Study of Future Demand For Radio Spectrum in Canada 2011-2015

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STUDY OF FUTURE DEMAND FOR RADIO SPECTRUM IN CANADA 2011-2015

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1 Introduction

This Report provides the outcome of an independent study of the Demand for Spectrum from 52 MHz to 38 GHz, across 15 different service sectors in Canada.

The Study has been conducted by Red Mobile Consulting (Red Mobile), in conjunction with its partner, PA Consulting Group (PA).

1.1 Executive Summary

The objective of this Study was to forecast the future demand for radio spectrum in Canada for commercial and government services, within the frequency range of 52 MHz to 38 GHz.

The Demand forecasts were to be developed for the period of 2010 to 2015. Five of the services were classified by Industry Canada as High-Value Services. The Demand forecast for these High-Value Services has been modelled in detail. In many cases for High-Value Services, it was important to study historic trends in a particular industry, and these historic trends have also been presented where helpful. As such, the baseline of year 2010 is presented, at minimum, for all modelled services. The remaining 10 services (Other Services) have undergone a varying degree of high-level analysis.

When reviewing the results, it is important to consider the objectives of the Study and the Methodology used. Given the time available, breadth of the topics, and vastly different areas of expertise required for the services covered by this Study, the overwhelming majority of the focus has been on High-Value Services. Therefore, while great effort has been made to make reasonable assumptions, develop a good understanding of the spectrum conditions, and vet these against input from stakeholders and sources of secondary research, there will be areas that have not been fully considered.

In order to understand the most fluid services, the Authors have spent close to one year observing and tracking changes and revising spectrum demand models. However, the assumptions about future technology and market developments can change. Also, for some services, users of the spectrum can implement the service in a manner that best suits their individual business, economic or market priorities. While the Study considers the major macro- and sector-level drivers, it does not attempt to delve into any specific user's situation.

As part of the Methodology, close to 50 industry Stakeholders were approached to provide input to the Study. For many services, especially the Other Services, the analysis has been conducted through input provided from industry Stakeholders. Stakeholder input has been considered in conjunction with other research to develop an understanding of that particular sector. It should be noted that, in some cases, the input provided by different stakeholders provides a contradictory or alternative view of the same service. The Report's intent is to present the varying views for the benefit of the reader. In addition, specific challenges for a particularly localized geographic area (i.e. congestion in a city), etc. have not been considered the only, and overarching driver to determine that there is a state of congestion throughout. However, where appropriate and possible, some of these specific challenges have been highlighted.

For the High-Value Services, where applicable, a market analysis has been conducted of the Service Demand. This Service Demand, and associated forecasts, were converted into Demand for Spectrum, taking into account several future factors, including improvements in spectral efficiency, evolution of technologies, etc.

An overview of the Methodology and key definitions are provided in Section 3 of this Report. As well, where applicable, the specific Methodology and associated Assumptions for forecast of Service and Spectrum Demand are presented in the individual service areas.

It should be noted that for the High-Value Services, three different Scenarios, representing different market conditions have been modelled. As the spectrum demand projections are developed using a variety of forward-looking assumptions, particularly for investments made in the implementation of the service (i.e. network rollout, technological upgrades, etc.), and future take-up and usage levels of services, the Scenarios attempt to provide a view of spectrum demand, should these conditions change. The Scenarios are explained in Section 4 of this Report.

The mandate of this Report does not include Policy development, nor is it the Report's intent to do so.

A summary of the findings for each service can be found below. Note that this is a partial summary of the findings as, typically, only the *Business as Usual* case is presented. To have a complete picture of the analysis and findings, the reader is encouraged to refer to the applicable sections.

Cellular Services

The Canada cellular market is experiencing rapid growth, with Canadian growth in mobile data consumption and smartphones as a percentage of overall devices, being one of the highest in the developed world in the 2010-2011 period. This has been fueled by several factors converging within a few years. Namely, added competition and more cost-effective 3.5G networks have driven down data tariffs considerably; the investment made by Canadian operators in new networks has resulted in significantly higher throughput rates, improving the user experience for data services; and Canadians are buying smartphones and mobile broadband devices (tablets, dongles, etc.) that show significantly rates of data consumption.

In fact, the cellular market in Canada has grown so quickly in 2010 and 2011 that the approach of the Study had to be modified to monitor the actual shifts in traffic over several recent months, and to revise the original projections. The current forecast for Service Demand show a growth of 30 times in *data* traffic between the period 2010 to 2015, and the overall cellular traffic, including voice, data, and messaging, is seen growing from approximately 4 Petabytes[1] (PB) to almost 75 PB in this same period.

The Study has modelled three spectrum demand scenarios: *Business as Usual*, *Wire-Free World* and *Low Investment*. The findings show that a substantial spectrum overhead is needed in addition to handling the offered traffic during the busy hour. The Study estimates that a total of between 300 MHz to 500 MHz of cellular spectrum will be needed by 2015, including overhead (consideration for network operation, future investment scenarios) to accommodate the service demand. The range of spectrum required depends on various factors discussed in the Report including the degree of investment made in upgrading networks to newer, more efficient technologies, addition of cells/sectors, provisions for new entrants, etc.

Operators may extend the capacity of their spectrum holdings by continuing to shift more traffic to their HSPA and LTE networks and/or adding more sites and sectors (densifying the cellular networks) in the capacity-constrained areas (i.e. the most urban areas and, also, the most densely populated rural areas). It should be noted that a study of this particular services area of 15 to 20 years is more valuable, as the period in which this Study was conducted was that of unprecedented growth in take-up. A longer-term Study period will allow for a better understanding of how spectrum demand will evolve.

Fixed Wireless Access (FWA) Services

The Study separates out Point-to-multipoint (PTM) from Point-to-point (PTP) FWA.

[1] 1 Petabyte (PB) = 1,000,000 GB

The Study has modelled three spectrum demand scenarios: *Business as Usual*, *Wire-Free World* and *Low Investment*.

Point-to-multipoint FWA: Canada has one of the highest penetrations of broadband Internet access of the Organization for Economic Co-operation and Development (OECD) countries. One of the opportunities for FWA growth is that more than 14% of the rural households are un-served or underserved.

The Study forecasts a significant service and spectrum demand to serve the broadband rural market using FWA (licenced and licence-exempt) PTM facilities and advanced HSPA-LTE cellular networks. The number of FWA subscriptions (below 6 GHz), grow from approximately 500,000 at the start of 2010 to almost 1M by 2015. Traffic is projected to grow from 15 to 45 GB/month per subscription during the same period.

The evolution in the mix of technologies has also been noted, with the addition of some FWA services starting to be delivered using cellular technologies in the 2013-14 timeframe.

The Study projects spectrum demand to double (from 150 MHz to 300 MHz) for the 2010-15 period to meet the broadband-access Service Demand for the *Business as Usual* scenario.

Point-to-point (PTP) FWA: The high-capacity point-to-point links provide an effective way to serve part of the large enterprise market and other high-speed connections requirement, in addition to multiple DS-3 fibre-optic (SONET) and wireline carriers.

In terms of the development of the market, the projections are for slow continued growth in links (on the order of up to 5%-10% per annum (pa)) and a more-rapid growth in traffic, on the order of a threefold growth in traffic per link, from 1TB/link/month to 3 TB/link/month.

PTP links require extensive spectrum. By 2015, the spectrum requirement varies according to the traffic scenarios and is projected as being between 500 and 1200 MHz.

