FINAL REPORT OF A STUDY INTO THE LIKELY RADIO SPECTRUM ENVIRONMENT IN THE YEAR 2000 AND BEYOND

Carried out for:

The Director
Long Range Planning
Spectrum Engineering Branch
Industry Canada
300 Slater Street
Ottawa, ON K1A 0C8

Under Standing Offer
67DDS-4-6983/03-ST

Contract Number:
67SPN-5-2063

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Glossary of Terms

AMPS	-	Advanced Mobile Phone System
ATM	-	Asynchronous Transfer Mode
BPCS	-	Broadband Personal Communications Systems
BSS	-	Broadcast Satellite Service
CBC	-	Canadian Broadcasting Corporation
CDMA	-	Code Division Multiple Access
CDPD	-	Cellular Digital Packet Data
COFDM	-	Coded Orthogonal Frequency Division Multiplexing
CRC	-	Communications Research Centre
CRTC	-	Canadian Radio-television & Telecommunications Commission
CWTA	-	Canadian Wireless Telecommunications Association
DAB	-	Digital Audio Broadcasting
DAMPS	-	Digital Advanced Mobile Phone System
DBS	-	Direct Broadcast Satellite
DECT	-	Digital European Cordless Telecommunication
DRRI	-	Digital Radio Research Inc.
DTH	-	Direct-to-Home
DVC	-	Digital Video Compression
ESA	-	European Space Agency
FCC	-	Federal Communications Commission
FDMA	-	Frequency Domain Multiple Access
FOS-2	-	A Next Generation Intelsat Satellite
FPLMTS	-	Future Public Land Mobile Telecommunications Systems
FSS	-	Fixed Satellite Service
Gbps	-	Gigabits Per Second
GEO	-	Geostationary Earth Orbit
GPS	-	Global Positioning System
GSM	-	Global System for Mobile Communications
GSO	-	Geostationary-Satellite Orbit
GWS	-	General Wireless Services
HEO	-	Highly Elliptical Orbit
IBOC	-	In-band on Channel
ICO	-	Intermediate Circular Orbit
IEEE	-	Institute of Electric and Electronic Engineers
IEO	-	Intermediate Earth Orbit
ITS	-	Intelligent Transportation Systems
ITU	-	International Telecommunications Union
IVHS	-	Intelligent Vehicle Highway System
IVS	-	Interactive Vehicle Systems
Kbps	-	Kilobits per second

LAN	-	Local Area Network
LEO	-	Low Earth Orbit
LMCS	-	Local Multipoint Communications Systems
Mbps	-	Megabits per second
MCS	-	Mobile Communications System
MEO	-	Medium Earth Orbit
MSAT	-	Mobile-Satellite
MSS	-	Mobile-Satellite Service
NCC	-	Network Control Centre
NPCS	-	Narrowband Personal Communications Systems
PABX	-	Private Automatic Branch Exchange
PBX	-	Private Branch Exchange
PC	-	Personal Computer
PCS	-	Personal Communications Systems
PMR	-	Private Mobile Radio
PSTN	-	Public Switched Telephone Network
RCMP	-	Royal Canadian Mounted Police
S-DAB	-	Satellite-Digital Audio Broadcast
SMR	-	Specialized Mobile Radio
SRT	-	Subscriber Radio Telephone
CP	-	Transmission Control Protocol
TCP/IP	-	Transmission Control Protocol/Internet Protocol
TDM	-	Time Division Multiplexer
TDMA	-	Time Division Multiple Access
UHF	-	Ultra High Frequency
UMTS	-	Universal Mobile Telecommunications System
VHF	-	Very High Frequency
VSAT	-	Very Small Aperture Terminal
WIM	-	Weigh-in-Motion
WLL	-	Wireless Local Loop
WRC	-	World Radiocommunication Conference

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Executive Summary

This *Study into the Likely Radio Spectrum Environment in the Year 2000 and Beyond*, carried out by Lapp-Hancock Associates Limited, addresses the major changes in spectrum use predicted for the period 2000 to 2020. It also draws conclusions on the Spectrum Management approaches required to meet this changed spectrum use environment.

The study included the following elements of spectrum management:

- Strategic elements involving overall policy; socio-economic factors; the radio spectrum as a whole and factors that provide links between applications.
- Mobile systems
- Point-to-point and point-to-multipoint microwave systems
- Space systems
- Broadcasting
- The spectrum above 40 GHz
- The Longer Term Future

The key findings and predictions of this major study are given in summary form below. This study has shown that the use of the radio spectrum is in a period of revolutionary change. In the past the radio spectrum was primarily used for long distance communications. The trend of spectrum use is now the reverse of this situation. Long-distance communications are now primarily by terrestrial and sub-oceanic fibre optic (wireline) links and the use of the spectrum is becoming more and more dedicated primarily to short mobile links with very significant frequency reuse. **Personal mobility is now the driver of spectrum use.**

* * *

While the current major move toward mobility in all forms of telecommunications had cellular and trunking technologies as its initial drivers, these technologies arose at the right time to meet key economic and social needs. The thrust is now to expand the use of mobile services from the business sector to include the residential sector. It is this potential expansion that at once is the most uncertain, and the one most likely to have greatest impact on spectrum use in the year 2000 and beyond.

The basic affordability of public telecommunications services, as well as the rate structure for such services, is likely to be a major factor in determining universal growth of telecommunications mobility.

In the opinion of the project team, mobility in telecommunications is at a key strategic crossroads. The direction taken will determine, by the year 2000, whether or not telecommunications mobility will become an ubiquitous residential and business infrastructure or remain merely a good key business tool. Much evidence points to one over-riding strategy which will be the major determinant of the future direction of telecommunications mobility. This strategy is whether or not public mobile services move toward a flat rate charge or maintain the current usage charges. This decision is predicted to have a major impact on future spectrum use.

* * *

If broadband mobile service becomes ubiquitous in Canada there is likely to be a demand for internet access and other data services to be carried. This would significantly increase over-the-air traffic density.

Low cost messaging, that is narrowband PCS, is expected to grow considerably in the next few years and into the 21st century.

Both of these factors would require increased spectrum allocation. It should be emphasized, however, that this is dependent upon the socio-economic acceptability of PCS as a whole.

* * *

Broad-band wireless local loops will become one of the most important applications of wireless technology in the future. Again this will require increased spectrum allocations, possibly in the higher gigahertz bands.

* * *

For future spectrum regulation to be effective it must have the flexibility to meet the changing social-economic and technical needs of spectrum use. **Digitization, and real-time, software driven, dynamic frequency assignments could dominate the mobile spectrum, requiring a completely different approach to spectrum management.** Overall, the role of spectrum management in the future is likely to be to mandate the provision of the desired services while protecting essential spectrum required for scientific purposes, the public health and well-being, national interests, the protection of the consumer, and for similar matters relating to the public good. The need to specify specific services and specific technologies within specified bands will no longer be relevant except to facilitate progress and protect the consumer.

The success of **spectrum management in the future** will rely upon a complex interplay of regulation, the social-economic impact of allocations and from the business decisions of the service providers. While all of this will be backed by new and emerging technologies, it will not be these technologies that primarily shape the spectrum needs of the future. These major changes in the spectrum usage drivers **will require new and better models of spectrum management.**

Perhaps the most far-reaching example of such a new model is the likely requirement for Strategic Regulation, rather than the current tactical regulatory approach where each band is regulated by a detailed range of documents published by Industry Canada. **The trends toward ubiquitous frequency re-use; automatic *intelligent* frequency assignments; advanced intelligent network technologies; and toward interference resistant spectrum usage (CDMA) will require carefully planned, long-term, spectrum regulatory directives rather than today's closely managed environment.**

* * *

With the advent, over the next 20 years, of digital audio broadcasting (for radio) and digital television, **it is very likely that the whole matter of the allocation of VHF and UHF spectrum to broadcasting services will require strategic review and decision.**

* * *

The resonant effects of the various cavities forming the human skull have the potential to significantly increase the biological impact of the transmissions from personal communications telephones. In particular to resonance of the skull in the lower gigahertz range and the resonance of the eye socket around 30 GHz are of concern.

As both the low gigahertz and 30 GHz frequency bands are under consideration for both terrestrial and satellite hand-held terminals, it can be expected that the potential for health hazards, and the need for appropriate regulations to overcome potential such hazards will be yet another strategic spectrum management consideration for the year 2000 and beyond.

* * *

In urban areas, Intelligent Transportation Systems (ITS) are expected to have little effect on spectrum usage: however, in rural areas, ITS are likely to become a major user of spectrum for both mobile and fixed applications.

* * *

Over the next 10, 20 and more years, Canadians will use an ever increasing array of satellites with vastly different characteristics. There are new technologies for the ground terminals and the satellites themselves, including onboard switching and intersatellite links. All these changes are going to lead to significant differences in the way in which radio spectrum is used for satellite communications.

The next 15 years could see a further lessening of the regulations surrounding satellite communications, including an *open skies policy* between Canada and the U.S. that will allow users to access satellite space in either country. The remaining obstacles to full interconnection between satellite and terrestrial systems are likely to be withdrawn and the licensing of ground stations made significantly easier.

* * *

The radio spectrum above 40 GHz is the latest *unused segment* of the spectrum. It has the potential for very wide bandwidth services, high frequency reuse, and has the capability for mass production low cost devices for many terrestrial applications. As such it is expected to be perhaps the most active sector of the radio spectrum in the year 2000 and beyond. Much activity above 40 GHz will be for entirely new applications for which the transmission, interference and propagation characteristics are not well known. In addition, physical resonant frequencies in this segment of the spectrum are still being found as equipment sensitivity is improved. **In addition, the current ITU spectrum allocation limit of 400 GHz can be expected to be extended as new physical resonant frequencies and further applications are found for this part of the radio spectrum.**

* * *

Work is currently underway on a staggering array of initiatives in wireless technology with one objective: to provide telecommunications of any kind, to anyone, anywhere, at any time. The interesting feature of this conclusion is that it is exactly the conclusion that was reached by the TeleCommission studies that launched the Department of Communications in 1971; and that which led the Canadian telecommunications industry to the declaration of Vision 2000 in 1990. The truth of the matter is that progress towards the goal of seamless, ubiquitous communications has been constant and steady since the introduction of the telegraph, and is accelerating with the introduction of each major technological advance.

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FINAL REPORT OF A STUDY INTO THE LIKELY RADIO SPECTRUM ENVIRONMENT IN THE YEAR 2000 AND BEYOND

1.0 INTRODUCTION

This *Study into the Likely Radio Spectrum Environment in the Year 2000 and Beyond*, carried out for the Long-Range Planning Directorate of the Spectrum Engineering Branch of Industry Canada by Lapp-Hancock Associates Limited, addresses the major changes in spectrum use predicted for the period 2000 to 2020. It also draws conclusions on the Spectrum Management approaches required to meet this changed spectrum use environment.

2.0 OBJECTIVE AND SCOPE OF THIS STUDY

The objective of this work is to assist Industry Canada in developing a projection of the radio spectrum environment appropriate to the year 2000 and beyond, as an input to Industry Canada's strategy for spectrum use in this timeframe.

The scope involves the following elements of spectrum management:

- Strategic elements involving overall policy; socio-economic factors; the spectrum as a whole, and factors that provide links between applications.
- Mobile systems
- Point-to-point and point-to-multipoint microwave systems
- Space systems
- Broadcasting
- The spectrum above 40 GHz
- The Longer Term Future

Among the factors that were considered for each of these elements are the following. It should be noted, however, that not all of these factors are appropriate to each element:

- Established technology developments trends

- Government policies
- The trend for wireless telecommunications to become a key infrastructure in many economic sectors
- The trend to world convergence of the computer, telecommunications and cable television industries
- Planned systems and emerging services
- Evolution of existing services and systems
- Research and laboratory technology indications
- International developments
- Socio-economic factors
- The agenda of, and Canada's interest in, WRC '97
- New services in the next five to ten years that will be using the spectrum, and how they will impact on how the spectrum is managed
- Changes in existing services due to new technologies expected in five to ten years
- Changes in wireline services due to technological developments and to the increase in wireless access expected in five to ten years
- Services spectrum users (service providers, manufacturers, users) would need as a result of the new regimes for authorization, i.e. Auctioning, Lotteries, etc.
- Technologies considered and being used for wireless access. The trends in this area, and any migration from one to other or integration. One specific issue will be competition between PCS and cellular wireless access applications and those of SRT (subscriber radio telephone) technologies at 1.5 GHz, 2.3 GHz and other MCS bands
- The possibility of integration of the BSS (sound) and MSS i.e. possible use of common bands, technologies, etc.

3.0 TIMESCALES BEING ADDRESSED FOR DIFFERENT SERVICES

It will be appreciated that some of the elements of this work have currently defined spectrum needs that reach well into the 21st century. Typical of these elements is satellite communications where some satellites now in the early stages of manufacture are expected to continue operations beyond the year 2010. In comparison, mobile communication is a highly dynamic element of spectrum management, where spectrum needs become quite speculative even by the year 2000.

It was felt appropriate to define the timescale limits for each of the services being addressed in this study, before they fall into the classification of a more speculative element, *The Longer Term Future*.

The timescales given hereunder, while to an extent arbitrary, are based upon the knowledge and experience of the Project Team:

- **Strategic and Socio-Economic Elements:** up to the year 2015. The intent here is to take as broad an approach as possible.

- **Mobile Systems:** up to the year 2005. This is a very dynamic area technically, but future spectrum needs will be greatly dependent upon socio-economic factors.

- **Microwave Systems:** up to the year 2005. Although traditional long-haul point-to-point microwave systems are expected to decline, the use of high capacity short-haul systems as backhaul for mobile cellular and PCS is likely to be a dynamic field, but these spectrum needs will be highly dependent on the same socio-economic acceptance factors as for mobile systems.

- **Space Communications:** up to the year 2015. While there are likely to be reasonably significant changes in spectrum use in space communications, brought about by increasing use of the Ka-band, for low-earth orbit satellites and highly elliptical satellite orbits, the spectrum usage is comparatively well defined up to the year 2015 due to the long planning cycle and operational timeframes of these applications.

- **Broadcasting:** up to the year 2010. During the period up to 2010 it is likely that socio-economic pressures for mobility will cause even greater lobbying for the transfer of spectrum currently used for urban television broadcasting to mobile use. Given the strength of both the broadcasting and mobile lobbies, the outcome of these pressures for change is uncertain. Also in this timeframe DAB is likely to succeed or fail and Digital TV is expected to be widely available.

- **The Use of the Spectrum Above 40 GHz:** up to the year 2010. Currently under-utilized, the spectrum above 40 GHz is likely to see considerable use during this timeframe and already there are conflicting pressures for this portion of the spectrum.

- **The Longer Term Future:** Although the foundations of the longer term future are rooted in present research and development, this section of the study will address elements of the spectrum beyond the timeframes identified above.

4.0 SPECTRAL SEGMENTS BEING CONSIDERED

The Canadian Table of Frequency Allocations: 9 KHz to 275 GHz, Revised to November 1995, identifies all allocations for each of the groups of services being addressed in this study. It has been agreed between the Project Authority and the Project Team that detailed evaluation of every frequency allocation is not only impractical, but unnecessary for a study such as this aimed at the projection of the radio environment in the year 2000 and beyond. The use of the spectrum for many applications is essentially static, particularly in the lower frequencies. Lower frequency limits for this study, for each element, were agreed upon. The upper frequency limit in each case is taken to be 40 GHz, except of course for that element addressing 40 GHz and above. In that case, the upper frequency limit is taken as 400 GHz. The following frequency limits were agreed upon with the Scientific Authority:

■ Mobile Systems	138 MHz to 40 GHz
■ Microwave Systems	1.7 GHz to 40 GHz
■ Space	148 MHz to 40 GHz
■ Broadcasting	54 MHz to 40 GHz
■ Spectrum above 40 GHz	40 GHz to 400 GHz

All work in this study is based on the spectrum allocations given in the November 1995 issue of the Canadian Table of Frequency Allocations. It will be appreciated that although these allocations were published less than three months ago, they are already obsolete in part by Canada's obligations under the Acts of the World Radiocommunication Conference of 1995. Before the year 2000 they will be further modified by the Acts of the World Radiocommunication Conference of 1997 and by the World Radiocommunication Conference of 1999.

