SERVICES FIXES DE RADIOCOMMUNICATIONS

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RÉSUMÉ

Une grande gamme de services voix, données, images et multimédias ont commencé de s'étendre à la collectivité des abonnés d'affaires et résidentiels. Le moteur de la poussée technologique est l'avancement des techniques appliquées aux semi-conducteurs. La pression du marché est fondée sur la valeur et la fonctionnalité, ce qui pose de plus en plus le principe de "l'attribution des largeurs de bandes à la demande".

L'auteur examine quelques impacts possibles qu'ont l'avancement technologique et l'innovation de produits et de services sur la demande de radiofréquences pour les "services fixes de radiocommunications".

ORIGINAL : ANGLAIS

THE IMPACT OF TECHNOLOGY ON FIXED RADIO SERVICES

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Abstract

Over 2/3 of long-haul telecommunications traffic in North America is currently carried by microwave radio. Microwave radio is the major user of frequency spectrum. The body of this paper examines the likely impact of technological progress on trunk and feeder microwave systems, and on their chief competition, fiber optic systems. It concludes with some comments on the practicality of in-building wireless terminal connection.

Introduction

The hypothesis advanced in this paper is that, in Canada, in the "Fixed Services" bands, radio usage is limited by demand, standards, regulation, engineering and technology, in that order. The availability of appropriate base technology is not limiting progress today, nor is it likely to do so in the next 10 to 15 years.

For the purposes of this paper, Fixed Services are grouped into two major categories:

(1) Trunk (i.e. long haul microwave, including spurs) and feeder (i.e. local point to point and point to multipoint links)
(2) Access (i.e. the last meter to the user's terminal).

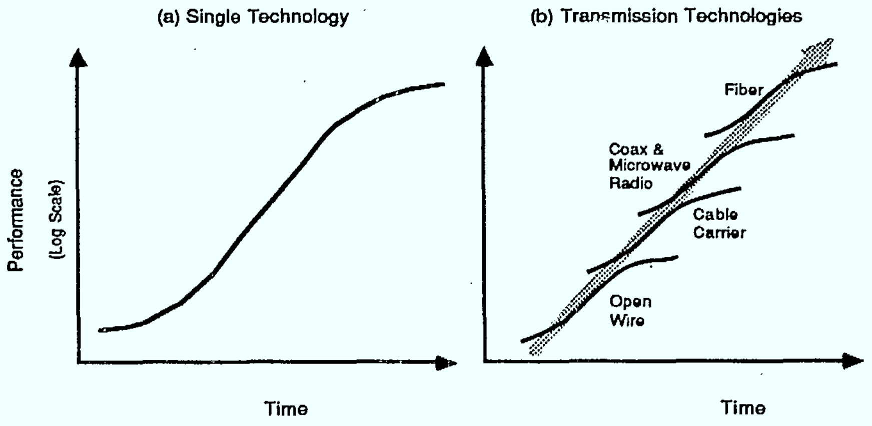
Most attention will be given to the impact of technology on trunk and feeder services: some comments will be made on the practicality of in-building wireless terminal connection.

Trunk and Feeder Services

Typically, the performance of a technology progresses along an S-curve (Fig. 1a). At first performance improves slowly, but once past the bottom knee of the curve, progress is exponential. Eventually the limits of the technology are approached, and further advances become increasingly difficult. An alternative high performance technology is then sought. If one defines performance in terms of the capacity of a single transmission facility, then this has been the pattern which transmission technologies have followed. One voice channel on a pair of open wires gave way to open wire carrier systems, then cable carrier systems (first analog, then digital), co-axial and radio systems, and finally fiber systems (Fig 1b).

This does not mean that microwave radio systems are dead: merely that their capacity will increase and their costs decrease less rapidly than that of fiber systems.

Fig. 1 Technology Trends



Microwave Radio and Fiber Optic Transmission Systems are in direct competition for most trunk and feeder applications. Although cost is usually the primary determinant of the winning system, such matters as the ultimate capacity of the system, performance (most notably outage characteristics), spectrum availability and right of way issues are contributing factors.

Capacity

Today's long haul digital microwave radio systems typically employ 64 QAM modulation and achieve a spectral efficiency of 4.5 b/s/Hz, or 2 DS-3s per 20 MHz radio channel. For a 500 MHz bandwidth system, consisting of 10 regular and 2 protection channels in each direction, this translates into a system capacity of 20 DS-3s (Fig. 2).

256 and 1024 QAM systems are now beginning to become possible. Further engineering refinements should make 2048 and 4096 QAM systems practical by the mid 1990s. Progress beyond 4096 QAM is unlikely without a major breakthrough in modulation techniques. Thus the ultimate capacity of a 500MHz bandwidth microwave system is likely to be 60 DS-3 channels, although conceivably co-frequency operation could double this number.

Today's fiber systems typically operate at 565Mb/s, or 24 DS-3s per fiber. For a system consisting of a 12 fiber cable, with 5 regular and 1 protection fiber in each direction, this means 120 DS-3s per cable. Two channel wavelength division multiplexing doubles this to 240 DS-3s per cable.

Gb/s GaAs logic coupled with frequency and mode controlled lasers will make 2.4 Gb/s, 4 channel WDM systems with a capacity of 960 DS-3s per 12 fiber cable practical by the early 1990s. Cable size could of course be increased if required.

In summary, today's fiber systems have 6 times the capacity of today's radio systems. This ratio is likely to increase 24 or more by the early 1990s.

Fig.2 Capacity Comparisons

Radio	QAM	DS-3/Ch	DS-3/Band
(500 MHz band, 10 + 2 2-way channels)	64	2	20
	256	3	30
	1024	3	30
	4096	4	40

FOTS	Gb/s	DS-3/Fiber	DS-3/Cable	Ditto,2 Ch WDM	Ditto,4 Ch WDM
(12 fiber cable, 5 + 1 2-way)	0.565	12	60	120	240
	1.2	24	120	240	480
	2.4	48	240	480	960

Costs

Consider a 1,000Km long transmission system. Total costs consist of get started costs and incremental (capacity dependent) costs. The latter increase as channels have to be added to the system.

For a radio system, get started costs depend on the terrain, tower heights, type of radio equipment, etc., but rarely vary more than ±20%. Incremental costs are incurred with every radio channel added (today at every 2 DS-3 increase in system capacity). Overall system costs are dominated by radio equipment costs.

With a fiber system, installation costs dominate (Fig 3): the type of terrain is the major determinant of cost. Get started costs can range from below to many times higher than those for a radio system. Incremental, or capacity dependent costs, are proportionally much lower than those for radio, due to the high per channel capacity of fiber systems.

For both types of system, installed first costs per circuit-Km drop dramatically with system cross section or capacity, and slowly with increasing system length (Fig. 4).

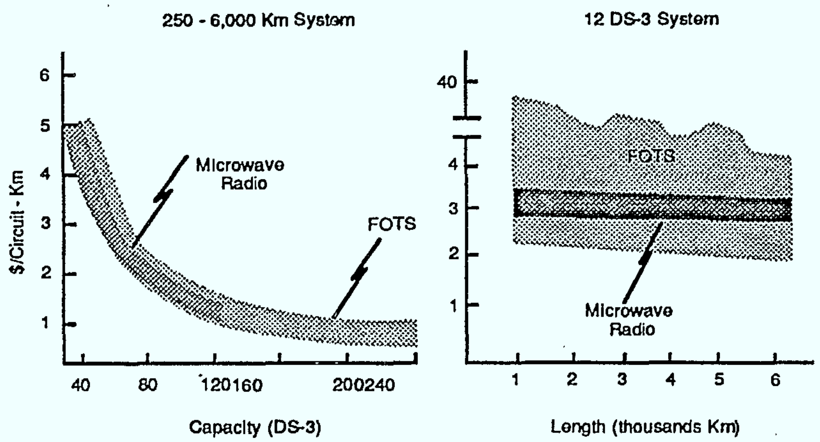
Fig. 3 FOTS Costs*

		%
Real Estate and Buildings		2.4
Right of Way		10.5
Cable:	Installation	58.2
	Material	12.8
Electronics:	Start-up **	11.7
	1st Channel	4.4
Total		100.0

* Bell Canada portion of Telecom Canada 565 Mb/s FOTS System

** Power, protection channel, etc.

Fig. 4 Typical Installed First Costs



In summary, for systems where the capacity requirement is less than the limit which can be obtained using radio, the terrain to be traversed will usually determine whether radio or fiber is more cost effective. Except where the fiber cable can be ploughed into place, radio usually wins today, and will likely continue to do so in the future.

Performance

Under normal conditions, most digital transmission systems peform identically. The most dramatic difference between systems is in their outage characteristics. Radio systems suffer from frequent, very brief outages on individual channels, which the system design takes into account. Fiber systems suffer from cable cuts. Here, the mean time to restore service is usually measured in hours. Taken in conjunction with the large cross section of fiber systems, the frequency of these cuts requires that serious thought be given to route diversity.

Design Objectives

The design objectives for long haul digital radio systems are low cost and high spectral efficiency, coupled with acceptable (outage) performance. The primary technique for achieving these objectives is increased modulation efficiency. Per circuit-Km costs can be further improved through the use of wider bandwidth radio channels, but this does nothing to improve spectral efficiency (Fig. 5).

Fig.5 Digital Radio - Design Objectives

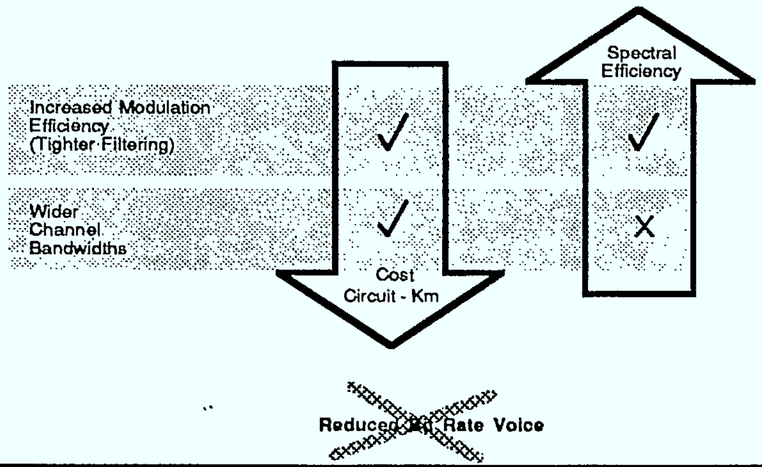


Fig. 6 lists the major impediments to achieving increased modulation efficiency, and the potential solution to each. There are no fundamental obstacles to be overcome. Achieving acceptable performance at modulation efficiencies of 13.5 b/s/Hz (4096 QAM) is a matter of engineering.

A similar situation exists with respect to the use of wider channel bandwidths (Fig. 7), but here regulatory and co-ordination issues complicate the situation.

Fig. 6 Increased Modulation Efficiency (Tighter Filtering)

Impediment	Potential Solution
More Signal Levels	Monolithic A/D Converters
Excessive LC Complexity	SAW Technology
Poorer Residual BERs	Forward Error Correction (FEC)
Poorer Dispersive Fade Margin	More Complex Equalisation
Poorer Thermal Fade Margin	Higher Tx Power Dual Tx/Rx Space Diversity
Poorer Interference Margins Incompatibility with Analog	Adaptive Tx Power Control

Fig. 7 Wider Channel Bandwidths

Impediment	Potential Solution
Regulatory	Negotiation
Co-ordination	Ditto
Poorer Dispersive Fade Margin	More Complex Equalisation
	Multiple Carriers on one T/R
	Dual Tx/Rx Space Diversity
	Minimum Dispersion Combiners
Poorer Thermal Fade Margin	Higher Tx Power

In summary, there are no fundamental technological obstacles to achieving digital radio systems with spectral efficiencies of 60 DS-3s per 500 Mhz of bandwidth. Demand will control the level of engineering effort applied to achieve such systems, and hence the timing of their availability.

System Choice

With the advent of 1.5 and 45 Mb/s digital services, traffic is likely to increase significantly. A combination of microwave radio and fiber systems will be needed to provide the network capacity and diversity required.

Feeder Services

The rate of growth of new services is difficult to predict, particularly when that growth is still below the bottom knee of its S-curve. The ability to provide service on short notice is essential. Performance requirements for a single hop "feeder" radio are considerably less stringent than those for a long-haul system. A bit rate transparent (up to say 276Mb/s) but spectrum efficient, shoe box sized, window/tripod mounted, block licenced, 18/25 Ghz, short range radio is within the range of today's technology. Such a radio would do much to foster Canada's leadership in the provisioning and growth of broadband digital services.

Access

Wireless or cordless telephones for in-building access have long attracted the attention of radio engineers. Apart from their convenience, particularly for domestic usage, the major attraction of such systems is their ability to substantially reduce telephone relocation costs. To date, lack of (sufficient) radio spectrum has hampered the development of such systems. Now, cellular technology coupled with very low power transmitters ($\leqslant$1mW), are making such systems practical.

Broadband wireless access has even more to commend it. Fiber based local area networks (LANS) are approaching the knee on their growth curve. The ability to provide ready access to such networks without disruptive cable extensions and/or rearrangements is clearly advantageous. The technology to do this is now available. The high attenuation rate at 26GHz (due to water vapour) and at 60GHz (due to oxygen absorbtion) make these bands suitable for short range in-building access applications. With bandwidths of 1.75 and 5 GHz respectively, 100% coverage of all (voice, data and broadband) communications needs is possible.

Conclusions

Technology is not limiting the use of radio for fixed services. With the introduction of fiber systems, there should be adequate spectrum for future requirements. Imaginative system design, standards and regulation should be used to foster the growth of broadband services.

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THE UNOFFICIAL WHITE PAPER ON DND SPECTRUM REQUIREMENTS TO THE MID TWENTY-FIRST CENTURY

by

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ABSTRACT

1. Spectrum Management responsibilities within DND; DND's Director of Frequency Spectrum Management (DFSM) will present a very brief outline of his organization and its departmental, national and international responsibilities.

2. DND's purchasing plans for spectrum occupiers to the year 2000; DND attempts to forecast its equipment requirements at least 20 years before the intended purchase date. Those emitters that are planned for acquisition until the year 2000 will be outlined by the author under the following headings:

   name of project, name of all emitters in each project, and for each emitter: the intended tuning range, the expected bandwidth requirements, spread spectrum considerations, equipment type and location.

3. An outline of a number of spectrum related systems which are currently under development or in the planning stages.

4. Post 2000 tentative plans and interests in new technologies.

5. Examples of spectrum related technologies which are of specific interest to the military; Amplitude compandored single sideband modulation, Stand-Off Army Airborne Surveillance and Target Acquisition System, Stationary High Altitude Relay Platform (SHARP), the next generation of remotely piloted vehicles (RPV's), cellular and trunking systems, free channel search systems, controlled lobe/null antennae, space based radars and position locating and reporting systems (PLRS).

6. Examples of radio technologies which have the potential for military applications; space to earth power systems, beamed energy devices, laser creation of an ion path to allow artificial tropospheric scatter communications, improved buried antenna systems and the use of oxygen (and other) molecules' resonant frequency to control link distance.

LIVRE BLANC NON OFFICIEL SUR LES BESOINS DU MDN EN FRÉQUENCES DU SPECTRE D'ICI LE MILIEU DU VINGT-ET-UNIÈME SIÈCLE

par

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RÉSUMÉ

1. Responsabilités en matière de gestion du spectre, remplies par le MDN; Le Directeur de la Gestion du spectre des fréquences radioélectriques du MDN présente une très brève description de sa direction et des responsabilités qu'elle assume à l'échelle ministérielle, nationale et internationale.

2. Plans d'achat de matériel radioélectrique par le MDN d'ici l'an 2000; Le MDN s'efforce de prévoir ses besoins en matériel au moins 20 ans avant la date prévue de l'achat. Les émetteurs dont il est projeté de faire l'acquisition d'ici l'an 2000 sont décrits par l'auteur sous les rubriques suivantes: titre du projet, type de tous les émetteurs qu'il est projeté d'acheter; dans le cas de chaque émetteur: la gamme des fréquences qu'il est prévu de syntoniser; la largeur de bande nécessaire prévue; utilisation eventuelle des techniques d'étalement du spectre; type d'équipement et emplacement.

3. Description des systèmes R.F. en cours de développement ou de planification.

4. Plans provisoires et prévisions d'utilisation de nouvelles technologies après l'an 2000.

5. Examples de technologies d'utilisation du spectre présentant un intérêt militaire; la modulation à bande latérale unique avec compression et expansion d'amplitude; le système aéroporté de surveillance et d'acquisition d'objectifs à distance de securité, de l'armée de Terre; la plate-forme relais fixe de haute altitude (SHARP); la prochaine génération de véhicules télécommandés; les systèmes cellulaires et à plusieurs canaux; les systèmes de recherche d'une voie libre; les antennes à commande de gain minimal des lobes; les radars satellisés; les systèmes de radio-localisation.

6. Examples de technologies de radiocommunication offrant des possibilités d'applications militaires; systèmes d'alimentation espace-Terre; dispositifs générateurs de faisceaux d'energie; création par rayon laser d'un conduit ionisé pour les radiocommunications par diffusion troposphérique artificielle; systèmes améliorés d'antennes enfouis; résonnance en fréquence de la molécule d'oxygène pour mesurer la distance des liaisons.

ORIGINAL : ANGLAIS

THE UNOFFICIAL WHITE PAPER

ON

DND SPECTRUM REQUIREMENTS

TO THE MID 21ST CENTURY

by

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SPECTRUM MANAGMENT RESPONSIBILITIES WITHIN DND

1. Gentlemen, I am most pleased to speak to you today. It is not well understood in the electronics community that the Department of National Defence is the major spectrum user in Canada. DND has some 24,000 individual frequency assignments. When this is translated into bandwidth, I am sure this audience will begin to understand that the plans of DND may, at times, impinge on the wishes of the commercial users of the spectrum. I therefore think it most appropriate and gratifying that I have been asked to speak to you to outline the spectrum management responsibilities of my Directorate and to give you; in as specific a manner as I can, what I feel the Department's spectrum allocation needs will be until the mid 21st century.

2. (Slide 1) The Directorate Frequency Spectrum Management is responsible, on behalf of the Department of National Defence, for all electromagnetic emissions radiated by the Department's equipments into the environment. My Directorate's major responsibilities are outlined on this slide. You will note in item 2 that DFSM manages the 225 to 400 MHz band and the aeronautical mobile (off route) bands (a small portion of the 3-23 MHz band). There is a formal agreement between the Department of Communications and DND giving DND the responsibility for the day-to-day management of these bands. Long term plans for these bands and for the equipment occupying the bands, is of course, advised to the Department of Communications on a continuing basis. (Slide 1 off)

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3. (Slide 2) To accomplish these duties, I have a staff of nine people who are organized as shown on this slide. As a matter of interest, for several years my Directorate has been searching the world for a suitable post-graduate program in Intersystem EMC for the DFSM 2 occupant. We were unsuccessful until very recently when we arranged with Dr. Kubina of Concordia University here in Montreal to supervise the studies of an officer. My next DFSM 2 will start his 2 year Master's program in the fall of this year. (Slide 2 off)

DND'S PURCHASING PLANS FOR SPECTRUM OCCUPIERS UNTIL THE YEAR 2000

4. The Department of National Defence attempts to forecast its equipment requirements at least twenty years before the date of intended purchase. In this portion of my presentation I intend to outline to you, in spectrum terms, the systems shown on this slide (Slide 3). For each of these systems I intend to provide you with the expected tuning range, bandwidth requirements, whether the device will utilize spread spectrum techniques or not, the expected number of equipments that will be located in Canada and their geographical locations - if known, and the locations of any training facilities for these devices, again, if known. (Slide 3 off)

Low Level Air Defence (LLAD) System.

5. (Slide 4) The Low Level Air Defence System, or LLAD, is, as its name implies, a system intended to shoot down low flying aircraft. This is a particularly tricky problem due to the angular velocity between a stationery platform and a high speed low flying aircraft. (Slide 4 off)

6. There are two weapons platforms associated with the LLAD. (Slide 5) The ADATS, which is a missile system, is installed on a modified armoured personnel carrier chassis; (pause) (Slide 5 off) (Slide 6) and the Sky Guard system, which is a 35 mm gun system, mounted as shown on this slide. (pause) (Slide 6 off)

7. Each platform is equipped with emitters. (Slide 7) The ADATS radar visible here at the top and to the right of the missile cannisters is manufactured by Contraves Italiana and has a tuning range from 8.5 to 9.0 GHz. It is a frequency hopping radar of which further details are classified. Each ADATS platform has a Hazeltine Identification Friend or Foe (IFF) associated with the radar. These operate in the standard 1030/1090 MHz range. These IFFs will be replaced by the new NATO Identification System when it becomes available. There will be three ADATS training systems in Canada, located at the Tracadie range and/or CFB Chatham, NB. (Slide 7 off)

8. (Slide 8) The Sky Guard 35 mm gun system has two radars associated with each platform as shown in the upper left corner on this slide. Both of these radars are frequency hopping radars. The first is a search radar operating from 8.6 to 9.5 GHz and the second is a tracking radar operating in the 34.0 to 34.45 GHz range. Both are manufactured by Ericsson and further detail on these radars, unfortunately, is also classified. Again there is an IFF associated with each of the platforms operating in the 1030/1090 MHz band. (Slide 8 off)

9. (Slide 9) As to the operational deployment of these systems, most are designated for deployment in Germany at our Canadian Bases at Baden and Lahr, as shown on this slide. However, since the Canadian Air/Sea Transportable Brigade only functions as an entity when called upon, the equipment assigned to it as listed here will be located in Canada and could be used by the army at CFBs Gagetown, NB; Valcartier, Que; Petawawa, Ont; Shilo, Man; and Wainwright, Suffield or Cold Lake, Alberta. Additionally, it is possible from time to time that they would be used to supple- ment the training systems at CFB Chatham and the Tracadie Range in N.B. (Slide 9 off)

Tactical Command, Control and
Communications System (TCCCS)

10. (Slide 10) Departmental studies conducted since 1968 consistently reflected the conclusion that the existing Tactical Command and Control, Information and Communication System used by the Canadian Land Forces was inadequate for actual combat operations on the modern battlefield. After much debate and analysis, approval was secured to fund a system which would provide the Canadian Land Forces with a secure, survivable, flexible, integrated and responsive Tactical Command, Control and Communications System or TCCCS. Thus was born the 1.5 to 2 billion dollar TCCCS project which is to be fielded in the post 1990 timeframe. (Slide 10 off)

11. (Slide 11) Of the many emitters planned for TCCCS, the primary combat net radio is the VHF FM radio which forms the basic Mobile Communication System of the Canadian Army. We expect to purchase approximately 10,000 of these radios for deployment at Canadian Forces Bases in Canada and with our army deployed in Europe. At the present time, each army base in Canada has approximately 100 - fifty KHz wide frequencies assigned to them. You will note that the TCCCS combat net radio has a maximum bandwidth of 25 KHz.

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12. The secondary combat net radio is a high frequency amplitude modulated radio operating in the tuning range from .5 to 40 MHz. The Department intends to purchase approximately 1000 of these radios. These will normally be used in the ground wave mode, however, sky wave can be used as well. DFSM expects that these radios will be 3 KHz single side band radios.

13. Characteristics of the TCCCS A/G/A radio are as shown, as well as the very short range radio and the long range radio.

14. Up until now I have been talking about narrow-band radios with a single channel capability. In addition to these netted radios, the army has a requirement for wide-band systems to accommodate multi trunks and high speed data. There will, therefore, be an area system superimposed on the electronic environment of the combat net radio. It is expected that these wide band systems will work in the 4400 to 5000 MHz band in that portion presently allocated to DND for wide-band systems. This allocation is from 4460-4540 MHz and 4900-4990 MHz. DFSM would expect to see line-of-sight microwave systems and perhaps tropospheric scatter systems forming part of the area system. The number of systems to be purchased is not known at this time but DFSM would expect these systems to be concentrated in the major army training areas. (Slide 11 off)

<u>Canadian Patrol Frigate (CPF)</u>

15. (Slide 12) on June 29, 1983, the Minister of National Defence announced the 3.85 billion dollar contract for six Canadian Patrol Frigates or CPFs. It is expected that the first CPF will be operational in late 1989. I have included the CPF in this briefing since the Canadian ships' electromagnetic signature will be very evident in coastal waters, especially the east coast. Also, when these ships are travelling in the great lakes system, DFSM would see there being some inhibitions on the ships use of its radars, etc. (Slide 12 off)

16. (Slide 13) The high frequency 1000W CPF radio will have a tuning range of 1.5-30 MHz with a 3KHz bandwidth for SSB and a 6KHz capabilty for data transmission.

17. The VHF radios will work in the 30-88 and 156-174 MHz bands. Both will be restricted to 25 KHz tuning increments.

18. The UHF radio will operate in the military band with bandwidths up to 50 KHz for data transmission. These CPF radios will have a power output of 150w and be capable of satellite operation.

19. The navigational radar will be the standard commercial ship's radar operating at 9375 MHz. It, of course, will be in operational use wherever the ship is located. (Slide 13 off)

20. (Slide 14) The other radars on board the ship will be as shown on this slide. We foresee some operational restriction on the use of these radars in coastal areas to ensure the intersystem electromagnetic compatability of the radars with existing civil microwave systems. (slide 14 off)

Potential Canadian Military Use of Satellite Systems

21. (Slide 15) Gentlemen, I'm going to have to tread lightly on this next subject. Much of the future planning for Canadian military satellite usage is still classified and as you can see, certain requirements are unique to the military. I will not be able to be as specific as I am sure you would wish me to be. Nonetheless, I think what follows will interest you. (Slide 15 off)

22. (Slide 16) At the present time the Canadian forces have access to three satellite systems: NATO SATCOM; fleet SATCOM; and the Canadian ANIK series. NATO SATCOM comprises a series of satellites in geostationary orbit working in the 7/8 GHz band. In NATO nations, this band is reserved for military satellite usage. Canada has two ground terminals on NATO SATCOM: the first one in Carp, Ont, just west of Ottawa; and the second at Folly Lake in Nova Scotia. These ground satellite terminals have been in, and working, for several years and are used on a daily basis for communications between Canada, NATO headquarters and other NATO nations. FLEET SATCOM is a satellite operating in the 225-400 MHz band and has ten 15 KHz channels, one 500 KHz wide-band channel and twelve 5 KHz channels. The fleet SATCOM series of satellites is intended to be replaced by the LEASAT series. However, the launching of the LEASAT satellites has run into difficulty due to the problems with the space shuttle program. The Canadian Patrol Frigate will have a ship satellite terminal capable of working the fleet SATCOM/LEASAT series. (Slide 16 off)

23. I intend to discuss Canadian Forces future plans for the use of satellites in two areas. First, our wish list, those things that we feel are an operational requirement but which must await budgetary approval; and second, our firm plans for satellite usage in the immediate future. I will be discussing the major part of the latter under the North American Air Defence Modernization Program, which will be the next topic in this presentation.