This would be another service area where a prolonged study period of 15 to 20 years provides a significantly more valuable view of the demand for Spectrum.

Backhaul Microwave Facilities

The Study has modelled three spectrum demand scenarios: *Business as Usual*, *Wire-Free World* and *Low Investment*.

The relative traffic (GB/mo) levels of the microwave backhaul facilities in the prime microwave bands (i.e. 11/14/18/23 GHz) bands to carry cellular network and FWA broadband traffic (to collector points or concentrators) for the period 2010-2015 were modelled. Then, these traffic levels of cellular and fixed networks were converted to spectrum demand for the same period.

Results suggest that the prime microwave backhaul bands (i.e. 11/14/18/23 GHz) bands will see an increase in their demand for spectrum over the period of 2010-15, as HSPA and LTE networks drive growth in cellular traffic, and as fixed networks increase their appetite for high-capacity microwave backhaul links.

The spectrum demand is expected to grow from approximately 900 MHz in 2010 to between 2600 and 3400 MHz, depending on the scenario used. It should be noted that several assumptions are used to project this demand, and the demand for this service is highly sensitive to some of these assumptions.

Broadcasting Services

The service covers Over-the-air TV (OTA TV), FM Radio, and DTH Satellite broadcasting.
The Study has modelled three spectrum demand scenarios: *Business as Usual*, *Wire-Free World* and *Low Investment*.

OTA Television: The Study finds that the spectrum demand for OTA Television is relatively flat. However, within the DTV Allotment Plan, a small number of spare channels are available for growth. Moreover, within the ATSC digital channel of 19.3 Mbps, there are opportunities for broadcasters to offer a mix of HDTV, SDTV and mobile TV programming within an assigned 6 MHz OTA TV broadcasting channel. The demand for spectrum will remain at 270 MHz; however, service growth will occur within the allotted 6 MHz channels.

FM Radio: The Study notes the congestion of FM Radio spectrum in large markets, such as the Greater Toronto Area. There will be continued pressure as AM stations aspire to convert to FM broadcasting. The use of IBOC digital broadcasting within existing FM channel allotment may offer a way forward to expand the use of the FM band. But, it is envisaged that the FM radio spectrum will remain the single most congested band of any of those assigned to the High-Value Services, over the period of the Study, and there are limited grounds for expecting this to change in the years immediately following 2015.

DTH Satellite: The Study modelled three scenarios of DTH Satellite service and spectrum demand. The number of SDTV is estimated to grow from 951 to 1532 programs, from 2010 to 2015. Similarly, the number of HDTV grows from 162 to 494 programs. In 2010, about 800 MHz (orbital-MHz units) is needed for the equivalent of less than 2 DTH satellites. However, in 2015, depending on which scenario is used, a range of 1000 MHz to 2600 MHz (orbital-MHz units) will be needed. For the *Business as Usual* scenario, the equivalent of 3.5 DTH satellites will be required. As the two DTH satellite operators have already procured the equivalent of 3.5 DTH satellites, there is sufficient satellite capacity to meet the service demand for the period of this Study.

Satellite Services

Three services are covered as part of this section. These include: Mobile Satellite, Fixed Broadband Satellite and Fixed Bent-pipe Satellite communications.

The spectrum demand for the first two services was modelled in detail. The Study has modelled three spectrum demand scenarios for these two services: *Business as Usual*, *Wire-Free World* and *Low Investment*. A high-level analysis has been presented for Bent-pipe Satellite.

Mobile Satellite Service (MSS): The Study projects an increase in subscribers and the take-up of mobile data services. Substantial increases in traffic are offset by the gain in spectral efficiency due to moving from 1G to 3G technology. The net effect is that spectrum demand for Mobile Satellite Services is projected to be fairly steady over the next five years, as subscribers upgrade to newer technology.

MSS subscriptions have been projected to grow from 120,000 in 2010 to 190,000 by 2015. While voice traffic continues to be low, users with newer data capable devices are projected to generate 40 MB of data traffic per month, per subscriber by 2015. This results in an overall MSS traffic volume rising from 450 GB to almost 10,000 GB over the same period for the *Business as Usual* scenario.

As a result of the shift to newer, more efficient technologies, the spectrum demand is projected to remain comparable with, or less than, what it is in 2010 (remain in the 60-100 MHz x orbital slot range for *Business as Usual* scenario). The projections for the other scenarios are sensitive to the changes modelled, and should be reviewed in the Report.

Fixed Broadband Satellite: Rapid growth in subscribers and a slow growth in the volume of data traffic per subscriber are projected. The combined effect is a close-to-tenfold growth in traffic over the five-year period going from 500 Terabytes[2] (TB) in 2010 to more than 5000 TB in 2015 for the *Business as Usual* scenario.

Large-scale gains in spectral efficiency for these services over the five-year period are not anticipated and, consequently, the demand for spectrum, as measured in MHz x orbital slots, is observed to follow the growth in traffic. The resulting demand grows from just over 800 MHx x Geostationary orbital slot (GOS) to over 5000 MHz x GOS. The projections for other scenarios vary significantly as a result of the sensitivity to changes modelled.

Bent-pipe: An analytic overview has been presented for the fixed "bent-pipe" satellite service. Due to the large number of Canadian and foreign satellites serving the North American market, including Canada, it is difficult to quantify demand. Furthermore, there are many types of satellite telecom services being delivered and a large number of satellite network operators, service providers and a large pool of fixed satellite users. Very little information was available to study the service and spectrum demand for this category of fixed satellites.

This is another area where a longer-term evaluation period of 15 to 20 years would be more valuable to study the demand for spectrum.

Land-Mobile Services

An ad-hoc analysis of the demand for spectrum was conducted for this service. Input from stakeholders and research was used to determine current pressure points and where there is a need for future spectrum.

The Study reaffirms the presence of very high congestion in spectrum use for the 150, 450 and 800 MHz bands. While spectrum for particular applications may not be readily available in the preferred band(s), users have been accommodated or offered alternative spectrum in less-encumbered bands (900 MHz, 220 MHz or others). Public records have shown that the demand for VHF, UHF and 800 MHz frequencies have exceeded spectrum availability in certain large cities and areas of the country.

This area will experience improvement through introduction of newer, more spectrally efficient technologies and other measures that are expected to provide some relief. However, while regulatory measures, alongside industry trends, may help in releasing frequencies in congested land-mobile bands, any released frequencies are expected to address pent-up, or ongoing, demand in these bands. Also, some of the technology enhancements will start to make a more significant difference in the later part of the Study period. Therefore, despite the migration of users, technology enhancements and regulatory measures, little net-change is expected in the overall demand for spectrum in the bands already seeing pressure, with some increased usage of the currently underutilized bands over the 2010-2015 period.

Public Safety Service

Similar to land-mobile, an ad-hoc analysis was conducted to determine the demand for spectrum for this service. Input from stakeholders and research was used to determine current pressure points and where there is a need for future spectrum.

In summary, groups of 150/450/800 MHz land-mobile frequencies are not available for new Public Safety (PS) systems due to congestion, especially in border areas and dense urban cities. Despite developments including use of newer, more spectrally efficient technologies; narrowbanding; use of 700 MHz spectrum; and use of cellular networks for some PS applications, it is expected that any released frequency assignments will be used up to serve existing demand.