5.0 FINDINGS AND PREDICTIONS

5.1 Strategic and Social-Economic Elements

5.1.1 Scope and Objectives

During the course of this study it became apparent that the likely radio spectrum environment of the future would be dependent on far more than technology and technical issues. Indeed social-economic factors and the strategic approaches taken by governments, regulators, spectrum users and manufacturers will almost certainly overshadow the technological drivers.

It will be recalled that comparatively recent technologies such as Telidon and Beta VCRs have disappeared essentially without trace because the general public either did not see a need for them or had more useful or cost effective alternatives. A further example of the power of Canadian society was the huge backlash against the cable television industry as a whole when the general public rebelled against *negative option* marketing.

To address these matters this initial and perhaps key section of the report has as its scope all strategic and social-economic matters likely to impact on the radio spectrum environment in the year 2000 and beyond. Its objective is to examine the key drivers from a strategic sense, the linkages between the various segments of spectrum and the critical social-economic decision points.

5.1.2 Findings

In reviewing the various elements of this study relating to overall strategy and social-economic impact, it was found that these could be readily classified into the following headings:

- The Strategic and Social-Economic Impacts of Mobility
- Regulatory Trends and Impacts

The Strategic and Social-Economic Impacts of Mobility

While the current overwhelming trend toward mobility in all forms of telecommunications had cellular and trunking technologies as its initial drivers, these technologies arose at the right time to meet key economic and social needs. In an increasingly competitive environment, the executives of all types of businesses and professions have found it necessary to be accessible essentially anywhere at any time. Emergency services also use these technologies to greatly reduce response times and improve efficiencies. The service and retail industries have also found that delivery and maintenance fleets with mobile radio can greatly improve customer service levels and increase overall efficiencies.

The trend is now for the use of mobile services to move out of the business sector into the residential sector. It is this potential trend that at once is the most uncertain, and the one most likely to have greatest impact on the spectrum use in the year 2000 and beyond.

Currently, with telephone companies charging a flat rate for local calls, wireline telephone service penetration is at 99%, with approximately seventeen million phone numbers in use in Canada. If the cost of local cellular and/or PCS calls drops to close to the PSTN rate by means of a flat rate, the number of telephone numbers per family may triple or quadruple, based on the natural human need for mobility, requiring some 50 million mobile telephone numbers, together with the radio spectrum to support them.

The basic affordability of public telecommunications services, as well as the rate structure for such services, is likely to be a major factor in determining universal growth of telecommunications mobility. The marketing of a large number of features over recent years in all aspects of public telecommunications has possibly pushed price elasticity to near its limits.

Over the next decade there is likely to be a demand for data and other services to be carried over it. Any change away from voice traffic is likely to significantly increase call length. For example Internet access calls could easily average an hour at a time, thus increasing individual channel use by orders of magnitude. In addition such traffic could well overlap the current peak traffic periods for voice. Both of these factors would then require a significantly increased spectrum allocation. However, it is expected that in the future, these calls which will be carried over the broadband PCS, in some applications, will not be handled by the PSTN, but by high speed packet type of data networks similar to those supporting today's ADSL services. Hence, call length will no longer be a measure for data traffic.

Messaging, that is narrowband PCS rather than traditional paging, is expected to grow considerably in the next few years and into the 21st Century. In part, this is due to its main thrust being to remain at the low end of costing for wireless communications to address the reality of the current economic environment. Messaging and paging could therefore become one of the more viable options for personal mobility.

Regulatory Trends and Impacts

It is perhaps self-evident that the multi-faceted activity of spectrum regulation is one that, to be effective, must have the flexibility to meet the changing social-economic and technical needs of spectrum use.

Regulatory authorities all over the world have been reviewing their spectrum regulatory policies to meet the challenge of accommodating very large numbers of users and services with a variety of distinct needs without intolerable congestion. The mobile needs stem from applications which include data and image transmission as well as the traditional voice traffic. This means that the spectrum will be more and more dedicated to short mobile links replacing local loops (both terrestrially and via satellite) and specialized short haul fixed links.

Wireless local loops will become one of the most important applications of wireless technology in the future. Opportunities for local loop replacements are likely to change the nature of the telecommunications access network. This could be through the local telephone exchange or through the cable television network. Wireless local loops are likely to be used for a wide variety of applications including interconnection to computer networks and TV distribution services. Factors impacting on this include the cost of equipment, type of technology used, and the timing of its introduction. The time of introduction is tightly coupled with the development cost of the emerging technology and to the availability of spectrum.

Digitization and real-time, software driven, dynamic frequency assignments will dominate the mobile spectrum, requiring a completely different approach to spectrum management.

Overall, the role of spectrum management in the future is likely to be to mandate the provision of the desired services while protecting essential spectrum required for scientific purposes, the public health and well-being, national interests, the protection of the consumer, and for similar matters relating to the public good. In this report the likely future role of spectrum management is termed STRATEGIC REGULATION. The need to specify specific services and specific technologies within specified bands will no longer be relevant except to facilitate progress and protect the consumer.

Thus the long-term trend towards reducing the regulations controlling the use of satellite communications should also continue. Looking back 20 years, Telesat had a virtual monopoly on satellite communications and there were restrictions on the ownership of ground stations and there were various other limitations. Since then, the federal government has gradually but deliberately eased many of these restrictions. The next 15 years should see a further lessening of the regulations surrounding satellite communications, including an *open skies policy* between Canada and the U.S. that will allow users to access satellite space in either country. The remaining obstacles to full interconnection between satellite and terrestrial systems should be withdrawn and the licensing of ground stations made significantly easier.

Another significant regulatory factor which will effect the use of the spectrum as a whole in the future is the strategic approach that Canada takes to the matter of licence fees for the use of the radio spectrum.

The trend over the last 20 years regarding licence fees has been away from a nominal fee policy, first to full-cost recovery for government spectrum management operations, to, over the last five years or so, planned over-recovery of spectrum management costs.

This general approach has been reflected on a world-wide basis with the market value of radio spectrum licences being taken into account when jurisdictions assess licence fees.

Perhaps the most high profile of these approaches is that of the auctioning of spectrum, primarily but not solely in the United States. In particular a recent spectrum auction in that country attracted approximately $20[1] billion U.S. to the government coffers and was publicized as the single largest investment in new technology in history. Further, it was stated to be the driver to the FCCs decision to grant flexibility in the use of the PCS spectrum.

As to be expected, there is a major dichotomy of public opinion regarding any form of charging for the radio spectrum, other than, as a maximum, recovery of regulatory and administrative costs. The spectrum is seen as a renewable public resource, and one that should be used for the public good. Notwithstanding this, there now is a feeling of inevitability that most jurisdictions, in the future, will use the radio spectrum as a revenue producing mechanism.

In general it is hoped, and expected, that Industry Canada will take a reasonably balanced approach to licence fees, possibly in effect to *lease the spectrum* to users at an annual rate that reflects, in part, the market value of such spectrum. This could be on an estimated basis for the first licensees of a new band or service. After both the viability and value of the service has been established, subsequent licenses could be auctioned on an ANNUAL fee basis. The initial licenses would then have their subsequent annual fees adjusted to the mean of the annual fees obtained by the auction. By this means Industry Canada could obtain much needed revenue, while at the same time retaining maximum control over the spectrum while minimizing the *property rights* accruing to the licensee and the excesses of the U.S. auction system.

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[1] Quote from FCC at VTC '96 Conference.

A further future change in spectrum management expected to impact upon Industry Canada is the trend (and the need) toward a global approach to spectrum management. Driven in part by the move toward significant use of low earth orbit (LEO) satellite for universal mobile telephone services, it is expected that individual jurisdictions will be required to relinquish some of their current local spectrum management authority for the common good.

The very nature of LEO satellites is their universal coverage. Thus frequency allocations that are different in each ITU region are quite inappropriate. The massive trend toward telecommunications mobility will also lead to significant pressures for commonality of terrestrial mobile frequencies and standards to permit *universal roaming*.

A further dimension to spectrum regulation that will become more important in the year 2000 and beyond is that of the spectrum above 40 GHz. In the past, little use has been made of this section of the spectrum. However, it has two conflicting characteristics requiring careful world-wide spectrum management in the future. The first is the fact that many physical resonant frequencies are found in this portion of the spectrum making it a key tool for the disciplines for earth observation, space science and radio astronomy. These three disciplines use radiometric *passive* means to observe these key environmental factors. As the resonant frequencies (and certain atmospheric windows) are critically frequency-specific, there are no alternatives to them. In addition, the very high receiver sensitivities required for data gathering make them particularly sensitive to direct and indirect interference, including man-made variations of the *noise floor.*

At the same time the high levels of atmospheric and precipitation attenuation make this section of the spectrum ideal for short distance, wide bandwidth, high frequency reuse, fixed and mobile applications. These characteristics of course coincide with those needed for wireless local loops, PCS in buildings and interactive vehicle systems (ITV) such as collision avoidance and en route traffic control.

The whole future of broadcasting in its traditional form is yet another strategic issue facing the Spectrum Management Branch of Industry Canada in the timeframe under consideration. Driven by technological change, broadcasting is another use of the spectrum which is moving into an evolutionary crossroads that will become critical around 2000 to 2015. In the past, over-the-air broadcasting has been considered to be a national cultural resource and has been allocated significant spectrum throughout the majority of the frequency bands up to approximately two gigahertz.

The virtually ubiquitous use of cable television in urban areas, combined with the fact that television (and FM radio) frequency allocations are ideal for mobile applications, has given rise to considerable pressures for the reallocation of these broadcasting frequencies in urban areas. So far these pressures have been insufficient to change the national policy.

Finally, this section on strategy and social-economic impacts would not be complete without consideration of the potential health impact of universal telecommunications mobility.

Although virtually all portable personal transmitters will be of low power, the fact that the transmitters will be in hand-held units which are pressed against the skull during use means that the electro-magnetic field strength at the skull is quite high. While of course all radio frequencies are non-ionizing, they do have a heating effect which is potentially dangerous at high levels. Very considerable research has taken place as to the biological effect of the UHF frequencies currently used by cellular telephones. All indications to date are that the power levels used are insufficient to cause harm.

However, in considering frequencies that are allocated to hand-held mobile applications, a further factor must be taken into account, that of the resonant effects of the various cavities forming the skull, and the potential for such resonances to significantly increase the biological impact of the electro-magnetic fields. To-date, two cavities have been considered. The first of these is the complete skull which, it is understood, resonates in the low gigahertz range. The second is the eye cavity which, it is understood, resonates at about 30 GHz. Before the extensive use of telecommunications mobility becomes a reality, further research into the biological effect of these frequencies will be needed, leading to appropriate regulations.

5.1.3 Likely Impact of these Findings on the Spectrum

It is perhaps useful to first highlight a major general trend in the use of the radio spectrum.

In the past the radio spectrum was primarily used for long distance communications, for example continent-spanning microwave links; trans-oceanic satellite links; wide area mobile communications and wide area broadcasting. The trend of spectrum use is now the reverse of this situation. Long-distance communications are now primarily by terrestrial and sub-oceanic fibre optic (wireline) links and the use of the spectrum is becoming more and more dedicated primarily to short mobile links with very significant frequency reuse.

In the opinion of the project team, mobility in telecommunications is at a key strategic crossroads that will determine, by the year 2000, whether or not telecommunications mobility will become a ubiquitous residential and business infrastructure or remain merely a good key business tool.

Much evidence points to one overriding strategy which will be the major driver of the future direction of telecommunications mobility. This strategy, which is likely to be determined on an essentially equal basis by public opinion; government strategy and policy; and the strategies of the major service providers, is **whether or not public mobile services move toward a flat rate charge for local calls or maintain the current usage charges. This decision is predicted to have a major impact on future spectrum use, with the former approach acting as a catalyst to a massive expansion in mobile telecommunications and in future spectrum requirements.**

Also, any service which will increase call length, over that of the current *voice message average* will significantly increase spectrum allocation that would be required.

5.1.4 Likely Impact of these Findings on Spectrum Management

The success of **spectrum management in the future** will rely upon a complex interplay of regulation, the social-economic impact of allocations and from the business decisions of the service providers. While all of this will be backed by new and emerging technologies, it will not be these technologies that primarily shape the spectrum needs of the future. These major changes in the spectrum usage drivers **will require new and better models of spectrum management.**

Perhaps the most far-reaching example of such a new model is the likely requirement for Strategic Regulation, (see page 7) rather than the current tactical regulatory approach where each band is regulated by a detailed range of documents published by Industry Canada. While these were appropriate to past and, to an extent, current needs, **the trends toward major frequency re-use, automatic *intelligent* frequency assignments; advanced intelligent network technologies and toward interference resistant spectrum usage (such as CDMA) will require carefully planned, long-term, spectrum use directives (i.e. Strategic Regulation) rather than today's closely managed environment.**

Regional and jurisdictional differences in frequency allocations will gradually become counter-productive and more and more spectrum management decisions will be made through the ITU on a universal basis minimizing national spectrum management activities. Overlaying this trend will be the general thrust toward *Strategic Regulation* described above.

It is emphasized however that the path to both Strategic Regulation on the national basis, and more encompassing ITU regulations on the international basis, will be neither smooth nor fast. There are likely to be many false turns and detours before the overriding need for, and universal benefits of, these approaches are generally recognized. (The current situation regarding spectrum allocations for Digital Audio Broadcasting (DAB) is sadly indicative of these pitfalls.

Both national and international regulations will be required to permit maximum use to be made of the spectrum above 40 GHz by potentially conflicting applications.

With the advent of digital audio broadcasting (for radio) and digital television, both of which are likely to be implemented on a large scale over the next 20 years, it is very likely that the whole matter of the allocation of VHF and UHF spectrum to broadcasting services will require strategic review and decision.

As both the low gigahertz and 30 GHz frequency bands are under consideration for terrestrial and satellite hand-held terminals respectively, it can be expected that the potential for health hazards, and the need for appropriate regulations to overcome such hazards will be yet another strategic spectrum management consideration for the year 2000 and beyond.

5.2 Mobile and Mobile-Satellite Services

5.2.1 Scope and Objectives

This section examines all mobile services and their use of the spectrum between 138 MHz and 40 GHz.

As identified in section 5.1 *Strategic and Social-Economic Elements*, above, the use of the spectrum for mobile services of all types is expected to be a main driver of spectrum use in the year 2000 and beyond. Most other applications such as microwave systems and satellite communications (other than for video distribution), will act, to a large extent, as support services to mobile applications. Also included in this sector are *wireless local loop* applications that, although they are not always strictly mobile applications, have many of the characteristics of such applications, particularly when used in an urban environment.

5.2.2 Findings

The unparalleled advancement in mobile radio technology and the tremendous growth in an array of new communication services has created unprecedented demand for radio spectrum. Regulatory authorities all over the world have been reviewing their spectrum regulatory policies to meet the challenge of accommodating very large numbers of users and services with a variety of distinct needs without intolerable congestion. These needs stem from applications including voice, data, and image modes.

In order to provide a strategic input on the future use of the spectrum by mobile services, an exhaustive review of current usage and a projection up to the year 2005 were carried out. It was assumed that mobile wireless communications with existing technology is only feasible below 3.5 GHz for fast moving terminals, but this may change with advancements in the technology.

Current mobile services may be divided into three main categories:

- services that are used by federal, provincial and municipal governments for national defence, law enforcement and public safety and air traffic control

- services used by the private sector data networks, electronic news gathering, transportation systems such as IVS and collision avoidance systems and similar applications such as dispatch services (fleet, taxi cab, courier, etc.).

- services to the public such as paging, railway and aeronautic passenger communications, cellular telephone service and Personal Communications Systems (PCS).

In the first category, the Department of National Defence (DND) is the biggest user of radio spectrum. Discussion of DND applications is, however, beyond the scope of this study. In addition, a substantial number of frequencies in this category are used for voice and data applications by the RCMP, Revenue Canada, Provincial Police, Health (ambulance service), and government maintenance services.

In the second category, conventional and dispatch-oriented services find applications in land, maritime, and aeronautical mobile services.

Both of these first two categories are classified as Private Commercial services and use spectrum in the VHF, lower UHF and higher UHF bands. The spectrum for Private Commercial Services may be divided into two ranges - below and above 512 MHz. The main emphasis in the use of spectrum below 512 MHz has been to increase the capacity. In the Private Commercial category, besides the use of spectrum for older types of services, the most important emerging technology is that of Trunked Radio Systems (TRS). SMR is an open entry competitive service introduced to stimulate development and production of spectrum-efficient trunking technology to meet existing and new user needs. It also enhances the development of new techniques and services such as mobile data, mobile fax, intelligent transportation services, and low resolution mobile video. This sector is very congested and steps are being taken to rationalize spectrum allocation within this band.