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24. As to our wish list - the Canadian military has difficulties in using Canadian commercial satellites for military operational needs. (Slide 17) First, the ANIK series of satellites does not meet the military requirement in four areas:

a. The satellite coverage is limited to North America and essentially Canada.

b. The 6/4 GHz satellite, which has coverage up to the arctic ocean, shares the band with fixed systems. Thus it is difficult to quickly locate a transportable satellite ground terminal in the southern portions of Canada because of the time consuming coordination with the fixed system user. The 14/12 GHz satellite, although partially operating in an exclusive satellite band, does not give coverage to the arctic coastline.

c. The ANIK series of satellites are vulnerable both to direct attack and to jamming; and finally

d. There is no inter-satellite link between the ANIK satellites and others. Thus full earth coverage is not available should the Canadian Forces be deployed in, say, the southern hemisphere. (Slide 17 off)

25. It is obvious that the most desireable solution to these difficulties is for the Canadian military to own its own satellite system with intersatellite links to military satellites of other friendly nations. This is, of course, a tremendously costly and diffficult project to get on the way. Therefore, it is our intention to proceed in stages with the hope of ultimately having our own system.

26. (Slide 18) First, we have embarked on a program involving the construction of a transportable satellite ground terminal system. This system is expected to be completed this summer and will operate at 14/12 GHz with the ANIK satellites. It will be used by the Canadian Forces Communication Command to provide rear link and restoral communications for voice, teletype and data in support of Canadian forces operations in Canada. (Slide 18 off)

27. The next phase will see the construction of more military satellite ground terminals with the intention that these terminals be capable of operating with satellites of opportunity, such as the NATO SATCOM and the ANIK E series.

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28. The final phase would be the development of a Canadian military backbone carrier for tactical and strategic communications. There are obviously several options that can be considered - from military owned space, ground and control segments, to various leased/shared arrangements. In any event, any new military satellite owned by the Canadian Forces is not likely to be operating in the normal civil satellite bands. We are doing some research into the higher satellite tuning ranges and we expect new satellite systems to be high band, state-of-the-art systems.

North American Air Defence Modernization (NAADM) Program

29. (Slide 19) The North American Air Defence Modernization Program or NAADM comprises the new radar chain that will be established along the east and west coasts of Canada and Alaska; and the series of radars across the Arctic Ocean as shown on this slide. It includes the communications necessary to move the radar information down south to the Control Centres located at North Bay, and Colorado Springs in the USA. NAADM, as well, envisages the establish- ment of Forward Operating Bases for Canadian Air Force and United States Air Force fighter aircraft and USAF airborne surveillance aircraft. (Slide 19 off)

30. (Slide 20) NAADM will comprise eleven long range radar sites utilizing the General Electric AN/FPS 117 radar which operates in the 1250-1400 MHz band. This radar has a bandwidth of 1.8 MHz on a single frequency and 148 MHz while it is hopping. Between the eleven long range radar sites will be (Slide 20 off, Slide 21) thirty-six short range radar sites acting as gapfillers. These radars will utilize Sperry equipment operating in the 1218-1398 MHz range with a bandwidth of 1.2 MHz. They are also frequency hopping radars. (Slide 21 off)

31. (Slide 22) Each radar site will have communications facilities as depicted on this slide, comprising an RF group satellite ground terminal on the ANIK D/1 and D/2 (6/4 GHz) satellites; G/A/G UHF and VHF; emergency HF; and LF for a Non Directional Beacon. (slide 22 off)

32. (Slide 23) In addition to the HF single channel radios and the satellite ground terminal links to the south, the Canadian military is exploring the options available for a secure secondary link capable of operating through the auroral zone which, as you realize, is an area of high absorption. There is a possibility that this system will be an adaptive HF system utilizing spectrum sounders in order to have real time information regarding the sporadic E layer. (Slide 23 off)

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POST 2000 PLANS AND INTERESTS IN NEW TECHNOLOGIES

33. (Slide 24) I would now like to cover briefly our post 2000 plans and interests in new technologies. Some of our programs are listed on this slide. (Pause) (Slide 24 off)

Amplitude Compandored Single Sideband (ACSSB) Modulation

34. (Slide 25) The spectrum managers of all NATO nations are concerned that the military operational types using communications systems tend not to be very interested in spectrum conservation. It is only now that we spectrum managers have been able to convince the operators that we are starting to run out of spectrum in a number of bands. This is especially critical when viewed in the battlefield scenario. All NATO nations are attempting to improve the spectrum efficiency of their electronic devices and one such system is the ACSSB system.

35. My Directorate is sponsoring a project with the Communications Research Center to develop an ACSSB radio capable of carrying a voice conversation with approximately 2 KHz of bandwidth. The difference between the ACCSB that we are sponsoring and that which is intended for the civil mobile satellite users is that the signal processing in the military version will be done in the frequency domain (by utilizing a fast fourier transform) rather than in the time domain. The real advantage of such systems in addition to being spectrum conservative, is their ability to operate at or near the noise floor. As shown on the slide, since receiver noise does not contain the compression rules, the noise does not get expanded at the receiver end. CRC and DFSM will first attempt to build ACSSB radios utilizing the 30-108 MHz band, which is the band for our combat net radio. The second stage will be to develop a similar radio operating in the 225-400 MHz band. The concept, of course, seems to be suitable for use in any band. (Slide 25 off)

Standoff Army Airborne Surveillance Target Acquisition System

36. (Slide 26) The Standoff Army Airborne Surveillance Target Acquisition System will be an airborne drone system used for surveillance beyond the forward edge of the battle area (or what used to be known as the front line trenches). It will comprise a radar surveillance system operating in the "X" band and a data link operating back to the controller in the "KU" band. You could expect these systems at the major Canadian army bases. (Slide 26 off)

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Next Generation of Remotely Piloted Vehicles (RPV)

37. (Slide 27) For the next generation of Remotely Piloted Vehicles or RPVs, Canada is interested in developing its own standoff airborne surveillance system and we would see that system as comprising a data link which would carry commands to the air vehicle and real time video from the air vehicle's sensor (TV or thermal imager) to the ground control station. We see this system coming into being in the mid 1990s and continuing in use until the early 2000s. We are even now negotiating with our European allies to try and determine a suitable frequency band for the video and telemetry. (Slide 27 off)

Stationary High Altitude Relay Platform (SHARP)

38. (Slide 28) The SHARP system is a pseudo satellite, operating above the jetstream but still within the atmosphere. The military interest in SHARP lies in two areas:

a. as a radio relay platform for total battlefield coverage; and

b. as a replacement facility for any damaged military satellite formerly covering the battlefield.

39. As you heard from Dr. Barrington this morning, the SHARP aircraft is extremely light but strong. It is carried to height piggybacked on the back of another aircraft until above the jetstream where it is released to continue to its operating altitude under its own power. Once in position, the station keeping electrical propulsion system receives its power from the ground microwave system as shown on this slide. (Slide 28 off)

Cellular and Trunking Systems

40. (Slide 24 back on) DND remains interested in the possible military application of Cellular and Trunking systems. The spectrum savings are of as much interest to the military as they are to the civil community. The susceptibility to enemy jamming efforts, however, remains a concern, for as the channel capacity increases the frequency itself becomes a more and more inviting target.

Free Channel Search Systems

41. An alternative to achieving the anti-jam margin of a frequency hopping radio appears to be available in Free Channel Search systems. Such a system essentially scans the spectrum utilizing a pseudo random code known by all radios on the net and when the control station finds a frequency that is not occupied at that moment, all stations on the net are informed and communications begins using that frequency. There are several European radios using this technique. It is especially attractive for use in the very crowded 30-108 MHz band used by the combat net radio.

Controlled Lobe/Null Antenna

42. As I expressed earlier, the Military is interested in having as little as possible of our own electromagnetic energy arriving at the locating devices of the enemy forces. One way of doing this is to control the output power levels of the transmitter and another way is to control the directionality of the beam. Our wish list would see this Controlled Lobe/Null Antenna system utilizing several antennas capable of measuring the phase difference of incoming signals and insuring that the outgoing signal was phase differentiated in the reciprocal direction of the received signal.

Position Locating and Reporting Systems (PLRS)

43. The PLRS is a system whereby a user can request from the master station his geographic location; and the master station can demand the user transponder to provide the user's location. It is a ground based system operating in the 420-450 MHz band using a pseudo noise code spectrum spreader and a frequency hopping wave form. Up to 460 users can be controlled by the master station using frequency and time division multiple access technology. The system is being built now and is expected to be in use in the 1988/89 timeframe and should remain in service until post 2000. (Slide 23 off)

POST 2020 DEVICES OF MILITARY INTERST

44. Finally, ladies and gentlemen, I would like to discuss some items that are being experimented on now or which shortly will be. Their fruition depends mostly on the amount of effort we are willing to expend to develop them. (Slide 29)

.../11

Space to Earth Power

45. Space to Earth Power is the use of a satellite to gather solar energy and convert it into microwave energy for transmission to the earth. This could serve as a source of power for isolated military installations.

Beamed Energy Devices

46. There is a potential to use low frequency and high frequency Beamed Energy Devices to disturb the magnetosphere and thus control atmospheric ducting allowing radio paths. As well there is the possibility of using lasers to create an ion path to provide an artifical common scatter volume for quasi tropospheric scatter communications.

Buried Antenna Systems

47. New developments in Buried Antenna Systems point to survivable systems in the military sense, with greater ground wave coverage than standard above ground systems while still retaining good directionality.

Lasers

48. The use of blue/green Lasers to communicate with submarines is now in the experimental stage. Also, the laser has the potential for creating an ion path which could be used for a long wire type antenna.

Resonant Frequencies

49. The possibility exists to precisely control link distances using the Resonant Frequencies of the oxygen (and other) molecule.

Radar

50. The possibility also exists to have Radars with sufficient resolutions to give optical quality pictures.

Pilotless Aircraft

51. A Pilotless Aircraft is not an RPV, as we now think of a remotely piloted vehicle, but a completely armed fighter aircraft without the low G force limitations imposed by a pilot.

.../12

Light

52. And finally DND foresees some electronic circuitry using photons inherent in Light rather than electrons thus eliminating the heat buildup problem. Along with these photon powered devices, chemical or biological luminescent power sou_ces are also expected. (Slide 29 off)

53. Ladies and gentlemen, that concludes my briefing. I will attempt to answer any questions you may have during the Panel Discussion later this afternoon.

mobile services in the year 2000 and beyond: personal thoughts

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Abstract

A number of mobile products and services have evolved over the past two decades: mobile telephony; cordless phones; pagers; dispatch services; mobile data services. Facing differing demands for mobile communications services, our industry has traditionally responded in an *application specific* manner. The cost of application specific development is prohibitive and requires a large and clear demand. Clearly, this approach is no longer suited to our rapidly changing environment.

Mobile services may be considered an extension to the services offered by the fixed network. The standardisation effort which has culminated in the definitions associated with Integrated Services Digital Networks is indicative of the fixed networks response to the challenge. It is imperative that we provide basic *information transport* services, which have no regard for information content, as the foundation of future mobile services.

Résumé

Au cours des deux dernières décennies, bon nombre de produits et services mobiles ont vu le jour: téléphones mobiles, téléphones sans fil, récepteurs de recherche de personnes, répartiteurs, services de données mobiles..... Notre industrie reçoit des demandes de services de communication mobile divers et y a toujours répondu de façon sectorielle. Le coût de conception de telles applications est prohibitif et ne peut être amorti que par une demande manifeste et répandue. De toute évidence, nortre milieu évolue très rapidement et cette approche n'y est plus adaptée.

On peut présumer que les services mobiles sont un prolongement des services offerts grâce au réseau de services fixes. La normalisation a été couronnée par les définitions liées aux réseaux numériques à intégration de services et représente avec justesse l'adaptation apportee aux reseaux de services fixes en raison des circonstances. Il nous apparaît essential de fournir les services de base en matière de transmission de l'information, quel que soit le contenu informationnel. Une telle démarche constituera l'assise des services mobiles que nous fournirons ultérieurement.

1. Introduction

This paper forms the basis of a talk for presentation at Spectrum 20/20: A Symposium on Spectrum Usage, Future Directions in Canada, jointly sponsored by the Radio Advisory Board of Canada and the Department of Communications.

Forecasting the future is fraught with difficulty. History is replete with examples of predictions which subsequently proved incorrect. In the late 1940s and early 1950s, many experts predicted that nuclear-generated energy would be much cheaper than fossil-fueled power. In the 1960s, it was projected that supersonic transport jets would be common in the skies by the 1980s.

There are also examples of successful forecasts. The Whirlpool Corp, for example, decided against the introduction of a major new home appliance to automate ironing, on the advice of a company forecaster. The predicted widespread use of permanent-press fabrics was sufficient to offset the demand for anything more than the household iron. Despite occasional embarrasing failures, forecasting is a heavily relied upon tool for research and development decisions.

The successful development and deployment of any new product or service depends upon the "right" combination of market need, the technology capability and the availability of resources. A radio telecommunications product or service must also run the gauntlet of the regulatory environment, which has both enabling and disabling characteristics.

Because of limited foresight and the difficulties in planning technology, a diverse range of mobile products and services have evolved over the past two decades: mobile telephony; cordless phones; pagers; dispatch services; mobile data services. Facing differing demands for mobile communications services, our industry has traditionally responded in an *application specific* manner. This has in turn produced fragmentation of spectrum usage and of the supply and support industries. The cost of application specific development is prohibitive. Clearly, at a time when demands are changing rapidly, and there is already heavy congestion of radio frequency spectrum, we can no longer adopt the application specific approach.

Future mobile sevices may be considered an extension to the services offered by the fixed network. The standardisation effort which has culminated in the definitions associated with Integrated Services Digital Networks is indicative of the fixed networks response to the challenge. It is imperative that we provide basic *information transport* services, which have no regard for information content, as the foundation of future mobile services. We refer to this application independent approach as the Wireless Integrated Network, WIN.

In this paper we begin by discussing an entirely new mobile service, personal portable telephone service. We continue with a projection of the changes which may occur in the dominant mobile telecommunications service, Land Mobile Cellular, and indicate how these services fit into WIN. Finally we briefly describe how the WIN subsumes a number of existing services.

2. Personal Portable Telephone

2.1 Background

There is clear market demand for personal portable telephone service, PPT. This market demand is indicated by the growing sales of "hand-held" and "transportable" units designed for operation with the existing 800/900MHz Land Mobile Cellular systems. Further indication is provided by the enormous sales volume enjoyed by the "cordless telephone" instruments. A recent market survey undertaken by Arthur D. Little indicates that 50% of the adult population will own or use a personal communications device by the year 2000.

The PPT will be physically small, light-weight, and operate from internal energy supply. The requirement for prolonged operation without the need to replenish internal energy supply indicates that the device will operate using low radiated power, perhaps a few milli-watts. The Land Mobile Cellular approach to providing radio coverage contributed to reducing the radiated power of a mobile telephone by an order of magnitude; from 25 down to 3 watts. Application of similar technology leads to a PPT support infra-structure which comprises a pattern of tiny cells.

2.2 Services

Straightforward telephony, the support of two-way telephone conversation is likely to remain the dominant telecommunications service for some time. The PPT will support two-way telephone conversations. No system can legitimately claim to offer telephone service unless at least inteconnection exists with the Public Switched Telephone Network, PSTN. A major force shaping the future of the PSTN is the efforts towards international standards for Integrated Services Digital Networks, ISDN. Least cost mobile telephone service will only accrue if the mobile telephone service is integrated into the network providing telephone service in the year 2000: the ISDN. We anticipate that the PPT service will extend the services offered by the ISDN over a short radio channel. In the WIN, we refer to **b** and **d** channels, which map in some manner into the B and D channels of ISDN. The integration of mobile and fixed telephone service has significant impact on both the technology and the regulatory environment of both the ISDN and the Wireless Integrated Network, WIN.

The widespread use of PPT service will have significant impact on the operation and use of the fixed telephone network. The PPT is a personal service; telephone calls are placed to a particular subscriber, not to a station. Since the subscriber is mobile, the number assigned to that subscriber no longer has location significance. Consequently, the network must first find the subscriber, and then route the call based on the location information retrieved. Fortunately, the call-processing software used in the fixed network is being modified to cope with mobile subscribers. Further modifications will be required to integrate a wide-area paging system into the subscriber location procedure. Use of the network may also change. A calling party will have no knowlege of the called party's location. With the current tariff structure, the calling party may inadvertently incur long distance charges. Various schemes have been proposed to address this problem. One potential solution is the adoption of distance insensitive charging: the call costs the same, no matter where on the globe it terminates.

The result of the integration of the fixed and mobile telephone service allows the PPT to offer all the voice services currently supported by the fixed network in the year 2000. Services such as call forward, call waiting, etc... The adoption of digital speech allow private and if necessary secure transmission of the telephone conversation over the radio channel.

By extending ISDN services over the radio channel, the PPT service will also provide integrated access to both packet switched and circuit switched data services. Much of the utility of a wireless telephone in the workplace is lost if, for instance, the user must return to the desk to retrieve information before being able to reply to a query. Such a system will contribute little to solving the problem of telephone tag. The ability to retrieve information, while maintaining the connection to the calling party provides the potential of increased office productivity.

There are a number of services which may be offered which are well suited to packet switched data techniques supported by the mobility afforded by the radio channel. Using packet techniques over the **d** channel to support a data connection would suffice for casual information retrieval, such as in the example given above. Personal portable computers, akin to Allan Kay's Dynabook, would require greater transmission rates, and would be supported by packet switched data services over the **b** channel.

2.3 Spectrum Requirements

2.3.1 Bandwidth Considerations

ISDN provides at its Basic Access two 64Kbps channels, the 'B' channels, together with a 16Kbps signalling channel, the 'D' channel. Even with state-of-the-art digital modulation schemes designed to operate over the mobile radio channel, providing the full 144Kbps represents significant spectrum occupancy per user. Frequency re-use is dependent upon the carrier to interference ratio which modulation system can withstand, and still provide acceptable error performance. If we assume 2bps/Hz, then each user will require 144KHz of spectrum to maintain a duplex connection if the **b** and **d** channels have equivalent transmission rates as the B and D channels respectively. Supporting a 1B+D service would require 80KHz.

We anticipate considerable demand placed on this system. If the PPT is deployed in the office, the traffic figures of 0.1 Erlangs per subscriber observed on existing PBX installations would be applicable. In high traffic business areas, local peak densities of greater than 100,000 subscribers per square kilometer, will occur. (We assume three dimensional frequency re-use since 100,000 subscribers per square kilometer represents one person per ten square meters - a realistic floor loading figure for many offices.) Simple arithmetic yields a peak load of 10,000 Erlangs/square kilometer. To achieve such densities, requires technological progress in two major areas:

i. less equivalent bandwidth per duplex voice channel. This can be achieved by improvements in voice coding schemes, reducing the bit rate required to provide acceptable speech quality, and by improvements in the modulation schemes thereby increasing the bps/Hz;

ii. improvement in frequency re-use factor, which requires reduction of cluster size. The limit on the reduction achievable is determined

Cell diam. meter	Cell area sq. km.	Traffic per cell Erlangs	Bandwidth per cell MHz	Overall Bandwidth (MHz) 16-cell cluster	7-cell cluster	3-cell cluster
1589	1.98	992	80	1280	560	240
1112	0.972	486	40	640	280	120
689	0.372	186	16	256	112	48
473	0.176	88	8	128	56	24
320	0.081	40	4	64	28	12
211	0.035	18	2	32	14	6
114	0.01	5	0.8	12.8	5.6	2.4

Blocking: 2%,Erlang B
1000 Erlangs/km^2
80kHz / duplex voice channel

Table 2-1

by the carrier to interference ratios that the modulation scheme can withstand yet still return acceptable error performance.

Generally, improving the bps/Hz worsens the carrier to interference ratio for acceptable performance.

As an estimate of the bandwidth required to support this service, let us assume that the PPT uses radio spectrum only to support mobile traffic: the user inserts the PPT subscriber unit into a device on his desk, which routes traffic into the existing wire-based system. Further, let us assume 10% mobile traffic, yielding 500 Erlangs per square kilometer as the mean traffic density. Let us assume further, that we provide 1B + D service requiring 80KHz per subscriber. Table 2-1 indicates the bandwidth required to support the busy hour demand for service with blocking probability of two percent, for various cell sizes. Conservation of radio frequency spectrum would indicate that the personal portable telephone will be supported by a system of extremely small cells. This is also congruent with the need for small radiated power levels necessary for prolonged operation of the personal portable telephone from internal energy supply.

The practicality of three cell clusters has yet to be demonstrated. Radio propagation inside a building is highly variable: the radiated power levels are low to maintain tiny cells; the in-door antennae may be low compared to the normal obstructions in the office. The radio coverage is, for instance, affected by opening a steel filing cabinet door. With such radical and rapid changes to the environment, it is impractical to engineer the system *a priori* using standard statistical radio frequency propagation models. The system will perform dynamic channel assignment based on current radio environment information, and therefore adapt to its environment. Such an adaptive system has other benefits: it can be shown to be more efficient; it allows for easy installation and expansion. The regulatory environment needs to be established to allow this method of operation.

Straightforward telephony will remain the dominant telecommunications service for the foreseeable future. We have noted that the spectrum requirements may be reduced by reduction in the equivalent bandwidth per duplex voice channel. However, restricting the entire WIN to the bit rates required to support acceptable speech falls in the trap of application dependency. There are a number of data services which may be anticipated, some using much lower, and some using much higher bit rates than required for speech. Dynamic bandwidth assignment places the least restriction on the services which may be offered.

2.3.2 Frequency Considerations

The choice of frequency band will have significant affect on the introduction of the service and cost of the equipment. The frequency bands below 1GHz are heavily congested. The greater availability of spectrum at higher frequency bands increases the probability of access to the larger bandwidths required to support larger cluster sizes, increased subscriber load, and higher data rate services. However, increasing the frequency of operation has drawbacks.

Allocation of spectrum for this service will precipitate commercial development efforts. Experience indicates that we may expect a time delay between the allocation of spectrum and the emergence of products. If allocation is far removed from existing allocation, then we will be able to leverage little from our current experience in the high volume production of 800MHz Land Mobile transceivers, with the concomitant delay in service introduction date.

It is not clear when or if integrated circuit technology based on silicon will yield adequate performance at frequencies above approximately 1.5GHz. While other materials, such as gallium arsenide, have higher carrier mobilities, suitable processing to achieve the high yields required for low cost production have yet to be demonstrated.

The power conversion efficiency of transmitter output stages tends to fall with increasing signal frequency, leading to increased power consumption for a given power output. This is not consistent with operation for prolonged periods from internal energy supply.

Higher frequencies are subject to greater shadowing effects from both humans and building material resulting in more holes in the radio coverage. Adopting full dynamic channel allocation provides the potential of extending coverage by installation of additional basestations. This adds to the complexity, and therefore the cost, of the individual basestations, and also increases the installed cost of the system simply by increasing the number of basestations required.

The demand for PPT service is evident now. Neither delaying the service introduction date, nor high cost of equipment is consistent with providing a personal portable telephone to 50% of the adult population by the year 2000.

We have described an entirely new service. The allocation of spectrum to the PPT service must take account of a number of factors, including the status of the present table of allocations. The new service may require some form of frequency sharing with existing or other projected services. The table in Annex A is extracted from the work of Working Group 85 which was submitted to the second meeting of CCIR Interim Working Party IWP8/13, Future Public Land Mobile Telecommunication Systems. The table list some candidate bands in Canada.

2.4 Deployment

We see this service first being deployed in the workplace, followed by deployment in the residential environment. The technology exists to deploy the system in the workplace before the end of the decade, provided appropriate spectrum allocation is available. There is currently no spectrum allocation to this type of service.

Providing support outside a building will require installation of basestations. We anticipate a continuation of the in-building cell structure. Because of the low radiated power of both the PPT and the supporting basestations, the cell areas will be small. With such small cells, continuous radio coverage over a wide geographic area will require the installation of a large number of basestations. We therefore anticipate holes in the radio coverage. Incorporation of the wide-area paging receiver into the personal portable telephone will allow the subscriber to be alerted to an incoming call attempt, even if outside a full service area. Integration of the two services would allow, for example, the personal portable telephone to automatically return the call upon entry into a service area.

One type of basestation may be fixed: attached to the ISDN via Basic Access connection. We may also support the PPT from a vehicle mounted Land Mobile Cellular transceiver. The Cellular transceiver acts as a repeater for the PPT, while the PPT acts as a cordless control head for a Land Mobile Cellular tranceiver. Indeed, since the PPT contains a unique identifier, any Cellular transceiver may extend service to any PPT. We integrate the existing cordless and cellular telephone service. This mode of operation is currently used by various Police Departments, so the technology exists.

It is interesting to speculate on the source of funding for this deployment. The traditional source of funding for workplace telephone service, the employer, may well fund the deployment in the full knowledge that the personal portable telephone may also be used to provide cordless telephone service in the employees residence, or be used as the cordless control head to the cellular telephone in the car, or the maritime radio in the boat.

Any particular person may not need to purchase a basestation to support cordless telephone at home. Since all the information required to uniquely identify the subscriber is exchanged with the network, cordless telephone service may, for instance, be supported by a neighbours basestation. The neighbours basestation will be connected via ISDN Basic Access and therefore be capable of supporting at least two simultaneous conversations. The neighbour is now a partner with the telephone company in providing cordless telephone service, and is presumably entitled to a share of the revenue.

2.5 Summary

We have described a second generation personal communications system. The system draws much from the cordless telephone service, the land mobile cellular service and from the fixed networks that currently provide telecommunications services. The PPT is similar in its telephony aspect to the cordless telephone, with the exception that the phone works anywhere, although not necessarily everywhere. The PPT service does not compete with Cellular; indeed, part of the support infra-structure for the PPT is the Cellular transceivers. The PPT service complements the fixed network by offering that unique characteristic of wireless equipment: mobility.

3. Land Mobile Cellular

3.1 Background

The first commercial mobile telephone system in the North America was established in St Louis, Missouri, in 1946. Since then, Mobile Telephone Systems have progressed through several stages, culminating in Land Mobile Cellular Mobile Systems. Cellular mobile telephone service in the 800MHz band was first examined in Canada in September 1981, when the federal Department of Communications, DoC, issued a discussion paper entitled "Radio Licensing Policy for Cellular Mobile Radio Systems and Preliminary Mobile Satellite Planning in the Band 806-890 MHz." Following a detailed review of the comments to the discussion paper, DoC issued "Cellular Mobile Radio Policy and Call for License Applications" in October, 1982. We now have commercial systems operating in many cities in Canada, including Ottawa, Toronto, Montreal, Vancouver and Calgary.