[2] 1 Terabyte (TB) = 1000 GB

Input provided to Red Mobile by PS stakeholders was reviewed in conjunction with that provided by other industry players to Industry Canada as part of the 700 MHz Consultation. There are varying perspectives of how much spectrum is needed for optimal operation in the new 700 MHz spectrum. Some of these perspectives are presented in this Study. Mobile broadband communications, and interoperability are important for PS agencies, and deployments in the new 700 MHz band are expected to facilitate this.

Despite the new 700 MHz spectrum, it is expected that the 800 MHz land-mobile spectrum used by PS will continue to grow at current growth rates, in large urban areas over the Study period.

Amateur Radio

The findings from stakeholder input are used to identify pressure points and potential demand for this service.

While demand has been steady for the most part, there is some pressure on bands, including 144-148/430-450 MHz band. Some of this pressure may be alleviated by the use of other bands for voice. There is also repeater operation congestion experienced in the 144/430 MHz bands in some urban areas.

In some cities, wideband amateur fast-scan video activity is presently occupying 6 MHz wide channels using cross-band video repeaters in the bands 430-450 MHz, 902-928 and/or 1240-1300 MHz. It is becoming difficult to assign spectrum for these new applications in these cities.

However, despite the occurrence of high usage for certain amateur services in particular bands, there is no additional demand for spectrum identified for this sector in the 2010-2015 time frame.

Aeronautical Services

The findings from stakeholder input are used to identify pressure points and potential demand for this service.

It has been reported that all aeronautical services in the band 108-137 MHz and 328-335 MHz have been experiencing congestion. In particular, the band 108-111.975 MHz, assigned to an Internet Locator Server (ILS) localizer, is lacking frequencies in dense urban areas. Also, congestion exists for VHF communications at airports.

In order to meet the growing service demand, several bands in VHF, UHF and SHF will require additional frequency assignments during the 2010-2015 time span.

It should be noted that Aeronautical services use international frequency allocations, internationally set and followed standards and technologies based on International Telecommunications Union (ITU) and International Civil Aviation Organization (ICAO) requirements. In some instances, it can take 15-25 years to migrate legacy technology systems to new digital installations.

Maritime Mobile Services

The findings from research are used to identify pressure points and potential demand for this service.

This research did not find any additional spectrum requirements in the 2010 to 2015 period. However, in certain areas (i.e. a port), due to extensive maritime activities, particular VHF maritime communication frequencies will experience heavy usage and saturation.

It is expected that Canada will continue to follow international standards, allocation plans and particular maritime mobile frequency designations should continue. Over time, more spectrum-efficient maritime mobile technology should increase the communications capacity of the assigned spectrum.

Military Services

Similar to PS and land-mobile, an ad-hoc analysis was conducted to determine the demand for spectrum for this service. Stakeholder input was used to determine current pressure points and where there is a need for future spectrum.

The Study notes that, in many instances, the identification of new spectrum for major military systems tends to be collaboration with NATO countries and the NORAD organization. New spectrum requirements are identified several years in advance, and requirements are negotiated at appropriate ITU committees and WRC conferences to gain appropriate International Allocations and regulatory status in the ITU Table of Frequency Allocations.

The military is expected to continue to modernize its assets within the existing spectrum assigned, to share some of the spectrum with government and civil users and to collaborate to ensure that spectrum is used efficiently and meets the highest needs.

It is expected that additional spectrum will be needed for AMT service, while taking into account the availability of equipment. Other than for AMT services, additional areas of demand for new spectrum have not been identified for the 2010-2015 period.

Radiodetermination Services

The findings from stakeholder input are used to identify pressure points and potential demand for this service. There are some services that overlap between the input provided for radiodetermination and space science services.

Radiodetermination services include a range of radionavigation and radiolocation systems.

The identification of new spectrum for radiodetermination tends to be a collaborative exercise in an attempt to meet the needs of ITU members. Of additional significance to Canada are the needs of NATO countries. The WRC 2012 Conference is expected to consider making a primary allocation of radiolocation service in the band 15.4-15.7 GHz.

It is expected that radiodetermination systems will continue to be modernized within existing frequency bands.

Space Science Services

The findings from stakeholder input are used to identify pressure points and potential demand for this service. There are some services that overlap between the input provided for radiodetermination and space science services.

The identification of new spectrum for Space Science Services tends to be a collaborative effort among the member countries of the ITU forum.

The Study has identified areas where spectrum demand may occur for Space Science in the 2010 to 2015 period. These areas include the 2 GHz band for space operation to support small research satellites and RADARSAT.

Also, there is a potential need for additional spectrum in the 5 and 8 GHz bands for future Earth Exploration Satellite Service projects (RADARSAT-equivalent).

Consumer Devices

The findings from stakeholder input and research are used to identify pressure points and potential demand for this service.

The Study does not show additional demand of spectrum for consumer devices to occur in the 2010 to 2015 period. However, some of the bands (960 and 2400 MHz) are heavily populated with consumer devices, and can experience localized congestion in the presence of several devices operating in the area (i.e. conference centre, airport, etc.)

New technologies are increasingly using higher licence-exempt bands in the 5 GHz range. It is estimated that less than 20% of the spectrum in the new 5 GHz band (bands 5150-5250 MHz, 5250-5350 MHz and 5470-5600 MHz) is heavily occupied.

Medical Devices

Findings from research are used to identify pressure points and potential demand for this service.

While the proliferation of wireless enabled medical devices is expected to grow, demand of additional spectrum for medical devices is not expected to occur in the 2010 to 2015 period, as a result of the short-range, low-power communications of many devices.

The new medical telemetry band at 1400 MHz should replace the use of TV broadcasting spectrum, which is subject to more interference from over-the-air digital TV broadcasting.

1.2 Background

In Canada, radio frequency spectrum, which is managed by the Ministry of Industry, is considered a strategic public resource that provides benefits to different Canadian stakeholders, including the private sector, commercial users, consumers, defence, national security, science and public safety.

The spectrum allocation process in Canada is independent. However, it also aims to take into account different global policies issued by the World Radio Conference (WRC) — which will take place in 2012 — and the International Telecommunications Union (ITU). The allocations are formally set out in the Canadian Table of Frequency Allocations (CTFA) and are a necessary input to this Study.

The development of spectrum policies, allocations and technical standards in Canada is strongly affected by developments in the United States and, in many cases, by global dynamics. This has been taken into account in this Report while preparing the spectrum forecast. Industry Canada has set out to perform, and recently completed, a thorough study of current radio spectrum allocations and assignments. This study, called, "*Radio Spectrum Inventory: A 2010 Snapshot – Canada*"[3] (Inventory Report), has been extensively referenced as input to this Report.

1.3 Scope of the Study

The scope of this Study covers two broad types of spectrum users, namely government and commercial/private users, and 15 categories of services and applications in the radio-frequency bands from 52 MHz to 38 GHz. The Study provides the demand for spectrum during the period 2011 and 2015. However, as can be noted, where a historic perspective was valuable in determining trends, the Study does go several years back to understand the long-term trend.

[3] Radio Spectrum Inventory: A 2010 Snapshot – Canada: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10023.html

As part of the scope, the Study reviews and references Industry Canada's Inventory Report, and does so for all services in order to summarize the current utilization of spectrum. The intent of this is to provide the reader a perspective of what the current spectrum allocations are for each service.

As part of this Study, Industry Canada identified five of these services as High-Value Services (italicized in the service list below). These High-Value Services have undergone significantly more research and analysis, and the demand for spectrum has been analyzed and modelled in detail using a proprietary modelling tool.