The last category, that of telecom interconnected services, which includes cellular telephones and Personal Communications Services (PCS), will be the main users of the radio spectrum in the high UHF and microwave bands. This sector has been growing at a very rapid pace and could cause spectrum shortage in the future. The purpose of PCS is to fill the gap between existing wireless telecommunications and to create new services. PCS will have an impact on telecommunications networks in terms of enhanced flexibility and functionality. A broad definition of PCS includes current Cordless Telephone, Advanced Cordless Service and Advanced Paging Services. In fact PCS will provide all those services currently provided by the cellular network, plus enhanced integrated voice, data and image services. Other services may include portable facsimile service and mobile computing, wireless local area networks, wireless local loop and wireless PBX services. These will be offered through both cable television systems and through the Switched Telecommunications Network (STN).

PCS will use inexpensive pocket-sized terminals which may be activated by smart cards. Personal communication will rely on considerable network intelligence and will use advanced signalling protocols including SS-7.

PCS in its most primitive form is the cordless telephone which is now used in conjunction with over 20% of all Canadian telephones. It occupies only 10 radio frequencies in one of the many license-exempt bands. In the United States, the new 1.9 GHz PCS service is projected to attract over 60 million users (a penetration of approximately 25%) within the first ten years of its operation. Its future in Canada is more indeterminate. PCS could provide competition to existing cellular, paging and private radio services, with the addition of two-way video, tele-conferencing, and data services. Ultimately the PCS may develop into a ubiquitous global network; but in most areas it is likely to complement cellular services.

5.2.3 Predictions

Based on a very detailed review of current R&D literature (see Appendix A(iii)) and upon interviews with key Canadian stakeholders in mobile communications (see Appendix B(iii)) the following predictions for future mobile spectrum needs, classified by major application headings, are made. **It should be noted that the basis for these predictions is primarily technical. They are thus open to modification by the strategic and socio-economic issues discussed in Section 5.1 above.**

Mobile Telephony

Cellular telephony has been growing at a rate of about 36% per year. Paging services have seen a similar growth rate. Over the next ten years new technologies will lead to a continuation of these growth rates. These technologies include:

- More options in the cordless services including community-based cordless services.

- Cellular Digital Packet Data (CDPD), an innovative service to deliver short message services. In this system, the system scans for an idle channel to send short messages. The voice traffic enjoys priority over the data traffic. The use of the voice channels to also carry data will increase channel utilization.

- Mobile high speed file transfer systems over wireless LAN's and mobile computing are also predicted to be a major application.

Mobile Communications Applications to Transportation Systems

Vehicle identification and intelligent transportation services are predicted to be a dynamic and growing sector. Applications include:

- vehicle identification for theft recovery,
- entry into restricted zones,
- automatic toll systems,
- anti-collision devices,
- radio controlled light rail systems,
- advanced train control systems,
- truck location systems,
- hot box detection systems,
- vehicle location systems.

Wireless Consumer Electronics

Major growth areas predicted in this application sector are:

- radio tag systems used to control the movement of people in health care institutions;

- radio tag systems used in monitoring performance of certain processes, e.g. mail sorting systems;

- inventory control systems, electronic price tag systems and point-of-sale systems;
- remote controls in intelligent buildings, perimeter control systems.

It should be noted, however, that these applications are expected to primarily use spectrum in the unlicensed Industrial, Scientific and Medical allocations in the 900 MHz, 2.4 GHz, and 5 GHz bands.

Mobile-Satellite Services

Mobile satellites are and will be used to provide access to telecommunications to subscribers in rural and remote areas. Cellular and PCS systems are often impractical in such areas. The LEO satellite constellations will offer low-power PCS with features including mobile telephony, data and image distribution, and international and intercontinental paging.

5.2.4 Likely Impact of these findings on the Spectrum

The three segments of the radio spectrum traditionally used in mobile communications are frequencies below 512 MHz, between 512 and 1 GHz, and above 1 GHz. The predicted future loading of these spectrum segments is discussed in the following sections.

Below 512 MHz

The frequencies below 512 MHz are primarily used for Private Commercial Services. Three bands fall into this range; low band, 27.5 to 50 MHz (638 channels); high band, 138-174 MHz (600 channels); and the UHF band, 450-470 MHz, (302 primary pairs, 9 one way paging, 8 two way simplex channels).

These bands represent about 75% of the Private Commercial Service licenses and 81% of the transmitters. By the year 2000, Toronto, Montreal and Vancouver will experience significant shortages. The population of these cities has been increasing over the years but the number of frequencies available in these bands has not increased, with the consequence that the number of mobiles per capita is decreasing.

The congestion is likely to be reduced and spectrum efficiency increased within this band by spectrum re-farming. For this purpose new regulations governing spectrum allocation are likely to be required to encourage users to replace older, spectrum-inefficient systems with more efficient technologies. In this regard, a number of issues have to be resolved. For example:

- What kind of new technology is necessary, and what metric should be used to compare the candidate technologies?
- What is the benchmark technology which could be used to compare spectrum efficiency of competing systems?
- How to monitor the use of technologies by the operators?

Further study is required on these issues. The benchmark technology must be selected to provide a standard against which to measure technical improvements and increases in spectrum efficiency. The study should then define a methodology which allows a comparison of any technology with the benchmark technology.

Frequencies Between 512 GHz and 3 GHz

The 800-900 MHz band is used for cellular telecommunications, private land mobile radio and unlicensed wireless systems. This range of frequencies is used very extensively because its propagation characteristics are well suited to cellular networks and equipment costs are low.

The frequencies above 1 GHz have traditionally been used for privately operated fixed microwave links, auxiliary broadcast and cable television, government owned operations, and satellite communications.

The 1700 to 2300 MHz band is well suited for both terrestrial and satellite PCS services, including multimedia.

In Canada, the PCS broadband licences in the 1850 Mhz to 1975 Mhz have been awarded to the following operators: Rogers Cantel Mobile Inc., Mobility Personacom Canada Ltd., MicroCell Network Inc., and Clearnet PCS Inc. The first two have been assigned 10 MHz bandwidth to add PCS services to their existing cellular services, while the latter two have been assigned 30 MHz each.

Technology-based market predictions suggest that the current allocations may not be able to meet the future demand for services. In addition, there will be evolutionary pressures on the spectrum as information-based mobile services are added. These will greatly increase the average time a given channel is used and thus effectively linearly increase spectrum use.

Above 3 GHz

The currently held view that 3.5 GHz is the upper frequency limit for mobile communications is changing with the advancement in transceiver technology. It is likely that, with the advent of powerful signal processing technologies, the impact of fading on the signals will be minimized and use of frequencies higher than 3.5 GHz will become feasible. Europe is already evaluating the feasibility of using 5 GHz band for mobile wireless services.

In the United States, General Wireless Services (GWS) is being proposed for operation in 4660-4685 MHz. GWS will introduce new services and enhance the existing ones.

5.2.5 Likely Impact of findings on Spectrum Management Activities

Pressure for new mobile service spectrum in the band covering frequency 2.5 to 5 GHz is likely. Spectrum currently allocated for fixed microwave facilities may be the most appropriate source of new spectrum but its reallocation to PCS may create some difficulties.

Overlaying PCS services over this spectrum may resolve some difficulties in the short term. However, the following issues must be resolved:

- How much spectrum would be required for PCS type of operations when overlaid over the existing services?
- How many licenses could this spectrum support?
- What will the impact of reallocation (or overlaying) be on the existing services?

This section will address these questions qualitatively since quantitative assessment requires an understanding and modelling of complex relationships between technology, economic factors, and attitude of the society towards new services. The current growth of nearly 30% per year is unlikely to continue, but it is possible, subject to a health growth in the economy and reasonably low prices of user terminals, a sustainable yearly growth of 20% may be achieved; if there is a healthy growth in the economy, combined with low cost user terminals. This, however, does not mean that new spectrum will be required every year. Extensive frequency reuse and control of interference will reduce the requirement of spectrum to much lower than the growth rate.

Sharing the spectrum by a variety of services can also play a significant role in reducing the need for new spectrum. The concept of wideband services sharing the spectrum with narrowband services has been extensively studied by many researchers. In this regard, interference control will play an important role.

How much additional spectrum will be needed to meet future demands can only be answered by a detailed study of a later date. It is possible that new technologies which counter channel fading will be developed thus allowing the use of frequencies higher than 3.5 GHz for wireless mobile applications.

One of the most important future applications of wireless technology is in Wireless Local Loop. Opportunities for cellular and PCS as local loop replacements are likely to change the nature of the telecom access network. Connection could be with the local telephone exchange or cable television network. Wireless local loop may be used for a variety of applications including interconnection to computer networks and TV distribution services. The wireless local loop could operate at 18 GHz, 28 GHz; 38 GHz or 56 GHz. It is not clear however, which technologies or devices will be preferred for such wireless local loop operations. An indicator of this is the fact that the current LMCS wireless local loop license applications are primarily for digital wireless local-loop technologies yet to be proven.

Notwithstanding this, there is little doubt the wireless local loops are likely to have an immense impact on spectrum usage and management.

5.3 Microwave Systems

5.3.1 Scope and Objectives

This section examines fixed services, that is point-to-point and point-to-multipoint services. The frequency range of interest is from 1.7 GHz to 40 GHz (and occasionally beyond). Fixed services are now, and certainly will be in the future, dominated by those that are generically *backhaul*. As such, the existence of a particular demand for these services depends on the success of other services, especially mobile. Those services are covered in other sections of this report.

One service that is covered here (because it is partly fixed and partly mobile) is Interactive Vehicle Systems (IVS).

5.3.2 Findings

In general, as new services are demanding spectrum, microwave is losing spectrum to them; at the same time, new services are expecting microwave backhaul. This is creating a *tension* for microwave manufacturers and users.

A meeting with Harris Farinon put a perspective on what is happening in *traditional* microwave bands. The 2 and 4 GHz bands are being lost to other services. 6 GHz is now full (but see below for possible lessening in its use). 10 GHz is available, but the traffic it can carry is limited by the size of the band. The upper 6 GHz and lower 8 GHz band are already being used in part by MSS feeder links. In the 18 GHz band, Teledesic will be using 18.8 to 19.3 GHz. Because 23 GHz is shared with inter-satellite links, the maximum permitted EIRP will be reduced.

The paragraph above does not consider IVS. There is an expectation that spectrum will be available for this application. The list of proposed and existing IVS subsystems is instructive:

- Non-stop tolling systems,
- Closed circuit television,
- Weigh-in-Motion (WIM),
- Ice warning,
- Emergency call systems,
- Vehicle location (using GPS),
- Speeding vehicle detection,
- Variable message signs,
- Collision avoidance,
- Travellers' advisory radio.

Non-stop tolling systems are operating in Portugal, Austria and Thailand. Closed circuit television and emergency call systems are in operation in many parts of the world, including Canada.

Some of these systems will use infrared, and so are not of interest here. Others need radio/radar for sensing: frequency allocations are essential here. Fortunately, because these systems are of very low power, considerable frequency reuse will be possible.

Others (e.g. closed circuit television) can use point-to-point radio, coaxial cable or fibre back to a hub; from the hub to the control complex requires either fibre, satellite communications, terrestrial radio or coaxial cable. Other subsystems operate at a lower data rate, but the data rates are still substantial. The most economical choice may be radio, but highway operators may be forced to use less economical media for backhaul.

Broadcast-type services, e.g. traveller's advisory radio, may well piggyback on other broadcast services. In the near term, they may use sub-carriers on broadcast FM radio; in the longer term, they may use ancillary data channels on Digital Audio Broadcasting (DAB).

Urban expressways are expected to use fibre and/or coaxial cable so IVS will have a relatively small impact on spectrum crowding in and around cities. In rural areas, instrumentation will be less dense so operators will favour radio.

Personal Communications Systems (PCS) operators are expected to use 15, 18 and 23 GHz for backhaul.

Most interviewees expect Wireless Local Loop (WLL) to require significant bandwidth to handle all services to the home, including video; therefore, frequencies above 30 GHz will probably be used. 56 GHz seems to be a possibility. One question arises: will communications at 56 GHz be sufficiently robust? One solution is to use lower frequencies where robustness is assured; SR Telecom are developing a TDMA system operating at 350 to 400 MHz.

A new point-to-point service, which is in field trial now is CellularVision. The Calgary trial is now performing to specifications. However, this application must be critically evaluated. CellularVision, as it now exists, is an analog FM system designed to carry 49 TV channels, using 2 GHz between 25.25 and 29.5 GHz. As such, it is not an efficient user of spectrum, and so should not be permanently allocated spectrum. It is possible that a digital system is in development. If it is, given the expected intense competition for spectrum, should digital CellularVision be granted permanent frequency allocations?

At the present time, fibre has largely replaced 6 GHz radio for long-haul communications; the radio system is retained as a backup. It should be possible, in the timeframe under review, to re-farm the terrestrial portion of the 6 GHz band to other uses; however, the current operators may be reluctant to *let go*.

There are proposals for sharing of bands between fixed services and broadcasting, specifically Digital Audio Broadcast (DAB). There is a concern here: low-power fixed services may be swamped by higher-power broadcasting.

5.3.3 Predictions

Based on current evidence and plans for spectrum use, spectrum is likely to be reassigned to other services at a time when the need for backhaul for these services is increasing.

The growth pattern of microwave is heavily dependent on which *other services* succeed. One may succeed for a while and then be replaced by another. Thus the spectrum available for fixed services may decrease, and the need for backhaul increase, while a number of other services (e.g. mobile) attempt to gain critical market share. Once the market *settles out*, more spectrum may be available for fixed services. In any event, there will be more fixed services than there are now.

IVS and WLL are largely unknowns at this time. If WLL at 56 GHz proves to be robust in urban areas, it will have relatively little effect on the spectrum usage, because of frequency reuse. If it turns out to be fragile at 56 GHz, it may turn out to be a major user of lower frequencies, probably below 1 GHz.

In urban areas, IVS is expected to have little effect on spectrum usage: sensors (and only some of them) will use spectrum; however, in rural areas, IVS is likely to become a major user of spectrum for both mobile and fixed applications. Mobile applications have to use radio (although some can use infrared); and, depending on spectrum availability, highway operators may be forced to use fibre or coaxial cable along the right-of-way, even where it is not economical.

5.3.4 Likely Impact on the Radio Spectrum

Requests for frequency allocations for fixed services are expected to increase over the next five years. Whether they will continue to increase depends on whether the consumer will be willing to pay for mobile, as compared to wireline, communications.

IVS may be a very significant user of spectrum, both for mobile and fixed applications. For fixed applications, substitution of media is possible; however, this implies that highway operators may be compelled to use fibre or coaxial cable. For mobile applications of course, such substitution is not possible.

5.3.5 Likely Impact on Spectrum Management Activities

It is now possible to install and start up a link in the 15, 18 and 23 GHz bands in as little as a day. It is government approval that takes the time. To reduce the role of government and to speed up commissioning of links, implementation of a wide area licensing policy should be considered. This type of policy is one in which an operator is granted exclusive use of particular channels in a specific geographical area for as many links as he wishes. Frequency reuse (and protection) within this area are his concern; Industry Canada coordinates frequency reuse between geographical areas. This policy might be implemented temporarily or permanently, for part of a band or for all of it.

The particular case in point at this time is PCS. Here operators are expected to deploy systems rapidly, and failure to be able to do so is a competitive disadvantage. Specifically, the policy might be implemented temporarily — for 18 months or so — for the 15 and 18 GHz bands; it might be put in place permanently for part or all of the 23 GHz band.

A note should be made about auctions. Inputs to this study lead to the belief that, in part, the FCC auctioned channels because they were unable to manage the immense number of applications they received.

Proposals for sharing bands between high and low-power services should be considered carefully. If a high-powered transmitter is operating on a channel adjacent to a low-power transmitter, the results could be disastrous!

A challenge for Industry Canada is how to retain sufficient spectrum for fixed services while enabling the implementation and expansion of new services. Reducing fixed-service spectrum too much may severely affect mobile and IVS services.

5.4 Space Systems

5.4.1 Scope and Objectives

The term *Space Systems* encompasses a wide range of applications, however the dominant usage of this band is for satellite communications. Other important space applications include Space Research, Earth Observation Satellites, Radio Astronomy, Amateur Satellite, and Meteorological Satellite.