The Electronic Industries Association in the United States issued a standard method of assigning channels, the EIA CIS-3 protocol, which has been adopted across North America.

These two actions have brought about the revolution which has occurred in land mobile telecommunications in North America. The adoption of standards has allowed equipment manufacturers to mass produce the radio-telephone. For the first time in history, the mass consumer is able to experience ubiquitous mobile telephone service as a result of the plummeting cost of Cellular mobile products and services. The much larger production volumes coupled with much larger subscriber base associated with the 800MHz Land Mobile Cellular service will lower the cost of Cellular products and services to the point that Land Mobile Cellular service will become the dominant mobile telephone service.

We anticipate the introduction of digital techniques into Land Mobile Cellular systems. There are several forces acting in this direction. The 800MHz Land Mobile Cellular system offers mobile telephone service, and as such, requires interconnection with the Public Switched Telephone Network. As in the case of the personal portable telephone service, the Land Mobile Cellular Service will become integrated with the Integrated Digital Network, ISDN. We refer to the **B'** and **D'** channels over the mobile radio channel which map in some way onto the B and D channels of the ISDN. It is unlikely that the **B'** and **D'** channels will provide the same signalling rate, error performance or delay characteristics as the wire-based ISDN; the mobile radio channel presents one of the most hostile radio environments for digital transmission.

While systems in Canada have yet to experience difficulties, some 800MHz Land Mobile Cellular systems in the United States are heavily congested. By adopting digital techniques, Land Mobile Cellular systems will reduce the bandwidth required to support a telephone conversation, by taking full advantage of technology improvements in digital voice coding.

3.2 Services

The Cellular systems will continue to support two-way telephone conversations. The voice will, however, be transmitted using coding techniques potentially different from those used on the fixed ISDN. In addition to coping with mobile subscribers, the ISDN must potentially provide network services, which, for instance, perform transcoding of the various voice coding schemes in use simultaneously in the network.

The use of digital techniques, provides for encryption of the transmitted signal to address the privacy and security issues associated with radio transmission. Further, by extending the ISDN services, a large number of the voice services available from the fixed network will be available to the mobile user, such as calling number identification.

The 800MHz Land Mobile Cellular system is an example of an application specific system with which our industry has responded to the demand for mobile telecommunications services. This system was designed to provide mobile telephone service, which it achieves by transmitting an analogue representation of the voice on a frequency modulated carrier. Sending high speed data on this system is arduous. Subscribers to the Cellular service are demonstrating market demand for mobile data services by providing data modems, at both the mobile transceiver and the computer site, specifically for operation using the cellular radio link. These digital data transmission operate at relatively low speed, as a consequence of attempting to coerce a system designed for analogue transmissions to carry digital data. By adopting digital techniques, and by adhering to the tenets of ISDN, the future WIN will provide access to both packet switched and circuit switched data services. We anticipate the emergence of public packet radio networks, supporting a variety of data related services. Not all the data services will require equal bandwidth, and packet radio provides a ready solution to the sharing of the spectrum, which is entirely consistent with the WIN. Vehicle location and health reporting for example, could be handled by such a service.

As noted in the previous section, we anticipate support of PPT service from a Cellular transceiver. It is likely that the services supported via a Cellular transceiver will be a sub-set of those supported from a basestation connected directly to the wire. With both basestations and PPT potentially mobile, engineering such a system *a priori* is infeasible. Dynamic channel assignment is essential.

3.3 Spectrum Requirements

3.2.1 Bandwidth Considerations

As noted earlier, ISDN Basic Access B channel provides 64Kbps, and the D channel provides transmission rates of 16Kbps. It is extremely unlikely that such transmission rates will be afforded a single subscriber to the Cellular system. It is, however, important to maintain both a **B'** and a **D'** channel; the ability to exchange signalling information simultaneous with **B'** transmissions provides the basis of the additional services. Part of the **D'** channel traffic is the information necessary to coordinate handover between cells.

The spectrum requirements are based upon anticipated subscriber load. For the purposes of spectrum estimation, we consider only vehicular traffic in a city centre, such as Ottawa. The city centre approximates uniform structural layout: average city block size 125 metres; four lane street. The average occupied length per vehicle during rush hour, traditionally the busy hour for vehicular mobile telephone traffic, is 7 metres. Simple arithmetic yields a maximum vehicle density in the city core of 9142 vehicles per square kilometre.

Cell diam. meter	Cell area sq. km.	Traffic per cell Erlangs	Bandwidth per cell MHz	Overall Bandwidth (MHz) 16-cell cluster	7-cell cluster	3-cell cluster
2513	4.96	992	25	400	175	75
1760	2.43	486	12.5	200	87.5	37.5
1089	0.93	186	5	80	35	15
748	0.44	88	2.5	40	17.5	7.5
506	0.20	40	1.25	20	8.75	3.75
334	0.088	18	0.63	10	4.38	1.88
180	0.025	5	0.25	4	1.75	0.75

Blocking: 2%,Erlang B
200 Erlangs/km^2
25KHz /duplex voice channel

Figure 3-1

Based on current experience, the traffic loading per subscriber varies between 0.01 and 0.05 Erlangs in the busy hour. We adopt 0.02 as a realistic figure. Once again, simple arithmetic yields an approximation of 200 Erlangs per square kilometre.

If we also assume that the spectrum occupancy for a duplex voice connection may be reduced to 25KHz, we may now tabulate the spectrum requirements for 2% blocking probability, as shown in Table 3-1. The spectrum requirements are substantial: for example, with 1Km cell diameter, and 7 cell clusters, there is a requirement for 35MHz to support the anticipated vehicular traffic. Further, this estimate takes no account of the traffic generated by the hand-held units, nor by the support of the PPT service.

3.3.2 Frequency Considerations

Once again, any additional allocation of spectrum must take account of the status of the present allocation table. Candidate bands in Canada are shown in the table in Annex-A.

We anticipate additional spectrum allocation close to, adjacent to, or overlapping the existing allocation for Land Mobile Cellular service. The deployment is considered in the following section, and indicates a transition phase. This will require regulatory environment which allows the overlay of the future digital cellular system upon the exisiting 800MHz Land Mobile Cellular service.

3.4 Deployment

There is an 800MHz Land Mobile Cellular system currently in place which is providing mobile telephone service to large numbers of users. We obviously cannot abandon the service providers and the subscribers who have invested in Cellular products and services. We can expect to support the owners of today's equipment for some considerable time. As we phase in the future products and services, it is unreasonable to expect ubiquitous service, yet we will have a subscriber population accustomed to the extensive Cellular coverage. Consequently we anticipate a transition phase, where both the old and the new are supported.

3.5 ...and beyond

We have described a second generation cellular system, providing integrated access to services provided by the fixed network. The system uses digital techniques, and follows closely the tenets of the ISDN. While access to packet switched data services is offered, the system is still heavily based on circuit switching techniques. A third generation cellular system will use fast packet switching techniques. The implementation of fast packet switching in the WIN must wait for that technology to be implemented in the fixed network.

3.6 Summary

We have described another facet of the Wireless Integrated Network, which, by providing basic mobile telecommunications services, forms the basis on which to build a large class of mobile telecommunications services. Some examples are provided, but the services which this approach can provide are limited only by the imagination of the manufacturers and service providers, and potentially the regulatory bodies.

4. Other Mobile Services

4.1 Background

We have described a Wireless Integrated Network, which is capable of providing a large class of mobile telecommunications services. We have described in some detail the manner in which the existing cordless telephone service and the 800MHz Land Mobile Cellular service are integrated into the WIN. In this section we illustrate the power of the application independent approach, by selecting a number of existing services and showing how their needs are covered by the WIN.

4.2 Police Fire and Ambulance

There are a number of private mobile radio systems currently in operation, which provide mobile service to, for instance, the Police, Fire and Ambulance services. All these services may be support by the Wireless Integrated Network. Provision may be made in the WIN to give priority to the emergency services without providing a separate network, in much the same manner as the fixed telephone network. The WIN could provide the level of privacy and security required by the emergency services. In situations where being able to hear all other users is important, WIN merely establishes a conference call.

Law enforcement agencies make extensive use of digital data. A typical application is the transmission of facsimile pictures of suspects to law enforcement agent vehicles, where data throughput requirements are high in order to provide a high quality picture in short time. This application is adequately supported by data services available through the WIN.

By combining the resources, capital, development, spectrum, etc... the provision of basestations to support emergency services extends the coverage of WIN, while at the same time providing lower cost emergency service radio communication.

4.3 Pager Services

Although a number of proprietary systems are in operation, the most widely known standard for pagers is POCSAG, Post Office Code Standardisation Advisory Group, which was introduced into service in 1980. This standard provides for transmission of 512bps in a 450KHz channel. The need to avoid system saturation, and the limitation of

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Annex - A

Candidate Bands vs Canadian Use

CANDIDATE BANDS MOBILE ALLOCATION	CCIR STUDY GROUP 9 USAGE (FIXED)	CANADIAN FIXED USAGE AND FREQUENCY PLAN	CANADIAN FREQUENCY NOTIFICATIONS IFL OF MARCH 86
862 - 902 MHz primary all regions		SRSP-300.9 VLC/LC (A)	74
902 - 928 MHz primary regions 1 and 3; secondary region 2		SRSP 300.9 VLC/LC (A)	104
928 - 942 MHz primary all regions		SRSP 300.9 VLC/LC (A)	92
942 - 960 MHz primary regions 1 and 3; secondary region 2		SRSP 300.9 VLC/LC (A)	215
1427 - 1525 MHz primary all regions	REP. 1057 REP. 379-4 REP. 380-1	SRSP 301.4 VLC/LC/MC (A) & VLC/LC (D) SUBSCRIBER RADIO SYSTEMS RADIO ENTRANCE LINKS MCS (VLC DATA/VOICE)	193
1525 - 1535 MHz secondary all regions		(MARITIME MOBILE-SAT)	
1660.5 - 1668.4 MHz secondary all regions		(RADIO ASTRONOMY) (SPACE RESEARCH)	
1668.4 - 1690 MHz primary all regions		(METEOROLOGICAL AIDS) (METEOROLOGICAL AIDS)	
1710 - 2450 MHz primary regions 2 and 3 secondary - region 1	REC. 283-4 REP. 1057 REP. 390-1	SRSP 301.71 1710-1900 - VLC/LC/MC (A) & - VLC/LC (D) SRSP 301.9 1900-2290 - HC (A) & MC DIG - WIDE-BAND RADAR CONVEYANCE SRSP 302.3 2290-2450 - MCS (VLC DATA/ VOICE	860
2450 - 2690 MHz primary all regions	REC. 283-4	SRSP 302.5 2450-2548-MCS (VLC DATA/VOICE VLC/LC (A) & (D) 2548-2686-MCS VIDEO/ITV 2686-2690-VLC AL & (D)	18

		Analogue (A) (Voice Channels) (Voice Channels)	Digital (D) (Min. final cap) (Min. final cap):
VLC	Very Low Capacity	1- 24	56 kb/s
LC	Low Capacity	25- 120	1544 Mb/s
MC	Medium Capacity	121- 600	44 Mb/s
HC	High Capacity	601-1200	90 Mb/s
VHC	Very High Capacity	1201 and up	274 Mb/s
MCS	Multipoint Communication Systems		

NEW BROADCAST SERVICES STUDIED WITHIN THE EUROPEAN BROADCASTING UNION (EBU)

by

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ABSTRACT

Developments in terrestrial sound broadcasting during the past years have concerned the specification of a radio data system, mainly to assist listeners in tuning a receiver. As a result of this work a new CCIR Recommendation relating to the RDS system for FM broadcasting was agreed in 1986. For AM broadcasting (LF/MF and HF) the work is still going on, and no solution has yet been found.

The introduction of the Compact Disk has raised the expectations of broadcasters for an improvement of the quality of sound in radio, and also in television. This has initiated a study of digital audio broadcasting (DAB). With a new modulation method, OFDM (Orthogonal Frequency Division Multiplex), theoretically a uniform coverage with 16 programmes could be achieved within 4 MHz. The part of the spectrum that would be ideal would be within a possible extension of Band II in the range 108-112 MHz, at present used by the aeronautical ILS service which, according to our knowledge, will be transferred to the UHF range.

The same modulation method as for terrestrial DAB would be ideal for satellite sound broadcasting in the 1 GHz range. Studies have shown that an allocation of 28 MHz could provide up to 16 high-quality stereophonic radio services per service area for automobile, portable and fixed reception with a uniform beam coverage matrix. However, for planning in Europe national coverages with single beams, the frequency allocation may have to be increased by a factor of three.

Digital sound in terrestrial television may be achieved in some Europen countries within the short term by making use of an additional carrier for the digital signals within an existing television channel, maintaining the analogue sound for reasons of compatibility with existing receivers. With the increasing use of the MAC/packet system for direct satellite broadcasting within the 12 GHz range, it may become possible in the future to change existing terrestrial standards using PAL and SECAM to a D2-MAC/packet system which might then require a rearrangement of existing television channels without any increase of the spectrum at present available.

To permit any significant improvement in the picture quality to be achieved, a significant increase in bandwidth relative to the standards agreed to date will be required. In the EBU the view is held that HDTV could be best implemented within the 20 GHz range. The present objective pursued within the EBU would be to establish an HDTV DBS service within the next 10 to 15 years.

NOUVEAUX SERVICES DE RADIODIFFUSION ÉTUDIÉS PAR L'UNION EUROPÉENNE DE RADIODIFFUSION (UER)

par

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RÉSUMÉ

Les développements de la radiodiffusion sonore de Terre au cours des dernières années ont mené à la spécification d'un système radio de données, principalement pour aider les auditeurs à syntoniser leurs récepteurs. Une nouvelle recommandation du CCIR portant sur ce genre de système pour la radiodiffusion a été adoptée en 1986. En ce qui a trait à la radiodiffusion AM (LF/MF et HF), les travaux se poursuivent et aucune solution n'a encore été trouvée.

L'avènement du disque audionumérique a éveillé les attentes des radiodiffuseurs en ce qui a trait à l'amélioration de la qualité du signal sonore de radiodiffusion et de télévision. Il en a découlé l'étude de la radiodiffusion audionumérique (RAN). Grâce à une nouvelle méthode de modulation, le multiplexage par répartition en fréquence orthogonale (MRFO), il devrait être possible théoriquement d'assurer une couverture uniforme de ces émissions dans une bande de 4 MHz. La région du spectre qui conviendrait le mieux serait la bande II élargie dans la gamme des 108-112 MHz actuellement utilisée par le service ILS aéronautique, qui serait déplacé dans la bande UHF.

La même méthode de modulation du signal de radiodiffuison audionumérique de Terre s'appliquerait de façon idéale à la radiodiffusion sonore par satellite dans la bande de 1 GHz. Des études ont montré qu'une attribution de 28 MHz permettrait d'assurer jusqu'à 16 services stéréophoniques de grande qualité par zone de desserte destinés à être captés par des stations montées à bord d'automobiles, portables et fixes si l'on utilise une couverture à faisceau uniforme. La planification des zones de service nationales européenes par faisceau unique pourrait nécessiter trois fois plus de fréquences.

La télévision sonore numérique de Terre pourrait voir le jour à très court terme dans certains pays européens, si l'on parvient à utiliser une onde porteuse supplémentaire du signal numérique dans un canal de télévision, tout en gardant le signal sonore analogique pour des raisons de compatibilité avec les récepteurs existants. L'utilisation accrue du système MAC/paquet par la radiodiffusion directe par satellite dans la bande des 12 GHz devrait permettre, à l'avenir, de remplacer les standards de Terre existants PAL et SECAM par un système D2-MAC/paquet, ce qui pourrait nécessiter alors la redisposition des canaux de télévision, sans augmenter le nombre de radiofréquences actuellement disponibles.

Il faudra prévoir une augmentation importante de la largeur de bande des standards adoptés à ce jour pour permettre l'amélioration substantielle de la qualité de l'image. A l'UER, on croit que la mise en service de la TVHD se ferait mieux dans la bande des 20 GHz. L'objectif actuellement poursuivi à l'EUR serait d'établir d'ici les 10 à 15 prochaines années un service de télévision directe haute définition par satellite.

NEW BROADCAST SERVICES STUDIED WITHIN THE EUROPEAN BROADCASTING UNION (EBU)

by

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Terrestrial sound broadcasting using amplitude modulation takes place in Europe in the LF, MF and HF band, and no interference changes can be expected in the near future, except that the interference situation is steadily getting worse due to the ever increasing transmitting powers and the number of transmissions taking place in these bands. For example, stereophony on medium waves will certainly never generally be utilized in Europe even if it were successful for car and home listening in the United States. Nowadays the most popular band for terrestrial sound broadcasting in Europe is the FM range (87.5-108 MHz). This band was replanned in 1984 at an ITU Conference in Geneva, and the new plan will now be put into service. Several new problems have arisen in this context. The number of FM stations, especially low-power ones, has been increased in the past few years, and with that trend has increased the interference potential for the stations in operation for quite some time. Tuning will become more and more difficult with portable and car radios, since the density of transmitters that can be received at any given location is very high. This problem will soon have been solved in Europe with the widely planned introduction of the Radio Data System RDS, which is also the subject of the new CCIR Recommendation 643, adopted at Dubrovnik in May 1986. Attempts are being made now in the EBU to extend the automated tuning functions at least also to AM sound broadcasting. However, at this stage, no solution is yet known as to how this objective can be achieved.

Digital sound broadcasting systems have been studied in Europe for quite some time, and these studies are still being continued. In this context one has to distinguish between two completely different cases. Technical possibilities that have become available for the use of a larger number of sound channels accompanying a television programme, e.g. with the new MAC/packet family of systems, are of little interest to radio programme makers, since they cannot reach with these techniques the majority of listeners equipped with portable or car radios. The same is true for the DBS digital sound broadcasting system, developed in Germany, which uses a television channel to broadcast a multiplex of 16 stereophonic programmes in compact-disc audio quality. Although there is some likelihood that this system will be used in the 12 GHz range in Germany (FR) for domestic DBS or cable radio reception, there is not the slightest indication that other countries in Europe would have an interest in such a system. If they want to use DBS possibilities for radio as well, the MAC system would generally offer sufficient channel capacity to achieve the same objective. So what is really important for satellite sound broadcasting would be the possibility to receive the signals on portable and car radios. Such an objective has been pursued now within the EBU for more than 10 years, and a number of experiments and studies have been carried out to this end. The situation at present is the following: A band allocation in the range between 0.5 and 2.0 GHz could in principle be made by the forthcoming Second Session of the WARC-ORB, to be held in Geneva in autumn 1988. Provision has been made for such a decision with Recommendation PLEN/C of the First Session of that Conference, held in 1985, as a consequence of Resolution 505 adopted by the WARC 1979. The technical feasibility of such a system is at present being studied also by the CCIR, i.e. in JIWP 10-11/1, and the EBU has just agreed a contribution on the modulation characteristics to be envisaged and the width of the spectrum that would be required. The proposal made assumes frequency interleaving with digital modulation using an orthogonal frequency division multiplex (OFDM). This technique is particularly well adapted to the propagation problems caused by multipath effects in conjunction with small antennas used with portable and car radios. Another reason for aiming at such a system is the future possibility to use the same technique for digital terrestrial sound broadcasting, possibly with receivers that have common elements for terrestrial and satellite reception.

In the terrestrial case also no frequency band is available, and what would be particularly attractive here is to implement the new service within the existing infrastructure of VHF/FM sound broadcasters, i.e. to use the same audio links and transmitter locations and to provide coverage areas comparable to those achieved now with FM. It is obvious that such an objective could only be achieved in a frequency range close to Band II (87.5-108 MHz), and the use of the band itself can practically be excluded because of the high density of assignments made already for FM broadcasting. So, the possibility envisaged by the EBU concerns the adjacent range, 108-112 MHz, at present used by the aeronautical ILS service which, according to our knowledge, will be transferred to the 5 GHz range (microwave landing system).

Whilst for a terrestrial digital sound broadcasting system 4 MHz of spectrum space would be sufficient to achieve theoretically a uniform coverage of 16 stereophonic programmes, for digital satellite sound broadcasting 28 MHz would be required at least. However, for national coverage planning using single beams, the frequency allocation may have to be increased by a factor of up to three.

Clear advantages of digital systems in terms of spectrum usage have been identified in the studies carried out within the EBU. These concern the possibilities for sharing on the basis of limited geographical separation because of the lower power flux density required in comparison to FM, and the potential for substantially more efficient use of the spectrum in a global plan.

Digital sound in terrestrial television may be achieved in some European countries within the short term by making use of additional carriers within an existing television channel. The analogue sound will of course have to be maintained for reasons of compatibility with existing receivers. The "NICAM 728", which is recommended by the EBU, is for the time being restricted to PAL television standards B, G and I. The countries which are likely to use the new system are the United Kingdom and some Scandinavian countries. In Germany (FR) and also in the Netherlands an analogue stereophonic system has already been in use for many years, so that a change to digital sound will not be required there. In the long term, i.e. after the year 2000, the MAC/packet system will of course be fully established for use in satellite broadcasting. Then it will become interesting to use the MAC standard also for terrestrial broadcasting, and a rearrangement in the planned television channels as now used might perhaps be considered in this context. The whole question is at present under study within the EBU, and results permitting a forecast of the long-term trends will not be available before 1988.

To permit any significant improvement in the picture quality of television to be achieved, a significant increase in bandwidth relative to the standards agreed so far will be required. In the EBU the view is held that HDTV could best be implemented within the 20 GHz range. It is envisaged that the implementation of an HDTV service, at 22 GHz for example, could take place on a time scale of approximately 10 to 15 years from now, with a competent WARC making the appropriate allocation of the spectrum to be used. In this context it should be noted that, unlike Regions 2 and 3, Region 1 does not yet have an allocation for satellite broadcasting in the 22.5-23.0 GHz range. Of course, Region 1 has allocations in the 42 GHz and 85 GHz ranges, but the technologies to use these ranges for DBS are certainly not yet within our reach. Consequently it is upon the 20 GHz range that the EBU is concentrating its studies. Using the experience in the EBU for planning the 12 GHz range, first planning exercises were carried out in the 20 GHz range. An RF bandwidth of 40-60 MHz per channel is expected to allow two channels per country, based on national coverage with elliptical beams and on 500 MHz of available RF bandwidth. For the transmission coding and the modulation, three approaches are under consideration as far as the vision signal is concerned: analogue, digital and hybrid (analogue/digital). In each case, component coding is envisaged. For the sound, digital coding is assumed and the bit-rate chosen will depend on the sound-coding method and the number of sound channels required for an HDTV service.

As far as feeder links to broadcast services are concerned, the EBU is engaged in studies aiming at the establishment of frequency plans using the same principles as for the planning of the down-links. Various assumptions are made in these studies as far as the location of the transmitting Earth-stations are concerned. Possibilities for SNG (satellite news-gathering) are under study, although the possibilities for using this technique in Europe are completely different from those encountered in the United States, due to the different regulatory procedures applied.

SPECTRUM NEEDS FOR SATELLITE SERVICES BEYOND THE YEAR 2000

by

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ABSTRACT

This paper discusses the likely satellite-based services available by the year 2000 and their demand on available spectrum. Canada's geography and population density and distribution has a natural affinity to satellite to solve many types of problems.

This paper lists the technologies available to carry out many new applications via satellite and reviews the value of the application in the context of Canadian home consumers, Canadian business and government.

The paper suggests that several evolutionary developments in communications technology will have changed significantly the current users of spectrum to a new set of users. In the discussion, a case for 6/4 GHz and mobile spectrum bands dedicated to satellite usage is put forward due to terrestrial alternatives in place and in use.

The paper concludes that spectrum planning and policy must keep step with service and technology developments to:

1. ensure the freeing-up of mobile spectrum;
2. initiate the release of 4 and 6 GHz bands for dedicated satellite service;
3. reverse historical patterns of forcing satellite technology to co-ordinate with terrestrial technologies due to developments in terrestrial alternatives so that Canada's needs for satellite services are met with a logical spectrum occupancy plan.

BESOIN DE FRÉQUENCES LIÉS AUX SERVICES PAR SATELLITE DES ANNÉES 2000

par

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RÉSUMÉ

L'auteur traite des services par satellite qui seront probablement offerts d'ici l'an 2000 et de la demande de fréquences qu'ils susciteront. A cause de sa géographie, de sa densité de population et de la répartition de cette population, le Canada doit tout naturellement recourir aux satellites pour résoudre de nombreux problèmes.

Le mémoire passe en revue les technologies disponibles, qui permettent de tirer de nouvelles applications de l'utilisation des satellites, et en examine les valeurs des points de vue des foyers, de l'entreprise et du gouvernement du Canada.

L'auteur montre que plusieurs mouvements évolutifs dans le domaine de la technologie des télécommunications entraîneront l'apparition de nouveaux utilisateurs complètement différents des usagers actuels du spectre. Au cours de la discussion, une attention très particulière est accordée aux bandes de 6/4 GHz et du service mobile réservées à l'exploitation par satellite à cause des possibilités que présentent les systèmes de Terre en place.

Il est conclu que la planification et la politique d'utilisation du spectre doivent tenir compte du développement des services et de la technologie de manière à :

1. décongestionner les régions du spectre attribuées aux services mobiles

2. libérer les bandes 4 et 6 GHz pour les services spécialisés par satellite

3. renverser la tendance historique voulant que la technologie des satellites doive emboîter le pas aux technologies des systèmes de Terre en raison des possibilités de développement qu'offrent ces systèmes, de sorte qu'un plan logique d'occupation du spectre puisse être élaboré pour répondre aux besoins du Canada en services par satellite.

ORIGINAL : ANGLAIS

SPECTRUM NEEDS FOR SATELLITE SERVICES BEYOND THE YEAR 2000

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Introduction

It is not possible to predict the future with precision but by considering present trends in developing services and by considering the logical effects of new technology developments being applied to future services we can catch a glimpse of the shape of the future.

One thing is certain, satellite services of many kinds are here to stay. Even today, although the average Canadian is not aware of it, satellite services are becoming an essential part of our way of life. With our major broadcasting networks and movie networks in place bringing all Canadians, even in remote areas, closer together. Radio and telephone services, domestic and international, are growing and providing the benefits of instant communications across Canada and to the world.

Canada's geography and unique population distribution makes a natural evolution into dependency on many kinds of satellite services necessary and economically justified.

Extrapolating trends, with imagination, can provide a structure around which planning and policy development can proceed to keep pace with service development.