Per the scope of the Study, the demand for the remaining services was determined based on a combination of input from stakeholders and users, industry interviews, sources of secondary research, regulatory body reports, etc. This information was then analyzed, where applicable, to highlight any pressure points and areas for potential changes in demand for spectrum.

List of services covered in this Report:

1. *Cellular Services*
2. *Fixed Wireless Access Services*
3. *Backhaul Services*
4. *Broadcasting Services*
5. *Satellite Communication Services*
6. Land-Mobile Services
7. Public Safety Services
8. Amateur Radio
9. Aeronautical Services
10. Maritime Services
11. Military
12. Radio Determination Services Communications
13. Space Science Services
14. Consumer Devices
15. Medical Devices

1.4 Predicting Developments in the Demand for Spectrum

Red Mobile Co. (Red Mobile) has been assigned to conduct a Study of future demand for radio spectrum in Canada. Augmenting Red Mobile's expertise, in the wireless industry and relevant regulatory practice, is PA Consulting, a global consultancy experienced in similar demand forecasts.

Red Mobile's team has significant experience in working on several client engagements in North America, South America, Europe, Asia and the Middle East. This has allowed the team to gain significant international hands-on experience, in addition to the appreciation of global and regional trends, and local variations. Red Mobile's consultants have a strong understanding of similar worldwide initiatives to evaluate spectrum demand and shaping related policy initiatives.

Work initiated on this Study in December 2010 and continued through to December 2011. As a result, where most applicable (i.e. Cellular, etc.) and possible, the evolution and changes in service demand have been tracked through the course of the year and reviewed several times, as part of an overall due-diligence process. Red Mobile conducted the market research and analysis of all 15 services and has developed the Service Demand forecasts.

For the purpose of market research and analysis, several Industry Stakeholders *(See Appendix B)* were asked to provide input to questionnaires. In addition, interviews and correspondence were used to further solicit input or clarify a position. Where possible, projections were reviewed against other sources as a sense-check. Once the market research and analysis were complete and the Service Demand was determined, Red Mobile worked alongside PA Consulting, who modelled the demand forecast for five of these services, classified as High-Value Services (explained in the next section). The spectrum demand needs for the other services have been covered through a high-level ad-hoc analysis, and have not been modelled, in alignment with the scope of this Report's mandate.

2 Organization of Report

This spectrum demand Study follows the radio service categories identified by Industry Canada. The organizational structure is as follows, including the types of service applications covered in a particular section.

1. Cellular Services

This section covers mobile commercial services deployed in the Cellular, PCS and AWS bands as assigned by Industry Canada, and it also includes the future use of BRS and 700 MHz bands. Technologies covered include:

- GSM, GPRS and EDGE;
- CDMA, 1xRTT and EV-DO;
- 3.5G - HSPA/HSPA+; and
- 4G - LTE and WiMAX

Current national and regional operators and deployments are taken into account, as well as potential future changes with spectrum assignment in the 700 MHz and BRS bands. A wide range of service offerings — including voice, email, messaging, web browsing, video streaming, download, social media, interactive and converged services — have been considered. In addition, the evolution of connected devices has been taken into account. A detailed 2005-2010 model is developed for service demand, where historic evolution is assessed, as well as future demand. In developing models for this section, significant primary research was undertaken, including the monitoring of actual changes in various parameters, including monthly changes evolution of subscribers, devices, distribution of traffic over HSPA vs. legacy technologies, data usage, etc. In addition, the cell/sector counts for each technology were determined. Each stakeholder's input is held in confidence and, therefore, not disclosed. It is important to note, that, while stakeholder input was used as a sense-check and for fine tuning, the projections and numbers are based upon independent research and analysis and do not indicate any specific operator's situation.

2. Fixed Wireless Access (FWA)

The FWA section covers point-to-multipoint (PTM) systems below 6 GHz, which provide broadband Internet access to a segment of the home and business market. Licensed and unlicensed spectrum, using WiMAX and proprietary technologies in applicable bands, has been modelled. FWA applications supported using cellular technologies (i.e. HSPA/LTE) are covered in this section.

This section also covers point-to-point (PTP) FWA in bands above 20 GHz.

3. Backhaul Services

This section covers the use of backhaul microwave links to support wireless backhaul of traffic from FWA and cellular networks. Microwave facilities are used in Canada, in addition to wireline (fibre-based) facilities, to support the combined backhaul of cellular networks and FWA systems.

Point-to-point links using FWA technology for enterprise connectivity (typically 24/28 GHz band) in the access network are addressed in the FWA section.

4. Broadcasting Services

The broadcasting section covers over-the-air (OTA) digital TV broadcasting and OTA FM Radio. Furthermore, broadcasting satellite, or Direct-to-Home (DTH) satellite broadcasting, service is covered under this section for Canada's two DTH satellite broadcasters. This section covers advanced technologies being implemented, including:

- ATSC (Advanced Television Systems Committee) for OTA TV;
- IBOC (In-band On-Channel) for FM; and
- MPEG 2 for broadcasting satellite and a range of digital service offerings on OTA TV channels from SDTV to HDTV and mobile TV broadcasting

5. Satellite Communications Services

This section covers broadband satellite communications (Ka-band) providing broadband Internet access to households and businesses, as well as mobile satellite services, which have now evolved from voice to 3G capacities. Also, this section briefly addresses the conventional fixed satellite communications (bent-pipe types using the C- and Ku-bands). Both Canadian and foreign satellite networks serve various segments of the Canadian satellite market. New Canadian satellite networks use orbital-spectrum resources on the geo-stationary orbital arc to serve both the Canadian and North American satellite market. The Study considers available satellite capacity and needs for the Canadian market.

6. Land-Mobile Services

This section covers the land-mobile services, such as trunk mobile and wide-area dispatch for voice, paging, telemetry, data, etc., used by hundreds of thousands of users over a number of bands (VHF and UHF). Also, the section covers the specialized public safety services using traditional land-mobile spectrum for wide-area dispatch of voice and data.

7. Public Safety Services

This section covers public safety (PS) services using specialized systems for wide area dispatch-voice, data service (files download, image, surveillance, etc.) used by first responders, such as fire, police and EMS. In addition to the land mobile spectrum, a number of bands have been assigned exclusively to PS for voice, data and broadband Internet access, which are part of the Study. Under the public safety definition, a number of government and utility radio applications (where life and property protection is involved) qualify to access spectrum as public safety for mobile voice, data and broadband access.

8. Amateur Radio

This section covers the wide range of amateur radio uses of radio communications and the many bands available for such services, including voice, data, video, emergency assistance, research, image, Internet access, satellite, etc.

9. Aeronautical Services

This section covers a multitude of services essential to ensure the operation and safety of civilian and military aviation, as part of the domestic Air Navigation System (ANS). Some of the services and systems covered include the VHF radionavigation (VOR, ILS, ATCS and VHF communications), airport surveillance radar, airborne radar, radio altimeters, aeronautical mobile, global positioning satellite service (GPS) and other applications for Canadian ANS operation.

10. Maritime Services

This section covers the VHF maritime mobile services, which include mobile applications for inter-ship and ship-to-shore communications, communications used for safety and ship movement, automatic ship identification and surveillance systems, vessel traffic services and other communications.