In one sense, satellite communications is a very mature technology. It is 34 years since Canada's first experimental satellite, Alouette 1, was launched and Telesat Canada has been a major force in satellite communications for 27 years. Yet the global satellite communications industry is currently going through a period of major change. The industry is literally reinventing itself. There are new technologies, new applications, new radio bands that are being used for satellite communications, and new players in the industry.

Over the next 10, 20 and more years, Canadians will use an ever increasing array of satellites with vastly different characteristics. There is a whole alphabet soup of different kinds of orbits: LEOs, MEOs (or IEO), HEO, as well as the original GEO. There are new technologies for the ground terminals and the satellites themselves, including onboard switching and intersatellite links. All these changes are going to lead to significant differences in the way in which radio spectrum is used for satellite communications.

5.4.2 Findings: Current Use of Space Bands

Analyzing the Canadian Table of Frequency Allocations for entries that contain the words *satellite*, *space*, or *radio astronomy*, yielded nine pages of single-spaced information. That volume of information is not included in this report, but it is useful to document those bands that are more frequently used and referred to by various people who were interviewed for this study.

Figure One: Examples of Canadian Usage of Spectrum for Space-related Applications

BAND			APPLICATION
	(MHz)		
429.5	-	430.5	Ionospheric backscatter measurements
1400	-	1427	Radio Astronomy (Hydrogen Line)
1452	-	1492	DAB and S-DAB
1530	-	1559	MSAT forward link
1610.6	-	1613.8	Radio Astronomy (OH Line)
1616	-	1626.5	Iridium service links
1620	-	1626.5	Big LEO
1631.5	-	1660.5	MSAT reverse link
2204.99	-	2361.99	Radio Astronomy
2483.5	-	2500	Odyssey
2750	-	2850	Canadian Solar Flax measurement program
3700	-	4200	Satellite-to-Earth (*C-band*)
5270	-	5330	Radarsat (C-band)
5925	-	6425	Earth-to-Satellite (C-band)
	(GHz)		
10.9405	-	10.9455	MSAT Ku/Ku link
11.7	-	12.2	Satellite-to-Earth (FSS)
12.2	-	12.7	Satellite-to-Earth (BSS)
12.75	-	13.25	MSAT feeder links

Many different ways in which the space bands are currently used were identified as follows:

- Cancom currently uses the C- and Ku-bands for TV distribution, data distribution, VSATs, Business Television, and mobile data services for the trucking industry.

- CBC and private TV broadcasters also use the 6/4 GHz and 14/12 GHz bands for the distribution of radio programming (both mono and stereo).

- Teleglobe Canada uses all the Intelsat and Inmarsat bands: L-band, C-band, and Ku-band; the applications include fixed and mobile communications for voice telephony, data and video.

- Telesat Canada also uses the C- and Ku-bands for its wide variety of satellite services to broadcasters, government organizations and businesses.

- TMI uses both L-band and Ku-band. L-band is used for links between mobile terminals and MSAT; the 1530-1559 MHz band is used for the downlink to the mobile terminal (also known as the *forward link*); the 1631.5-1660.5 MHz is used for the uplink from the mobile terminal (MSAT *reverse link*). TMI also uses allocations in the 13/11 GHz band for the high speed links to and from the hub station in Ottawa. These are the *feeder links* referred to in Figure One.

- Radio Astronomy uses a number of different bands, including 1429.5 - 1430.5 MHz which is used by the University of Western Ontario and the Algonquin Radio Observatory for ionospheric backscatter measurements. The band 2204.99-2361.99 MHz is assigned to *deep space* communications and is used passively for radio astronomy and geodesy by mutual agreement with the NASA Deep Space Network. Finally, the band 2750-2850 MHz has been used by the Canadian Solar Flux Measurement Program since 1947.

5.4.3 Predictions: New Space Bands and Services

There is an amazing number of proposals and plans for new types of satellite services and the use of new bands. This section contains projections based on the current evidence and plans for spectrum use. It must be emphasized, however, that not all the plans are fully approved. The following projections are based on the results of the interviews.

Cancom hopes to diversify into a number of new areas:

- Audio broadcasting at either L-band or at 2.5 GHz in the S-band;
- Wireless cable applications in the 17-28 GHz band, e.g. CellularVision;
- VHF/UHF band for little LEOs;
- 2 GHz band for PCS.

Teleglobe's plans include:

- The new Intelsat FOS-2 satellites will use C-band and Ku-band (but not Ka-band); they will be operational in 2002.

- Teleglobe is also heavily involved in the Odyssey system that will use Ka-band for feeder links and L-band for links to the mobile terminals.

- Teleglobe may be part of the new Teledesic system that will operate entirely at Ka-band with 60 GHz ISLs. The Ka-band allocation was approved at WRC'95.

Telesat plans to expand into the following new bands:

- Telesat is in the process of filing for the use of the DBS bands (12.2-12.7 GHz and 17.3-17.8 GHz).

- Telesat has filed for the use of a GEO in the *extended Ku-band* (11.45-11.7 GHz and 13.75-14.0 GHz).

- Finally, Telesat has filed for the use of the Ka-band (18.7-20.2 GHz and 28.5-30.5 GHz). The top 500 MHz in each band is the most important from Telesat's perspective.

Mobile and personal communications via satellite are a major growth area, and TMI hopes to expand its operations into other bands in the future:

- In the 2 GHz band, TMI hopes to use 1990-2025 MHz and 2160-2200 MHz for mobile satellite services using hand-held terminals working with a geostationary satellite. The TMI objective is to introduce the service in 2000. The satellite will likely be a North American regional satellite. (Note: This band is now used for terrestrial, fixed services; MSS applications can now commence effective January 1, 2000.)

- TMI has filed for other bands that, if approved, would be used for secondary applications if there is room on the spacecraft. These bands are similar to the frequencies used by Iridium and Odyssey. The applications are low bit-rate data and the technology is likely to be CDMA because of sharing problems in these bands.

- There is also the possibility that a new TMI satellite would use the same part of L-band as the current MSAT.

- As the volume of MSAT traffic increases, it will be necessary to increase the allocation for the feeder link. The likely expansion bands are: 11.2-11.45 GHz and 12.75-13.0 GHz.

- Other new applications and services could be identified by TMI in the future. One example is a national paging service operating via satellite in the 900 MHz band.

Iridium Canada is moving quickly towards its new satellite PCS services that will include voice, data transmission, fax and paging. The first generation Iridium service will be fully operational by September 1998, and parts of the band will be used as early as July 1996.

Iridium is also planning its second generation system for the year 2000 and beyond. The key difference is the move to S-band, with service links in the 1970-2010 MHz band (uplink) and 2160-2200 MHz (downlink). From a user perspective, the main impact of the extra spectrum will be higher-speed data services.

A number of new applications and services were identified during the course of the study. Emphasis is on the consumer with residential-type services aimed at the suburban/rural markets. Some are just being introduced now, others may well be introduced in the years ahead:

- Multimedia wideband services

- Desktop video conferencing using 64 KBPS and up

- Residential access to the World Wide Web via satellite for hobby usage, school work, and general interest

- Higher data speeds than are currently available; DirectPC is the first step towards this

- Tele-Medicine and Tele-Education

- Services aimed at small businesses, including special forecasts for farmers such as crop data, etc.

- Full electronic tax filings

- Better educational services in rural/remote areas

- Library access

5.4.4 Projections: New Space Technologies

In the course of this study, numerous new space technologies were identified:

Spacecraft Technologies

- Inter-satellite links, e.g. Telesat is considering the development and use of links to other satellites, e.g. selected European and/or U.S. satellites. This would likely use the 50-60 GHz band.

- Inter-satellite links using radiowaves; Iridium will be the first commercial implementation of inter-satellite links.

- Onboard processing, e.g., the Iridium satellites will incorporate some routing functions.

- Improved antenna design, e.g:

  - Phased array antennas;

  - cellular-type antennas linked with very narrow spot beams;

  - Flat plate antennas using an active phased array technology: this will probably be used for Ku- and Ka-bands, but not C-band.

  - Less bulky antennas; this improvement will be driven by the proliferation of wireless technology of all types, technologies that will evolve and become more efficient.

- The use of Ka-band;

- Use of spot beams: 2 options are available. The first is the use of fixed spot beams for the Canadian and U.S. markets and a steerable beam for other markets, e.g. South America. The second option is to have a fast-hopping beam that is used for all applications

- Ion thrusters for station keeping;

Transmission Schemes

In addition to the above satellite technologies, numerous improvements in transmission methodology are predicted:

- Better multiple-access techniques including wavelength multiple access.
- *Joint detection*, a technique to reduce the noise component of a co-channel signal. This leads to a significantly improved signal-to-noise ratio for the recovered signal.
- Improved vocoding techniques to reduce the bandwidth requirements.
- Improved data transmission techniques for higher bit rate services that would be required to meet the market demand for higher data-rate access to Internet and other services.
- The use of DVC will continue to grow; a key trend will be the movement towards a single, standardized implementation.
- There will be ongoing improvements in modulation and coding techniques; TMI expects that the bandwidth for a voice signal on MSAT will drop from 6 KHz to 5 KHz over the next few years.
- There will be better data compression techniques.

Other Predictions

- More military satellite technologies will be transferred to the civilian sector. One example of this in the past was the Qualcom technology for tracking trucks via satellite.
- New mobile services are expected that will fully utilize the capabilities of L-band and S-band; these bands are well suited to these applications.
- At Ka-band, there will be significant development of space-diversity feeder links to overcome rain fade problems; the spacing could be 35 to 50 km.
- Also at Ka-band, transmit power controls will be used extensively to further help overcome rain fade problems.

- For the little LEOs, the bands of choice will continue to be UHF/VHF. The benefits are simpler, lower cost receivers. A key disadvantage is the availability of spectrum.

- Ground stations will increasingly have Frame Relay interfaces and direct video interfaces.

- Receivers for satellite and terrestrial digital radio will be significantly different from today's radio receivers. Technological improvements will likely occur in antenna design and in the integration of display panel into the receivers. The panel will likely be used for: a) controlling the radio receiver; b) storing of information about the radio station and programming; and c) ancillary data of all types including weather, road conditions, tourist information, etc.

- In the area of radio astronomy, radio telescopes will be implemented that have a lower noise temperature and hence an increased sensitivity, typically at the higher frequencies.

5.4.5 Predictions: Longer Range View

The previous section has described trends that are already apparent based on current evidence and plans for spectrum use. Looking further ahead, there are additional predictions and projections that are further in the future and are therefore more speculative.

Speculation Based on Growth Patterns and Trends

There are several megatrends that are apparent today and will have a major but unknown impact on space systems beyond 2005.

A key megatrend is the well-known movement towards convergence, i.e. the overlapping of traditionally separate technologies and markets. **Paradoxically, the satellite industry is not only following this trend, it is also moving towards divergence.** In divergence, there will be an increasing number of specialized technologies that are being developed for very specific niche markets and applications. Each of these sectors will have their own preferred spectrum, their own players, and their own dynamics. This report earlier referred to the proliferation of types of orbits, including GEO, LEO, MEO (or IEO) and HEO. Satellites in all types of orbits will co-exist in the future.

There will be one trend toward the continued use of relatively large satellites in geostationary orbit. These satellites will continue to have orbital lives of 12-14 years.

Hence, the future Anik F satellite(s) will be designed using technologies selected from the list presented earlier. The Anik F satellite(s) will be launched in the early part of the new century and will be in orbit up to about 2015. It is therefore relatively easy to predict the type of technologies that will be onboard those satellites.

At the same time, the LEO satellites are being deliberately designed to have a shorter lifetime. The Iridium satellites, for example, have a design life of 7 years. The philosophy is twofold: a satellite that has a much shorter design life is simpler and therefore less expensive to build. Second, with the pace of technology moving as fast as it is, it will be better to have two generations of satellites in a timespan traditionally occupied by one generation. By about 2005-2008, the first generation LEOs will be replaced by the second generation. The specific nature of the second generation LEOs and the specific types of satellite PCS services to be provided are very speculative.

Projections Based on Growth Patterns and Trends

The following projections are made based on current growth patterns and trends; by their nature, they are somewhat speculative:

- Increased emphasis on services to individual users, rather than services to organizations.
- Smaller, less expensive ground terminals.
- A mixture of spacecraft types, including large, long-life geostationary satellites and smaller, less expensive LEOs.
- There will be continued improvements in the efficiency of the use of radio spectrum; this will be accomplished through advances in transmission schemes, audio and video encoding schemes, and data compression.
- The total traffic volume carried by satellites will not only increase, but increase at a faster rate than the efficiencies identified above. This means that the total spectrum required for satellite communications will continue to increase for the next 20 years at least.
- In general, all existing bands designated for space communications will continue to be used in the future. There will likely be some softening of the use of C-band, but all other bands will be in high demand.
- It is increasingly likely that future satellites that Canada is involved in will be regional and/or global systems. The Anik F satellites, for example,

could well be owned and operated on a North American basis rather than a purely Canadian basis. More Canadian companies will participate in global satellite systems, following the lead of Teleglobe's involvement in Orbcomm and Odyssey.

- The long-term trend towards reducing the regulations controlling the use of satellite communications will continue. The projections include an *open skies policy* between Canada and the U.S. that will allow users in either country to access space capacity in either country on a wide open basis.

The Distant Future

Looking to the year 2015 and beyond, the current trends and evidence become far less useful, the following projections are highly speculative and are based on the knowledge and experience of the Project Team:

- There will be a global personal communications network in which satellite and terrestrial technologies are fully integrated. The users will generally be unaware of whether their communicator is using satellite or terrestrial technologies.

- Satellite cell phones will be far smaller than they are today; they may not quite reach the size of a *Star Trek communicator*, but they will certainly be pocket sized.

- Similarly, satellite data transmitter/receivers will be fully integrated into a wide range of innovative devices.

- Nationally-owned satellites will be a rarity.

- Because of the above, Industry Canada will have less authority over the use of satellite bands in Canada; WRC'11 and WRC'13 could well allocate satellites bands on a global basis. Because of the difficulty in sharing satellites bands, footnotes by any one country will not be permitted.

- With the trend to convergence, the distinction between the various types of satellites services will disappear. There will be integration of BSS, FSS and MSS. For example, broadcasting (in its most generic form) to moving vehicles via satellite will be common place. It will be equally difficult to differentiate FSS services from other types of satellite services.

- With the use of dedicated spectrum, the use of the BSS, MSS and FSS categories will have disappeared.

- Auctioning of spectrum will exist on a global basis, i.e., organizations will bid for the right to use dedicated spectrum anywhere in the world for specialized satellite services. This money will likely be collected by a global organization such as the ITU and/or the U.N. itself.

- These newer services will increasingly use wider channels to cope with an increasingly noisy radio spectrum environment. All types of traffic will use a common backbone network; there will be no dedication of radio bands to specific types of satellite applications.

- Virtually all Canadian satellite spectrum allocations and policies will be made in Geneva not Ottawa.

- Far more spectrum will be allocated to satellite communications than is the case today.

In total, the radio spectrum environment in Canada in 2015 will be substantially different than the one in 1996.

5.4.6 Problems of Spectrum Use

The interviews conducted for this study revealed a wide range of concerns and problems regarding the use of the radio spectrum for satellite communications.

General Problems

- A primary problem will be intense political fights for the right to use parts of the spectrum. As more organizations and people use ever increasing amounts of technology, the demand for the use of spectrum will increase.

- Iridium is facing a major challenge in getting spectrum approvals throughout the world. There will be 16 gateways and 184 countries with service links; Iridium needs a licence in each country.

Ka-Band Problems

A number of concerns and problems were raised with respect to Ka-band:

- Rain fade at Ka-band is a serious problem for high availability applications; one solution is to focus on those applications where very high availability is less of a problem, e.g., consumer applications

- Another concern is the health problem with the use of hand-held satellite terminals at Ka-band. Although little information is available, it is known that the eye cavities resonate at that frequency and this could cause serious eye problems. (At 30 GHz, the wavelength is one cm, which is about the size of an eyeball.) This health hazard issue is one in which there is insufficient hard information.

- Ka-band terminals will initially be expensive; however, costs will go down with time.

- At Ka-band, fading is a problem for mobile users.

- There will be increased use of Ka-band, particulary for multimedia applications.

Spectrum Management

- There will be a spectrum scarcity for mobile satellite applications.

- The coordination process for GEOs, LEOs and MEOs has a long standing approach of giving priority to the satellites in GEO orbits. This may change in the future.