Our task is to foresee and develop services which will meet the emerging needs of all Canadians.

<u>The Year 2000</u>

The start of the 21st Century will see a broad range of satellite based services in place and being introduced.

Telesat's Anik E satellites will be nearing the end of their useful life and design and procurement of the next generation will be beginning. Very likely, a number of Direct Broadcasting Satellites will be in orbit and serving North America, providing a wide range of domestic and International Broadcast services to individual households in Canada and the U.S.

High Definition Television will be available to the consumer, by satellite distribution and possibly wide-band fibre in some urban areas.

Satellite services will have touched all areas of Canadian life in one way or another - Home Shopping, Banking, Information retrieval of all kinds is possible and an everyday occurrence with VSAT technology combined with wideband fibre networks. Major business centres will be linked to smaller centres by satellite feeder links.

A wide range of Educational services will have developed to provide improved standards of education for all Canadian children. National and Regional Education centres will be able to download educational material to classrooms on a call-up basis via satellite. Health services and access to specialists for consultation and diagnosis will be available for all who need them regardless of location.

Mobile telephones and data terminals will be standard in every vehicle with all Canada Coverage provided by a Mobile Satellite System (MSS). Maritime and Aeronautical communications and traffic control will be firmly in place via satellite with emergency location and Radio Determination Satellite Services available in every corner of the country.

Spectrum Planning Needs

Satellite services can aid the full commercial development in Canada. They can ensure equalization of services between urban and rural/remote Canadians so that no matter where one chooses to live in Canada, the quality of life will be similar. The sensible development of satellite services can bring these benefits to all Canadians in a practical economical fashion provided that careful planning and spectrum engineering takes place in the near future. Canada must continue to be assertive and pro-active in making our needs known to our United States neighbors so as to bring the necessary changes to fruition.

In the case of Mobile Satellite Services, spectrum issues and decisions can have serious impact on the economic viability of planned services. An example would be the proposed concept of reverse band operations for L-band mobile satellite spectrum sharing. While the idea may appear attractive from the point of view of spectrum efficiency, it would result in severe technical and hardware constraints which, if implemented could seriously affect the commercial viability of the MSAT venture and be a very difficult scheme to co-ordinate with other users. For a broad range of mobile services to develop, re-allocation of the spectrum should be considered. For example, the trend in Urban areas to serving individual homes and businesses with cable and wideband fibre should be reviewed. This trend may make converting some over-the-air broadcasting in the UHF and VHF bands to cable delivery only economically justifiable, thus freeing up badly needed spectrum for mobile development.

Radio Determination Satellite Services are required in Canada for navigation and emergency location. These can be provided as a logical adjunct and companion to Mobile Satellite Services in Canada, and adequate spectrum has to be found and allocated on an exclusive basis for future growth.

In order for necessary satellite services to develop in a way which is economical, exclusive spectrum must be available in the bands which are best suited for such services. Wherever terrestrial alternatives, such as fibre, are available which do not depend on Radio spectrum for their growth, serious consideration should be given to spectrum re-allocation. As technology develops, historical reasons for spectrum usage must be reviewed and spectrum planning must recognize these changes.

Terrestrial message services are clearly developing in the direction of wideband fibre and high-capacity digital radio systems. Perhaps the time has also come to consider planning for exclusive use of portions of the shared spectrum for satellite services. These bands are well suited for Canadian use and are already heavily utilized by the CBC and others. If we are to continue to make best use of satellite technology for the benefits of all Canadians, then innovative planning must be initiated. An orderly transition to dedicated spectrum, considering the economic life of existing facilities, can be achieved.

Conclusion

Satellites are here to stay and an important part of the future for Canada. Spectrum planning and policy must keep step with service development and technology change. We should:

1. Ensure efforts are directed towards allocating sufficient spectrum to support a commercial mobile satellite service.

2. Initiate study on the feasibility of release of portions of the shared spectrum for dedicated satellite usage.

3. Reverse historical patterns of forcing satellite technology to co-ordinate with terrestrial technology when viable alternatives exist for terrestrial use which do not rely on valuable radio spectrum.

The growth and development of commercial satellite services will depend on a progressive spectrum plan which is in concert with the technological changes and market demands. Canada must be assertive in our negotiations with the United States on spectrum matters to ensure Canada's future needs are met.

EVOLUTIONARY IMPACT OF NEW COMMUNICATIONS SERVICES ON FUTURE FIXED SERVICE SPECTRUM USAGE

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SUMMARY

The Canadian telecommunications network has been making tremendous strides in terms of both technological changes and capacity for meeting the growing communication needs of today's information society. A variety of message, data and image services have already begun their inexorable spread to the business and residential sectors. By the turn of the next century the network will be required to handle massive volumes of information. Many current services including electronic messaging, information retrieval systems, message switching and point-of-sale services will have evolved into general-purpose business services that will be more commonly used. It is anticipated that there will be a greater need for on-demand variable and large bandwidth capability for existing and new communications services. In addition, customized services, like virtual network services with user programmability, will find greater applications for corporate private networks.

To meet this new challenge, the network is increasingly being digitized and is evolving towards the integrated network architecture of ISDN. Although fiber is rapidly becoming a dominant transport medium replacing radio and copper for growth, digital radio will be needed in long-haul routes complementing fiber systems to meet network survivability requirements. In addition, digital radio will continue to be used where it is more economical, i.e. routes with existing structure, remote locations and areas with difficult terrain, and in local exchange networks for rapid deployment applications. In its role of complementing fiber systems with 565 - 1800 Mbps or higher capacity, digital radio will also need to have a much larger capacity, both from per RF channel and route capacity perspectives. This will require the use of wider channelling plans, allocation of additional fixed service spectrum above 23 GHz, higher route capacity through the use of multiple radio bands for long-haul routes and radio equipment with higher spectrum efficiency.

INCIDENCES DES NOUVEAUX SERVICES DE COMMUNICATIONS SUR L'ÉVOLUTION DE L'UTILISATION DU SPECTRE PAR LES SERVICES FIXES, DANS L'AVENIR

par

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RÉSUMÉ

Le réseau canadien de télécommunications s'est transformé de façon spectaculaire, tant du point de vue de la technologie que de celui de sa capacité de répondre aux besoins croissants de communications de la société contemporaine de l'information. Toute une gamme de services de transmission de messages, de données et d'images ont déjà amorçé une perçée irréversible sur le marché des services d'affaires et celui des services résidentiels. Au tournant du XXI^{e} siècle, le réseau devra acheminer des volumes gigantesques d'information. Un grand nombre de services actuels, y compris les systèmes de messagerie électronique, les systèmes de recherche d'information, les services de commutation de message et les services aux points de vente se seront transformés en des services d'affaires polyvalents dont l'utilisation sera plus généralisée. On prévoit un besoin plus marquant de services à largeur de bande variable et à grande largeur de bande à fournir sur demande pour des services existants et de nouveaux services. De plus, les services personnalisés, comme les services de réseaux virtuels comportant une possibilité de programmation par l'usager, seront plus largement utilisés pour les besoins des réseaux privés des entreprises.

Afin de relever ce nouveau défi, le réseau canadien est de plus en plus numérisé et il adopte progressivement l'architecture de réseau intégré des RNSI. Bien que les câbles de fibres optiques soient en train de supplanter les liaisons hertziennes et le câble en cuivre pour la croissance des réseaux, les liaisons hertziennes numériques seront nécessaires sur les voies d'acheminement à grande distance, en tant que complément des réseaux de fibres optiques, pour répondre aux besoins de survie des systèmes. De plus, les radiocommunications numériques continueront d'être utilisées dans tous les cas où il sera plus économique de le faire, c'est-à-dire dans le cas des artères faisant partie des structures existantes, des emplacements éloignés et des régions présentant des accidents de terrain marqués et dans les réseaux à accès local utilisés pour des fins d'exercice exigeant un déploiement rapide des effectifs. En tant que complément des réseaux de fibres optiques d'un débit de 565-1800 Mb/s ou plus, les réseaux de radiocommunications numériques auront également besoin d'une capacité beaucoup plus grande en voies RF et en voies d'acheminement. A cette fin, il faudra utiliser un plan élargi d'espacement des voies, attribuer des fréquences supplémentaires au-dessus de 23 GHz, et utiliser des antènes à plus grande capacité avec des radios à plusieurs bandes pour les voies d'acheminent à grande distance et pour le matériel radio à rendement spectral supérieur.

ORIGINAL : ANGLAIS

Spectrum 20/20 Symposium

EVOLUTIONARY IMPACT OF NEW COMMUNICATIONS SERVICES ON FUTURE FIXED SERVICE SPECTRUM USE

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1. INTRODUCTION

The advent of the information society is changing our day to day activities. This is quite clear, particularly, in the telecommunications environment. The telecommunications carrier industry in Canada has undergone significant changes over the past decade. A variety of voice, data and image services are being offered and further new services are being planned to meet rapidly growing and emerging new customer requirements.

Telecom Canada has been on the leading edge in providing a wide spectrum of telecommunications services, which are at the forefront of modern telecommunications scenes in Canada and to a large extent in the world (1). Before we discuss the main subject of this paper, it will be well worth reviewing the services Telecom Canada offers today - what they are, how fast they are growing and the evolution that is foreseen. This should provide a sound basis for the subject of this paper.

2. CURRENT TRENDS IN COMMUNICATIONS SERVICES

Digital data services started in 1973 when Telecom Canada (then Trans-Canada Telephone System) introduced the world's first national digital data service - Dataroute™. Dataroute supports multiple data rates, point-to-point and point-to-multipoint channellized transport services with an economical tariff structure. The speeds offered range from 100 bps through 1.2 kbps to 56 kbps with recent extension to 112 kbps to meet new demands.

Datapac™ is a well known public packet switched data network. When introduced in 1976, it was one of the first nation-wide commercial packet switched networks in the world. Datapac provides a wide range of packet assembly/disassembly services to computers and terminals using CCITT defined packet mode data transmission protocols. Packet switching is considered one of the most efficient uses of today's communications facilities, thus resulting in lower communications costs.

The growth of the Datapac network has been explosive over the past few years. The network currently supports approximately 30,000 customer connections, and is growing at an annual rate of about 30%. Figure 1 shows the current growth and its trend to year 1997. The Datapac service has had a significant impact on Canadian business. Datapac is used extensively for bulk data transfer and interactive applications such as time-share computing and centralized reservation systems. The service has also allowed retail businesses to implement point-of-sale terminals which are used for credit card verification, inventory control and data collection. Also Datapac is used to provide access to electronic directories, third party data base services and to text messaging services. The access speeds are currently up to 9.6 kbps and this will soon grow to 56 kbps or higher. Datapac currently provides international connections to over 50 foreign packet networks.

Datalink™ is an end-to-end digital circuit switched service introduced in 1983. Datalink supports synchronous data transmission at speeds of 2.4 kbps to 9.6 kbps and recently has been enhanced to support 56 kbps.

Megaroute™ is an integrated digital service supporting a non-channellized point-to-point DS-1 (1.5 Mbps) transmission rate. This service was introduced in 1985. The demand for this service is growing rapidly in two dimensions: One is Megastream™, a service subset of Megaroute which supports channellized nxDS-0 services which can be configured under customer control. The other dimension is that requirements for speeds of DS-1 rate and higher are growing for existing and new applications.

The early introduction of digital transport services has been complemented with the introduction of intelligent communications services such as electronic mail and directory services.

Envoy 100™ is a universally accessible public electronic messaging system introduced in 1981. More than 50,000 users are subscribing to this service which is growing at an explosive rate to meet the needs of rapid and efficient transfer of information requirements.

iNet 2000™ is an intelligent network function which permits users to access and manage data for various applications, typically data base access, directory services, file transfer and information services applications. It is expected that this market segment will rapidly grow with the customers' needs for simpler access to more information database services.

Today, Telecom Canada is at the forefront of communications as we progress in the evolution of the information society. This is illustrated by the current dramatic increase in demand for voice, data and image services, but as we progress towards the future, we also foresee significant changes in the market environment for new telecommunications services.

3. FUTURE REQUIREMENTS

The network is well positioned to meet today's market requirements but a combination of factors are causing users to reassess their existing and future service needs. New technologies, new service applications, tariffs, regulatory decisions and competition are all contributing to increased user awareness of the existing and possible future options available to meet their telecommunications needs. Consequently, market demands are expected to change significantly over the next decade.

New business opportunities are changing the way we do business. The telecommunications network will also change significantly over the next decade to meet the emerging needs of the information society, as indicated by the following market trends.

- The telecommunications industry will experience significant growth due to increases in information handling and processing by the knowledge workers.

- Communications and information processing will be increasingly specialized by market segments such as manufacturing, education, health, financial, etc.

- Market segmentation will result in a constant stream of new applications and terminal products that will contribute to a steadily increasing flow of information through the network.

- Customers will need flexible and wider bandwidth, high performance network management capabilities and economical tariff structures.

. Customers will need wide-band services to be provided on-demand with reduced provisioning intervals. In some cases, such a need will require the rapid deployment of digital radio in the local exchange network.

These trends are indicative of future communications requirements but Telecom Canada's main challenge is to plan the evolution of the network to provide these new requirements efficiently, and in a timely manner with new cost effective technologies.

Some of these new service requirements are rapidly becoming visible. For example, Integrated Office Systems (IOS) utilizing Local Area Networks (LANs) are evolving as the basic office tool for information handling. The capabilities and efficiencies of IOS are becoming a primary factor in the evolution of the office environment. The requirement to interconnect LANs with high bandwidth facilities will result in a growing demand for Metropolitan Area Networks, Wide Area Networks and the need for efficient interworking with the public network for voice, data and image services. The capability of IOS is also stimulating the interest of the building industry with the emergence of the "Intelligent Buildings" and "Smart House" concepts which will impose new service requirements on the network. This trend, coupled with the need for new intelligent services in the office, will provide an opportunity and stimulus for additional low and very high bandwidth data transfer services between the home and office through the network.

The development of the Integrated Services Digital Network (ISDN) concept and related technologies have reached a stage where numerous market trials are beginning. The characteristics of ISDN indicate the potential for feature enhancements of many existing services and new large bandwidth services. Bell Canada is scheduling a market trial to begin in mid-1987 to assess the market potential and service requirements.

Over the next decade telecommunications will be broadly redefined as a service business that can provide users with a selective array of services over and above the traditional information transport functions with a steady movement towards universal information services.

The network's capability to support a variety of services must be examined in conjunction with its three basic functional elements, namely, the 'transport' or 'carriage' element, the 'connectivity' or 'switching' element and the 'intelligence' or 'control/signalling' element. The advent of new, multibandwidth digital switches and intelligent network components linked with digital signalling systems provides a network infrastructure that will be attractive for many new types of services. For example, it is foreseen that private network facilities for large corporate business customers can be set up as a software controlled virtual network overlaid on the public network. This type of service will prove very attractive and will discourage large private corporations from building their own switching and transport facilities and possibly using a scarce spectrum resource inefficiently.

The capability of the network to handle the information services in the future will be dependent upon the capacities of its three functional elements. However, from a spectrum usage perspective the capacity of the transport network element is of main interest. Although the period around year 2000 is too distant to specifically estimate the future capacity for the transport network, nevertheless a rough indication of the needed capacity could be ascertained from the growth rates of existing services. Figure 2 shows the growth trend of message toll services which use the major portion of the transport network capacity. From the growth trend, it would appear that the required increase in capacity for message toll traffic over a 10 year period would be more than 50%.

Considering the explosive growth of today's data services such as Datapac (as in Fig. 1) and the explosive growth of a variety of emerging new services, these together with the message toll services by the turn of the century would require enormous increase in the capacity of the transport network.

The transport network function, which is the ability to transport any type of information and its corresponding signal format between users, is provided through the use of a variety of transmission media such as microwave radio, fiber, copper wire and satellite. The choice of a medium in any specific route or section of the network is dependent on several factors with cost-effectiveness and capacity being the key ones.

Carriers currently are the major users of the fixed service spectrum, since microwave radio relay systems today provide the bulk of the intercity transmission facilities. Efficient management of the spectrum use has been possible through the traditional and cooperative planning effort by the carriers and the DOC through the Radio Advisory Board of Canada (RABC). With the prospect of the explosive growth in network capacity in the future, the need for the timely availability of appropriate and adequate fixed service spectrum could be a critical factor. To assess this impact by future services on spectrum usage, it is necessary to review the current and future trends in transport media usage.

4. TRANSPORT MEDIA TREND

Microwave radio which was introduced in the 1950's using analogue technology has rapidly replaced copper based technology to become the dominant transport medium for the provision of intercity facilities. From the beginning, efficient spectrum management has been a major objective in further increasing the capacity and cost-effectiveness of radio routes. For example, the multiplexing of TV and 120 voice channels on the same RF channel, improving the loading capacity from initial 480 voice circuits to 1320 voice circuits and doubling of the 4 GHz analogue route capacity through the use of cross-polarization channels, have significantly improved the spectrum efficiency and cost-effectiveness of analogue radio systems.

4.1 Current Trend

As discussed earlier, point-to-point microwave radio relay systems presently provide the bulk of our intercity network facilities required for voice, data and video services. Since 1979, digital radio technology has been increasingly used for all radio growth. Spectrum efficiency has also doubled more recently to 4.5 bits/s/Hz. Other transport media, such as fiber optic transmission systems (FOTS), fixed-satellite and traditional copper cables serve to complement the use of radio as dictated by economics, transmission performance and route diversity considerations. In the local exchange network, radio use has been initially limited to remote regions in applications such as exchange radio telephone service (ERTS) and subscriber radio systems (SRS).

As a result of the declining trend in fiber cost combined with the doubling in fiber transmission system capacity every few years, fiber systems are finding increased use in supplementing the intercity radio facility. In the local exchange network which up to now has been dominated by copper, fiber systems are also being used increasingly, particularly in inter-office trunks and in major feeder routes to meet increasing on-demand customer needs for wide-band services. Integrated wide-band services such as Megaroute (1.5 Mb/s) and its subset Megastream are expected to be heavily used as local and intercity services.

Until recently, there has been very little use of microwave radio in the local loop plant of major metropolitan areas. But with the offering of Megaroute and the proposal for an even wider bandwidth service at DS-3 (45 Mbps) rate, there will be increasing need for digital radio systems in the 18 GHz and 23 GHz bands for the provision of local exchange facilities. Such radio use is indicative of the continued importance of radio as a prime transport medium for many years in the future.

More recently, there is a growing interest in the use of very low-power radio devices for providing wireless communications for office information networks, e.g. in-building LANs. Frequency bands in the range 30 MHz to 3 GHz are currently of interest. In this regard the DOC has gazetted for public comment a proposal to assess this technology which may have potential applications in the future.

4.2 Future Trend

As we move to the turn of the century, it is expected that the network will be evolving rapidly to become digital end-to-end. This not only provides economy for voice telephone services but also provides the opportunity to provide a full spectrum of digital voice, data and visual network services integrated on a common network technology infrastructure.

Fiber systems are expected to be more widely deployed in the intercity network and in the exchange network feeder plant to serve large business customers. Increasing use of fiber in the loop plant to residential subscribers may also be seen in this time frame.

Although fiber is becoming a dominant transport medium, digital radio technology will continue to be deployed to establish a resilient and diverse hybrid fiber and radio network infrastructure.

4.3 Future Areas of Digital Radio Application

Based on the current trend towards constant improvements in cost and performance, digital radio is expected to remain as a prime and competitive transport medium for many applications, some of which are briefly discussed as follows:

(a) Long-Haul Applications - Although long-haul fiber systems have potentially almost limitless capacity, their availability performance characteristics are generally poorer than digital radio. Like any cable-based system, and despite the most careful placement in restricted access rights of way, fiber will be subject to occasional cable-cuts. Customers will not be willing to tolerate long interruptions in service. On the other hand, radio systems rarely suffer long service interruptions due to the failure of towers or associated structures. Hence the need for alternate parallel systems which can provide both diversity and restoration capabilities to meet network survivability requirements (2).

Failures on long-haul fiber systems will be particularly disruptive to the network due to their large inherent capacity and the expected duration of these failures, typically several hours. As a result, it is necessary to address the question of quality of network service under failure conditions. Adequate service under failure conditions is provided by a combination of diversity and restoration. Radio provides the ideal technology for this purpose. Radio will continue to carry very substantial amounts of traffic, and in addition the protection channels on the digital radio will be used for restoration of the failed fiber facility. Prudent network planning will also provide for restoration of failed radio channels on the protection channels of the fiber.

(b) Remote Regions and Rough Terrain Areas - In this case radio is usually the technology of choice. The initial low capacity, low growth rate requirements for such applications combined with the high placement cost of fiber would favour the use of the digital radio alternative.

(c) Exchange Network - Fringe and Remote Areas - In many applications, radio will continue to be cost-effective for the provision of basic exchange telephone service to sparsely distributed subscribers in remote areas and areas with difficult topography. Depending upon the concentration of subscribers, an appropriate type of multi-point communication system (MCS) will be needed to meet normal service requirements.

(d) Exchange Network - Rapid Deployment - There is increased customer expectation that wideband or high speed digital services should be provided on-demand. However, fiber facilities to the customer premises may not be available when required thereby creating a problem in the local exchange network. Such cases would require the use of digital radio which would be rapidly deployed to provide service on-demand.

5. SPECTRUM CHARACTERISTICS FOR FUTURE DIGITAL RADIO

5.1 Wider RF Channelling Plan

Several factors, such as requirements for larger bandwidth services and digital multiplex standards for broadband services could influence the need for a wider RF channelling plan to achieve the desired transmission capacity. The proposed new Synchronous Optical Network (SONET) standard permitting connectivity of larger bandwidth services would provide bandwidth in multiples of approximately 50 Mbps. Further, the fiber system capacity is rapidly increasing and by the turn of the century will be beyond the 1.2 - 1.8 Gbps range. For long-haul digital radio systems, assuming a spectrum efficiency in the range of 6-9 bits/s/Hz per polarization, it would be necessary to have a channelling plan permitting the use of at least 40 MHz wide RF channels to allow more capacity for efficient interworking with fiber systems.

To meet the increasing demand for wide-band digital services in metropolitan areas, the higher frequency bands at 18 GHz, 23 GHz and above are most suitable. Higher frequencies permit savings through the use of small and compact equipment and antenna designs which can be more readily accommodated on roof top locations. Even with the expected improvement in spectral efficiency from a current value of 1 bits/s/Hz to say 2-4 bits/s/Hz, RF channel bandwidths wider than the present maximum of 80 MHz may be needed for larger bandwidth services.

5.2 Use of Multiple Bands

In order to provide adequate digital radio route capacity to meet growth, route diversity and network survivability requirements, the use of more than one frequency band in a long-haul route will often be required. For example, the combined capacity of lower 4 GHz, upper 4 GHz and 8 GHz radio bands will be required on some routes to provide diversity and restoration capability.

5.3 Additional Frequency Bands

For long-haul applications, the current spectrum allocations for fixed services in the 1-10 GHz range are expected to be adequate to meet foreseeable digital radio requirements.

For the local exchange network, the 18 GHz and 23 GHz bands are expected to be exhausted by the turn of the century. Consequently, it will be necessary to provide additional fixed service (digital) allocations in the 25-31 GHz and 37-40 GHz bands. To meet customer on-demand rapid service needs for wide-band services, separate spectrum for such a service should be allocated in the 18 GHz , 23 GHz bands and above.

6. IMPACT ON TELECOM CANADA NETWORK

The telecommunications networks of Telecom Canada presently make large use of the fixed services spectrum. In keeping with current practice, our main objective will continue to be to make efficient use of the digital radio spectrum wherever it provides a cost-effective alternative. The following lists the application areas in the network requiring the use of the fixed services spectrum that would be influenced by the new communications services at the turn of the century:

(a) Telecom Canada's long-haul radio network consists of two back bone routes, namely the Trans-Canada route and the

Inter-Provincial route. The 8 GHz digital radio (7725-7975 MHz/8025-8275 MHz) on both routes presently provides the bulk of the digital facilities and growth. The analogue radio in the lower 4 GHz band (3500-4200 MHz) which was capped in 1979 with the advent of the first 8 GHz route continues to provide facilities for message, data and video services.

To meet increasing demand for low cost, high capacity long distance facilities, Telecom Canada has begun the construction of its first long-haul coast-to-coast fiber system paralleling the radio routes (3). The fiber system is being implemented in phases and is expected to be fully operational by 1991.

Following the completion of this fiber system, a very high capacity and cost-effective digital radio system using state-of-the-art technology with a spectrum efficiency of 6-9 bits/s/Hz, is proposed in the early 1990's to be overbuilt on the two existing radio routes using initially the upper 4 GHz band (4400-5000 MHz). Subsequently, the same digital radio technology will be introduced in the lower 4 GHz band to gracefully evolve from analogue into mixed analogue/digital operation, and finally changed to full digital operation. Because of the change over from the 20 MHz analogue channelling plan to the wider 40 MHz digital channelling plan, the lower 4 GHz analogue system will have to be significantly unloaded. Consequently, the availability of the upper 4 GHz band will be essential to facilitate the roll over of the lower 4 GHz analogue radio into the digital operation. With the exhaustion of capacity in the lower and upper 4 GHz bands, it may then become necessary to upgrade the 8 GHz band digital radio using state-of-the-art technology available at that time.

It should be noted that the use of all the three radio bands, i.e. lower 4 GHz together with upper 4 GHz and 8 GHz, will be required to provide the necessary capacity to meet appropriate route diversity and network survivability requirements in conjunction with the fiber system.

In digitizing the lower 4 GHz band, it may be difficult to retain any analogue channels for video services. On the other hand there may be significant performance and cost opportunities to be gained in transferring the video services to digital facilities.

(b) For the local exchange network, the 18GHz and 23 GHz bands currently used are likely to be exhausted. Additional frequency bands, e.g. 25-31 GHz and 37-40 GHz using wider channelling plans will be required to meet wide-band service requirements. Further, separate band segments should be allocated in the 18 GHz, 23 GHz bands and above for on-demand rapid service needs for wide-band services.

(c) In remote geographical areas where the use of traditional loops would be prohibitively more expensive, multi-point communications service (MCS) in the 450 MHz/800MHz/1500MHz bands using digital technology will be needed. It should be noted that the 1500 MHz band is currently used extensively by Telecom Canada members for the provision of analogue MCS systems.

(d) For fringe areas, the 150 MHz and 450 MHz bands will continue to be needed for the provision of basic exchange telephone service.