11. Military Services

This section covers the specialized needs of the Canadian military. It includes a wide range of radio services and applications to support military operations, such as mobile, satellites and radiodetermination, including radar systems, radionavigation, aeronautical and maritime communications. Some military radio service needs are covered in other service sections of this report and are identified in such cases.

12. Radiodetermination Services

This section covers two main categories of radiodetermination services, namely, radionavigation and radiodetermination (radar) applications. This includes a wide range of applications for aviation, maritime transportation, military operations, environment (e.g. weather radar), etc.

13. Space Science Services

This section covers the space science services broadly associated with space operation, space research, earth exploration satellites, meteorological and radio astronomy. This includes a wide range of frequency bands and service space science applications by several key government agencies and users.

14. Consumer Devices

This section covers the use of a number of licence-exempt frequency bands by many millions of wireless (consumer and business) devices/products. These include phones, Wi-Fi routers, Wi-Fi connections to electronic home devices, smartphones, tablets, etc. A number of frequency bands accommodate the operation and growth of these consumer and business devices.

15. Medical Devices

This section covers the use of wireless applications to support a wide range of medical monitoring and telemetry devices as part of providing advanced medical care through remote diagnostics, monitoring of vital signs, as well as other innovative applications.

3 Approach to Forecasting the Demand for Spectrum

3.1 The Approach Taken for Quantifying Projection of Demand

3.1.1 High-Value Services

The mandate for High-Value Service was to develop a detailed analysis of the demand for spectrum. As such, the approach taken for these services was for Red Mobile to first develop a top-down forecast of subscriber, device and traffic evolution, based on a combination of primary research, industry stakeholders' input and other resources, regulatory body reports and data-bases, including Industry Canada, the CRTC and FCC, as well as various credible sources of secondary research. Red Mobile used the fore-mentioned sources, in addition to its in-house expertise, to develop the forecasts for each of the services. These forecasts are referred to as the Demand for Services in this Report.

Some of the parameters for consideration included:

- Cellular, FWA and satellite communications:
  The approach was to conduct a detailed top-down market analysis and forecast of the (1) number of subscribers, (2) breakdown of subscribers or device type, where applicable (feature/smartphone, tablet, dongle, etc., for cellular), (3) traffic-per-subscriber, based on device type, divided by application (i.e. voice, messaging, web browsing, email, etc.), where applicable.
- Broadcasting:
  The approach was to determine the (1) number of channels and to break down the numbers by (2) channel type and (3) technology.
- Backhaul:
  The approach is to (1) generate separate traffic forecasts for each network type (i.e. fixed networks and cellular), then (2) estimate what percentage goes over microwave, and (3) how it is distributed and retransmitted over microwave links in the network.

In determining the Demand for Spectrum for High-Value Services, Red Mobile worked with PA Consulting Group to develop input parameters and key assumptions needed to develop spectrum demand. PA's PRISM model and its associated methodology were appropriately customized, where necessary, for the scope of this Study and for the unique requirements of the Canadian market.

Therefore, the following process was used:

- Conduct relevant primary research and leverage in-house expertise;
- Review stakeholder input and sources of secondary data;
- Review existing data regarding the usage of each service – traffic, subscribers, as well as how these have evolved;
- Derive detailed estimates of current and future traffic for each service, broken down by application and technology where appropriate;
- Derive detailed assumptions regarding how these traffic volumes will convert into spectrum demand. Some factors include: spectral efficiency, frequency reuse, across each type of network, geographical and temporal distribution of demand;
- Use the PRISM model to apply these assumptions and to calculate the demand for spectrum for each service, with selective breakdowns by technology or by network type;
- Use the PRISM model to explore alternative scenarios and compare them with the main *Growth as Usual* projections.

In practice, there has been some iteration in this process as the detailed bottom-up assumptions used in the model have been validated in the light of the initial projections.

3.1.2 Other Services

The mandate for the other services was to conduct a high-level ad-hoc analysis of service and spectrum demand, where possible, and to highlight the potential impact on demand, based on stakeholders' input. Therefore, these services were not modelled in detail. The approach taken for these services was for Red Mobile to first develop a synopsis of the market for the particular service and to develop an associated questionnaire, as well as to gather input from industry stakeholders.

In addition, industry participants and stakeholders were interviewed, where applicable, and credible secondary sources were used as identified. This provided the direction for the demand for both services and spectrum. As opposed to the High-Value Services, where stakeholder input was provided in confidence and has not been shared in this Report, for some of the services (i.e. Military or Public Safety) the stakeholders are given, therefore, to make the information more valuable, the sources for input — where they are government bodies — have been identified with permission. Pressure on spectrum is identified where applicable.

Therefore, the following process was used:

- Conduct relevant primary research and leverage in-house expertise.
- Review stakeholder input and sources of secondary data.
- Review existing data regarding the usage of each service from Industry Canada's Inventory Report and stakeholder input, i.e. frequency assignments, pressure points, etc.
- Where applicable, derive high-level estimates of current and future changes in service and spectrum demand.

In practice, there has been some iteration in this process.

Table 3.1.1 — The approach taken for modelling of services

Note: High-Value Services (shaded boxes) were modelled in detail using PRISM, while the remainder received varying degrees of analysis to determine impact on spectrum throughout the next five years.

Service name	Description of technology and users/usage	High Value	Approach to forecasting the demand for spectrum			
			A. Stake-holder engage-ment	B. Self-reporting by users of spectrum	C. Bespoke ad-hoc analysis	D. In-depth model-ling of traffic and demand
Cellular	2.5G (GSM, 1XRTT) 3G (GPRS, EVDO) 3.5G (HSPA) 4G (LTE, WiMAX) Voice and IP data	Yes	Yes	Yes	Yes	Yes (3 scenarios)
Land Mobile	Narrowband, trunking, APCO PS, Government, commercial carriers		Yes	Yes	Yes	

Public Safety	APCO, narrowband and broadband, All PS agencies		Yes	Yes	Yes	
Broadcasting (Radio and Television)	Terrestrial and Satellite. Digital TV (DTV), In-band digital FM and AM radio. Transition to digital within Channel 2-51 and radio bands	Yes	Yes	Yes	Yes	Yes (3 scenarios)
Amateur Radio	Various technologies and applications, depending on bands		Yes	Yes		
Backhaul	Digital microwave radio relays in several bands; Backhaul for cellular, power utility, broadcast STL, CATV head ends	Yes	Yes	Yes	Yes	Yes (3 scenarios)
Fixed Wireless Access	WiMAX, other digital technology. Broadband access in FWA, WCS, MCS, LMCS bands	Yes	Yes	Yes	Yes	Yes (3 scenarios)
Satellite Services	Satellite comms – voice and data; civil, not military. Multimedia satellites in C-, Ku-, Ka-Bands; MSS in L-band and 2 GHz bands. DTH Broadcasting (Analyzed here for Canada, and Demand presented in Broadcasting section), program carriage, telecom, Internet backbone, broadband access, government service, mobile satellite. Fixed Bent-pipe Satellite. Communications were analyzed using ad-hoc analysis	Yes	Yes	Yes	Yes	Yes (3 scenarios)
Aeronautical Services (Comm-unications, Navigational Aids and Surveillance)	Air navigation and air traffic management. Transport Canada, NAVCAN		Yes	Yes		
Maritime Services (Communications, Navigational Aids and Surveillance)	Mobile stations: ship station and coast stations. Government, vessels, crafts, port authority		Yes	Yes		
Military	Excluding Radar (covered separately). Comprising: weapons systems, communications systems (incl. land mobile, satellite)		Yes	Yes	Yes	
Radio Determination Services Communications	Radionavigation and Radio-location use for aeronautical navigation (incl. GPS) and Radar applications, i.e. for navigation and non-military		Yes	Yes		
Space Science Services	EESS, space research, space operation, radio astronomy. Government and agencies, university, satellite operators		Yes	Yes		
Consumer Devices	LE-exempt wireless: Blue-tooth, Wi-Fi, DECT, R-LAN UWB		Yes	Yes		