- More and more systems require the exclusive use of spectrum. For example, the Teledesic system does not share spectrum very well.

- There is also a trend to residential services using small antennas that are installed by the consumer. Again, these residential satellites services do not share spectrum very well.

- Technology is moving ever more rapidly and there is a concern that the spectrum management process may not be able to keep up.

- There will be increasing orbit congestion. Some of this will be real congestion, especially in the more popular orbital slots. In other places, there will be *paper congestion* based on the problem with coordinating multiple *paper* satellites, some of which will never be built. Paper congestion is an ITU issue rather than a Canadian issue.

- Spectrum availability will continue to be a problem. At C- and Ku-band, this will not be much of a problem, Ka-band and L-band will be more difficult.

- Canada's proximity to the U.S. leads to problems. There will be an ongoing requirement for Canadian spectrum applications to be compatible with U.S. applications.

- One example, of the difficulty of the coordination with the U.S. is the 1452-1492 MHz band for satellite digital radio. There are current in this band U.S. government and U.S. civilian air-to-ground telemetry applications in this band. It will be very difficult to reach an agreement with the U.S. for satellite digital radio in Canada in this part of the L-band.

- There will be a more general problem of coordination with other systems. It will be increasingly difficult to achieve coordination while having sufficient operational freedom; the penalty will be increased complexity of the technology. Iridium Canada, for example, needs to coordinate with Odyssey, LMCS, FSS, and Radio Astronomy.

- There will be increased problems with spurious and out-of-band emissions, in particular with space board transmitters using spread-spectrum digital modulation technique, as well as from various terrestrial equipment types.

- There will be an increasingly confused and chaotic radio spectrum environment.

Other Concerns

LMCS services will be introduced, possibly in the 28 GHz band. The lower part of this band is used in the U.S. for military applications, thereby leading to possible coordination problems.

5.4.7 Government Policies and Socio-Economic Factors

Many of the experts interviewed for this study spoke not only of the new technologies, products and services, but also emphasized the various restrictions and constraints. Some of these challenges are formidable and it will be a non-trivial task for the federal government to address these issues. Some of the issues relate directly to government policies, others relate to broad socio-economic factors. With the trend to privatization and less government, it is increasingly likely that these factors will be left for the private sector to resolve. The key issues include:

- Many of these new satellite systems will cost substantial sums of money to develop and deploy. There is a segment of the population that will not be able to afford them. Several questions arise: Should the government subsidize these services? Should there be universal coverage? Or should the service providers be allowed to deploy services on a selective basis?

- There will be on-going competition between satellite and cable/submarine systems. The capability and traffic capacity of fibre systems will continue to grow; the current capacity of a fibre systems is 5 Gbps; laboratory systems now transmit at 100 Gbps; these new systems will start to be installed at the turn of the century.

- Linked to the competition between satellite and cable systems is the ever decreasing cost of fibre systems that now cost 1/10th of what they used to cost.

- Also linked to the competition between satellite and fibre is the reality that the carriers will never *wire the world*. There will be an explosion of multimedia applications, and many of these will use satellites.

- Business activity in Asia will continue to increase. As the economies of Asian companies grow, they will need increasing numbers of international satellite links, including links to North America.

- Industry Canada will increasingly be under pressure to make the use of spectrum more efficient and more in line with the requirements of users and the general public. Similarly, Industry Canada will be under pressure to increase the *re-farming* of spectrum, including moving users to lightly loaded bands. This type of policy change is subject to intense lobbying from those who wish to use the band and those who are very reluctant to be moved.

- Regulatory changes will likely provide improved cross-border applications. TMI is looking forward to not only continuing the arrangements for transborder roaming, but also for the actual provision of services into the U.S. domestic market. As part of this, TMI accepts that there will be reciprocity and U.S. suppliers will have access to the Canadian market.

- The overall state of the Canadian economy will influence the sales of satellite terminals of all types. This in turn influences the pressure for use of radio spectrum.

- Although all those interviewed are opposed to any move by Canada towards FCC-style auctioning of radio spectrum, there is also a certain resignation that it may be inevitable.

- Linked to the trend towards a more confused radio spectrum environment is the concern of radio astronomers that they are working at the threshold of sensitivity. Radio astronomy is therefore heavily dependent on cooperation with industry and government and requires a well managed electromagnetic spectrum.

To a greater or lesser extent, many of the issues raised above will have a major impact on the success of any new service. For example, there is a proposal for the use of the 1452 - 1492 MHz band for satellite digital radio. The success of this venture depends on:

- A successful agreement with the U.S. for the use of this band for satellite digital radio.

- The timing of the roll-out of terrestrial digital radio in Canada

- The degree of market acceptance of digital radio

- The speed of roll-out of digital radio elsewhere in the world, because this will have an impact on receiver prices in Canada

- The speed at which the Europeans roll-out the Archimedes satellite system.

5.4.8 WRC'97 and WRC'99

Although the experts consulted for this study recognize the importance of the WRC meetings, most monitored the activities rather than were active participants.

Telesat is very involved in the World Radiocommunication Conferences. For WRC'97, Telesat is interested in the protection in the Ka-band frequencies, intersatellite links, and inter-sharing of the 18.6 - 18.8 GHz earth exploration band. Telesat has no issues for WRC'99 at this time.

TMI's objectives for WRC'95 included being able to use the 2 GHz band effective January 1, 2000 rather than January 1, 2005. TMI also opposed the expressed interest by non-GEO MSS operators to use the MSAT feeder link band for feeder links in the reverse direction. TMI believed that allowing this would have introduced new constraints to TMI's operations. TMI achieved both of its objectives.

TMI has not focused much on WRC'97 or WRC'99, due to a lack of resources and a preoccupation with its current activities.

Iridium is preparing for WRC'97. Its spectrum allocation will be revisited at that time. Iridium will also seek an increase in its feeder-link allocation.

Radio astronomers in Canada are interested in WRC'99; they hope that Task Group I/3 will remain in existence and will recommend limits to out-of-band emissions, especially for space-borne systems.

5.4.9 Impact of Convergence

Convergence is defined as technologies and markets that were previously distinct are increasingly over-lapping each other. Examples are the use of telephone lines for video-on-demand or the use of cable television facilities for Internet access.

Convergence will have an impact on satellite communications that is every bit as substantial as its impact on terrestrial technologies.

There will likely be convergence between broadcast and mobile services, e.g. for datacasting over MSAT. This would likely include the distribution of multimedia services at 64/128 KBPS.

An unknown issue at this time is the extent of convergence between DBS and other satellite services. Early indications are that high speed data distribution will be carried over the same facilities as the TV signals. This could well expand in the future to the distribution of a wide range of audio, data and multimedia services.

Convergence also means that some companies will broaden their definition of their market to include new sectors. For example, there is a potential role for Telesat in L-band multimedia services. Similarly, because the DAB band is close to those bands used by MSAT, the spacecraft hardware would be similar and it is possible for TMI to move in the direction of adding DAB services. It will be relatively easy for TMI to add a DAB card to its MSAT receivers. Such a possibility is, however, speculative at this time.

Another type of convergence is the merging of radio programming and information dissemination. This will manifest itself in two related ways. First, the audio programming and data information will be collected in one location for uplink as a composite signal to the satellite. Second, the audio receivers will evolve and look more like a computer terminal. In the future, there will be a display screen that will likely be touch-sensitive and the receiver would incorporate processing capability and software.

5.4.10 Likely Impact on Radio Spectrum

The preceding sections have shown that there will be considerable changes in space and satellite communications in the next 10-20 years. These changes include technology, applications, and regulatory areas. In total, there will be substantial impact on the use of the radio spectrum. The major changes, as defined in the preceding pages, are:

- All the current satellite bands will continue to be used for the foreseeable future, including the VHF, UHF, L, C, and Ku-bands. In addition, there will be significant activity to open new bands for satellite applications. There will be pressures to allocate more spectrum at L-band, Ku-band and Ka-band.

- In general, the availability of spectrum will be one of the factors that will limit the growth of satellite communications in the future. The only exception is that the demand for spectrum at C-band may soften.

- Unlike the last 20 years, the next 10-20 years will see very significant specialization in the design of satellites and the types of services each satellite supports.

- The primary drivers will be mobile and satellite PCS services, and satellite services to individuals rather than organizations. Examples of services to individuals include DBS/DTH, satellite digital radio, DirectPC, satellite PCS, and satellite DAB.

5.4.11 Likely Impact on Spectrum Management Activities

The pace of technological change will continue to be rapid, and there is a concern that spectrum policy and spectrum management will be unable to keep up. Linked to this is the reality that future satellite systems are far more likely to be regional or global systems than has been the case in the past. Spectrum allocations will have to be made on a global basis. This means that the role of spectrum management within Industry Canada will decrease, with decisions increasingly being made in Geneva rather than Ottawa. The very nature of Low Earth Orbit satellite systems is that they are very poor at sharing spectrum. Therefore, there will be a trend to dedicated spectrum.

A further impact on spectrum management activities is the likelihood of spectrum auctioning. A theme heard throughout the interviews and discussions for this study is that, while many organizations are opposed to FCC-style auctioning, there is also a realization that it may be inevitable.

Finally, because of the nature of all the changes described above, it is likely that the spectrum management process, at least as it applies to satellite communications, will become increasingly confused and disorderly. The projections made earlier about the future demonstrate clearly that the big challenge for spectrum management within Industry Canada is to stay ahead of the technology curve and to adapt promptly to a rapidly changing environment.

5.5 Broadcast

5.5.1 Scope and Objectives of the Section

This section examines radio and television (with ancillary data services), and the means of delivering these and other services to the home.

Existing bands considered are:

- 535 - 1605 KHz AM radio
- 54 - 88 MHz VHF television
- 88 - 108 MHz FM radio
- 174 - 216 MHz VHF television
- 470 - 806 MHz VHF television

One additional band is considered:

- 1452 - 1492 MHz Digital Audio Broadcast

5.5.2 Findings

Canada is advancing towards Digital Audio Broadcasting (DAB) service. The DRRI has field trial transmitters operating in Toronto, Ottawa, Montreal and Vancouver, using the Eureka 147 standard in L band. Operational DAB will likely be seen in the next few years (probably by the year 2000). Currently, the high cost of receivers is limiting even experimental use; however, by 1998, a second generation of receivers for Eureka 147 is expected to be available, targeted at the European market. Because the Canadian system is identical to the European, these receivers will also be available here.

AM and FM broadcasting could be phased out by about 2010 but there may be political unpopularity of eliminating them. When the AM and FM bands cease to be used, they will be available for other uses; however, one might ask: what uses? At this point it appears that AM may become a hobbyist's or amateur band; the future use of the FM band is uncertain, but mobile use is the most likely.

Because DAB uses relatively low-power transmitters, from its inception multiple transmitters will be required in a city. This will improve the shaping of contours. One point is apparent, field trials of rebroadcasting are showing that, in spite of the signal being digital, degradation does occur.

Feeder links will be required to DAB transmitter sites. These links are expected to be hub to sub-hub and sub-hub to node.

Ancillary data channels will be an important source of revenue for broadcasters (or transmitter operators). A list of expected data services is given in Figure **Two**. DAB will be able to serve mobile as well as fixed customers, unlike digital television.

A question arises as to DAB in the United States. The laboratory tests of In-band on Channel (IBOC) were largely unsuccessful. Receiver manufacturers doubt whether IBOC will become operational; even some U.S. broadcasters have some doubts.

Figure Two: List of Likely Ancillary Data Channel Services for Digital Audio Broadcasting and Digital Television

Market Segment	Applications
Consumer Information Services	Broadcast information, e.g. artist, song, album, store Commercial information, e.g. store locations, prices News information Sports information Traffic information Weather information Remote scoreboard Pay-per-channel Pay-per-day Distance education
Business Information Services	Financial information, e.g. stock, bond and currency reports Promotional messages Vertical market specialized information services Private data network transmission Catalog, pricing distribution Agricultural, commodity information
Messaging Services	Dispatch systems Paging, i.e. one-way paging with alphanumeric display Emergency announcements Electronic mail distribution Special events announcements Electronic billboard content distribution Real time promotional material
Geo-position/Telemetry/ Control Services	Dynamic status notification for public transportation Lane closure, dynamic highway flow control Real time traffic signal control and synchronization Differential GPS reference data IVHS - positioning Public utility load management

If the U.S. does stay with IBOC, the Canadian and U.S. systems will be incompatible, both as to system and as to frequency band. Canadian car radios will not operate in the U.S. The possibility exists that, after much political wrangling, the U.S. may adopt Eureka 147; however even if they do, the thinking is that they may use a different frequency band (because the Canadian band is allocated to aircraft telemetry in the U.S.) It will be at least ten years (2006 at earliest) before the U.S. has DAB.

Digital Television

Digital television is likely to come to Canada due to competitive pressures from the U.S. When this will happen is somewhat uncertain because the adoption of a digital television standard in the U.S. is fraught with political considerations. Even so, digital television is expected to *arrive* in Canada, and be widely available, in the next ten to 15 years (2006 to 2011).

Broadcasters will incur significant costs in implementing digital television. Because they do not expect additional revenue from advertisers (or, in the case of the CBC, from government), they will be looking to ancillary data services for additional revenue. They will compete with DAB and with one-way data service suppliers as suppliers of *bandwidth*. Where high data rates are required, they will have an advantage over DAB and other narrowband service suppliers.

Already, as studio equipment reaches its expected lifespan, broadcasters are replacing it with digital equipment. It has been pointed out that the production of digital programs is significantly more expensive than analog: the higher resolution allows the eye to be more demanding.

The penetration of digital TV receivers (and thus, the market share) depends on the availability and cost of digital receivers. Little is known about the intentions of the manufacturers, all of whom are offshore. Given the lack of a standard in the U.S., a *wait and see* attitude is reasonable.

Because of political (and social-economic) factors, analog and digital television will be operating in parallel for a number of years. During this period, it is expected that the existing television bands will be fully utilized, assuming that there is a digital transmitter for each analog transmitter. Analog television is expected to continue to be in operation until after the timeframe. When it is eliminated, spectrum will be available for other uses.

Eventually in urban areas, cable, and, (when it becomes a reality), fibre-to-the-home, will eliminate the need for over-the-air (OTA) television for all local and most distant signals. In rural areas, local signals are mostly on VHF now and remote signals are received from satellites. After the conversion to digital, it may be possible to reduce spectrum allocation for television to the VHF band (and possibility a small portion of the UHF band). Spectrum would then be available for other services.

In urban areas, feeds to neighbourhood nodes will be fibre; however in rural areas, they will be radio (and may offer fewer services). This will constitute yet another demand for fixed microwave services.

Direct Broadcast Satellite Television

Direct Broadcast Satellite Television transmissions were authorized by the CRTC in 1995 and were expected to become a major force in the distribution of entertainment television, in competition to the cable television companies.

To date one of the two licensees, Power Direct has announced that it will not implement its license, while the second licensee ExpressVu, has had successive delays in the implementation of its DVC DBS system, from its originally announced implementation date of September 1995. Current indications are that there will be further delays in implementation, exacerbated or even prevented, by the partial failure of Anik E1, allowing the cable TV companies to implement DVC and the range of services permitted by this technology, prior to effective competition by Canadian DBS service providers.

Given the present delays with respect to Direct Broadcast Satellite (DBS) Television the question arises: Is using DVC DBS likely to become a *significant player* that significantly impacts on spectrum use within the timeframe? Current predictions are that while DBS services could well occupy a position in the Canadian broadcasting sector, it is likely to be a secondary position with mainly a non-urban market. As such, the impact on spectrum use is likely to be minimal as compared with the current (non-compressed) use of satellite channels by broadcasting.

5.5.3 Predictions

Based on current evidence and plans for spectrum use, terrestrial DAB will be operational in Canada before the year 2000.

Digital television is expected to begin operation in Canada in ten to 15 years, due to competitive pressure from the United States, and will operate in parallel with analog up to at least the end of the timeframe.

One manufacturer, a significant supplier to telephone companies, is developing a sub-T1 WLL product. Clearly, with the expectation that low-bandwidth WLL will go into significant operation before the end of the century.

Eventually, homes will be *wired* for a gamut of services, with the last kilometre being by radio, from a node transceiver.

While it is predicted that by the year 2000 there is likely to be at least one Canadian supplier of DVC DBS services, it is considered unlikely that this will have a significant impact upon spectrum requirements. By this time it is likely that a number of uncompressed satellite services will have been withdrawn, creating sufficient DVC satellite channels for the expected requirements.