7. CONCLUSION

The growth of today's communications services and the introduction by the turn of the century of a host of future information services will require an enormous increase in the capacity of the telecommunications network, including the microwave radio network. Although the steady growth on the large base of message toll services will still provide the largest portion of traffic volumes in the network, the large growth in information services is expected to have increasingly more significant impact on need for capacity. In view of this trend, the members of Telecom Canada have been carrying out research to exploit the transmission efficiencies of fiber and digital radio systems needed to provide the future capacity. We believe that by using state-of-the-art spectrally efficient digital radio systems, existing fixed services spectrum allocations, including the upper 4 GHz band, will likely be adequate for intercity network requirements. Some additional frequencies above 23 GHz will be required for the local exchange network and separate band segments will need to be allocated for on-demand rapid service needs.

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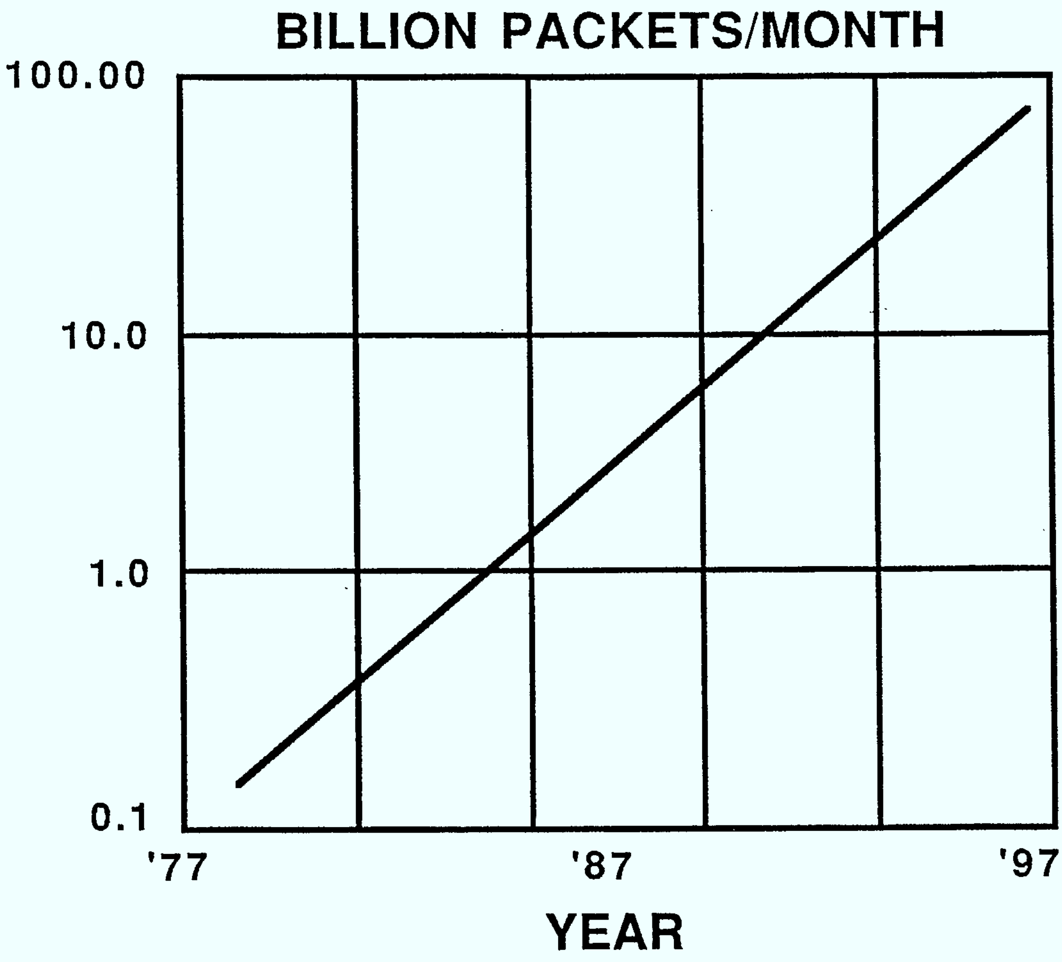

FIGURE 1: DATAPAC GROWTH

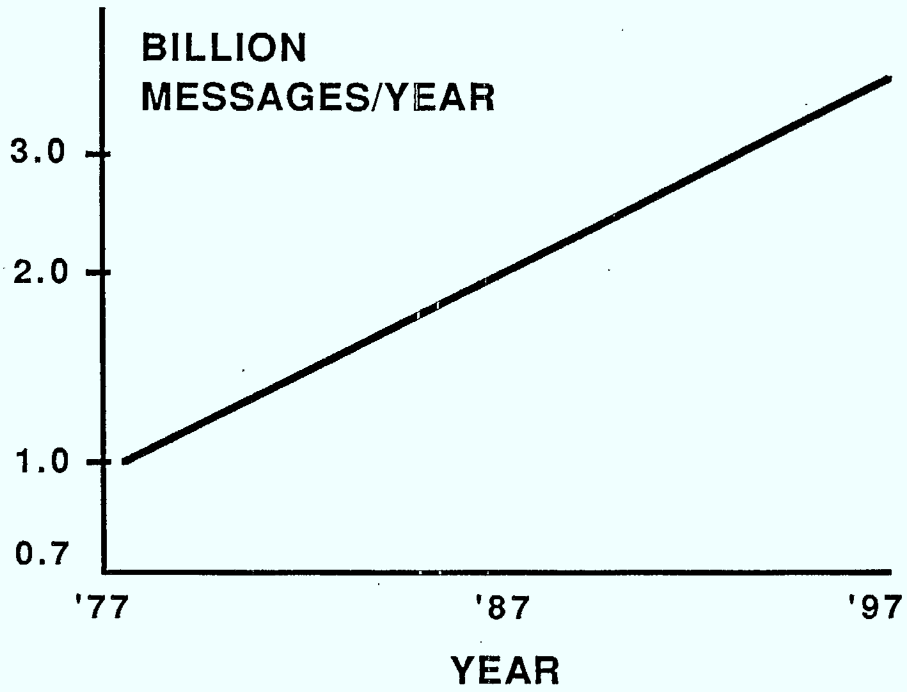

FIGURE 2: MESSAGE TOLL GROWTH

THE INTERNATIONAL DIMENSION IN SPECTRUM UTILIZATION

by

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ABSTRACT

International agreements are of a political and economic character no less in telecommunications than in other commerce and industry. But radio communications require accord on a significant range of technical elements as a basis for international coordination. Appropriate frequency bands must be identified for development of new services and introduction of new technologies; compatibility (reasonable protection from interference) must be assured among the shared uses of the frequency spectrum, and regional and world-wide interoperability is required for some systems or services.

International radio regulatory and administrative arrangements are carried out through the International Telecommunication Union, its Administrative Conference and its International Frequency Registration Board (IFRB). The ITU's International Radio Consultative Committee (CCIR) contributes to the process by its studies of technical and operating questions, and by its recommendations on spectrum utilization and characteristics of systems. Many countries devote specific research to this process.

In this paper, technical elements underlying international coordination are examined for mobile services, television and sound broadcasting, satellite fixes service, microwave radio relay, and certain other uses such as radionavigation, space research and radioastronomy. Examples of some possible interactions between apparently unrelated services illustrate additional dimensions of the coordination problem, such as the question of compatibility between safety services at VHF and broadcasting service planning in an adjacent band, and concern about possible interference from digital television studio equipment.

Recent developments and trends are reviewed, with implications considered for future spectrum utilization, including cellular mobile radio systems and personal communications, high definition television and broadcasting in the multi-media era, the evolution of satellite communications, and the trend to digital wide-band high capacity radio relay systems compatible with fibre optic networks. In spite of increasing technical complexity, problems of international coordination of spectrum resource sharing are becoming less susceptible to technical solution because of growing emphasis on non-technical factors.

LA DIMENSION INTERNATIONALE DE L'UTILISATION DU SPECTRE

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RÉSUMÉ

Dans le domaine des télécommunications comme dans les autres secteurs du commerce et de l'industrie, les ententes internationales revêtent un caractère politique et économique. Cependant, en radiocommunications, il faut s'entendre sur une importante gamme d'éléments techniques pour assurer les assises d'une coordination internationale. Il faut désigner les bandes de fréquences nécessaires pour le développement de nouveaux services et l'adoption de nouvelles technologies; assurer la compatibilité (un niveau raisonnable de protection contre le brouillage) entre les diverses utilisations partagées du spectre des fréquences radioélectriques, et garantir l'interopérabilité de certains systèmes ou services à l'échelle régionale ou à l'échelle mondiale.

Des ententes réglementaires et administratives internationales en matière de radiocommunications sont conclues par l'intermédiaire de l'Union internationale des télécommunications, de ses Conférences administratives et de son Comité international d'enregistrement des fréquences (IFRB). Le Comité consultatif international des radiocommunications (CCIR) de l'UIT contribue au processus en effectuant des études sur des questions techniques et opérationnelles et en formulant des recommandations sur l'utilisation du spectre et les caractéristiques des systèmes. Un grand nombre de pays consacrent des travaux de recherche spécifiques à ce processus.

Dans le présent document, on examine les éléments techniques qui sous-tendent la coordination internationale des services mobiles, de la télévision et de la radiodiffusion sonore, du service fixe par satellite, des relais hertziens à micro-ondes, et de certaines autres utilisations comme la radionavigation, la recherche spatiale et la radioastronomie. On y donne des exemples de certaines interactions possibles entre des services entre lesquels il n'existe aucune relation apparente, pour illustrer d'autres dimensions du problème de la coordination, notamment la compatibilité entre les services de sécurité fonctionnant dans la bande des VHF et la planification des services de radiodiffusion dans une bande adjacente, ainsi que les préoccupations que suscite le brouillage pouvant être causé par le matériel numérique de studio de télévision.

On y passe en revue les progrès et tendances de l'heure, ainsi que les incidences pour l'utilisation future du spectre, des nouvelles technologies, notamment les systèmes radiotéléphoniques mobiles cellulaires et les radiocommunications personnelles, la télévision à haute définition et la radiodiffusion multimédia, l'évolution des télécommunications par satellite et la tendance à l'utilisation de réseaux hertziens numériques à large bande et à grande capacité, compatibles avec les réseaux de fibres optiques. Malgré leur complexité technique de plus en plus marquée, les problèmes de coordination internationale du partage de la ressource spectre deviennent moins susceptibles d'être réglés par une solution technique, en raison de l'importance accrue des facteurs autres que techniques.

ORIGINAL : ANGLAIS

THE INTERNATIONAL DIMENSION IN SPECTRUM UTILIZATION

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Introduction

Our neighbors and friends, and the popular press in many countries, readily perceive telecommunications as a richly developing and highly technical domain. Advances in video information services, computer communication, and satellite systems top lists of marvels of high technology.

A range of technical elements in radiocommunications requires international understandings and arrangements. Regional or world-wide operability of systems or networks is based on agreed standards and technical coordination. Sharing of the limited spectrum resource depends on a measure of common understanding of the relevant physical laws of wave propagation, understanding of performance of advanced communication technology, and agreed criteria for sharing. New radio technologies and services have to be accommodated in appropriate frequency bands and regulated to avoid harmful interference.

But arrangements and agreements in telecommunications whether concerning networks or frequency spectrum, are essentially of a economic and political character no less than in other international commerce. This mix of technical, economic, and political elements characterizes the international dimension of telecommunications, and particularly of the spectrum usage.

The development of standards, and the promulgation of the necessary regulatory and administrative arrangements are carried out in the framework of the International Telecommunication Convention and the International Telecommunication Union (ITU). ITU is the intergovernmental organization of 162 member countries signatory to the Convention. The seniority of ITU among all international organizations testifies to the compelling need for such coordination. ITU's role originated in the first agreements on transborder telegraphy more than 120 years ago, and was extended to radio soon after introduction of practical radiocommunications.

The Convention obliges all Members of the ITU to share the radio spectrum in a rational and economic manner, and to prevent harmful interference. ITU Administrative Radio Conferences allocate frequency bands for the various services, and establish regulations, frequency plans, frequency assignment and coordination procedures, intended to assure efficient and compatible use of the spectrum.

The Radio Regulations define the basic parameters and procedures necessary for spectrum sharing. Their Article 5, for example, requires conformity of technical characteristics of stations, such as frequency tolerance and spurious emission power levels with the standards. Article 9 requires that frequency assignments should be made in accordance with the Table of Frequency Allocations, or in such a way as to avoid harmful interference to services operating in accordance with the table. Article 27 gives specific provisions for terrestrial radiocommunication services, including radio relay, sharing frequency bands with space radio communication services above 1 GHz. These concern choice of sites and frequencies, and power limits, to avoid interference with satellites in the geostationary satellite orbit. Other articles impose analogous regulations on the space service to protect terrestrial radio relay links, including maximum power flux densities from satellites at the earth surface, or transmitted along the horizon by satellite earth stations. The choice of sites and frequencies to assure adequate geographical separation of radio relay stations and satellite earth stations is to be in accordance with CCIR Recommendations.

The International Frequency Registration Board (IFRB) records and registers frequency assignments made by the different countries, and performs some compatibility analyses, in accordance with requirements and procedures provided by the Radio Regulations and Administrative Radio Conferences. Notification to IFRB of assignments is generally required only if the assignment is capable of causing harmful interference to a service of another administration, or if the frequency is used for international radiocommunication, or if it is desired to obtain international recognition (protection) of the use of the frequency. Most microwave radio relay and land mobile frequency assignments are therefore a matter of national concern, requiring coordination with adjacent countries only where necessary.

ITU's International Consultative Committees, CCIR and CCITT, study technical and operating questions and issue Recommendations. The CCIs have membership of government telecommunication administrations, and also participation of recognized private operating agencies and scientific and industrial organizations, as well as international organizations such as Intelsat, International Maritime Organization (IMO), International Electrotechnical Commission (IEC). The CCIR recommends technical elements for spectrum utilization, and technical bases for administrative radio conferences. CCIR and CCITT both develop recommendations on system characteristics, the CCIR for radio systems and the CCITT for non-radio systems, for overall network questions for public telecommunications, and also for tariff matters.

Many countries devote specific engineering research to the CCI process, in laboratories of government, industry, or telecommunication operating organizations. It is important to remember that "telecommunications" today, as dealt with by ITU and defined by the Convention, has many aspects besides public network services: radio and television broadcasting, maritime and aeronautical communications, radionavigation and radar, meteorological and other special satellite services, telecommand and telemetry of space systems, and many private and military fixed and mobile services. Indeed, scientific uses of radio, as for radioastronomy and geophysics, and for dissemination of standard frequency and time are also part of the picture. The wide range of radio services which do not form part of the public telecommunication networks are of great economic importance and clearly figure in your conference devoted to the future of spectrum utilization.

A number of ways can be used to view international coordination of spectrum utilization. One can study the use of various frequency bands, or the structure and processes for allocation, planning and assignment of frequencies, or the needs of individual radiocommunication services. We choose an alternative to review actual ITU activities and decisions for the past twelve months. It gives a partial story, but concrete examples. We would emphasize administrative radio conferences and the CCIR activities.

Administrative radio conferences

Table 1 lists the ITU Administrative Radio Conferences in the last twelve months and shows their main results. There were two regional and one world conferences.

Regional Administrative Planning Conference for the broadcasting service in the band 1605-1705 kHz in Region 2 - BC-R2(1)

An additional frequency band (1605-1705 kHz) was allocated by the WARC-79 for the MF broadcasting service in Region 2 (Americas), subject to the preparation of a plan for its use. The planning conference consists of two sessions. The first one, BC-R2(1) held in 1986, defined technical criteria for establishing the plan, and a planning method and guidelines for the agreement to be used by the second session, having regard to the need for sharing with other services (fixed, mobile, radiolocation). The BC-R2(1) decided that the band 1605-1625 kHz will be used in the region exclusively by the broadcasting service, and the band 1625-1705 will be allocated to the broadcasting service on a primary basis, to the fixed and mobile services on a permitted basis and to the radiolocation service on a secondary basis.

The future plan, to be established by the second session of the Conference in 1988, will be an allotment plan. Allotment means the entry of a designated frequency channel in an agreed plan, for assignment by administrations under specified conditions. The plan will be based on the use of standardized parameters established by the First Session for 10 channels available in the band 1605-1705. The Region will be divided into allotment areas, to which a number of channels will be allotted in the plan. Each country will be entitled to use one or more of these channels. An allotment plan offers flexibility to administrations for setting-up new broadcasting stations.

Regional Administrative Radio Conference for the planning of VHF/UHF television broadcasting in the African broadcasting area and neighbouring countries - AFBC(1)

Twenty-four years ago, in 1963, Africa started to establish plans for sound and television broadcasting. The first TV plans provided for the installation of 5635 transmitting stations over the continent. Due to practical and economical limitations some amendments to the plans were necessary since that time. In 1986, according to the Resolution 509 of WARC-79, interested African and neighbouring countries met at the first session of the Conference to review and revise the VHF/UHF TV broadcasting plans in the band I: 47-68 MHz, band IV: 470-582 MHz and band V: 582-960 MHz. The purpose of this first session was basically to adopt the technical bases for the revision/establishment of the frequency assignment plans at the second session. The technical data concerning the propagation, protection and planning criteria, and planning methods were prepared by the CCIR in 1985.

World Administrative Radio Conference for the planning of the HF bands allocated to the broadcasting service - HFBC(2)

The WARC-79 decided to convene a world conference to solve difficulties encountered in HF broadcasting by planning the use of the allocated bands. The situation in this service was considered no longer satisfactory to meet the numerous and increasing requirements for use of HF bands allocated to the broadcasting service. It may be recalled that earlier such conferences, held in 1947 and 1952 had been unable to arrive at acceptable plans for HF broadcasting. The First Session of HFBC met in 1984 to adopt the technical standards, planning principles, and a planning method. The technical standards approved during the First Session were based mainly on CCIR results, including special preparatory studies.

The WARC HFBC(2) had two main objectives: first to consider one or more trial seasonal plans developed on the basis of the technical criteria and planning principles adopted by the First Session, and then to adopt the procedures for the preparation and implementation of seasonal plans based on the requirements submitted by administrations. Requirements are defined to provide a broadcasting service during a specified period of time to a specified reception area from a particular transmitting station. Analysis of the trial plans demonstrated that the HFBC Planning System could satisfy only a fraction of requirements submitted by administrations (some 18,000 requirements) and did not provide adequate continuity of frequency use. Consequently, the Conference could not adopt the HFBC Planning System as developed, and decided to improve it, with a view to eventual application in certain parts of bands, and to rely on a Consultation Procedure in the remaining parts of HF bands. The HFBC Planning System designates appropriate frequency assignments according to agreed criteria and methods, and having due regard to all countries' requirements. The Consultation Procedure foresees that each administration chooses frequencies to be used; once incompatibilities are identified by the IFRB as a result of the analysis of all notified frequencies, administrations solve them bilaterally. Once the system has become effective, 1880 kHz (60% of the total of 3130 kHz are available for short-wave broadcasting in bands between 6 and 26 MHz) will follow the application of the Consultation Procedure and 1250 kHz (40%) will be subject to the improved Planning System. In the lowest (6 and 7 MHz) frequency bands, where the congestion is most severe, only the Consultation Procedure is applied.

The Conference formulated principles intended to ensure the equality of rights of all countries, large or small, and the equitable access to the HFBC bands as well as more efficient utilization of those bands. All broadcasting requirements, current or future, national or international, are to be treated on an equitable basis; the planning process is to be flexible to take into account new requirements and allow modifications to the existing requirements. While the Conference did not compel single sideband broadcasting (SSB), it adopted a Recommendation that transmitters installed after 1990 should be capable of working either single sideband and double sideband or in the SSB mode alone.

It was also agreed that a future World Administrative Radio Conference, to be convened not later that 1992, will have to consider the improved HFBC Planning System and results of the Consultation Procedure. On the basis of the analysis of test results, the Conference will decide on the date of introduction of the dual approach. The satisfaction, on an equal basis, of a minimum of broadcasting requirements submitted, with a level of reliability to be adopted by the 1992 Conference, is assumed. In addition, the 1992 Conference will be requested to take steps to settle the question of the processing of national broadcasting requirements.

CCIR activities

Just a year ago, the CCIR XVIth Plenary Assembly at Dubrovnik approved Recommendations developed during the 1982-1986 period, in which some 2450 delegates from 54 countries participated in Interim and Final Study Group meetings. Some of the results:

- several Recommendations directed toward increased communication capacity of the fixed satellite service using the geostationary satellite orbit, including reduction of permissible off-axis radiation from earth stations, and allocation of increased allowances of permissible interference between satellite networks as part of the overall network noise;

- a new Recommendation was issued on performance criteria for digital satellite systems compatible with the performance of integrated services digital networks (ISDN) set out by the CCITT;

- new Recommendations were adopted on channelling arrangements for digital microwave radio-relay systems, and performance objectives consistent with requirements of ISDN;

- on the general aspects of spectrum utilization and monitoring, a revised Recommendation on Spectra and Bandwidth of Emissions modified some concepts of application of fundamental definitions; also significant were updated Reports on spread spectrum techniques, and a review of spectrum utilization between 40 and 3 000 GHz;

- new Recommendations were issued on analogue cellular land mobile telephone systems, and a decision taken for urgent study of future public land mobile telecommunication systems. This study, chaired by Canada, has in view a Recommendation on the characteristics of future mobile systems to be approved by the next CCIR Plenary Assembly. The study includes the concept of personal mobile communication, working across national frontiers, and suitable frequency bands to facilitate such international working;

- a Report giving technical characteristics of the Future Global Maritime Distress and Safety System was completed to facilitate implementation of the system by the International Maritime Organization; a new CCIR Recommendation specifies the characteristics and performance of search and rescue transponders (SAR) for locating survivors;

- a simplified and improved radio propagation prediction method for high frequency broadcasting, tested against a substantial data band, was approved, along with procedures for estimating reliability, providing the propagation prediction basis for the WARC-HFBC;

- substantially improved VHF/UHF propagation prediction bases were approved, applicable to radio-relay systems, earth-space paths, broadcasting and mobile services. New Recommendations applicable to frequency sharing between earth and space services were approved, covering evaluation of interference between stations on the surface of the Earth, between stations in space and on the surface of the Earth, and on the calculation of coordination distance.

Table 2 lists the administrative radio conferences for which CCIR preparatory work is underway. Later this year the world conference for the mobile services (MOB-87) will be held. The two conferences foreseen for 1988 are: the Second Session of the World Administrative Conference on the use of the geostationary satellite orbit, WARC-ORB(2), and the Second Session of the Region 2 conference BC-R2(2). The Convention provides for CCIR to hold conference preparatory meetings. Neither Recommendations nor Conclusions presented to an Administrative Radio Conference are mandatory, but their force is significant because of the consensus they represent with respect to the technical contributions of administrations. The technical elements of conference decisions are largely based on the CCIR work.

Preparations for the World Administrative Radio Conference for the Mobile Services (MOB-87)

In June/July 1986, a special meeting of CCIR Study Group 8 on Mobile Services prepared technical bases for the World Administrative Radio Conference on Mobile Services to be held in August 1987. The CCIR conclusions cover technical and operational elements to be dealt with in the agenda of the conference, to name a few: terms and definitions; the use of public correspondence with aircraft; maritime radiolocation systems using spread spectrum; choice of a frequency for transmission of meteorological and navigational warnings; digital selective calling for distress and safety communications; spectrum sharing considerations for the 1.6 GHz distress and safety band and the special problem of co-channel use of frequency bands around 1.6 GHz for radioastronomy and an earth station transmitter in the mobile satellite service; a number of other topics concerned with distress and safety services, including the Future Global Maritime Distress and Safety System. These items constitute a small fraction of the CCIR Report to the Conference which itself must consider more than 140 agenda items, most having impact on spectrum utilization. An even more recent contribution by the CCIR Interim Working Party on Public Land Mobile Telecommunications has been prepared for information of the conference. The report addresses frequency utilization issues in the future of land mobile communications.

Preparations for the Regional Administrative Radio Conference to establish a plan for the broadcasting service in the band 1605-1705 kHz in Region 2 (BC-R2(2))

For the First Session of the Conference, the CCIR prepared, inter alia, propsals for allotment planning procedure, for limitation of radiated power to 1 kW, for use of quarter-wave omnidirectional transmitting antennas, and for protection ratios for various services. The Session approved these proposals, and requested the CCIR to prepare for the Second Session recommendations concerning the relationship between physical and electrical antenna height in the 1605-1705 kHz band, and the sharing criteria for services using this band in Region 2. The relevant studies are carried out in the framework of a Joint Interim Working Party which meets in Lima (Peru) from 13 to 15 May this year. The Report of the JIWP will be submitted in due time as a Conference document.

Preparations for the World Administrative Radio Conference on the use of the geostationary-satellite orbit and the planning of the space services utilizing it (WARC-ORB(2))

The First Session of WARC-ORB has identified inter-sessional studies to be carried out by the CCIR to provide certain technical information for the Second Session. These can be divided into four topic groups relating to: Fixed-Satellite Service (FSS), sharing aspects Fixed-Satellite Service with Fixed Service (FSS/FS), Broadcasting-Satellite Service and Feeder Links, and Inter-Service sharing other than FSS/FS.

The CCIR studies include technical characteristics of the Fixed Satellite Service (FSS) in the frequency bands 30/20 GHz with a view to taking a decision on the future planning of these bands by a future competent Conference. The demand for satellite networks will vary between different frequency bands and in different arcs of the geostationary orbit. Thus, where constraints are applied to satellite network characteristics, it may be feasible to set mild constraints for some frequency bands and orbital arcs, where the demand is low, even though more stringent constraints have to be applied where the demand is high. Inter-sessional study is required to determine how this might be achieved. Potential benefits and disadvantages of orbit sectorization are to be studied, keeping in mind, for instance, reduction of inhomogenity of satellite systems, constraints on choice of orbit location, impact on efficiency of use of orbit/spectrum, and the need for guard arcs between sectors. The single entry permissible interference level for networks using the orbit is being revised.

Another topic to be studied is the concept of "burden sharing", including equitable interference and relocation, determination of the extent of parameter adjustment practicable over a period of time, and evaluation of the benefits and technical, operational, and economic problems arising from a requirement for flexibility of orbital position, as well as consideration what regulatory action might be appropriate, if any. The CCIR should also identify and evaluate various sets of generalized parameters for planning and coordination, determine an appropriate side-lobe reference radiation pattern for earth-station antennas for which the ratio of antenna diameter to wavelength is less than 150, and study the physical interference process including identification of the relevant factors and evaluation of the risks of such interference in the future.