Medical Devices	LE-exempt short-range wireless. Telemetry devices		Yes	Yes		

The Table A.1.1, in Appendix A, lists the stakeholders that were approached to provide input. While most stakeholders provided highly beneficial input, some did not respond. In addition to the direct input from stakeholders, in some cases, some stakeholders were interviewed or asked more detailed questions. Each stakeholder's input has been treated as confidential, other than where we received permission from agencies to release their names (i.e. DND, RCMP, etc.), and, in some cases, the user is obvious. In developing the projections for service or spectrum demand, several sources of information were used and combined with stakeholder input to develop the specific input data needed for the modelling process.

3.2 Forecasting the Relationship Between the Demand for Both Services and Spectrum

3.2.1 High-Value Services

The projections for the High-Value Services have been generated using the PRISM model. The model generates quantified projections of the demand for spectrum across a range of communications and media services and technologies. It generates projections for each year of interest, over a time frame of, typically, five to 20 years. In this process, the demand for services and the levels of offered traffic are primary drivers of the demand for spectrum.

However, the relationship between the two is not always so simple. There is a range of factors, which drives demand for spectrum. Each factor is different for each of the services and can be different for individual technologies. The model takes these inputs and uses them to quantify the relationship between traffic growth and growth in demand for spectrum. As a result, the relationship between growth in traffic and growth in demand for spectrum can take many different forms.

The results and the relationships for each of the five High-Value Services are given in Section 6 below.

An overview of the PRISM model is given below.

The PRISM Model

The PRISM model was based on background IP from a number of spectrum demand and valuation models developed by PA. It was primarily developed for an assignment for Ofcom, the UK regulator, to predict spectrum demand and shortages for six High-Value Services[4] in the UK over a 15-20-year time frame (2007-2025). A key part of the methodology was the development of PRISM as a comprehensive, yet flexible and adaptable, Excel-based model.

The methodology and, in particular, the PRISM spectrum requirements model was reused (with suitable adaptations) in the assignment delivered for Industry Canada. For this project, an innovative methodology capable of generating soundly based projections of spectrum requirements data for a wide range of uses — including four of the five services

[4] Cellular, Terrestrial Broadcast (split into TV and Radio for the Ofcom study), Short-Range Wireless Consumer Devices, Fixed Wireless Access and Backhaul. Satellite Communications and Satellite Broadcasting were added for the Industry Canada study.

required for Canada — have been pioneered.

The PRISM model is an extensive and comprehensive model amounting to some 70 MB of Excel and Visual Basic for Applications (VBA). The model is particularly relevant where substantial changes are expected in spectrum requirements over the next few years and where the usage drivers are complex. This applies to cellular systems and, to varying degrees, to the other four High-Value Services specified by Industry Canada.

Model Structure and Sample Inputs

The PRISM model provides a detailed bottom-up approach for forecasting the demand for spectrum, taking account of growth in service demand (traffic and subscribers, for mobile; channels, for TV broadcasting; etc.), but also covering the many factors that mitigate or occasionally exacerbate the effect of this on growth in demand for spectrum, for example:

- Growth in the number of base stations/changes in their deployment pattern;
- Changes in spectral efficiency;
- Changes in the installed base of devices (mainly for mobile);
- The distribution of demand over the day/week/year, and any changes in this;
- Headroom required in order to provide quality of service (e.g. low latency, high burst rates);
- Content compression;
- Cellular: the growth in femtocells and/or offload to Wi-Fi

The PRISM Model (cont'd.)

The model is also able to maintain separate forecasts of demand for each application (voice, SMS, Web browsing, email, downloads, live TV, etc.) for each service (Cellular, Broadcasting, FWA, Short-Range Wireless and Backhaul); to manage multiple scenarios for all of the demand projections and the technology assumptions; and to provide multi-dimensional reports on the resulting demand for spectrum over a time period of five to 20 years into the future.

An overview of the structure of the model is shown in Figure 3.1.1.

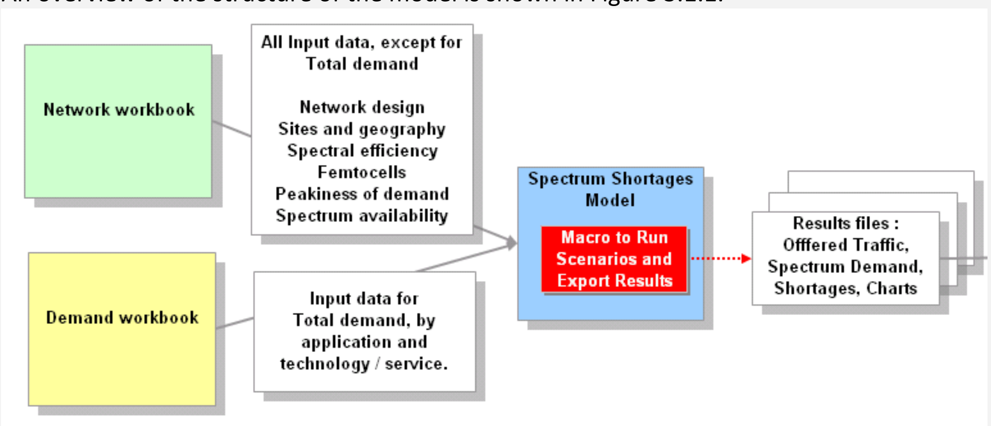

Figure 3.1.1 — PRISM: Model structure

The PRISM Model (cont'd.)

The model was designed to analyze the demand for spectrum, and any likely episodes or potential areas of spectrum shortage, over a five-to-20-year timeframe, covering up to 30 technologies spread across several entire services (e. g. Cellular, FWA, Backhaul).

The model caters to projected changes in subscribers, traffic, spectral efficiency, data compression and several other major factors affecting demand for spectrum.

Furthermore, it is designed to provide breakdowns of the demand projections by many of the relevant dimensions — notably by time, service-frequency band and by location type (the latter being particularly relevant for Cellular services, where demand can vary considerably between city centres, low-density suburbs and rural areas).

Overview of Model Usage

The model has been developed to allow a degree of reuse and reapplication in different geographies subject, of course, to the availability of the required input assumptions and parameters for the services being modelled.

Figure 3.1.2, below, shows the main menu, followed by the more detailed view of the structure of how the sections in the model fit together, shown in Figure 3.1.3, below this one.