5.5.4 Likely Impact on the Radio Spectrum

The existing allocations for DAB are expected to be sufficient, although slight widening of the band may eventually be sought. Television will continue to use the existing bands through to the end of the timeframe; in fact, they will be fully utilized with the advent of digital television.

When conversion to DAB is complete, the AM and FM broadcast bands will no longer be used. The AM band may become a hobbyist's band; the 88 to 108 MHz band will become available perhaps for mobile use.

5.5.5 Likely Impact on Spectrum Management Activities

DAB and digital television will change the nature of spectrum management for broadcasting: multiple services will be borne on the same carrier, and the *broadcaster* may not be the *transmitter operator*. It makes sense to license the transmitter and not the service. It should be the responsibility of the transmitter operator to ensure compatibility and technical quality of the services he carries. Industry Canada should deal only with the transmitter operator.

In the future, the existing large allocation to over-the-air television will no longer be required. The spectrum thus made available can then be re-farmed to other (mobile) services.

5.6 The Spectrum Above 40 GHz

5.6.1 Scope and Objectives

In the past, the radio spectrum above 40 GHz has been little used. However the advent of highly sensitive remote sensing techniques; the burgeoning interest in radio astronomy and space science; the use of this spectrum in free space for intersatellite links; and the potential for terrestrial short-haul, wideband, point-to-point and point-to-multipoint applications, has changed this segment of the spectrum into one in which there is very active interest.

In particular the fundamental sharing constraints brought about by the physical characteristics of the absorption and emission frequencies of molecules and atoms within this section of the spectrum is of major concern to Canada and many other jurisdictions. The retention of an interference-free environment for these bands is critical to the disciplines of earth observation, space science and radio astronomy. The importance of these environmental concerns has been recognized at the ITU, particularly in the agenda of WRC'97.

This section has therefore been included in this study with the scope of considering the likely applications of the spectrum above 40 GHz in the year 2000 and beyond, and their impact on spectrum use and upon spectrum management. The prime objective of this section is to ensure that the impact on the future of this portion of the spectrum is fully considered in any future Industry Canada strategy.

5.6.2 Findings

Two prime approaches were taken to ascertaining the future impact of radio spectrum above 40 GHz. The first approach was to carry out a detailed review of all appropriate documentation that could be readily accessed. A detailed listing of this documentation is given in Appendix A(vii). From the information gained in these reviews, together with the knowledge of the Project Team, the Canadian *stakeholders* listed in Appendix B(vi) were interviewed to ascertain their opinions regarding the likely applications for the spectrum above 40 GHz for the year 2000 and beyond.

From a culmination of these two information sources, the findings given below were derived.

A major application of the frequency spectrum above approximately 50 GHz is for remote sensing and earth observation. This band (and others both below and above it) includes emission and absorption resonance frequencies of many atoms and molecules contained both in the Earth's atmosphere and extra-terrestrially. The detection of these emission and absorption resonances is carried out by radiometric means and is highly susceptible to both direct and indirect interference. As these resonances are fixed and specific to the element or molecule being detected, there is no question of the use of alternative frequencies. The protection of these specific (and narrow) emission and absorption bands is therefore fundamental to earth observation, space science and radio astronomy and are of basic environmental concern, not only to Canada but to all jurisdictions. In addition there are a number of atmospheric *windows* which are key to satellite based earth observation of temperature and other parameters. While these have a little flexibility with regard to the specific frequencies used, rigorous protection against direct and indirect interference is still required for this radiometric (passive) application. This means that these frequencies cannot be shared and, for protection to be effective, allocations must concurrently apply to all regions of the ITU and must include protection from indirect interference such as increased *noise floors*, intermodulation products and harmonic products, as well as protection from direct interference.

A further significant projected use of the spectrum above 40 GHz is for inter-satellite links. Specifically, the Teledesic constellation of 840 satellites, with each satellite having eight inter-satellite links, is proposed for the 60 GHz band. In addition, discussions are going on between the European Space Agency (ESA), the Canadian Space Agency (CSA) and the Japanese Space Agency regarding future generations of Synthetic Aperture Radars (SARs) owned by these agencies with a view to their use as a cooperative remote sensing constellation. Inter-satellite links would be implemented between each remote sensing satellite and appropriate geostationary satellites feeding each jurisdiction. This would permit the *real time* gathering of Synthetic Aperture Radar images on a constant basis. From a Canadian viewpoint, both CSA and Telesat Canada would be involved in this application.

There is also expected to be significant use of the radio spectrum above 40 GHz for terrestrial fixed and mobile services. These applications would exploit the characteristics of short-range, high information carrying capacity, high intrinsic security and, because of the short ranges caused by atmospheric and rain absorption, the high frequency re-use factor.

Typical of such terrestrial applications would be:

- Personal Communications Systems (PCS), in particular in-building distribution.
- The field of Intelligent Vehicle Systems. Specific applications are likely to be short-range narrowbeam collision avoidance radars; roadside beacons; and short distance point-to-point backhaul applications to fibre optic trunks.
- Short-haul, wide bandwidth point-to-point links in urban areas. Many of these applications will be as replacement for *the last kilometre* of fibre optic trunks, avoiding the cost and inconvenience of digging up highways and urban roads. With typical path distances of less than a kilometre, the use of low-power, and significant frequency re-use, such links can be implemented at very competitive costs.

5.6.3 Predictions

The WRC'97 agenda includes a number of items aimed toward the protection of the resonance bands and *atmospheric windows* in the spectrum above 40 GHz. It is likely that the WRC'99 will complete this protection process. These actions will encourage the use of this section of the spectrum for inter-satellite links, and terrestrial short range point-to-point, point-to-multipoint, mobile and radio location services. These applications, combined with the activities of Earth Observation, Radio Astronomy and Space Science will combine, in the year 2000 and beyond, to make the spectrum above 40 GHz extremely active.

5.6.4 Likely Impact on the Radio Spectrum

The radio spectrum above 40 GHz is the latest *unused segment* of the spectrum. It has the potential for very high capacity or very wide bandwidth services, high frequency reuse for terrestrial applications and the capability for mass production low cost devices for many terrestrial applications. As such it is expected to be perhaps the most active sector of the radio spectrum in the year 2000 and beyond.

5.6.5 Likely Impact on Spectrum Management

High activity is expected in this band, as discussed in section 5.6.4 above, much of it for entirely new applications for which the transmission, interference and propagation characteristics are not well known. This, together with the fact that physical resonant frequencies in this segment of the spectrum are still being found as equipment sensitivity is improved, is expected to make the spectrum above 40 GHz a very important area of spectrum management for the year 2000 and beyond. In addition, the current ITU spectrum allocation limit of 400 GHz can be expected to be extended as new physical resonant frequencies and further applications are found for this part of the radio spectrum.

5.7 <u>The Longer Term Future</u>

5.7.1 The Scope and Objectives of the Section

"The future is an extension of the past. Today is the gateway; but the view through it is merely a glimpse of what the future will be". Anon., January 1996.

All referenced superscripts in this section refer to Appendix A(vii).

A view of the likely future radio spectrum in the years following 2005 or 2010 is presented in this section. The view is based on the widely held opinions of a number of leading research and development authorities that:

- wireless networks will provide most, if not all, of the services available in wired services, and that, further,
- the direction of those services will be determined, at least in the period considered by, current thrusts in research and development.

Thus, the hypothesis being presented is that the period in question will be dominated by the development and maturation of current technologies and techniques. This has always been true, and there is nothing new to this approach. However, the concept is particularly valid at the present time because of the fundamentally different nature of the processes at play in telecommunications technology. The differences lie in the digital nature of the information, the signals that represent it, the communication systems that distribute it, and the computer systems that manage and control them. That is, in *smart* digital systems.

It is always dangerous to be complacent about the reliability of foresight; however, the momentum of the technological innovations of the mid-1990's is so immense that it is unlikely that any major, unforeseen, breakthroughs in communications technology will radically affect the radio spectrum in the next five to ten years. Any radical new basic technologies in devices, signals or systems will only serve to increase the usage of wireless.

Demand for radio spectrum in the future will be driven by two basic forces. The first is the simple ability to use new portions of the spectrum. The second is the demand for more channels and for wider bandwidth channels. The ability to use channels grows relentlessly as the upper frequency at which devices can be made increases, and as the *intelligence* to utilize hostile, impaired, channels develops. The demand for more channels comes from the growth of existing and new information services in developed countries as well as from the introduction of services in developing countries.

Two current thrusts with substantial momentum will lead the expansion of spectrum utilization. These thrusts are personal mobility and broadband integrated digital multimedia communications. The key technology that will drive future the demands on the radio spectrum is development of wireless networks: from low-earth orbit satellites to personal communications systems to wireless local area networks to multipoint distribution systems to terrestrial network access facilities. The technology engine is fuelled by the growing capability for sophisticated computer signal processing and network management and control. Software must be recognized as the key factor in any view of the future radio spectrum.

The radio spectrum is used for a number of purposes. The traditional uses are mostly communications and broadcasting, with significant portions of the radio spectrum allocated to telemetry and control, radio frequency heating, astronomy and other uses. The state-of-the-art is characterized by:

- ubiquitous first generation analog mobile networks;
- some operational second generation digital and cordless networks;
- CDMA and advanced TDMA systems being advocated for personal communications;
- ATM being coaxed into wireless networks;
- wireless LAN's being actively pursued; and
- the design of better protocols for supporting multimedia services.

There has been a remarkable increase in the use of the spectrum in the past few decades with the introduction of communication satellites, extended television broadcasting and mobile communications. In the past decade, growth in radio communications has been dominated by the proliferation of portable and cellular telephones, pagers and other personal communication devices and services; customers have been added at the rate of 30-40% per year. The years ahead will be dominated by the response to a continuing demand for personal mobility. The demand will be met by the use of higher and higher frequencies, at higher and higher data rates, over more and more difficult channels in more and more complex networks through the exploitation of wideband digital signal processing technology. The future of wireless communications lies with the re-use of extremely high frequencies through the application of wideband, high speed, adaptive digital signal processing.

5.7.2 Findings

The findings presented in this section are based on a number of recent publications in pre-eminent learned journals. The work analyzed here originates in leading industrial and university research and developments laboratories, and is characterized by the same optimistic view of the future of wireless communications.

Within the next five to ten years, the wireless aspects of the future will depend on new and developing wireless communication systems and current research in wireless communications. The new wireless communications systems are personal communication systems and the current research is concentrated on high-capacity multiple access schemes. As the demand for personal communications and personal communication services grows there will be demand for more and more bandwidth. Likewise, as the bandwidth and utilization of the fixed services grows there will be increased pressure on the availability and capacity of wireless access loops.

As Ahmadi, et al. predict "intelligent network (IN) capabilities of integrated networks will support universal personal telecommunications [and] eventually the optical fibre network will be ubiquitous, entering every office, factory, and dwelling, and providing a wide range of multimedia services". In their Guest Editorial in the October 1994 issue of Journal of Selected Areas of Communication, these authorities note the symbiotic relationship between wireless networks and high capacity terrestrial fibre networks. They re-state the obvious, but often overlooked, fact that the capacity of fibre optic networks is awesome and continues to expand. Optical fibre is being deployed, rapidly, and will create a demand for spectrum to accommodate not only a wide range of personal mobility communications but also for network access and connectivity for integrated broadband multimedia services, and increased demand for long distance telephony, data and entertainment transmission and delivery systems. Ahmadi, et al. suggest that this will create a real challenge to network designers who are handicapped by limited radio spectrum. **They recommend that a long-term strategy should be developed internationally to remove all non-mobile services from the existing mobile bands up to 6 GHz.** They anticipate a user rate of 2 Mb/s for a variety of services. They identify future personal communication networks operating over a range of cell sizes from <3 m to >500 km, leading to the notion of *an intelligent multimode terminal* and its *supporting network that will be able to adapt to the variations in the radio channel, the interference levels, the area traffic loading and the service required*. One could add that new video compression algorithms and their integration into central processor electronics by Sun and Intel will take the current surge in video conferencing into widespread use. They foresee a revolution in network architectures carrying gigabits per second requiring intelligence that will make the current objectives in [intelligent networks] seem trivial.

Current (1995) research is concentrated on a wide variety of personal mobility services, including personal communication services (PCS), low-earth orbit satellite systems (LEO's) wireless local area network access and internetworking; and digital radio and television broadcasting, including local broadcast distribution (LMCS). Many of these applications involve digital signal processing, network management, adaptive elements and the use of spread spectrum modulation and CDMA.

The late 1990's have been described as *an exciting time for wireless communications*. The September 1994 Special Issue on Wireless Networks for Mobile and Personal Communications of the Proceedings of the IEEE credits the realization of mobile cellular networks as part of the reason. The desire for more functionality from personal communications has resulted in more research and development for wireless cellular and microcellular communications. Expected results include an increase in capacity, improvement in quality of service, and accommodation of diverse multi-rate traffic. Positive technical, market and regulatory conditions and the opening of additional spectrum (at 1.850-1.9900 GHz) are cited as reasons for increased competition.

Cellular communications have addressed the problem of terminal mobility. Wireless personal communications will extend this to include personal mobility. The two services have much in common, but the differences include *radio propagation and fading effects, interference, smaller cell sizes, the type of mobility and call delivery*. Current research includes propagation modelling, multiple access techniques for wireless communications (particularly spread spectrum systems), interference and traffic modelling, cell architectures, wireless data communications and integrated wireless voice and data networks, and low-earth orbit and geostationary mobile satellite communication systems. Areas of future research include identification of the most suitable systems, design and implementation of next-generation wireless communication networks.

Craig Partridge, an authority on ultra wideband networks, predicts, in a short article in the IEEE Spectrum Technology 1996 Issue, that "improvements in wireless have led to the expectations that all of the services of wired networks - including high-bandwidth multimedia - should be available in a wireless environment as well". He goes on to write that " meeting those expectations will require a great deal of work [meaning research in the context of the article] over the next few years". Partridge identifies a number of areas of market driven technological advances: 100 Mb/s FDDI or ATM local area networks serving PC's with 1 Gb/s buses; new Internet Protocols better designed to support real-time applications; and 100 Gb/s fibre transmission rates, with multiplexing techniques packing several of these channels into a single fibre reaching towards terabit bandwidths in each fibre. These bandwidths create the potential for applications that "previously required too much bandwidth to be feasible". Partridge notes the "ferment in access methods [flowing] from mobile wireless networking", in which the difficulties of proving good throughput have been overcome "by a series of improvements in signalling technology and access methods that reduce interference". He forecasts that a mature mobile wireless technology offers a welter of opportunities, from hand-held video conferencing to wireless PC configurations!

The 1995 International Switching Symposium presented the concept of Universal Telecommunications for the 21st Century. What the conference brought out was that "the boundaries between information technology, television technology and telecommunications are disappearing" and that "services, terminals and networks for multimedia communications are emerging". The tendencies in telecommunication network development were identified as person-to-person communications replacing terminal-to-terminal communications"; network intelligence (information storing and processing in the network), and flexible wired **or wireless** network access technology easily accommodating the increased mobility of persons and terminals; and that future networks will be based on ATM technology. The implications for the radio spectrum is increased demand for spectrum on one hand and integration of the wireless channels into the universal networks on the other.

In 1991, in a paper entitled *The Wireless Revolution*, Theodore Rappaport claimed that "over the past three years, the interest in wireless communications has been nothing less than spectacular". He tracks the growth of wireless demand from the introduction of CB radio through cellular phones to the cordless phone (of which 65 million had been sold in the U.S. by the end of 1991), to personal communication networks. He identifies experimental licensing for portable facsimile service, wireless spread spectrum PABX systems, and microcellular and personal communication services. He cites the FCC initiatives in offering pioneer preference access to reallocated spectrum for new wireless services. He predicted that as many as 75 million subscribers could be using wireless communications for some form of personal communications by now. Rappaport cites evidence that indicates a large research interest, in Canada and Europe especially, in personal communications, modulation, coding, diversity and system design. He noted research on the use of wireless in urban areas and within buildings of various kinds, citing the need for research into the health effects of microwave radiation.