CCIR studies on reverse band working (RBW, i.e. the use of a given band for both uplink and downlink working) are focused primarily on national and regional systems. Considerations are given to the impact of the introduction of RBW on the orbit/spectrum resources available to the FSS, on freedom to locate earth stations, on limits imposed on satellite antenna radiation patterns, on planning of other space and terrestrial services, and on the most economically way of implementing RBW. Inter-sessional studies are being carried out to ascertain how much benefit could be obtained from polarization discrimination between networks, and to determine if the technical content of Appendix 29 of the Radio Regulations should be revised in order to increase the accuracy with which the need to coordinate satellite networks evaluated, to simplify the application of the process and make it more practical. Spurious emissions from space stations, sharing criteria for various services, satellite sound broadcasting systems for individual reception by portable and automobile receivers, high-definition television, up-link power control, are also the topics for intersessional studies for WARC-ORB(2).

Some special topics in electromagnetic compatibility

There are a number of special issues in electromagnetic compatibility under study in CCIR, of which we can mention only a few.

We have mentioned the CCIR standard for digital studio television adopted in 1982 and extended in 1986 to recording, with current studies devoted to transmission aspects. The 13.5 MHz sampling frequency for colour component video signals was chosen to allow equal applicability to 625 line/50 Hz and to 525 line/60 Hz systems. It is of interest that the 9th harmonic of this sampling frequency falls at 121.5 MHz, coinciding with aeronautical distress frequencies. CCIR studies are underway to recommend radiation control criteria to avoid any potential interference. Certain preliminary analyses indicate that a radiation limit of about 30 uV/m at 121.5 MHz at 10 m distance, would probably be sufficient to protect the aeronautical services in that band. These values are in line with the CISPR limits for radiation from information technology equipment.

Another special compatibility question for aeronautical safety arises at the 108 MHz band edge separating VHF/FM broadcasting and aeronautical mobile bands. The concern is that high-powered FM broadcasting transmitters operating in the 87.5-108 MHz frequency band can interfere with mobile aeronautical services that use the adjacent band of 108-136 MHz over adjacent geographical areas. Two aeronautical radionavigational systems: Instrument Landing System (ILS) localizer (108-112 MHz) and VHF Omnidirectional Range (VOR) (108-118 MHz), and the aeronautical mobile (R) service (118-137 MHz) use this band. Frequencies allocated to the last service are reserved for communications related to safety and regularity of flight between any aircraft and stations concerned with flight along national or international civil air routes. Three different mechanisms are identified as capable to generate harmful interference: the out-of band and spurious emissions from the transmitters, desensization (front-end overloading) of the airborne receivers by a strong FM signal, and intermodulation due to interaction of several FM signals with non-linear devices in the airborne receiver, and a method of analysis and prediction of the interference, based on CCIR studies, was defined. Current studies are concentrated on further refining of protection ratio values for present and future airborne receivers against specific classes of interfering emissions and on improved prediction methods for intermodulation interference effects.

Earlier CCIR studies of this question, in a joint working group involving aeronautical and broadcasting experts, were used by the Region 1 VHF broadcasting conference in 1985. Continuing studies were requested with a view to consideration by a world conference. The joint group has, within the past month, prepared a guide for use in the implementation of FM broadcasting plans.

Spectrum pollution by non-telecommunication sources

There are two broad classes of potential radio-interference sources explicitly mentioned in the Convention: radio stations that convey intelligence, and all other electrical apparatus and installations. One large sub-class of electrical apparatus and installation is specifically pointed out in the Radio Regulations as a source of interference to radiocommunication services. It is Industrial, Scientific and Medical (ISM) radio frequency equipment.

About a hundred million ISM generators, worldwide, are activated every day. Many of them deliver power measured in hundreds of kilowatts or more, at frequencies spreading from 50 Hz up to the Gigahertz bands. They all are necessary to maintain manufacturing processes in various industries, to continue medical treatment in hospitals, to support scientific research in laboratories, to prepare meals in homes, and to make many other things without which our society could not continue in its present form. Each ISM generator, in addition to its intentional function, unintentionally radiates a fraction of its power into space. This is due to unavoidable imperfections in its construction and exploitation, and due to laws of nature. Consequently, it acts like an unintended radio transmitter. Although this radiation does not convey any useful intelligence, and although the power radiated amounts only a very small fraction of the nominal power, it can interfere with various radiocommunication services. If an ISM generator produce the same frequency at the same place and at the same time as the intended radio transmission uses, harmful interference may occur.

The WARC-79 took two key steps to limit such interference. Firstly, it designated new frequency bands for ISM applications. Secondly, it requested the CCIR to specify the limits to be imposed on the radiation from ISM equipment. The studies are now under way, in collaboration with the IEC and CISPR. This action, and ensuing CCIR studies, are of a basic significance. The ISM radiation limits recommended by the CCIR may be incorporated in the ITU Radio Regulations at some later Administrative Radio Conference. It would be then incumbent upon each of the 162 countries-signatories of the Convention to implement these limits in their national regulations as a mandatory requirement. Thus, the WARC-79 created a completely new situation with potentially important legal, technical and economic consequences. As ISM applications of radio waves have been implemented in many industries and services vital to the society, these consequences extend beyond the scope of telecommunications.

The future

We approach the question of future spectrum utilization on the assumption that development will reflect present trends. Certainly a first order effect is the acceleration of economic and social development in most of the world, with enhanced awareness and use of advanced technology. Electronic information services, and public and private telecommunications are widely accepted to represent one of the most rapidly growing sectors of industrialized economies, and great efforts have been underway to extend such facilities and benefits to developing countries. This translates to increasing communication capacity throughout the world and increased competition for the spectrum resource. It must be emphasized that this competition involves not only more capacity and more services but also the interests of an increasing number of countries.

Another main factor is the transition to digital systems. Digital technology is becoming, for reasons of economics and service capabilities, the mainstream of telecommunications. The bandwidth implications are significant. What use to be a 4 kHz voice channel now requires bandwidth for 64 kbit/s. A wide introduction of fiber optic cables may not reduce the demand for radio services. The economy of fibre optic cables depends upon high traffic density. Full exploitation of fibre optic facilities may even stimulate increased requirement for mobile communications on land, sea and in the air, and for connecting satellite and other radio links on routes where fibre optics would be less economic.

Radio and television broadcasting are today at cross-roads, especially in industrialized countries where satellite distribution and cable systems, and video cassettes offer an abundant choice of mass-information and entertainment media. The economic situation for broadcasting is eroding, and broadcasting organizations are actively pursuing new programming approaches, new services, and new technology. The growing use of satellite news gathering requires coordination of use of frequency bands and operational procedures in different countries. Digital sound and television studio production and recording for programme exchange have been the subject of a new international standard which supports equally any of the national colour broadcasting standards, NTSC, PAL or SECAM. Equipment is becoming available and digital studios are being implemented. The standard provides for a family of digital hierarchies ranging from high definition television (HDTV) rates near 1 Gigabit/s, through conventional television 216 Mbit/s, to reduced bit rate electronic news gathering. With HDTV production equipment available from about 30 companies worldwide, technical studies are shifting to transmission and distribution systems for the home viewer with important implications for future spectrum requirements. One CCIR working group is charged to study the possibility of a world-wide frequency band which might be suitable for satellite broadcasting of high definition television. With its significant implications for spectrum utilization, HDTV is a rich field for development of the needed signal processing and compression, and perhaps eventual digital transmission to the viewer.

Already in 1979, the World Administrative Radio Conference was confronted with greater demands for expansion of allocated frequency bands to different radiocommunication services than could be physically realized. There were some transfers of portions of the spectrum from one service to another, but there was a significant increase of the "shared" use of bands by two or often more services, as for example by mobile service and television, or broadcasting and fixed service. Thus, the progressive congestion of bands for each service is further complicated by sharing arrangements which require geographical separation, band segmentation, or other technical criteria for protection from interference. The subsequent series of planning conferences, held in the 1980's to plan in detail the use of frequencies in the various services and bands, encountered great difficulty. The situation justifies further sophistication of planning methods and improvement of technical criteria. But the physical limits of usable frequency bands, and of present technology, transform the problem largely into one of resource sharing, where political and economic considerations prevail.

To the complexity of band-sharing arrangements must be added the radio environmental consideration of non-telecommunications industrial and electronics pollution of the spectrum, addressed by the WARC-79. Interference from non-telecommunication sources is difficult to manage because it is difficult to identify and because control of radiation from such devices imposes costs on their users.

Requirements for communication bandwidth can only be expected to expand in future years, although there is reason to expect that technical advances such as high level modulation, spread spectrum, and packet techniques, might offer increased capacity of a given bandwidth for some services. It is interesting that international administrative arrangements for frequency utilization do not yet deal with spread-spectrum technology. The cost of development and introduction of these advanced techniques on a wide scale is one of the economic aspects of spectrum utilization. For some services, as short-wave broadcasting, it can be argued that significant change in technology cannot be implemented in less than a few decades out of consideration for investment in receivers.

To insist on a primary role of electronic and information systems in the economy and development of industrialized nations as well as developing countries, deserves commensurate national investment in spectrum management as a "system analysis" problem, with interdisciplinary study and management by teams capable of dealing with the full range of technical, economic and political factors. Obviously one of the objectives is an adequate position and effective interface for negotiations in the international framework. The technical elements remain very important and deserving of the most competent attention. A satisfactory consensus on the technical elements in international spectrum utilization serves to identify more clearly the political and economic issues and to stabilize the conference process.

TABLE 1

ITU ADMINISTRATIVE RADIO CONFERENCES
MAY 1986 - APRIL 1987

year	dates	place	title	number of participating countries	results
1986	14/4-2/5	Geneva	Regional Administrative Planning Conference for the broadcasting service in the band 1 605-1 705 kHz in Region 2 (1st session) - BC-R2(1)	20	The technical standards selected as a basis for planning, planning principles, method and criteria, guidelines for the agreement to be drafted by the 2nd session and guidelines for intersessional activities
1986	22/9-10/10	Nairobi	Regional Administrative Radio Conference for the planning of VHF/UHF television broadcasting in the African broadcasting area and neighbouring countries (1st session)-AFBC(1)	49	Revision of the provisions of the Final Acts of the African VHF/UHF Broadcasting Conference (Geneva, 1963) in certain frequency bands; technical bases for the establishment, by the 2nd session, of the frequency assignment plans for the Television Broadcasting Service
1987	2/2-6/3	Geneva	World Administrative Radio Conference for the planning of the HF bands allocated to the broadcasting service (2nd session) - HFBC(2)	116	Planning method: procedures for the preparation and implementation of seasonal plans; technical standards and procedures for future single-side band operation; review and revision of the relevant provisions of the Radio Regulations relating to the use of HF bands allocated exclusively to the Broadcasting Service

TABLE 2

CURRENT CCIR PREPARATORY WORK FOR THE FORTHCOMING ITU CONFERENCES

year	dates	place	title	tasks
1987	14/9-16/10	Geneva	World Administrative Radio Conference for the Mobile Services (MOB-87)	Revision of the provisions of the Radio Regulations for the mobile services, the mobile-satellite services and the radionavigation and radiodetermination satellite services; inclusion in the Radio Regulations of provisions required for the implementation of the future global maritime distress and safety system (FGMDSS); provisions, if necessary, for the use of public correspondence by aircraft.
1988	29/2-19/3	Geneva	Regional Administrative Radio Conference to establish a plan for the broadcasting service in the band 1 605-1 705 kHz in Region 2 BC-R2(2)	Frequency allotment plan and possibly assignments derived therefrom, regulatory procedures, and appropriate technical standards for the use of the band 1 605 - 1 705 kHz by the Broadcasting Service in Region 2; regulatory procedures governing the use of the band 1 625 - 1 705 kHz by other services in Region 2; procedure to be applied by administrations wishing to implement their allotments in relation to non-broadcasting stations of the other contracting members.
1988	28/8-5/10	Geneva	World Administrative Radio Conference on the use of the geostationary-satellite orbit and the planning of the space services utilizing it WARC-ORB(2)	Allotment plan and the associated regulatory procedures for the fixed-satellite service in certain bands; regulatory procedures for the fixed-satellite service in certain other bands; appropriate technical standards, parameters and criteria, pertaining to the fixed-satellite service in the frequency bands regulated by the allotment plan and improved regulatory procedures; revision, as necessary, of the regulatory procedures and appropriate technical standards, parameters and criteria pertaining to space services and frequency bands not to be subject to planning; revision, as necessary, of the definitions relating to space services; establishment of the provisions and associated plan for feeder links, in the bands 14.5 - 14.8 GHz (for countries outside Europe and for Malta) and 17.3 - 18.1 GHz, to stations in the broadcasting-satellite service in Regions 1 and 3.

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CANADIAN DIMENSIONS OF SPECTRUM MANAGEMENT - NATIONAL POLICIES AND OBJECTIVES

by

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ABSTRACT

In this paper, the radio frequency spectrum is viewed as a strategic resource, one which requires the establishment of broad long term goals and more specific national policies for its management to maximize its benefit to all Canadians.

With the specific legislated mandate given to the Minister under the Radio Act, the spectrum is continuing to be demanded by an increasing number of users. It one views the ever-changing social, economic and industry trends in Canada, national policies and objectives are required.

This paper covers initially some of the pressures and impacts outside of the department which demand review and analysis in terms of our objectives. These include international changes, Canada/U.S.A. agreements, developing technologies and industry structures. With any new focus in government philosophy or policy, coordination and discussion is required within government to ensure conformance with social and economic policies, industrial and regional development policies, federal-provincial relations and research and development strategies.

Any national policies and objectives must take into account the social, economic and technology demands being placed on the spectrum.

In the concluding part of this paper, national policies, objectives and principles are outlined for spectrum management in Canada specifically in relation to the future demands for technology and services which will arise in the 21st century.

DIMENSIONS CANADIENNES DE LA GESTION DU SPECTRE - POLITIQUES ET OBJECTIFS NATIONAUX

par

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RÉSUMÉ

Le spectre des radiofréquences est considéré comme une ressource d'importance stratégique qui nécessite l'établissement de buts généraux à long terme et, plus spécifiquement, de politiques nationales de gestion de cette ressource susceptibles de maximiser ses retombées sur tous les Canadiens.

Des radiofréquences sont continuellement demandées par un nombre croissant d'utilisateurs dans le contexte du mandat particulier que confère la Loi sur la radio au ministre des Communications. Des politiques et des objectifs nationaux sont nécessaires s'il faut s'adapter aux tendances toujours changeantes en matière sociale, économique et industrielle au Canada.

Le mémoire traite d'abord de quelques pressions et impacts à l'extérieur du Ministère qui exigent des examens et des analyses du point de vue des objectifs établis. Il s'agit des changements observés sur la scène internationale, des accords canado-américains, des technologies en voie de développement et des structures industrielles. Toute nouvelle idée-force formulée dans une doctrine ou une politique étatique appelle une coordination et des discussions, à l'intérieur du gouvernement, dans le but d'assurer la conformité aux politiques sociales et économiques, aux politiques de développement industriel et régional, aux programmes de relations fédérales-provinciales et aux stratégies de la recherche et du développement.

Toute politique nationale et les objectifs qu'elle poursuit doivent prendre en considération les demandes d'ordre social, économique et technologique que peut satisfaire le spectre des radiofréquences.

En dernier lieu, l'auteur décrit les politiques, les objectifs et les principes nationaux de la gestion du spectre au Canada, en insistant plus particulièrement sur la demande future de technologies et de services qui se fera sentir au XXI^e^ siècle.

ORIGINAL : ANGLAIS

CANADIAN DIMENSIONS OF SPECTRUM MANAGEMENT

NATIONAL POLICIES AND OBJECTIVES

by

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Department of Communications

In this paper, the radio frequency spectrum is viewed as a strategic resource, one which requires the establishment of broad long term goals and more specific national policies for its management to maximize future benefits to all Canadians.

This paper covers initially some of the pressures and impacts outside of the department which demand review and analysis in terms of our objectives. Any national policies and objectives must take into account the social, economic and technology demands being placed on the spectrum.

In the concluding part of the paper, objectives and principles as well as a framework for a national policy are outlined for spectrum management in Canada specifically in relation to the future demands for technology and services which will arise in the 21st century.

The Radio Frequency Spectrum - A Strategic Resource

As the radio frequency spectrum is a limited and strategic resource, broad long term goals and national policies are required for positive benefits to accrue to all Canadians in the new environment of converging communications and information technologies. These goals and policies must be able to pass the test of time in view of the varying demands and new technologies being developed. We simply cannot change policies or objectives for spectrum management every time there is a new service or a new innovative technique devised to maximize use of the spectrum.

Since the Minister has the legislated mandate for the spectrum under the Radio Act, national policies can be more readily established without the complex regulatory jurisdictional jungle that impacts many of the telecommunications areas.

From a spectrum resource point of view, the Canadian environment is a major factor as well as pressures and issues external as well as internal to government.

General Canadian Environment

In terms of the Canadian environment and its role in spectrum management, we should take into account the following: Canada has an enormous size, a diverse and sometimes difficult geography and a relatively small population largely concentrated in several principal cities.

As well, factors which directly affect Canada from a spectrum policy perspective include:

(a) Different cultures (native, English, French, multicultural) which demand greater broadcasting spectrum to reflect the diversity of requirements.

(b) Need for equitable spectrum sharing along the Canada-U.S.A. border (major population centres within 60 km) to minimize interference possibilities.

(c) Canadian specific requirements according to obectives and policies of Canadian legislation (Broadcasting Act, Copyright Act, etc.).

Due to these diversities, Canadian uniqueness and unique demands in many areas, Canadian ingenuity has made us leaders in telecommunications and more specifically in the application and use of satellite technology to accommodate Canadian users.

The radio spectrum, as a strategic resource, has allowed Canadians the ability to harness the technologies available and use them to their advantage in an orderly fashion for the social and economic benefit of Canada, which is consistent with our history and experience.

Pressures External to Canada

Turning now to those external relationships which have a direct bearing on Canadian spectrum management national policies and objectives, we would have to include the following:

(a) Conferences under the International Telecommunication Union (ITU) which set the longer term goals and agenda for the future. We must also include the relevant consultative committees for telephones and radio, the CCITT and the CCIR, and their recommendations.

(b) Bilateral agreements between Canada and the U.S.A. primarily for broadcasting, land mobile and satellite services.

(c) Emerging technologies available overseas and in the U.S.A. in advance of their use in Canada which users want to take advantage of.

(d) Advertising of products before they are acceptable for use in Canada.

(e) Different laws for radio use and different geography affecting propagation, which may not apply in Canada.

(f) Public experience and perceptions of radio communications, i.e. Is radio considered a necessity or an integral part of day-to-day personal and business activities?

Internal Coordination

With any new focus or change in government philosophy or policy, coordination and discussion is required within government among various departments to ensure conformance with policies of other jurisdictional areas such as:

(a) Cultural and multicultural need and development.

(b) Social development and evolution.

(c) Economic and regional development priorities.

(d) Industrial structures and development.

(e) Research and development policies.

(f) Trade and technology enhancements.

(g) Federal-provincial relations

Departmental Policies and Objectives

The Department of Communications seeks to fulfill its mandate to foster the orderly development and operation of communications for Canada in the domestic and international spheres, in part through the management of the radio frequency spectrum. By spectrum management we normally mean the set of policies, objectives, standards and regulations which allow for the harmonious existence of radiocommunications operations without causing harmful interference.

Within my sector, Telecommunications and Technology, the Telecommunications Policy Branch develops spectrum utilization policies which are intended to meet the varying and conflicting needs of users and to reflect the major responsibilities of the Minister of Communications:

(a) To optimize the utilization of the radio frequency spectrum, and the geostationary satellite orbit;

(b) To provide for the planning of the efficient and orderly growth of the Canadian radio telecommunications network as an entire system;

(c) To ensure that the public interest is served through the consideration of all relevant factors in the granting of licenses for new radio transmission facilities;

(d) To anticipate, analyze and resolve interference problems in the early stages of system development;

(e) To consider future system expansion plans and provide for these to the extent possible; and

(f) To ensure that Canadian radiocommunication systems conform to the extent practicable to the International Radio Regulations established by the International Telecommunication Union.

These responsibilities or objectives have led to a number of operating principles to accommodate as many users as possible and to facilitate equitable sharing. Among these, we can include:

(a) Maximization of Public Good

Since the radio frequency spectrum is a limited national resource whose use must be managed in the public interest and for the public good, generally those operations which provide and extend similar services to the greatest number of users or subscribers, or which use greater technical sophistication to increase the efficiency of spectrum use and hence the number of subscribers which can be served, are given preference in making frequency assignments.

(b) Spectrum Allocations

The Canadian Table of Frequency Allocations specifies the full range for existing and forecast needs of specific radio services to support specific types of service operation and optimal usage.

(c) Designation of Spectrum by Type of Use

The Department designates spectrum by type of use rather than type of user so that spectrum which is not required by one type of user is available for others.

(d) Frequency Priority

The Department recognizes a priority in the use of frequencies for various radio services, particularly systems which are considered to be essential in the provision of service to the public (police, fire, emergency, etc.).

(e) Encouragement of Non-Radio Alternatives

The Department will encourage non-radio alternatives where these could be more economical and could realistically be employed from a technological point of view.

(f) Maintenance of a Single National Standard

The Department remains committed to the principle of establishing a single set of national standards for radio systems applicable to all areas of Canada.

(g) Encouragement of New Technologies

The Department reviews systems proposals in terms of optimum and economically feasible usage of innovative and state-of-the-art practices.

These provide an overview of the objectives and principles from a "top-down" perspective of how the Department has been able to cope with the demands for spectrum until now.

Now, if we take into account the Departmental objectives and principles for spectrum management, the impacts within and outside of government and the emerging and future demands, a proposed national policy framework for the future can be developed.

NATIONAL POLICY FRAMEWORK

Within the context of the mandate of the Minister, the Department and other legislation, it is likely that in particular the Radio Act will undergo further review. Any national policies should be contained within any future legislation.

Taking into account these matters, consider these as a framework for national policy:

(a) The radio frequency spectrum is a national resource under the sole authorization of the Minister of Communications.

(b) The use of the radio frequency spectrum shall be consistent with the orderly development of telecommunications in Canada and the enhancement of national cultural, social and economic objectives.

(c) The use of the radio frequency spectrum shall be in accordance with international agreements to which Canada is a party.

(d) Innovation and research in all aspects of radiocommunications should be fostered in order that the benefits accrued can be extended to all areas of Canada and to all Canadians to broaden and otherwise improve Canadian radiocommunications systems and to strengthen Canadian industries engaged in all aspects of radiocommunication services, systems and equipment.

RESPONDING TO FUTURE DEMANDS

Our focus now must be directed toward those future demands for technology and services which will arise as we move toward the 21st century and the associated issues which will have to be addressed, taking into account our national policies to meet those demands.

Consideration will have to be given to new service offerings and their impact on spectrum demand. A few examples of those service offerings which will have to be reviewed include the following: High Definition Television (HDTV), Future Global Maritime Distress and Safety System (FGMDSS), Radiodetermination Satellite System (RDSS), generic Mobile Satellite Service (MSAT) at L-Band, Direct Broadcasting Satellite Service (DBS), air/ground public correspondence and very low-power devices.

Any of these demands for new spectrum or a reallocation of spectrum will require public discussion domestically as well as internationally. The 1989 ITU Plenipotentiary Conference will probably establish the schedule for international multilateral meetings into the 1990's, and a General World Administrative Radio Conference (WARC) will probably be scheduled. Before the year 2020 we could have perhaps two additional General WARCs. The Department will be obliged to implement the decisions from these General WARCs.

Some of the specific issues which will require addressing include:

(a) HDTV - the development of production and transmission standards.

- avoidance of multiplicity of standards to facilitate international program exchange.

- domestic implementation strategy.

(b) Satellite Orbit - ability to accommodate more satellites.

- improved antenna patterns.

- relaxation of interference limits.

(c) Standards - the department may be pulled more and more into rendering the licensing process flexible to take account of regional needs.

If we look ahead and attempt to foresee events at the turn of the century, there are a series of questions related to the spectrum we should probably be looking at with greater intensity. Let me put some of these forward for your thought and then we can consider whether these will meet the proposed national policy framework?

Consider the following:

1. Should we continue to allow the multiplicity of delivery systems for basic home services (telephone, broadcasting, cable) or should we concentrate on one delivery system?

2. Should we discontinue off-air broadcasting and require delivery by satellite-cable systems or other means?

3. Should we exploit to the greatest extent possible the use of the spectrum through a revival or revitalization of radio services?

4. Should we provide radio spectrum "on demand" or on the other hand, should we reserve spectrum for selected users?

5. Is the use of artificial intelligence or knowledge-based systems appropriate for future spectrum management?

6. How are we going to implement the new advanced television technologies taking into account the competing interests?

7. What selection criteria should we consider for radio system applicants in major centres where the spectrum is limited, heavily used and in greater demand?

8. Should more experimental applications be used to exploit emerging technologies?

9. Should "competitiveness" be a factor in spectrum allocations and assignments?

CONCLUSION

The intent has been to outline a national policy framework which takes into account the Canadian environment, domestic, government and international pressures to assist in our socio-economic and technological development.

RECENT U.S. SPECTRUM MANAGEMENT EXPERIENCE

by

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ABSTRACT

A review of the domestic spectrum management activities in the U.S. illustrates why spectrum management decisions have been termed some of the most difficult and most controversial decisions that the U.S. Federal Communications Commission has had to face. Simply put, many decisions devolve to evaluations of the trade off between satisfying spectrum needs by mandating the increased use of spectrum efficient technology and/or by allocating additional spectrum. Examples include direct broadcast satellite service, cellular radio telephone, private land mobile service (including public safety), and land mobile satellite service. Lack of a completely strong and satisfactory basis of information for decision making has given impetus to an alternative method for making spectrum management choices, namely, the flexible service allocation. In such a service, major details of the service, including the nature of the service itself, are left to the "marketplace," with the implicit presumption that the economics of the marketplace are better determining factors of public interests than are a priori regulatory determinations. The flexible service allocation, while generally supported by the majority of the current FCC Commissioners, is strongly contested by many in Congress, who believe that these decisions must be made by the FCC.

RÉCENTE EXPÉRIENCE AMÉRICAINE EN GESTION DU SPECTRE

par

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RÉSUMÉ

Une revue des activités nationales de gestion du spectre aux États-Unis indique pourquoi les décisions prises ont été parmi les plus difficiles et les plus controversées que la Federal Communications Commission ait jamais dû rendre. En termes simples, plusieurs décisions ont porté sur des évaluations d'un compromis tendant à répondre aux besoins de radiofréquences, soit par l'utilisation accrue de technologies de grand rendement spectral et (ou) par l'attribution de radiofréquences supplémentaires. Entre autres exemples, on pourrait citer le service de radiodiffusion directe par satellite, la radiotéléphonie cellulaire, le service mobile terrestre privé (incluant la sécurité publique) et le service mobile terrestre par satellite. L'absence d'une base de données solide et satisfaisante nécessaire à la prise de décision a entraîné l'adoption d'une autre méthode de choix des décisions de gestion du spectre, soit l'attribution souple des radiofréquences aux divers services. D'après cette méthode, les principaux détails concernant le service, y compris sa nature, sont laissés "au gré du marché", selon l'hypothèse que les économies de marché sont des facteurs plus déterminants pour l'intérêt public que les déterminations réglementaires à priori. Bien qu'elle soit généralement acceptée par la majorité des commissaires de la FCC, cette méthode d'attribution souple est vigoureusement contestée par plusieurs sénateurs qui estiment que les décisions plus haut mentionnées doivent être prises par la FCC.