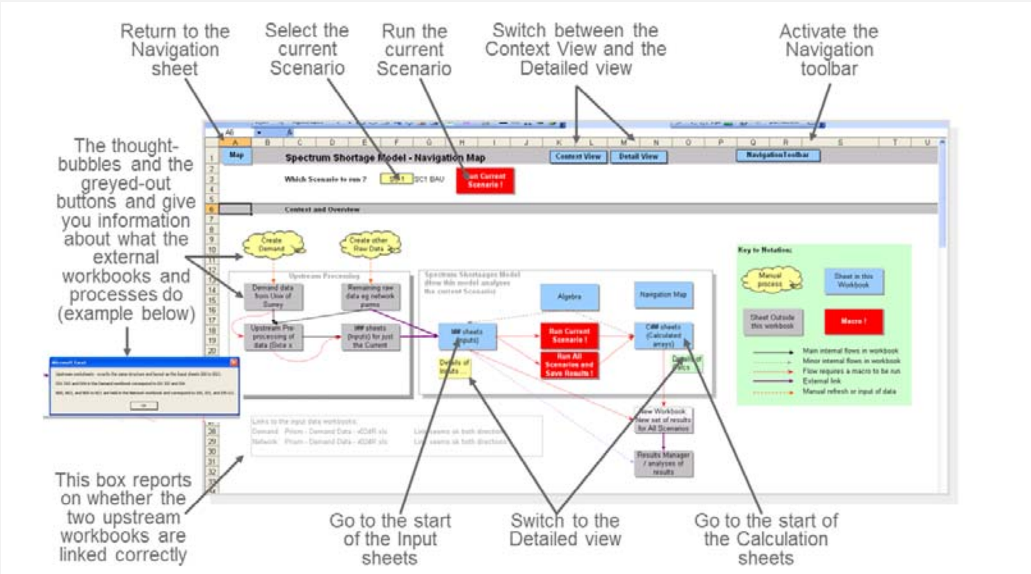

Figure 3.1.2 — PRISM: Main navigation menu

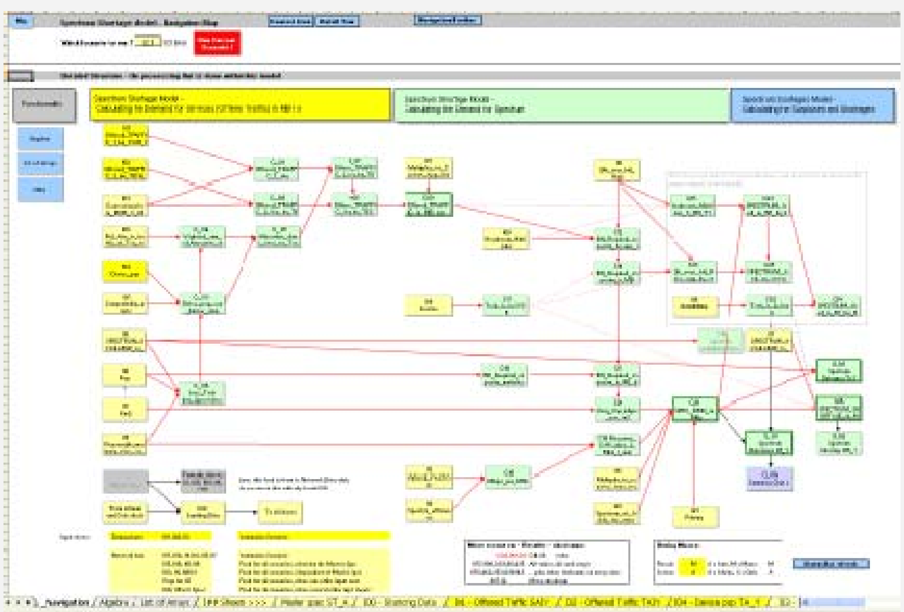

Figure 3.1.3 — PRISM: Detailed view

Behind each yellow navigation button on the detailed menu, above, there is one or more input sheets, each of which holds one set of related assumptions; Figure 3.1.4, below, shows a simple example of this.

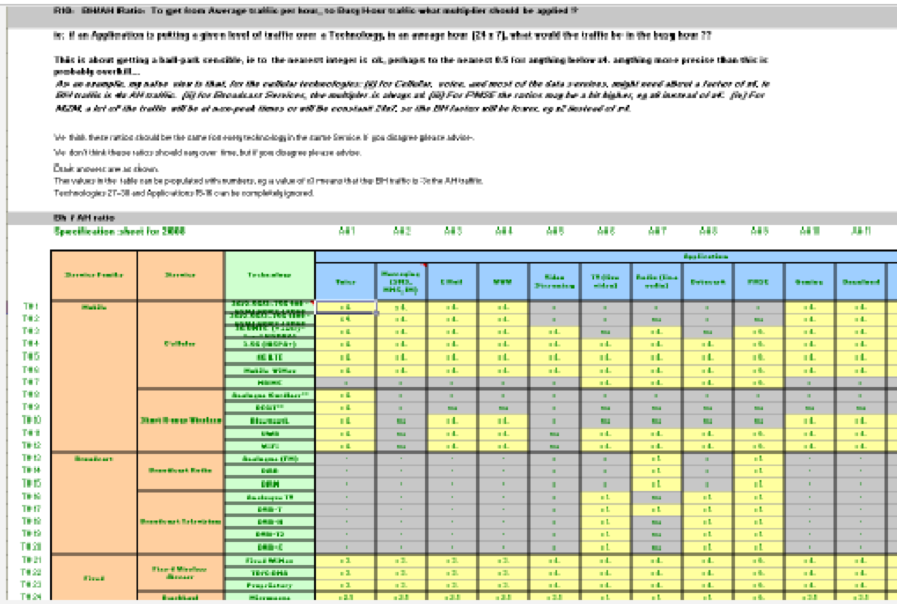

Figure 3.1.4 — PRISM: Example Input/Assumptions Sheet in the Model

The PRISM Model (cont'd.)

The model uses these inputs and assumptions to determine the traffic projections for each service and technology and, then, via further assumptions about how each technology works and how it is deployed, it determines the demand for spectrum from each technology and service. This is used to generate true bottom-up/demand-driven projections of the demand for spectrum, which take account of shifts in technology and networks, as well as growth in subscribers and traffic.

Advantage of the Model-based Approach using PRISM

The key function of the model is to enable market uptake data, for a range of different spectrum uses, to be translated into spectrum usage forecasts over time and for different bands. It does this in a flexible way using bottom-up analysis. So, in the case of cellular systems, for example, it takes into account certain factors, such as traffic patterns, neighbourhood types, propagation conditions, numbers and type of cell sites, the specific form of cellular system being used (i.e. HSPA, LTE, etc.), spectrum efficiency and the different types of mobile terminals. This information is all combined with the growth patterns, as dictated by the chosen scenarios, market conditions and a host of other factors, to produce spectrum usage estimates over time and in different bands.

These projections provide a higher degree of rigour than projections based on self-reported projections from users, or projections based on traffic growth, alone. Accordingly, the PRISM model has been used to underpin our analysis of the spectrum demand for the High-Value Services where the evolution in technology and demand is complex and where it warrants this higher level of sophistication.

3.2.2 Demand for Spectrum Defined

Prior to considering the modelling results, it is necessary to consider what is meant by the phrase "demand for spectrum," and how it can and should be interpreted.

There are many different measures of this demand. Definitions are shaped by, for example, the approach taken by posing the following questions:

- Is the "demand" an average, over the day/week/month/year, or for the peak period?
- What type of local area does the demand represent?
- What (if any) scaling-up is made to allow for quality of service — e.g. to handle random variation — local clustering/spreading of demand, short-term peaks and valleys, and "bursty" demand?
- Is the "demand" that of the traffic offered/demanded by the consumers/users of the service, or that of the service providers/operators?
- What assumptions are made regarding channel bandwidths, minimum frequency allocations, and paired versus unpaired spectrum?
- What, if any, provision is made for network management — testing/transition for new and replacement equipment, spectrum re-planning, re-farming of spectrum to deploy new technologies, and spectrum demand for "stranded" assets, such as RAN equipment that is deployed but which is now inefficient in its use of spectrum or is little used, e.g. because user devices have moved on to newer technologies?
- The approach taken in this Report reflects the aim of providing a view from a service consumer perspective wherever possible — not just for cellular, but for the other services, as well[5].