The evolution of Personal Wireless Communications was the theme of the January 1995 issue of IEEE Communications Magazine as well. In their Guest Editorial, Cox and Greenstein identify the rapid growth in several market segments of wireless communications as the stimulus behind an explosion in Wireless Personal Communications activity. They note the evolution from analog to digital systems which have more capability "to cope with the harsh radio environment". According to their editorial, many activities are taking place. For example, the trends towards large cells in sparsely populated areas and towards microcells within buildings, and the trend from wireless telephony to wireless data systems. Underlying technical threads exist: radio propagation, multiple access, modulation and detection techniques, wireless transceiver technologies, system architectures and control, and supporting intelligence in fixed networks. The demand for increased wireless service has led to new standards, techniques for digital wireless transmission and reception, and the enabling technologies for performing the sophisticated functions required in the transceivers and the system management.

As Bob Aaron notes in his Guest Editorial in the IEEE Communications Magazine of August 1995, which is devoted to Access to Broadband Services, "the continents are 'held together' by digital fibre optic systems carrying many thousands of circuits. End-to-end broadband access, switching, and control remain major obstacles to the realization of many of the multimedia services that have been 'hawked' on the information 'hypeway'". He writes that "the 90's will be the decade for the beginnings of broadband access - referred to in the information infrastructure as the 'on ramps'". The broadband access that the issue refers to is through wired facilities such as fibre and coaxial cable hybrids, although localized broadcast facilities are suggested as a means of achieving broadband subscriber loops. The implications on the spectral environment is that the wireless portions of the universal telecommunications network will have to provide bandwidths that are commensurate with the services on the networks.

Telecommunications in the latter half of the 1990's has been characterized by *convergence*: the melding of communications, computing, networking and entertainment technologies and services. Technology trials of such services as wireless cable television and cable-assisted wireless telephony are *stirring up a healthy mishmash of proposed new services, competitive traditional services, start-up enterprises, astonishing big-company alliances, and not a little confusion*.

The IEEE Spectrum 1996 Technology Analysis and Forecast Issue [12] identifies wireless local-area networks to satisfy the need of "professionals on the go and emerging nations building their information structures" for "data network access that is flexible as well as omnipresent" as an area, among others, "poised for takeoff".

The issue also highlights one-to-many information delivery services using multicast network capabilities as a factor driving market demand for wireless networks. Typical services of this class include Cellular Digital Packet Data, using TCP/IP Class D multicast addresses, a back-end infrastructure technology for wireless data networks. It is forecast that multicast networking will boost demand for wireless service. New wireless Local Area Networks (LAN's) using IEEE Standard P802.11 offer a choice of spread spectrum, microwave or infrared wireless technology. Wireless LAN technology is now available for laptop computers. It uses spread spectrum modulation, and operates as an unlicensed device at 2.4 GHz. Current paging technology includes two-way paging which lets users reply to, as well as receive, messages. These systems may be used to distribute e-mail, news, weather and sports updates to palmtop and laptop computers.

The August 1995 issue of the Journal on Selected Areas in Communications contains a Call for Papers for an issue on Wireless ATM. The Guest Editors (from Bellcore, Stanford University, NEC USA, and Alcatel) declare that "tens of billions of dollars are expected to be invested in both wideband and wireless networks over the next decade". They note that broadband access network investments are predominantly for fibre/coax and ATM platforms, and market demands on wireless communications are growing and will continue to grow rapidly. While wireless technology can provide nomadic access capability to ATM-based broadband networks, many technical and service issues related to integrating wireless access and mobility features with broadband ATM networks have received very little consideration. The Call for Papers states the situation for future portable broadband wireless access as:

- Portable broadband wireless access in the future will support mobility through ATM-based networks for broadband services, such as on-line multimedia information databases to provide news, entertainment and educational services. Information and personal communication services through portable wireless access are likely to be desired in a variety of venues, such as in offices, residential areas and from vehicles in the near future. While early deployment of emerging wireless access technologies is expected to be based on narrowband networks, the introduction of broadband networks and wireless integration can be expected to become increasingly important."

The Journal of Selected Areas of Communication issue on Wireless ATM will establish a forum for input from industries, universities and users from around the world. It is indicative of the direction of major research efforts that aimed at systems that will make substantial use of the radio spectrum.

5.7.3 Predictions for the Longer Term Future

The aggregation of the reports on new research and development summarized in the previous section present a picture of the wireless future that reads like science fiction; or, from a different perspective, like the time-worn predictions of Instant World, Vision 2000, and a host of other revelations heralding the day of ubiquitous, seamless, communications providing the means to communication information, in any form, to any one, at any time, anywhere.

There have been so many promises of utopian communications that it is easy to ignore the reality of the current trends. With the world immersed in the flamboyant publicity surrounding the *discovery* of Internet and the construction of the World Wide Web on top of it, it is even easier to overlook the fact that most of the oversold capabilities and services actually do exist, and are in fact very real.

The impact of universal, public, computer communications demand on the wireline systems is very serious. It is overloading subscriber loops, local switches and transmission facilities. It is creating a demand for bandwidth that will accelerate the installation of wideband bandwidth on demand to the home and office, in which wireless may play a major role.

The message here is that the likely future can be clearly seen in the present. If even only a fraction of the current research, development, innovation and investment activity in wireless communications is ever implemented, the demand for radio spectrum will be enormous and continuing.

5.7.4 Summary

The impact of current research and development on the likely radio spectrum in the longer term future will result in:

- demand for vastly increased wireless communications for personal communication systems and wideband network access; and
- smart systems able to operate in hostile environments with services tailored to the individual application and user.

5.7.5 The Impact on Spectrum Management Activities in the Longer Term Future.

The power of the technology and the demand for information services will be so sophisticated by the Year 2010, that the current trend toward a form of spectrum management that allows flexible technology and flexible services within given bands will be firmly established.

The role of spectrum management will be to allow the provision of the desired services while protecting essential spectrum required for scientific purposes, the public health and well being, national interests, the protection of the consumer, and so on. The need to specify specific services and specific technologies within specified bands will no longer be relevant except to facilitate progress and protect the consumer.

The research literature indicates clearly that work is underway on a staggering array of initiatives in wireless technology with one objective: to provide telecommunications of any kind, to anyone, anywhere, at any time. The interesting feature of this conclusion is that it is exactly the conclusion that was reached by the TeleCommission studies that launched the Department of Communications in 1971, that led the Canadian telecommunications industry to the declaration of Vision 2000 in 1990, and is the promise of the World Wide Web, and every other new telecommunications venture that comes along. The truth of the matter is that progress towards the goal of seamless, ubiquitous communications has been constant and steady since the introduction of the telegraph, and accelerating with the introduction of each major technological advance since then.

There is always the question of whether or not the progress will take place: whether it will be a market success or not. The indications now are that it will. The Chairman and the Deputy Chief Economist of the Federal Communication Commission, in reference to the recent spectrum auctions in the U.S. (the largest sale of property in history), note that "the investment in competitive wireless systems in the U.S. will be in the area of $50 billion over the next five to seven years - the largest single investment in a new technology in history." They attribute the investment to the FCC's decision to grant flexibility in the use of the PCS spectrum. This flexibility has two components: technical; flexibility and service flexibility. Service flexibility allows the use of spectrum to provide any service subject to the technical limitations of the frequency. Technical flexibility allows the use of any technology to provide service subject to interference to others and health risks. They see the U.S. mission to be to make spectrum available and to provide wide latitude in its use. They cite market forces to guide the spectrum to its highest value use. Hundt and Rosston suggest that several socially valuable uses should be protected in the market-driven environment. They mention low-powered shared use, educational television, international concerns, broadcasting, affirmative action, and other social goals.

In their paper, Hundt and Rosston set out a number of ways in which the FCC can make spectrum use more flexible. Included are area-based licensing with exclusive use, and reduction of service and technical limitations on existing licensees.

Should progress continue, wireless networks will provide every service and feature that terrestrial networks do. That in itself is a moving target, for terrestrial networks will continue towards multimedia traffic with integrated services on broadband fibre, with total user control over the look and feel of the operating environment.

If one accepts the reality of this vision, the role of the spectrum planner will be to accommodate the spectrum requirements for wireless internetworking, to encourage technologies that promote interoperability rather than those that isolate services in one band or one location or one application from those in another, and to avoid allocating spectrum to services that are clearly inconsistent with this view.

5.7.6 Spread Spectrum: Key to Future Unregulated Licensed Services

Old technologies do not die easily, and new technologies never completely replace old ones. However, spread spectrum modulation, or Code Division Multiple Access (CDMA), will become common and have a profound influence on radio spectrum utilization in the next decade. The consequences for the regulation of future wireless systems are liable to be profound. Thus, it is perhaps worth including a brief review of spread spectrum modulation and CDMA properties, as they pertain to multiple access wireless communications.

CDMA, is a multiple access technique based on **spread spectrum technology** where every user of a common communications channel has a distinct signal, or code, which occupies the entire frequency band.

Spread spectrum signals have bandwidths much wider than that of the data they carry. This provides the signal with substantial immunity to noise, interference, fading and multipath and makes it very difficult to intercept. The immunity to noise allows spread spectrum signals to be overlaid on existing services. The spread spectrum signal has been spread so that its power spectral density is very low, and can be undetectable to the existing service.

The use of different basis signals allows many users to exist simultaneously in the same band, hence the designation: Code Division Multiple Access. CDMA allows multiple access communications by a large population of uncoordinated users to a common spectral allocation in the same and neighbouring areas.

The signals from existing services act as noise to the spread spectrum signal, and vice versa.

The broadband signals have high temporal resolution. Individual discrete multipath components can be detected and combined coherently to improve performance.

The performance of the system depends directly on the amount of spreading, so that while the bandwidth of the transmitted signal stays the same, the spreading factor may be varied to account for varying propagation and noise conditions. The data rate may also be varied to adapt gracefully to changing load conditions

The transmitter sends information modulated on a distinctive signal. The receiver continuously compares all received signals against the distinctive signal. The receiver responds to the distinctive signal, and no others. This provides an anti-jam capability, that is a high tolerance to interference, whether it be intentional or unintentional.

The major impact on spectrum management is, of course, that CDMA systems require reduced system administration. The system is completely distributed; there is no centralized entity like a Network Control Centre. No access permission is required. Code allocation is only an administrative chore.

Sporadic users are also easily accommodated. The interference caused by a sporadic user is shared by all users (it's noise). The presence of extra users results in slightly lower performance for all users, not a *busy signal*, giving rise to the concept of ***graceful degradation***.

Spread spectrum permits frequency re-use. Different codes but the same frequencies, allows the entire spectrum to be used in all cells, or by all satellites.

Practically, too large a spread bandwidth implies very high speed and complex chip logic and the need for very fast sequence acquisition for burst transmissions. To overcome this, bands are often split into ***CDMA modules***.

Spread spectrum operates in frequency selective multipath because it covers more frequencies than those that fade. Resolution of multipath components allows ***multipath diversity*** to be used.

The distinctive signals allow each user to be automatically identified. Knowledge of all PN codes allows interfering signals to be coherently subtracted - cancelled! Knowledge of the angle of arrival allows unwanted signals to be cancelled.

5.8 Answers to Specific Questions in the Scope

During the development of the scope to this study, a number of specific questions were posed by the Long Range Planning Directorate. These are contained in the list of scope items given on pages two and three of this report. The majority of these questions have been answered in detail in the preceding portions of this section. However, the following items, while touched upon, have not been addressed in depth:

- The Agenda of, and Canada's interest in, WRC'97.
- Changes in wireline services due to technological developments and to the increase in wireless access expected in five to ten years.
- The competition between PCS and cellular wireless access applications and those of subscriber radio telephone technologies.
- The possibility of integration of the broadcast satellite service (sound) and the mobile satellite service.

This section addresses these remaining factors.

The agenda of WRC'97 is contained in the Final Acts of WRC'95. As both the full Final Acts, and the agenda, are readily available to the Long Range Planning Directorate, the details of the agenda will not be repeated here. However, the following agenda items have been selected as those likely to be of strategic importance and therefore of interest to the Directorate. The agenda item numbers have been retained for ease of reference.

- 1.4 Examination of, and taking necessary decisions on, the question of the HF bands allocated to the broadcasting service in the light of developments to date and the result of the studies carried out by the Radiocommunication Sector.
- 1.9.1 Issues concerning existing and possible additional frequency allocations and regulatory aspects as related to the mobile-satellite and fixed-satellite services.

- 1.9.4.1 Allocation of frequency bands above 50 GHz to the Earth Exploration-Satellite (passive) Service.

- 1.9.4.3 The existing frequency allocations near 60 GHz and, if necessary, their re-allocation with a view to protecting the Earth Exploration-Satellite (passive) Service systems operating in the unique oxygen absorption frequency range from about 50 GHz to about 70 GHz.

- 1.9.5 Allocations to the space research service (space-to-space) near 400 MHz.

- 1.9.6 The identification of suitable frequency bands above 30 GHz for the use by the fixed service for high-density applications.

* * *

There have been considerable changes already to wireline services as a result of wireless access and this trend is expected accelerate over the next five to ten years. While there has been considerable research into use of current twisted pair technology for the delivery of switched video to the home, this is seen as an interim technology, only with either fibre to the home or wireless local loops being used in the future. Of these it is considered that wireless local loops will provide the greatest flexibility and economy. The use of this technology will therefore have a significant impact on spectrum use. It is seen that wireline services will provide all long distant distribution both terrestrial and under the ocean for virtually all telephony and two-way data and video traffic. As such, very significant intelligence will be built into wireline services to cope with needs of mobile services and wireless local loops.

* * *

It is considered that there will be competition between SRT technologies and public mobile technologies for spectrum at all levels. While this will require traditional spectrum management activities in the near term, the concept of *strategic regulation* and the ability of many services to identify and use available channels in real time, is predicted to alleviate this problem in the longer term future.

* * *

While the integration of broadcast satellite services (sound) and mobile satellite services has on preliminary consideration considerable benefits, more detailed examination does not support this position. In Canada and Europe, the Eureka 147 standard for digital audio broadcasting has been accepted. In addition, the use of satellites in highly elliptical orbits (HEO) is currently the preferred approach to satellite digital audio broadcasting. Both of these elements of satellite digital audio broadcasting would tend to work against the integration of mobile satellite services and broadcast satellites services (sound).

6.0 CONCLUSIONS AS TO THE OVERALL RADIO SPECTRUM ENVIRONMENT IN THE YEAR 2000 AND BEYOND

This study has shown that the use of the radio spectrum is in a period of revolutionary change. Its traditional prime use for long distance communication is changing significantly to meet the demands of universal mobility. Concurrently technologies and the social-economic demands of the day are putting their own pressures on the use of the spectrum in the future.

In carrying out this study an abundance of information was obtained from all sources. The analysis of this information was a non-trivial task. From this analysis the conclusions given below were derived. The conclusions have been classified under the heading in which they were first reported in the body of the study. Thus the full information from which the conclusions were drawn may reside in two or more sections of the study.

It will be appreciated with the amount of information available it was practical to derive only the key conclusions emanating from this work. It is strongly recommended that for a full appreciation of the likely spectrum use in the year 2000 and beyond, that this study be reviewed in its entirety. Even the study itself is only a major sample of the information gained from the references and interviewees identified in the appendices.

It is perhaps appropriate to conclude this preamble by stating that both the use of the spectrum and its management are likely to be very significantly different in the next century than they have been over the last fifty years.

6.1 Strategic and Social-Economic Conclusions

In the past the radio spectrum was primarily used for long distance communications, for example continent-spanning microwave links; trans-oceanic satellite links; wide area mobile communications and wide area broadcasting. The trend of spectrum use is now the reverse of this situation. Long-distance communications are now primarily by terrestrial and sub-oceanic fibre optic (wireline) links and the use of the spectrum is becoming more and more dedicated primarily to short mobile links with very significant frequency reuse.

* * *

While the current overwhelming trend toward mobility in all forms of telecommunications had cellular and trunking technologies as its initial drivers, these technologies arose at the right time to meet key economic and social needs.

The trend is now for the use of mobile services to move out of the business sector into the residential sector. It is this potential trend that at once is the most uncertain, and the one most likely to have greatest impact on the spectrum use in the year 2000 and beyond.

The basic affordability of public telecommunications services, as well as the rate structure for such services, is likely to be a major factor in determining universal growth of telecommunications mobility. The marketing of a large number of features over recent years in all aspects of public telecommunications has possibly pushed price elasticity to near its limits.