ORIGINAL : ANGLAIS

Recent U.S. Spectrum Management Experience

by

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Traditionally, one of the most routine of all governmental activities has been the allocation of the radio spectrum. For over 50 years, spectrum allocation was a lazy event occurring on request and made possible by fortunate technological advances that opened for use higher and higher frequencies. This is an admittedly oversimplified construction; but, I think, it appropriately characterizes the long term view that spectrum resources significantly exceeded the demands.

For the most part, whoever asked for spectrum got it. We enjoyed an economy of abundance. Fortunately, not too many people asked and we did not really use radio for many things. A disproportionately large amount of spectrum was shared by the Navy and the U.S. Fruit Company for marine purposes. There were broadcast radio, of course, and the amateurs--actually finding new uses for radio. Low power communications devices did not exist until the late "30s.

Things got busier after World War II--FM broadcasting, television, and the use of microwave frequencies, to name a few "new uses." Still, it appeared as if necessity might indeed be the mother of invention. Even today, there are those who assume confidently that as the need arises we will somehow learn to use higher and higher portions of the spectrum. There seems to be a faith in some mysterious relationship between man's ingenuity and his need for spectrum. Some say that this is the same faith that assures people that, regardless of wretched excess, we will always have cheap energy.

Well, lately I must tell you, I have been experiencing a crisis of faith. I see the need for spectrum--everybody has the need--but all of a sudden I do not see any more spectrum without a significant development cost. Gone are the halcyon days when the FCC was able to accommodate the first requests for land mobile frequencies by shifting the FM band to spectrum lying fallow. Where in the past if someone asked for spectrum the Federal Communications Commission yawned and gave it to him. Now, lots of people want spectrum--and the FCC has found itself in the worst of all possible positions having to make value judgments--to choose between competitors.

Now it is axiomatic that what government fears most is having to make value judgments. This, of course, is simply because any value judgment can be wrong. And unlike any other form of human endeavor, governments simply cannot be wrong.

Unfortunately, in the spectrum allocation business there is plenty of room for error. In order to make reasonable judgments about whether various people should get spectrum, we need information. We have to know how much they need. We have to know why they can not use different spectrum. We have to know enough to determine the validity of an argument that a certain part of the spectrum is essential because it would cost too much money to manufacture receivers for another part of the spectrum. We have to be able to predict the cost of filters when installed in the millions. We must be able to assess accurately the demand for a product or service and make a judgment as to whether it will be a success. Finally, we must gather the same information from other claimants to the same portion of spectrum and then listen to the various parties heaping scorn and derision on the claims of their competitors.

I have reflected on occasion that participating in this welter of half-truths, exaggerations, and misinformation is not an edifying experience.

The imperfect process of the past has worked reasonably well because the competition for spectrum was less intense. Present exigencies require that we rethink our traditional approach to spectrum management and seek out alternatives to promote efficient spectrum use. As an indication that the Commission is viewing the matter with great seriousness our new Chairman, Dennis Patrick has added to the list of Commission objectives a new objective--to "Promote efficiency in the allocation, licensing and use of the electromagnetic spectrum." These are not empty words designed to placate concerned engineers. Every spectrum management decision will now be measured against the new objective. A new emphasis will be placed on getting the most out of this important resource.

The use of spectrum efficient technologies was integral to several aspects of the Commission's recent decision to allocate remaining reserve spectrum in the 800-900 MHz region among various services. This decision is contained in the Report and Order in

General Docket Nos. 84-1231, 84-1233 and 84-1234 adopted on July 24, 1986. In allocating ten megahertz of spectrum to the private land mobile radio service, the Commission opted for 12.5 kHz channel spacing instead of the 25 kHz spacing used in the current 800 MHz private land mobile channels. Many land mobile interests had advocated use of 15 kHz channels, primarily on the grounds that narrower channel spacings would reduce operating range due to increased adjacent channel interference. Nevertheless, the Commission placed a premium on spectrum efficiency and therefore opted for 12.5 kHz, thereby making an increased number of channels available.

To further promote spectrum efficiency, the Commission dedicated one-half of the new ten megahertz allocation for Specialized Mobile Radio systems, or SMRs, and required that all channels employ trunking. SMRs are operated by private carriers in the business of offering communications service for persons who are eligible in the private land mobile services. SMRs are inherently spectrum efficient because they allow users with diverse communications requirements to be grouped and served by a single system, instead of the Commission's traditional approach of dedicating certain channels for specific types of services. With SMRs it is less likely that spectrum will lie fallow. SMRs have been operating in portions of existing 800 MHz land mobile bands with success and the Commission's decision will further spread this type of spectrum efficient service.

The Commission has put emphasis on spectrum efficiency in other areas as well. In a Report and Order in Docket No. 84-279, adopted on March 1, 1985, the Commission amended its rules to permit narrowband operation, specifically, use of 5 kHz channels, in the congested 150-170 MHz private land mobile band. This action, in essence, created new channels in a band where under the former rules none were available. In a recent proposal in General Docket 87-14, the Commission proposed that the band 220-222 MHz be reallocated for narrowband land mobile services. This 2 megahertz of spectrum could provide 200 duplex channels. I should mention that the mere availability of narrowband technologies does not mean that they can be introduced easily across-the-board in other bands. Impact on existing systems, cost and other issues often make introduction of narrowband systems difficult. However, I expect that the Commission, faced with increasing demand for scarce spectrum resources, will continue to move vigorously in the direction of implementing narrowband, trunking and other spectrum efficient technologies.

A second method of obtaining more spectrum is to decrease our margins of error and take some more risks in particular to encourage more shared use of the spectrum. In Docket 85-172, for instance, we have proposed new sharing criteria that would enable landmobile use of UHF spectrum in eight of our largest cities. Although we are obviously comfortable with the protection criteria proposed, it must be recognized that we are giving up the luxury of over protection that was established in earlier sharing dockets. We are reducing a comfort level. There has been considerable controversy over this proposal. A federal advisory committee was established in order to obtain the best recommendation as to an appropriate sharing criterion. The broadcasters have raised the issue of possible harm to the future development of high definition TV and have also questioned actual land mobile needs. Obviously, it will take a while longer for the Commission to reach a decision; nevertheless, I view the sharing proposal as a harbinger of events. With increasing frequency we will have to perturb, if not radically alter, the kind of feudal system enjoyed by the beneficiaries of the block allocations concept. Naturally, we can expect that tearing up even a single cobblestone will cause discontent.

The third approach we are taking to solve our spectrum problems is even more controversial. It is to abandon our traditional allocations process and to consider spectrum as a good to be distributed according to market forces. The assumption is that society will make its own value judgments, and in this manner eventually spectrum will be used most efficiently--in an economic sense. All the Commission need do is establish some ground rules to minimize harmful interference and step out of the way. Our job becomes easier, profits are maximized, and spectrum achieves its highest value. (That is economic talk).

In two recent proceedings, the Commission proposed flexible allocations as a new approach to spectrum management. This approach would allow licensees to choose what services they will offer. Presumably licensees would offer the services that are most valued by the public and thus would have incentive to use their allotted spectrum efficiently in order to maximize profit. Of course, certain services, such as public safety services, could not compete for spectrum on an economic basis and would continue to require specific allocations.

In the Commission decision on the allocation of the 800-900 MHz reserve, two megahertz were allocated for a new general purpose mobile radio service. Service rules have not yet been developed. However, it is envisioned that this service will embody broad flexibility to permit licensees to choose the types of mobile service that will be offered. For instance, a licensee may decide that the best use of its frequencies is for paging, or for an air-ground telephone service, or for a personal radio service. Details such as how licenses will be issued, the size of the frequency blocks that will be licensed, size of the service areas, interference protection criteria, and other issues are significant details that have yet to be decided. However, you can expect to hear more on this in the future.

In a pending Notice of Proposed Rule Making in General Docket 85-172, the Commission proposed to permit TV broadcasters the flexibility to offer alternative services on TV channels 50 through 59. For example, a TV station that is currently losing money could decide that offering land mobile service would be a more valuable use of the frequencies. As you might expect, this proposal has been received with enthusiasm by some and distaste by others. No decision has been made as yet on the proposal.

We also expect in the near future to issue a proposal to add flexible features to the cellular radio service. The proposal is expected to be directed primarily at the additional ten megahertz of spectrum that was allocated to the cellular service in the Commission's 800-900 MHz allocation decision. However, we will be looking at the pre-existing spectrum as well. One idea under consideration is to give cellular operators the freedom to offer additional services in the cellular spectrum. We note that in many smaller cities and rural areas, more frequencies are available than are needed to satisfy the low level of cellular traffic. We also intend to add flexibility to the technical rules for the cellular service to permit the introduction of new spectrum efficient technologies. We believe that such changes can be accomplished without compromising the universal aspect of cellular service as it currently exists in the United States. That is, even with flexibility in services and new technologies, we believe cellular mobile telephones will continue to be able to move about from one place in the country to the next and work.

The prospect of allowing spectrum to be "allocated" by market forces is exciting. Many questions, of course, remain to be answered? Someone has to have the spectrum before it can be marketed. On the assumption that the spectrum is a valuable good, that means someone is going to get a windfall. How do we start? Do we have a lottery? Auction it off? How much spectrum do we place in the pot? Is there some critical mass necessary before a market develops and the spectrum's value is realized? Should we earmark the spectrum for nationwide use? This is one of the more interesting questions because its answer will have a dramatic impact on the types of uses of the spectrum. If spectrum is treated as a commodity, will it be traded as a commodity? Need we be concerned if it's perceived value is such that it is warehoused or hoarded? If the market works properly, then spectrum will be owned by those who value it the most. But can we assume it will be used efficiently? Remember we have a shortage now. Even an engineer can predict what will happen to the price of already scarce goods inefficiently distributed. And what of the incentives. Will there be movement to foster spectrum saving technologies if the effect is to lower the price of spectrum?

I think it is important to pursue this experiment in an attempt to answer some of these questions. It may be that we will discover that while particular communications needs are not satisfied by a spectrum market, others are satisifed remarkably well. Such a finding could lead to experiments with larger blocks of spectrum with a more directed purpose. It is reasonable to assume a hybrid system may prove successful.

I think a general purpose, decentralized or flexible radio service would be a useful alternative as a means of efficiently distributing spectrum. In many ways it would be a refreshing substitute for the present distribution scheme built largely around difficult value judgments by government. However, the market approach will never be the only method of allocating spectrum. Clearly, traditional allocations will have to continue for the various safety services. And because as a practical matter, we must anticipate resistance to any new scheme for doing things, some radio services, technically amendable to a spectrum market will probably remain traditionally allocated as well.

FUTURE TECHNICAL EVOLUTION OF NATIONAL SPECTRUM MANAGEMENT

by

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ABSTRACT

This paper reviews the technical and consultative tasks that any national radio frequency spectrum manager has to perform to assure a harmonious and efficient use of the spectrum by the current 29 radio services populating some 390 different bands in the ITU allocation table. It describes some of the specific tools like radio systems plans, standards and specifications and procedures used in Canada and the process followed for their development. Possible evolution and changes in the skills needed by the future spectrum manager to meet the challenges of the 21st century are commented on, with emphasis on the flexibility necessary to accommodate rapid changes in radio equipment produced using CAD/CAM techniques.

Equally, the increasing trend towards computer assistance in the process of spectrum management for licensing of radio stations, record keeping, coordination, electromagnetic compatibility and monitoring is reviewed with examples of applications in Canada. The foreseen direction of the evolution of these tools intended to increase the efficiency of scarce human resources is outlined.

The conflicts and adjustments needed to ensure the co-existence of existing radio facilities and those which will accommodate HDTV and form the transmission links in ISDN networks are outlined.

Some of the other technical challenges visible on the horizon involve more than the harmonious and efficient use of the spectrum by its users. Among these are considerations of the handling of multi-service facilities, consumer electronic equipment immunity, non-ionizing radiation limitations, etc. These may well require legislative provisions not traditionally associated with the management of spectrum.

L'ÉVOLUTION TECHNIQUE DE LA GESTION DU SPECTRE AU SEIN DE L'ÉTAT

par

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RÉSUMÉ

Cet article examine les tâches techniques et la consultation que le gestionnaire du spectre des fréquences radioélectriques devra effectuer à l'avenir afin d'assurer une utilisation du spectre à la fois harmonieuse et efficace dans les 29 services radio qui fonctionnent présentement dans 390 bandes du tableau des attributions de l'Union internationale des télécommunications. Des outils particuliers, tels que les plans de réseaux hertziens, les normes, les cahiers des charges et les procédures en vigueur au Canada, ainsi que leur mise en application, y sont décrits. On y discute de l'évolution et des transformations possibles des compétences qui seront requises afin que les gestionnaires du spectre puissent relever les défis du 21e siècle, en mettant l'accent sur la souplesse qu'exige l'adaptation aux changements rapides dans la production d'équipement radio occasionnés par les techniques CAO/FAO.

Par ailleurs, la tendance croissante à informatiser, entre autres, la délivrance des licences radio, la tenue des dossiers, la coordination, la compatibilité électromagnétique et le contrôle du spectre, est présentée à l'aide d'exemples illustrant la situation au Canada. L'évolution prévue de ces outils, qui devraient contribuer à accroître l'efficacité de ressources humaines limitées, est également soulignée.

Les conflits et l'adaptation nécessaire pour assurer la co-existence des installations radio actuelles avec celles qui devront accommoder la télévision à haute définition et servir de liens de transmission pour les réseaux numériques à services intégrés (RNSI) y sont exposés.

Certains autres défis techniques qui se profilent à l'horizon vont au-delà de l'utilisation harmonieuse et efficace du spectre. Parmi eux figurent l'exploitation des installations polyvalentes et la compatibilité électromagnétique des appareils domestiques, ainsi que les limites de la radiation de type non-ionisante. Ces questions pourraient exiger des mesures législatives que l'on n'associe pas normalement à la gestion du spectre.

ORIGINAL : ANGLAIS

FUTURE TECHNICAL EVOLUTION OF NATIONAL SPECTRUM MANAGEMENT

by

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Normally, national Governments or delegated national bodies are responsible for the management of the spectrum in their territories. They determine national policies, allocation plans, permissible systems and standards and specifications of equipment to permit a harmonious use of the spectrum in the national interest. To the extent that radio transmission takes place in an open medium every transmitter is a potential source of interference to the reception of other transmissions. Thus the methods of avoidance of interference, which are circumscribed by physical laws of propagation, and the technical characteristics of transmitters and receivers, remain one of the immutable constraints to policy formulation, as well as to the assignment of frequencies.

Additionally, the technical factors also determine the means of detecting and correcting interference. True that these considerations are not limited to each nation - hence the international dimension of spectrum management in which national administrations participate which is the subject of a companion paper at this symposium. The facts that 29 different radio services populate the spectrum, that currently many of these are interspersed in some 390 bands across the current 300 GHz of usable spectrum, that in many cases more than one radio service uses the same band, and that the propogation characteristics and technical parameters of equipment tend to be unique in each band, make the task of spectrum management complex.

It is also interesting to note that independent of which organizations in a country perform this task, or in what legal structure the organizations are imbedded, the technical tasks will need to continue to be performed. This is not to say that they will remain unchanged. The degree of emphasis will almost certainly continue to change amongst the various elements of the technical functions as it has done over the past decades. As has happened before, the optimum technical solutions may not always be selected. However, in a departure from previous experience, economic considerations which at one time significantly influenced the choices may take second place to geo-political factors, especially in the field of satellite technology. Nevertheless, any national option selected has to remain technically feasible and needs to be implemented in accordance with technical rules and restrictions applicable to that option - thus ensuring the continuity of the technical function.

Technical Bases for Policy Formulation:

Before any policy decisions for spectrum allocations are made the available technical options have to be analyzed for feasibility. And, to the extent that economics plays a part in the choice, the options have to be quantified or at least rank ordered. In this area, the complexity may increase as new technology is deployed; but the nature of the task is likely to remain unchanged. The interplay between costs and technical excellence is the essence of engineering; and the trade-off analyses will continue to be carried out. However, there are two other dimensions that are gaining added importance - national consultation and debate in international fora.

The increasing use of radio services by all nations has heightened the perception of the value of the natural resource of the spectrum. Equally, both internationally as well as within each nation there is enhanced competition for frequency allocations between the different categories of users who utilize one or other of the radio services. Not surprisingly competing interests often have divergent opinions on technical factors and the economic viability of the usage that each lobby champions. In this context, national consultation is essential not only to balance these needs in the national interest but also to ensure that the technical and operational constraints placed are such as not to impede innovation and the use of the allocated frequency bands. With the projected increase in the number of users and uses of the spectrum both consultations in the national as well as debates in international fora are likely to gain further prominence.

In Canada, the Radio Advisory Board of Canada is the most significant forum for such consultation. Formed in 1944 as an association of associations of users, service suppliers and industry, who utilize the spectrum, it advises the Department of Communications on all matters associated with the management of the spectrum. In its technical committees, proposals originating from its members or, in many cases, from the Department of Communications are discussed and formulated, and associated recommendations made. This is followed by the formal process of gazetting the proposal in the Canada Gazette. Comments by all interested parties are sought. These comments are considered by the Department and the proposal is amended. The final issue of the resultant documents - be they policy oriented, technical or regulatory - is announced in a subsequent Gazette notice.

Taking note of the special importance of Broadcasting in the national cultural mosaic of the country and the associated regulatory regime of the Canadian Radio-Television & Telecommunications Commission (CRTC), which licenses broadcasting stations, a further committee named the Technical Advisory Committee (TAC) also advises the Department on these matters in parallel with the Broadcasting Committee of the RABC. The Department in turn, from the spectrum management perspective, provides all the necessary technical support to the CRTC in the Broadcasting field. It issues not only the Technical Construction and Operating Certificate (TC & OC) for each broadcast station but also issues the technical documents for broadcasting. The process for the issue of the Departmental technical documents associated with all radio services including Broadcasting, however, is identical.

Technical Documents:

The following specific types of technically oriented documents are utilized in Canada to inform the public and users of the spectrum. These are:

Radio Standard Specifications (RSS)
Standard Radio Systems Plans (SRSP)
Radio Standard Procedures (RSP)
Broadcast Specifications (BS)
Broadcast Procedures (BP)

RSS's:

Radio Standard Specifications are primarily utilized to specify the minimum acceptable technical characteristics of equipment generally deployed in quantity by a large number of users in the same radio service. Two categories of RSS's exist; one which deals with licensed radio stations; and the second one which deals with licence exempt radio equipment. The RSS's deal almost exclusively with the minimum technical parameters that equipment must meet strictly from the points of view of effective spectrum usage and minimization of interference. They normally are not concerned with end to end transmission performance which is left to the discretion of the user, thus enabling him to choose the quality of equipment to meet his needs.

Almost all of the first category of RSS's are currently associated with mobile services and their subsets like cellular, conventional terrestrial, aeronautical, maritime, paging, transportable emergency beacons and the General Radio Service (commonly known as Citizen's Band). They are aimed at ensuring harmonious operation of such radio stations and enable fast licensing. For the latter purpose standardized computational methodology and propagation models are utilized to assess the potential for mutual interference. The mobile services covered by this category of RSS's currently operate below 1 GHz, mostly utilizing the conventional techniques of amplitude or frequency modulation. Both of these constraints are likely to be broken during the next two decades. Tamed frequency modulation (TFM), Amplitude Compandored Single Side Band (ACSSB), and narrow band digital utilizing sophisticated predictive codes, are all candidates for future deployment in the search for the more efficient utilization of the mobile spectrum. In apparent contradiction, the thrust to make provision for the extension of the Integrated Services Digital Network (ISDN) to mobile users will likely need larger bandwidths for individual mobile radio channels. The solution may likely be time shared usage, with the public mobile networks leading the way. It is an open question, if future RSS's covering the mobile and personal radio services will not, of necessity, contain technical parameters associated with system and channel sharing functions.

In the frequency domain the search for additional suitable frequency bands for terrestrial mobile is already underway in the 1 to 3 GHz range in CCIR working party IWP 8/13. The planned deployment of satellites for mobile services both in Canada and the U.S., the expansion of Inmarsat operations and the proposed Radio Determination Satellite Service all augur large quantities of associated mobile equipment in the foreseeable future. It is reasonable to expect that the current RSS's will need to evolve to cover the introduction of novel modulation techniques and that new RSS's will be developed to cover further frequency allocations.

The second category of RSS's generally deals with low power equipment which is exempted from licensing because of its limited range. The operation of such equipment is permitted in specific frequency bands. Apart from ISM equipment, garage door openers, alarm and control devices for toys - and more recently cordless telephones - are examples of such equipment. Historically this category of RSS's has dealt exclusively with the characteristics of transmitters like maximum power, permissible harmonic levels and stability; and such RSS's have been device specific. However, the trends forming are that more and more such devices may become available to the consumer at affordable prices and that a large number of consumers are willing to use them. Problems of mutual interference between such devices are already surfacing, and a number of different devices operating in the same frequency bands are being marketed for very specific purposes, under firmware control. Thus the evolution of this category of RSS's is likely to result in these being organized to cover all generically related devices according to their frequency bands of operation. Future RSS's in this category are also likely to contain some technical characteristics for receivers and equipment operations.

In the context of evolution of the Radio Standards Specifications some observations can be made. Firstly, the increasing use of Computer Aided Design and Manufacturing techniques will almost certainly have a significant impact on the variety of radio equipment covered by RSS's. The economic advantages of large scale manufacture which often led many national Administrations to select identical frequency allocations are not likely to remain as predominant as in the past. Secondly, to overcome the uncertainty associated with a specific evolving technology and its rate of deployment, it is more than likely that the spectrum manager will have initially to issue technical guidelines to permit experimentation, licensing and introduction of new equipment followed by RSS's. In the area of the ACSSB technique, in Canada this is the path being followed. Thirdly, the development of repeatable test methodologies that are incorporated in future RSS's will be a continuing challenge for the national spectrum manager; as will be the development of effective interference models.

That these models will also be debated in international fora to the extent that coordination in border zones of neighbouring countries cannot be performed without mutually agreed models is self-evident. It must be recognized, however, that the expertise of these fora is derived from their national participants. Hence, the national spectrum manager will need to develop it. Of course, in the process of doing so the national objectives of enabling the timely deployment of new or more economic services in the nation are also met. A national spectrum manager must hence constantly replenish the technical skills of his organization not only to keep abreast of nascent technology but also to forecast its possible applications in radio services in a timely manner. In a more general vein, the importance of the need for such replenishment is given further point when the technical manager presents the technical options to formulate national allocation policies. Here, as often happens, the time scales between making spectrum provisions and the maturity of a given radio service could exceed 10-15 years.

SRSP's:

Standard Radio Systems Plans (SRSP) are utilized in Canada to specify the sub-allocation of allocated frequency bands and the associated radio channelling plans. These generally refer to the "fixed" classification of radio services. The majority of these SRSP's deal with frequencies above 1 GHz though a few exist below this frequency. These exceptions deal with "fixed" systems in the lower frequency bands which were deployed some decades earlier and continue to be used primarily in remote areas where smaller communications capacities are sufficient and longer hops are economic. A more recent departure however should be noted. With the evolution of large scale cellular and trunking systems in the mobile service the requirements of integration, inter-operability and ease of expansion have led to the issue of SRSP's in the mobile services also. These are in addition to the RSS's for mobile equipment. There is no reason to expect that this trend will reverse in the foreseeable future.

The SRSP's are aimed at ensuring that the designer of specific systems, the manufacturers of the equipment, and the organizations which deploy systems covered by the SRSP's and become radio licensees, have a set of guidelines which reduce their risks. The risks associated with such systems are more onerous than those associated with, for example, private mobile systems. Adherence to the SRSP's and the technical parameters - like polarization, maximum permissible power and antennae characteristic - contained therein also facilitates the graceful and trouble-free expansion of the communications capacities of such systems. For example, taking into consideration the magnitude of investment in site development, provision of electric power, access roads and towers in a microwave communications route the possibility of use of the same locations for future expansion is a powerful incentive. Adherence to the technical parameters of the relevant SRSP enables such expansion to take place more easily than otherwise would be the case.

Historically, the pattern in development of SRSP's for "fixed" services has been to formulate a unique channelling plan for each frequency band. The plan normally accommodated a number of equal capacity - and bandwidth - radio channels. Prime examples of these were the 4 GHz and 6 GHz bands and their channelization. Debate focussed on questions like whether a two frequency plan or a four frequency plan was best in given circumstances, the degree of cross-polarization discrimination that could be achieved and whether at a given point in the development of technology the number of standby channels had to be 1 for n or 2 for n to give the desired degree of availability. The use of frequency modulation was accepted as the norm; and microwave systems were the exclusive domain of sophisticated users like the telephone and hydro companies.

More recently, this scenario has changed in many countries including Canada. Liberalization initiatives have tended to increase the number of users and licensees for such systems. The requirements of the non-telephone company licensees are generally to span shorter distances with a smaller number of hops with transmission qualities just sufficient to meet their particular needs, and often, with transmission capacities lower than those utilized for major trunk routes. In parallel the move is afoot for digitalization of all telecommunications facilities in most nations as evidenced by the ISDN initiatives. Radio usage will doubtless follow this evolution as it has already begun to do over the past few years in Canada.

Three other factors will affect the nature of future SRSP's for terrestrial communications. Firstly, the use of still higher frequencies like 18 GHz and 23 GHz for intra-urban communications will almost certainly increase, with a large number of private users as well as telecommunications service providers utilizing the bands. Secondly, multipoint communications/distribution services (MCS/MDS) will need to be accommodated in quantity. Such services - initially exemplified by Intructional Television (ITV) - often operating with omni-directional or low directivity antennas, in the 2 to 10 GHz bands, and with power levels adequate for direct reception in the home of video programing will pose special challenges of frequency planning and coordination. Thirdly, the introduction of Enhanced Definition TV (EDTV) and its evolution eventually to HDTV will pose special technical challenges. The transmission qualities required for program feeder links to such Broadcast transmitters are not known. They are, however, likely to be higher than those for colour TV, unless the current internationally accepted quality impairment allowance trade-off's, between Broadcast distribution and studio-transmitter links, are changed. It is also clear that the base bandwidth requirement for EDTV will be larger than that for colour TV. These considerations together may well mean that the bandwidth of the RF channels in the currently utilized microwave bands is not sufficient. A rechannelization could lead to the modification of considerable quantities of already deployed equipment. It would also mean very careful re-coordination of all users of the band whose use would have been coordinated in accordance with the existing channelling plans. The technical conflicts as well as questions of who pays for such modifications are inevitable. Alternatively, one could conceive of such EDTV/HDTV links being allocated exclusive spectrum. This, however, can only be done without excessive conflict in virgin bands towards the higher end of the useable spectrum with its concomitant economic disadvantages. The spectrum manager will be presented with a considerable challenge.

In response to these stimuli, the SRSP's of the future will evolve - as they have already begun to do. They will contain multiple channelling plans for the same frequency band, will cover as yet unharnessed bands, will allow for the graceful transition from analog to digital transmission in currently utilized bands and will contain more detailed information on the methodology of calculation of potential interference in each band to guide and assist the user in planning the deployment of his facilities. Further, as the demand for intra-urban short hop communications, not exceeding a few miles, grows it is very likely that together with SRSP's, for the band in question, RSS's which specify the characteristics of the equipment might also be needed to ensure rapid licensing.

A special mention of the fixed satellite service is warranted in this context. Due to the nature of this service as well as due to the large one time investments involved, and due to the limited number of equipment suppliers there is a tendency towards the adoption of common channelling by almost all nations in the bands allocated to this service. Further, the sharing and coordination criteria for this service are those agreed at the international meetings of ITU. It is true that single channel per carrier, TDMA as well as FDMA techniques are being utilized. Though each of these has its own unique set of coordination criteria the transponder bandwidths within which these are accommodated are standard. One recent entry to this scene, however, is the Very Small Aperture Satellite Terminal (VSAT). The space segment operator and the operators of the VSAT type networks need to exercise considerable system discipline to avoid harmful effects to other users. Happily, experience so far points to such being the case. For the spectrum manager the proliferation of VSAT type terminals may necessitate the issuance of an RSS. In the longer term, as spot beam technology is more extensively deployed and higher frequency bands in the 20 and 30 GHz regions are utilized for national or regional systems the so far over-riding considerations of international compatibility may well not be as compelling. SRSP's for national usage similar to the ones used for terrestrial systems may then become necessary.

RSP's:

The Radio Standards Procedure informs the prospective radio licensee of the steps he should follow to obtain a radio licence, the technical information he should present, the process of coordination that is invoked, the appropriate application form he should use, and the time scales he should expect. By a judicious combination of services covered by each RSP the number of RSP's in Canada has been reduced to seven.

The possibility exists that with the large scale deployment of a given type of equipment, in a particular radio service, a new procedure may be required. Such was the case with Television Receive Only (TVRO) Earth Stations in Canada. However, more significantly, in response to the introduction of high stability and accuracy synthesized equipment and the shorter production time scales possible with CAD/CAM techniques, the users of the spectrum are demanding - and will continue to demand - rapid licensing, in spite of the increasing complexity of coordination. This may well require modifications to the RSP's. It will aslo mean that new aids to improve both the accuracy and speed of technical computation and analysis for frequency coordination and assignment will become necessary.

Broadcast Specifications (BS)

These documents specify the minimum acceptable technical characteristics of Broadcast transmitters - AM, FM, VHF TV and UHF TV - to be consistent with the related allotment plans. Used by Broadcast transmitter manufacturers, they include parameters such as modes and depth of modulation, frequency bands and stability limits, permissible power and noise suppression criteria. Two basic trends are likely to lead to modifications of these documents. These are: the quest for improved video and audio quality, the delivery of a number of auxiliary services by Broadcast transmitters. AM stereo, stereo sound on a conventional TV channel, and the introduction of EDTV are examples of the first trend. Driven by the increased expectations of the public at large, due to its burgeoning use of compact disc and high-quality VCR's, this trend will almost certainly continue. The second trend is exemplified by the introduction of sub-carrier multiplex operation (SCMO) and Vertical Blanking Interval (VBI) usage.

In this context, it is worth noting that the technical challenge to accommodate EDTV, and the eventual evolution towards a yet higher quality of off-air TV service, coupled with the reduction of the traditional taboos associated with TV receivers will be substantial. The efficient use of the UHF spectrum will doubtless be its goal. Equally, the introduction of satellite Broadcasting will doubtless take place over the next two or three decades. These changes will result not only in the modifications to the current Broadcast Specification documents, but may well necessitate the development of new ones.

Broadcast Procedure (BP)

These documents incorporate primarily the allotment plans and frequency assignment criteria used among Broadcast stations as well as the procedures for application for a TC & OC. They also specify the format in which the information is to be provided and describe the technical information that should be included. Used by Broadcast consultants as well as by sophisticated Broadcasters who have their own engineering capabilities, these documents will need to be modified under the influence of the same changes as identified in the paragraph above.

The Tools of Efficiency and Speed:

Complexity in the functions of frequency coordination and assignment arises due to a number of factors. As the number of users of the spectrum increases, the mere task of record keeping becomes tedious and time consuming, as does the task of short listing those radio stations in a given location liable to interfere with or be interfered with by a newly proposed station. The number of propagation paths, for which the anticipated levels of interference to and from a newly proposed station, need to be computed increases roughly as the square of the number of existing stations with which such interaction is possible. The number becomes unmanageable especially in large metropolitan centres which usually are the hubs of commerce, industry and services - and consequently, also are large centres of telecommunications of all kinds including radio. The tasks of storing large quantities of data accurately, culling its exact sub-set, and performing a large number of calcultions are all tedious; and such tasks are often prone to human error. Fortunately these tasks are also eminently amenable to computer assistance. Of course, if a record keeping system existed, the accounting functions associated with the administration of radio licence fees would be a natural appendage to it.

In Canada, as in many parts of the world, the 1950's and 1960's saw an explosive growth in radio usage. At the same time, computing technology had moved forward. The Canadian Department of Communications recognized early the potential of computers to assist it in spectrum management tasks and has built an enviable reputation in this increasingly important arena. The first such applications were developed in the late 60's and were aimed at the record keeping portion of the tasks and consisted of a domestic frequency listing of radio stations in Canada for which international or bilateral coordination had been carried out. A few years later, computer programs implemented rudimentary propagation models and calculations to predict whether inter-system interference would occur between existing and proposed microwave radio-relays; and a separate microwave data base was gradually created. The integration of the licensing and accounting functions from several separate systems into a common one was considered a major step forward in the early 70's. Still, the data for each of these systems was stored independently and gave rise to redundancy and accuracy problems. During this decade the advances in radio technology and usage produced a sustained growth in spectrum demands which was reflected in an annual growth rate in the number of licences of 12%. This resulted in increased competition for the spectrum resource and led to a reduction in the bandwidths used for mobile communications, thus accommodating more users. The increased concentration of radio systems in metropolitan centres and areas of high economic growth in these years added further pressure on the available spectrum. It was no longer possible to assign a clear channel to each new mobile user, and sharing of frequencies became a common place occurrence; and the task of assignment of interference free frequencies to mobile users began to absorb an ever increasing number of skilled human resources.

Luckily, advances in computer technology during the same decade also occurred. Main computers became more powerful, and adequately flexible data base management systems had evolved; and mini/micro computer technology enabled the design of mobile equipment to rapidly collect and analyze real time data concerning the occupancy of radio frequency channels. The Department embarked on a multi-phase program to provide further computer assistance to the growing and increasingly complex tasks of spectrum management. An integrated spectrum management system (SMS) comprised of an assignment and licensing sub-system, an electromagnetic compatibility sub-system for land-mobile assignments and a spectrum occupancy sub-system was designed and implemented. A post-implementation review of this system - performed in 1984 - indicated that the Department was handling a 56% increase in the licensing workload with 8% fewer people. In large metropolitan areas such as Montreal and Vancouver, VHF land mobile frequencies were still being successfully assigned up to seven years after previously forecast saturation dates. In parallel, a specialized system was also implemented to handle the explosive growth of licencees in the General Radio Service (CB). Later, a microwave radio licensing sub-system (MRLS) was added to the SMS integrated system. The MRLS incorporated revised and updated models for inter-system interference among terrestrial radio-relay, satellite earth stations, space stations, radar stations and passive repeaters, using various analogue and digital modulation techniques. This integrated system has become the envy of many administrations and is a source of pride for us in Canada.

Other specialized computer based systems are used in Canada for planning and coordination purposes in the Broadcast spectrum bands. The planning systems are primarily concerned with the development of allotment plans for both audio and T.V. broadcasting, with each category - AM, FM, VHF TV and UFH TV - utilizing its relevant unique models. These models take into consideration the quality of service, typical receiver characteristics and propagation parameters - such as receiver taboos and fading ranges for given percentages of locations and time - as well as the forecast demands for these services. The coordination systems are primarily used in the selection of the specific power levels, the precise location of stations (in the context of the local topography), and the antenna patterns to provide the desired coverage. Here again, the increasing spectrum congestion and the advent of new services in adjacent bands requires continuous updating of the models and techniques to evaluate rapidly the anticipated levels of interference. These systems must therefore evolve continuously to meet the changing requirements of new bands, new services, and new technologies.

As the area of spectrum management expanded to meet the growing needs of the spectrum users, the efficient administration of the human resources involved in it also required special attention. The somewhat unique combination of technical, planning, regulatory, administrative and financial functions associated with spectrum management, requires its own unique classifications of tasks and resources for effective control. Further, the set of tasks associated with enforcement and monitoring of the spectrum can only be carried out, in most frequency bands in use, close to the user. Hence, the locations from which spectrum management personnel operate in all except the physically smallest countries, are dispersed. To deal with the diversity of the functions, the unique characteristics of the tasks and the geographical dispersion of the locations, a special computer-based management information system has been developed and is extensively used in Canada.

While the Department's initial efforts at computer assistance were directed towards the authorization and licensing functions of spectrum management, the availability of an integrated data base has permitted the development of useful applications to assist in the spectrum planning and enforcement functions also. The automated measurement of the occupancy levels of the land mobile channels in all frequency bands not only enables the sharing of these channels by a number of mobile users but also permits trend analysis to detect signs of congestion. The extensive studies and rigorous statistically valid techniques developed and imbedded in the computer analysis of the measured data enables the results to be used with confidence. The insight can therefore now be used to evaluate options during the spectrum planning and policy formulation process. Samples of various radio population can also be easily extracted and used for specific monitoring programs as well as for general enforcement activities. Recent developments are towards the gradual introduction of micro-computer controlled unattended transceiver equipments to increase yet further the efficiency and effectiveness of monitoring and enforcement activities. All of these systems have the common objective of utilizing the two scarce resources of the spectrum and skilled technical personnel more efficiently.

In this review, it is appropriate to acknowledge the considerable part that Canadian industry has played, and continues to play, in the development of the above specialized tools for the Department. Its participation from the conceptual stages of process analysis, initial design, system design, coding, system integration and implementation has been invaluable. The skills developed in this successful cooperation between the Department and Canadian industry will continue to be used by the Department in meeting the challenges of the future in the area of spectrum management and can also be beneficially utilized by such administrations as are desirous of doing so.

The 21st century will lead to more advances in both radio and computer technology. Improved computer hardware and more flexible operating environments will doubtless develop over the next two decades. Distributed data base technology with simultaneous updates may well become established and economic as the ISDN initiatives gather momentum. Each of these and similar advances will likely be employed in the Canadian spectrum management systems as they prove cost beneficial. Already, investigations are afoot to assess the capabilities and limitations of various expert system shells to meet the Department's future needs in spectrum management and to make available to more junior personnel some of the expert knowledge of our senior inspections staff. These investigations, although only in their infancy, have already resulted in a production system to assist our inspectors with their ship inspection tasks. Further work along these lines is planned.

In the euphoric field of computer applications, a few words of caution based on experience are appropriate. The adage of the manager about "garbage-in-garbage-out" holds true for spectrum management computer based systems as it does for all computer systems. The system is only as effective as the data on which it operates. A well designed system can ensure the integrity of the data by guaranteeing that the stored value of a given data element is utilized in all computations involving that particular element. The system cannot, however, ensure the accuracy of the data except if the value lies outside normal edit limits. Accuracy of the data stored in the system is the responsibility of the individual inputting it - and will remain so. Equally, the use of computer systems in spectrum management does not do away with the need for knowledgeable personnel to interpret the results obtained from such systems, and to make decisions. One of the main advantages of an effective computer system is that the spectrum manager can propose specific solutions - for example, filters or special antennae - to resolve a difficult assignment situation, and quickly determine if the proposed solution will solve the problem. Another factor to recognize is that a computer system which just mimics an existing process is not likely to increase efficiency as much as one in which the computer system design phase included a critical examination and streamlining of the process itself. Finally the introduction of computer assistance in a complex process involving technical, administrative and accounting functions can only be effective if its user has a high degree of confidence in it and yet feels that he is in control. Thus the final information presented should be in a format in which, apart from the recommended solution, options are presented by the system and the system user can interact with system in real time.

Other Technical Challenges

Some of the other technical challenges that the spectrum managers have to meet in the next two to three decades go beyond the harmonious and efficient use of the spectrum by its users. They will get involved in areas wherein their personnel have little technical expertise. They will have to expand their horizons not only to access such expertise but also to gain the confidence of such experts and the public at large to work out practical recommendations which strike an acceptable economic balance often between conflicting social goals and goods.

Among these challenges will be - to mention just three - the technical analyses and implementation of standards in the areas of consumer electronic immunity, non-ionizing radiation limits, and the spectrum planning and coordination for multi-service radio communication facilities.

Traditionally, electromagnetic compatibility has centered around the prevention of interference to radio reception, primarily because the only electronic circuits in household use were those of radio receivers or audio equipment associated with receivers. During the last couple of decades, however, the mechanical switch and relay have been replaced with solid state switches and microprocessors which control the former. Most modern appliances are controlled electronically in response to low-level signals from transducers and complex computer programs. Because of their low level, these signals are easily corrupted by electromagnetic energy induced on the electrical leads, or in the circuitry itself, by radio signals in the environment. This situation has been of limited impact, however, because the radio signals required to cause the problem to manifest itself must be quite strong - of the order of volts/meter - implying either high power transmissions or close proximity between the RF source and susceptible equipment. Nevertheless, problems do occur, in some instances with serious potential consequences. While the number of such occurrences to date represents a very small proportion of the consumer electronic equipment currently in service, two factors are moving us relentlessly toward a substantial increase. The first is the growth of new applications for "smart" circuitry in homes and the ever-increasing degree of control responsibility being assigned to them: security, appliance control, climate control, and fuel efficiency monitoring. Related to the growth of such devices is a corresponding potential seriousness of the effects of a malfunction. Going hand in hand with this is the introduction of new radio services which are tending to an ever greater extent to place transmitters in the domestic environment, in immediate proximity to the susceptible devices. CB radios, messenger service portables, and the cordless telephone are precursors.

In recognition of this trend, the Department published an Advisory Bulletin (EMCAB-1) in 1977, to stimulate manufacturers' consideration of immune designs for consumer electronics products. This bulletin provided to manufacturers and users alike, theoretical predictions of typical field strengths in the vicinity of radio transmitters of all types in a single document. Utilized not only by international fora but also by our colleagues in the United States, we believe, it increased the priority accorded the subject by the International Special Committee on Radio Interference (CISPR). The concern is spreading in a number of developed countries, many of which are taking steps to put into place voluntary or mandatory controls. Germany and Italy, for example, already have mandatory immunity requirements for some classes of equipment. In the U.S., the

Federal Communications Commission has been given regulatory powers by Congress in this field, though current efforts are focusing on the preparation of voluntary standards.

Following EMCAB-1, actual measurements of field strengths were carried out in the metropolitan areas of Toronto, Montreal and Ottawa, primarily at Broadcast frequencies. The results therefrom were extended by theoretical extrapolation to provide a statistical probability distribution of anticipated field strengths. The results indicated that if consumer electronic equipment was able to withstand field strengths of about 1 V/m and without malfunction it would work satisfactorily at 95% of the locations covered by Broadcasting signals. Coupling these data with the large number of lower-power stations, such as land mobile and CB transmitters distributed throughout the environment, an immunity level of 2 V/m, would appear to be sufficient to cover the same percentage of locations in the metropolitan areas of Canada.

At the same time, parallel studies, based upon the economically realizable isolation of radio and TV receivers, indicate that, with the exception of the IF, image and tuned frequencies, immunity in the range of 1-2 V/m radiated is practicable with some design effort. As a result, CISPR is tending toward adoption of a general radiated immunity limit for receivers in the range of 1 to 2 V/m.

Based on limited data recently acquired, it has been found that RF signals induced on the power mains by radio transmitters may reach about 1 volt, providing some guidance regarding targets for conducted immunity levels. A limit of 1 V conducted is achievable using filtering and shielding of leads, although internationally there is not, at the moment, as complete accord on this subject as on radiated immunity.

In Canada, the position taken has been that only an international accord would prove effective; and our efforts have been directed to its achievement. The objective has been to promote the development of voluntary national standards harmonized with CISPR, either to forestall the need for regulation or, failing that, to provide a basis for regulations founded on industry/Government consensus, at some future date.

In this context of the development of immunity standards, one of the most significant stumbling blocks has been the establishment of repeatable measurement methodology. This aspect will present a further challenge to the spectrum manager. In this general area, the spectrum manager will have to work with manufacturers of all types of electronic equipment - not just with radio equipment manufacturers.

Another issue which is likely to challenge the technical spectrum manager, and whose eventual solution would involve medical, physiological and perhaps even psychological experts, is that of non-ionizing radiation. Potential biological hazards to human beings due to exposure to high RF fields, found in the immediate vicinity of high power transmitters, have been recognized for some time. Physiological reactions attributable to thermal effects of RF radiation are well documented. Over the last decade in Canada, the associated limits for the general public set by national health authorities have been reduced from 10 mw/cm^2 to 1 mw/cm^2 averaged over a 1 minute period. So far these have not posed significant problems for the siting of radio transmitters. This situation may well change due to a number of factors. Some, as yet incomplete, studies indicate that psychological and neurological reactions due to prolonged exposure to even lower levels of RF radiation may be present. Also the trend towards the concentration of a number of high power transmitters at the topographically most desirable locations increases the total R.F. power flux density in the vicinity of such locations. Such changes, coupled perhaps with social pressures could pose a significant siting and operational constraint on future radio systems. Technically, the spectrum managers will have to be aware of and involved in accommodating to such changes. They will also have to plan the processes and procedures and identify the computations that may be necessary. The first and foremost task in this context will be the computation of radio field strengths in the near field of transmitters. Due to topological factors, reflections from nearby buildings and the myriad variations of antennas, perhaps all that can be done is to base predictions on computations moderated by a set of empirically derived modification factor founded in statistically valid sampling and analysis. In Canada, studies currently focused on broadcast emissions have already commenced. The area of site location for radio transmitters also has a non-technical dimension. It is equally likely to gain as much prominence due to considerations of the aesthetic tastes of local communities which often reflect themselves in local zoning bylaws. The spectrum manager most likely will have to increasingly provide guidance and advice to the local authorities in the drafting of such bylaws to avoid needless and time consuming conflicts with the legitimate users of the radio spectrum. As is the case of the avoidance of non-ionizing radiation hazards, a number of separate legislative jurisdictions will need to operate in harmony. Only time and experience will tell whether the current mandates need adjustment or if there is adequate flexibility in the existing legislative authorities and structures to ensure timely and adequate action.

The trend towards multi-service facilities is likely to face the spectrum manager with another series of new technical challenges. This trend is exemplified in the multi-service satellites, which are already here; and more are being planned - for example, to provide aeronautical mobile, maritime mobile, land mobile and fixed services. Mutli-band satellites providing broadcast services, distribution services and fixed services are likely to proliferate. Reference has already been made to the trend for terrestrial transmitters to be co-located at common sites. The complex electro-magnetic compatibility considerations of such facilities and sites are generally considered to be the preserve of their users and owners. However, these same considerations also restrict the specific frequencies that can be utilised from such locations without causing interference amongst themselves. This also means that, the spectrum manager's freedom to select, or recommend, the frequencies to be used based only on considerations of the efficient use fo the spectrum, will also be restricted. The manager's technical personnel will have to become familiar with - and in some cases become involved in - the site engineering of such facilities. Technical guidelines to be used in such cases may also become necessary, and will need to be kept updated as technological advances occur or new services are introduced.

Conclusion

The need to perform the technical tasks associated with spectrum management will continue in spite of the changes in technology and the introduction of new services. A case may be made that the tasks and associated trade-off's will become more complex in the future. The challenge to the technical managers will be to keep abreast of these changes, identify trends sufficiently in advance to make adequate spectrum provisions, develop the appropriate rules to enable efficient and economic utilization of the spectrum and to fashion the tools to improve the efficiency of skilled human resources employed in all aspects of spectrum management.

SPECTRUM MANAGEMENT - THE REGULATORY ENVIRONMENT

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ABSTRACT

Spectrum management principles and practices in Canada have a close link to international regulatory treaties and agreements. There will be a brief description of Canada's regulatory relationship to the International Telecommunication Union and the effect that these and other international agreements have on Canadian spectrum management practices.

Legislative instruments are among the most significant tools used to manage the use of the spectrum. Recent and future legislative initiatives will be reviewed. Important changes are taking place in the legislatve/regulatory environment. Parliamentary reform and regulatory reform have a major effect on the reasons for, and methods of, creating regulatory instruments. The relationship between the various levels of regulation will be described.

Radio licence fees are another important aspect of the spectrum management scene today. Revenues have been brought into balance in relation to the costs of managing the spectrum resource in Canada. All users of the spectrum now share in funding of the costs of all aspects of managing the resource.

GESTION DU SPECTRE - RÉGIME DE RÉGLEMENTATION

par

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RÉSUMÉ

Les principes et pratiques de la gestion du spectre au Canada sont très étroitement liés aux traités et accords internationaux de réglementation. Les rapports du Canada avec l'Union internationale des télécommunications en matière de réglementation sont brièvement décrits. L'effet que ces traités et accords et d'autres ententes internationales ont sur les pratiques canadiennes de la gestion du spectre est aussi examiné.

Les instruments législatifs sont au nombre des moyens les plus utiles servant à la gestion de l'utilisation du spectre. Des mesures législatives récentes et à venir seront révisées. Des changements notoires sont introduits dans le domaine des lois et de la réglementation. La réforme parlementaire et la réforme de la réglementation ont une incidence considérable sur les raisons qui sous-tendent l'élaboration d'instruments de réglementation et sur les méthodes suivies pour cette élaboration. Les rapports entre les divers paliers de réglementation sont aussi décrits.

Les droits de licence radio constituent aujourd'hui un important aspect de l'univers de la gestion du spectre. Les recettes sont établies en proportion directe des coûts supportés au Canada de sorte que tous les utilisateurs de radiofréquences participent aujourd'hui au financement de cette gestion dans tous ses aspects.

ORIGINAL : ANGLAIS

SPECTRUM MANAGEMENT...THE REGULATORY ENVIRONMENT

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The Link to International Regulatory Treaties and Agreements

One of the United Nation's specialized agencies is the International Telecommunication Union. Canada is one of the 162 nations which belong to that well-respected body. The actual provisions that are found in Canada's Legislation and Regulations have a strong relationship to the ITU's Regulations. The process of international frequency coordination to protect Canadian frequency assignments is based upon regulatory procedures contained in these ITU Radio Regulations.

Canada's relationships with its neighbours in this region of the world, such as the United States, are often set out in further agreements concluded pursuant to Article 31 of the ITU's Convention.

The Impact of International Regulatory Treaties and Agreements

In considering new uses of the spectrum, one must examine carefully whether the international regulations, as they currently exist, will permit international coordination of these new uses. If they do not, then Canada must work towards changing these regulations in a timely fashion.

These international regulatory obligations recognize the need for prudent management of the international spectrum resource.

There are some good examples where the international regulations either accommodated Canada's interests or were revised in time to accommodate these interests when the need arose or will arise. Some examples are the broadcasting satellite provisions in the international regulations for the 12 GHz band, the AM broadcasting frequency assignment plan and the allocations and regulations for the recently-introduced mobile services at 800 MHz including cellular radio telephone.

There are, however, a few cases where Canada has not been so fortunate. Most recently, for example, Canada has had some difficulty in coordinating appropriate frequencies for the mobile satellite service.

A potential cause for concern in the future is the growing congestion of the geostationary orbit over the Americas and the increasingly complex detailed frequency coordination required. Canada, and many other countries, are not yet satisfied that a suitable long-term solution exists.

The Regulatory Environment in Canada

The ongoing review of statues and regulations is carried out in Canada by a Standing Joint Committee of the House and the Senate. This was recently enhanced by the establishment of a Privy Council Secretariat responsible for Regulatory Affairs. This group performs a challenge function for regulations. A Minister is now specifically responsible for Regulatory Affairs. All of this is in addition to the long-standing legal review by Department of Justice lawyers in the Privy Council Office.

A federal regulatory plan, published annually in October, provides detailed information on all federal government regulatory proposals including the department's planned regulatory activities for the coming calendar year.

As a result of recent Parliamentary reform, separate legislative committees are now struck to examine each piece of legislation that comes to the House of Commons for approval. While they no longer deal with legislation per se, the Standing Committees of the House of Commons do provide broad policy guidance and an oversight function vis-à-vis departmental operations.

Regulatory Tools

The most obvious regulatory tools that are used to manage the radio frequency spectrum in Canada are, of course, the Radio Act and its subordinate regulations. As it exists today, the Radio Act is a rather short document written in language which describes enabling powers, responsibilities and duties. The more specific and detailed regulatory provisions are found in the regulations. There have been many suggestions that as a spectrum management legislative tool, the Radio Act should be improved and updated.

Licence Fees

Today, radio licence fees are an important aspect of the spectrum management scene in Canada as in most other countries. The licence fee structure has been adjusted in recent years to ensure that the costs of spectrum management do not contribute to a burden on the general taxpayer.

With the proclamation of Bill C-3 in March, 1987, all users of the radio frequency spectrum in Canada now pay a share of the costs of managing the invisible, yet finite spectrum resource. Greater self-regulation, a goal that is worth pursuing, should result from the establishment of a full cost recovery regime.

Conclusion

The regulatory environment, of which spectrum management is a part, is certainly a dynamic one. Both internationally and domestically, this environment is becoming more complex, more competitive and more demanding. Careful and constant attention to international regulatory fora is vital to protect and enhance Canada's interests.

International treaties and agreements are the unseen foundations of our domestic management of the spectrum. Up-to-date and effective domestic legislative instruments have a very important place in Canadian spectrum management.

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