In the opinion of the project team, mobility in telecommunications is at a key strategic crossroads. The direction taken will determine, by the year 2000, whether or not telecommunications mobility will become an ubiquitous residential and business infrastructure or remain merely a good key business tool. Much evidence points to one over-riding strategy which will be the major determinant of the future direction of telecommunications mobility. This strategy, which is likely to be determined on an essentially equal basis by public opinion; government strategy and policy; and the strategies of the major service providers, **is whether or not public mobile services move toward a flat rate charge or maintain the current usage charges. This decision is predicted to have a major impact on future spectrum use.**

* * *

If broadband PCS becomes ubiquitous in Canada there is likely to be a demand for fax data and other services to be carried over it. Any change away from voice traffic is likely to significantly increase call length.

Messaging, that is narrowband PCS rather than traditional paging, is expected to grow considerably in the next few years and into the 21st century. In part, this is due to its main thrust being to remain at the low end of costing for wireless communications to address the reality of the current economic environment. Messaging and paging could therefore become one of the more viable options for personal mobility.

Both of these factors would require a significantly increased spectrum allocation. It should be emphasized, however, that this is dependent upon the socio-economic acceptability of PCS as a whole.

* * *

Broad-band wireless local loops will become one of the most important applications of wireless technology in the future. Opportunities for local loop replacements are likely to change the nature of the telecommunications access network. This could be through the local telephone exchange or through the cable television network. Wireless local loops are likely to be used for a wide variety of applications including interconnection to computer networks and TV distribution services. **Again this will require increased spectrum allocations, possibly in the higher gigahertz bands.**

* * *

For future spectrum regulation to be effective it must have the flexibility to meet the changing social-economic and technical needs of spectrum use.

Digitization and real-time, software driven, dynamic frequency assignments will dominate the mobile spectrum, requiring a completely different approach to spectrum management.

Overall, the role of spectrum management in the future is likely to be to mandate the provision of the desired services while protecting essential spectrum required for scientific purposes, the public health and well-being, national interests, the protection of the consumer, and for similar matters relating to the public good. The need to specify specific services and specific technologies within specified bands will no longer be relevant except to facilitate progress and protect the consumer.

The success of **spectrum management in the future** will rely upon a complex interplay of regulation, the social-economic impact of allocations and from the business decisions of the service providers. While all of this will be backed by new and emerging technologies, it will not be these technologies that primarily shape the spectrum needs of the future. These major changes in the spectrum usage drivers **will require new and better models of spectrum management.**

Perhaps the most far-reaching example of such a new model is the likely requirement for Strategic Regulation, rather than the current tactical regulatory approach where each band is regulated by a detailed range of documents published by Industry Canada. While these were appropriate to past and, to an extent, current needs, **the trends toward major frequency re-use, automatic *intelligent* frequency assignments; advanced intelligent network technologies and toward interference resistant spectrum usage (CDMA) will require carefully planned, long-term, spectrum regulatory directives rather than today's closely managed environment.**

* * *

As to be expected, there is a major dichotomy of public opinion regarding any form of charging for the radio spectrum, other than, as a maximum, recovery of regulatory and administrative costs. The spectrum is seen as a non-renewable public resource, and one that should be used for the public good. Notwithstanding this, there now is a feeling of inevitability that most jurisdictions, in the future, will use the radio spectrum as a revenue producing mechanism, with many following the *spectrum auctions* route.

In general it is hoped, and expected, that Industry Canada will take a reasoned and balanced approach to licence fees, possibly to, in effect, *lease the spectrum* to users at a fixed rate that reflects, in part, the market value of such spectrum. By this means Industry Canada could obtain much needed revenue, while at the same time retaining maximum control over the spectrum while minimizing the *property rights* accruing to the licensee.

* * *

A further future change in spectrum management expected to impact upon Industry Canada is the trend (and the need) toward a global approach to spectrum management.

Regional and jurisdictional differences in frequency allocations will be counter productive and more and more spectrum management decisions will be made through the ITU on a universal basis. Overlaying this trend will be the general thrust toward *strategic regulation* described above.

* * *

Driven by technological change, broadcasting is another use of the spectrum which is moving into an evolutionary crossroads that will become critical around 2000 to 2015.

With the advent of digital audio broadcasting (for radio) and digital television, both of which are likely to be implemented on a large scale over the next 20 years, it is very likely that the whole matter of the allocation of VHF and UHF spectrum to broadcasting services will require strategic review and decision.

The virtually ubiquitous use of cable television in urban areas, combined with the fact that television (and FM radio) frequency allocations are ideal for mobile applications, has also given rise to considerable pressures for the reallocation, in urban areas, of these broadcasting frequencies to the mobile services.

* * *

Although virtually all portable personal transmitters will be of low power, the fact that the transmitters will be in hand-held units which are pressed against the skull during use means that the electro-magnetic field strength at the skull is quite high. All indications to-date are that the power levels used are insufficient to cause harm. However, the resonant effects of the various cavities forming the skull have the potential to significantly increase the biological impact of the electro-magnetic fields. In particular to resonance of the skull in the lower gigahertz range and the resonance of the eye socket around 30 GHz are of concern.

As both the low gigahertz and 30 GHz frequency bands are under consideration for terrestrial and satellite hand-held terminals respectively, it can be expected that the potential for health hazards, and the need for appropriate regulations to overcome such hazards will be yet another strategic spectrum management consideration for the year 2000 and beyond.

* * *

6.2 Mobile Systems Conclusions

The category of public switched services, which includes cellular telephones and PCS, will be the main users of the radio spectrum in the high UHF and microwave bands. This sector has been growing at a very rapid pace and could cause spectrum shortage in the future.

In the United States, the new 1.8 GHz PCS service is projected to attract over 60 million users (a penetration of approximately 25%) within the first ten years of its operation. Its future in Canada is more indeterminate. PCS could provide competition to existing cellular, paging and private radio services, with the addition of two-way video, teleconferencing, and data services. Ultimately the PCS may develop into a ubiquitous global network; but in most areas it is likely to complement cellular service.

* * *

Cellular telephony has been growing at a rate of about 36% per year. Paging services have seen a similar growth rate. Over the next ten years, the following technologies could lead to a continuation of a growth rate of perhaps 20%:

- More options in the cordless services including community-based cordless services.
- Cellular Digital Packet Data (CDPD), an innovative service to deliver short message services. In this system, the system scans for an idle channel to send short messages. The voice traffic enjoys priority over the data traffic. This integration of voice with data will increase channel utilization.
- Mobile high speed file transfer systems over wireless LAN's and mobile computing are also predicted to be a major application.

Technology-based market predictions suggest that the current allocations may not be able to meet the future demand for PCS services. In addition, there will be evolutionary pressures on the spectrum as information-based mobile services are added. These will greatly increase average access times and thus effectively linearly increase spectrum use.

* * *

By the year 2000, Toronto, Montreal and Vancouver will experience significant spectrum shortages for all mobile services. The population of these cities has been increasing over the years but the number of mobile frequencies available has not increased, with the consequence that the number of mobiles per capita is decreasing.

The congestion is likely to be reduced and spectrum efficiency increased by spectrum re-farming. For this purpose new regulations governing spectrum allocation are likely to be required to encourage users to replace older, spectrum-inefficient systems with more efficient technologies. In this regard, a number of issues have to be resolved. For example:

- What kind of new technology is necessary, and what metric should be used to compare the candidate technologies?
- How to monitor the use of technologies by the operators?
- What is the benchmark technology which could be used to compare spectrum efficiency of competing systems?

Further study is required on these issues. The benchmark technology must be selected to provide a standard against which to measure technical improvements and increases in spectrum efficiency. The study should then define a methodology which allows a comparison of any technology with the benchmark technology.

* * *

The currently held view that 3.5 GHz is the upper frequency limit for mobile communications is changing with the advancement in transceiver technology. It is likely that, with the advent of powerful signal processing technologies, the impact of fading on the signals will be minimized and use of frequencies higher than 3.5 GHz will become feasible. Europe is already evaluating the feasibility of using 5 GHz band for mobile wireless services.

* * *

Wireless local loop may be used for a variety of applications including interconnection to computer networks and TV distribution services. The wireless local loop could operate at 18 GHz, 28 GHz; 38 GHz or 56 GHz. It is not clear however, which technologies or devices will be preferred for such wireless local loop operations.

* * *

Wireless local loops could have an immense impact on spectrum usage and management and could be a driver of fixed and mobile integration.

* * *

6.3 Microwave Systems Conclusions

In general, as new services are demanding spectrum, microwave is losing spectrum to them; at the same time, new services are expecting microwave backhaul. This is creating a *tension* for microwave manufacturers and users. For example, Personal Communications Systems (PCS) operators are expected to use 15, 18 and 23 GHz for backhaul.

* * *

The growth pattern of microwave is heavily dependent on which *other services* succeed. One may succeed for a while and then be replaced by another. Thus the spectrum available for fixed services may decrease, and the need for backhaul increase, while a number of other services (e.g. mobile) attempt to gain critical market share. Once the market *settles out*, more spectrum may be available for fixed services. In any event, there is likely to be a future use of back-haul fixed services greater than there are now.

* * *

In urban areas, IVS is expected to have little effect on spectrum usage: sensors (and only some of them) will use spectrum; however, in rural areas, IVS is likely to become a major user of spectrum for both mobile and fixed applications. Mobile IVS applications have to use radio (although some can use infrared); and, depending on spectrum availability, highway operators may be forced to use fibre or coaxial cable along the right-of-way, even where it is not economical.

* * *

6.4 Satellite Systems Conclusions

Over the next 10, 20 and more years, Canadians will use an ever increasing array of satellites with vastly different characteristics. There are new technologies for the ground terminals and the satellites themselves, including onboard switching and intersatellite links. All these changes are going to lead to significant differences in the way in which radio spectrum is used for satellite communications.

* * *

All the current satellite bands will continue to be used for the foreseeable future, including the VHF, UHF, L, C, and Ku-bands. In addition, there will be significant activity to open new bands for satellite applications. There will be pressures to allocate more spectrum at L-band, Ku-band and Ka-band.

In general, the availability of spectrum will be one of the factors that will limit the growth of satellite communications in the future. The only exception is that the demand for spectrum at C-band may soften.

* * *

For satellite communications, major spectrum trends are:

The Ka-band (20-30 GHz) will open up. At Ka-band, space-diversity feeder links should help to overcome rain fade problems; the spacing could be 35 to 50 km.

New mobile services are expected that will fully utilize the capabilities of L-band and S-band; these bands are well suited to these applications. This will lead to a spectrum scarcity for mobile satellite applications.

For the little LEOs, the bands of choice will continue to be UHF/VHF. The benefits are simpler, lower cost receivers. A key disadvantage is the availability of spectrum.

* * *

The coordination process for GEOs, LEOs and MEOs has a long standing approach of giving priority to the satellites in GEO orbits. This may change in the future. More and more LEO systems will require the exclusive use of spectrum. There is also a trend to residential services using small antennas that are installed by the consumer. Again, these residential satellites services do not share spectrum very well.

There will be increasing orbit congestion. Some of this will be real congestion, especially in the more popular orbital slots. In other places, there will be *paper congestion* based on the problem with coordinating multiple *paper* satellites, some of which will never be built. Paper congestion is an ITU issue rather than a Canadian issue.

* * *

The next 15 years should see a further lessening of the regulations surrounding satellite communications, including an *open skies policy* between Canada and the U.S. that will allow users to access satellite space in either country. The remaining obstacles to full interconnection between satellite and terrestrial systems should be withdrawn and the licensing of ground stations made significantly easier.

6.5 Broadcasting Conclusions

Canada is advancing towards Digital Audio Broadcasting (DAB) service. The CBC has field trial transmitters operating in Toronto, Ottawa and Vancouver, using the Eureka 147 standard in L-band. Operational DAB will likely be seen in the next few years.

* * *

AM and FM broadcasting could be phased out by about 2010 but there may be political unpopularity of eliminating them. When the AM and FM bands cease to be used, they will be available for other uses.

* * *

Digital television is likely to come to Canada due to competitive pressures from the U.S. When this will happen is somewhat uncertain because the adoption of a digital television standard in the U.S. is fraught with political considerations. Even so, digital television is expected to *arrive* in Canada, and be widely available, in the next ten to 15 years (2006 to 2011).

* * *

In urban areas, cable, wide-band local loops or fibre-to-the-home could eliminate the need for over-the-air (OTA) television. In rural areas, local signals are mostly on VHF now and remote signals are received from satellites. After the conversion to digital, it may be possible to reduce spectrum allocation for television to the VHF band and possibly a portion of the UHF band. Spectrum would then be available for other services.

* * *

Given the present delays with respect to Direct Broadcast Satellite (DBS) Television current predictions are that while DBS services could well occupy a position in the Canadian broadcasting sector, it is likely to be a secondary position with mainly a non-urban market. As such, the impact on spectrum use is likely to be minimal as compared with the current (non-compressed) use of satellite channels by broadcasting.

* * *

6.6 The Spectrum Above 40 GHz Conclusions

The radio spectrum above 40 GHz is the latest *unused segment* of the spectrum. It has the potential for very wide bandwidth services, high frequency reuse, and has the capability for mass production low cost devices for many terrestrial applications. As such it is expected to be perhaps the most active sector of the radio spectrum in the year 2000 and beyond.

* * *

Much activity above 40 GHz will be for entirely new applications for which the transmission, interference and propagation characteristics are not well known. In addition, physical resonant frequencies in this segment of the spectrum are still being found as equipment sensitivity is improved. Both of these factors are expected to make the spectrum above 40 GHz a very important area of spectrum management for the year

2000 and beyond. In addition, the current ITU spectrum allocation limit of 400 GHz can be expected to be extended as new physical resonant frequencies and further applications are found for this part of the radio spectrum.

Both national and international regulations will be required to permit maximum use to be made of the spectrum above 40 GHz by potentially conflicting, applications.

* * *

6.7 Conclusions Relating to the Longer Term Future

It is always dangerous to be complacent about the reliability of foresight; however, the momentum of the technological innovations of the mid-1990's is so immense that it is unlikely that any major, unforeseen, breakthroughs in communications technology will radically affect the radio spectrum in the next five to ten years. Any radical new basic technologies in devices, signals or systems will only serve to increase the usage of the wireless rather than wireline links to the user.

* * *

Demand for radio spectrum in the future will be driven by two basic forces. The first is the simple ability to use new portions of the spectrum. The second is the demand for more channels and for wider bandwidth channels. The ability to use channels grows relentlessly as the upper frequency at which devices can be made increases, and as the *intelligence* to utilize hostile, impaired channels develops. The demand for more channels comes from the growth of existing and new information services in developed countries as well as from the introduction of services in developing countries.

Two current thrusts with substantial momentum will lead the expansion of spectrum utilization. These thrusts are personal mobility and broadband integrated digital multimedia communications. The key technology that will drive future demands on the radio spectrum is development of wireless networks: from low-earth orbit satellites to personal communications systems to wireless local area networks to multipoint distribution systems to terrestrial network access facilities. The technology engine is fuelled by the growing capability for sophisticated computer signal processing and network management and control. Software must be recognized as the key factor in any view of the future radio spectrum.

* * *

The years ahead will be dominated by the response to a continuing demand for personal mobility. The demand will be met by the use of higher and higher frequencies, at higher and higher data rates, over more and more difficult channels in more and more complex networks through the exploitation of wideband digital signal processing technology. The future of wireless communications lies with the re-use of extremely high frequencies through the application of wideband, high speed, adaptive digital signal processing.

* * *

There have been so many promises of utopian communications that it is easy to ignore the reality of the current trends. With the world immersed in the flamboyant publicity surrounding the *discovery* of Internet and the construction of the World Wide Web on top of it, it is even easier to overlook the fact that most of the oversold capabilities and services actually do exist, and are in fact very real.

* * *

Work is currently underway on a staggering array of initiatives in wireless technology with one objective: to provide telecommunications of any kind, to anyone, anywhere, at any time. The interesting feature of this conclusion is that it is exactly the conclusion that was reached by the TeleCommission studies that launched the Department of Communications in 1971; that led the Canadian telecommunications industry to the declaration of Vision 2000 in 1990; and of every other new telecommunications venture that comes along. The truth of the matter is that progress towards the goal of seamless, ubiquitous communications has been constant and steady since the introduction of the telegraph, and is accelerating with the introduction of each major technological advance.

* * *

APPENDIX A

DOCUMENTS REVIEWED

APPENDIX A
DOCUMENTS REVIEWED

i) General

(1) Canadian Tables of Frequency Allocations, Industry Canada, Revised to November 1995.

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APPENDIX B

APPENDIX B

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