The primary measure of "demand" as discussed in the Report is outlined in the box below.

Main Definition of "Demand for Spectrum" used for High-Value Services

How much spectrum is required to serve the offered traffic?

The demand covers all traffic, for all users of the service, not just those on one network. The demand is for the busiest hour in an average week.

Demand is assessed for a range of different types of local areas of differently built environments and population densities. The national demand is generally taken as being the highest[6] of the demand figures in any of these local area types.

For communications technologies, a degree of scaling-up is applied to allow sufficient spectrum to provide an acceptable quality of service — to handle random variation, local clustering, short-term peaks and valleys, and "bursty" demand. Typically, the adjustment for this is a scaling factor in the range 1.5 to 2.

The spectrum demand figures include the effects of spectrum pairing for those

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5 With some limitations for Broadcast services, where the modelling uses channel-growth projections, provided by the broadcasters.

6 With some exceptions:
• for satellite communications: national demand is the sum (not the max) of the demand in all local area types;
• for broadcast: the concept of local area types is of limited relevance and is not applied.

technologies that can use only paired spectrum, or for which paired spectrum is the norm.

For Broadcasting services, the traffic originates from the broadcaster, rather than the viewer or listener. The definition of "traffic offered" uses the traffic generated by the broadcaster rather than being primarily centred on the numbers of viewers or listeners.

For satellite technologies, the most widely accepted measure of spectrum demand is slightly different. Rather than simply expressing the demand in MHz, the figures need to be expressed in MHz x Geostationary Orbital Slots, to reflect the reuse of spectrum across multiple slots.

The main definition used in this study is the "Spectrum Demand that results from these calculations.

It is the spectrum required to carry the traffic offered, with a realistic demand profile and at an acceptable quality of service. In short, it is the spectrum demanded by consumers and users of the service.

Where applicable, exceptions are made and stated in the analyses for the individual services.

These definitions are applied consistently across the five High-Value Services.

We believe that this view of "demand," including allowance for a busy hour, busy neighbourhood and allowing for quality of service, is more useful than a view based on average traffic in an average location. It represents the true consumer-oriented view of what spectrum is required.

There is also an exception made in the specific case of FM radio, where demand is limited by the 20 MHz of spectrum that is compatible with the technology. For FM radio, the definition of "demand" used in this Report is constrained to fit within the spectrum that the technology currently offers.

Sensitivity Analysis and Alternative Measures of Demand

From a network operator viewpoint, there are additional sources of demand. These arise from considering how the demand is delivered.

The main issue is that the "demand,“ as defined above, is determined without taking into account the considerations for practical operations of a network. These may include considerations for minimum channel widths, network evolution planning and testing, network management, etc.

This aspect of the definition may have a particularly large impact on the spectrum demand of terrestrial communications services, especially where there is much change in technology and traffic, such as cellular service.

The box below outlines several further sources of spectrum demand, which would take the projections from a consumer-oriented view of demand to an operator-oriented view.

Factors not included in the main definition of "Demand for Spectrum" used for High-Value Services, but included in sensitivity analysis

The first sensitivity analysis includes the additional spectrum required to allow for the channels' bandwidths to have discrete quantities, and for minimum allocations per network operator, including some for new operators where there is a likelihood of them entering the market and a fair chance of them becoming economically viable.

The second sensitivity analysis then adds to this the spectrum required by network operators for network strategy and management:

- Spectrum held for technologies arriving soon, but not yet deployed;
- Spectrum required in case a technology substitution is faster or slower than expected;
- Spectrum held for recently useful but now unused/fully obsolete technologies;
- Spectrum needed for testing prior to launch of new services.

For Cellular and Fixed Wireless Access, where these factors are particularly relevant, the report assesses the effect of including these additional sources of spectrum demand. This is presented as a sensitivity analysis after the main results for each of these two services.

Finally, it is worth setting out some of the sources of demand for spectrum, which have been excluded from the scope of the Study[7].

These include:

- Additional spectrum that would enable operators to increase revenue, reduce costs or increase market power;
- Additional spectrum that would be required to allow large numbers of new entrants to attempt to compete (with the likelihood that some may not be economically viable);
- Any fallow spectrum, i.e. which may be allocated to licensees but which cannot be used[8];
- Spectrum for guard bands.

Interpreting the Modelling Results:

Finally, before moving on to consider assumptions and results, it is advisable to bear in mind the following characteristics of a model-based quantitative approach to projecting the demand for spectrum:

7 Taking the view that: this is a Spectrum Demand study, and not a study of spectrum value or of spectrum required to allow complete economic freedom; and that the Study is on a Service-by-Service basis rather than aggregate view across Services.

8 For example, if a spectrum and licensing plan combines TDD and FDD allocations, operators may be unable to use one of these sets of allocations, due to there not being sufficient economically viable equipment that uses the technology. If this situation persists, then the spectrum allocated to this technology remains unusable, even though it is licenced and allocated.

- The highly quantitative nature of the model means that it generates specific numbers for all of its projections, based on the data and assumptions that are used as foundations for these projections.
- Projections are point estimates, rather than ranges. They serve to illustrate one potential trajectory for spectrum demand.
- Projections are most reliable if treated as directional indicators and/or estimates of the scale of likely changes in spectrum demand, i.e. will it stay about the same, double, halve, or do something else? Therefore, projections are *not exact* predictions, but good indicators of the trend.

3.2.3 Other Services

As mentioned previously, for the other services, analysis was conducted based on information from the inventory report, stakeholder input, interviews with Industry and review of secondary research material. Each service section identifies the specific sources of information used and the approach used to determine the impact on spectrum and to identify pressure points.

4 Alternative Scenarios that May Unfold over the Next Five Years

4.1 Drivers of Change

For the High-Value Services, the primary drivers throughout the time frame of 2010-2015 are anticipated to be:

- Growth in traffic per device, particularly data;
- Continuing investment by networks, e.g. increasing the number of base stations and sectors;
- For Cellular services: migration to newer technologies and the related improvements in spectral efficiency;
- For Satellite Communications: growth in the number of users;
- For Broadcast: migration to higher bit-rate channels, e.g. HDTV and continued growth in the total number of channels offered;
- For Backhaul: some continuing substitution from microwave to fibre for high-traffic links.

4.2 Defining the Future Scenarios and their Demand for Capacity

A set of projections have been developed for these — and a range of other — drivers and used these to generate projections for a central scenario, referred to in this report as Scenario 1, or *Growth as Usual*. This is the scenario that we would consider to be a plausible extrapolation of past trends in Canada.

Alongside the *Growth As Usual* scenario, a range of alternative futures have been considered, and for two of these alternatives, full alternative sets of projections for the spectrum demand throughout the 2010-2015 time frame have been generated. These two alternative scenarios are as follows:

- Scenario 2: *Wire-Free World*. Canada experiences an even more rapid progression to higher levels of wireless communications. Demand grows at a somewhat faster rate than in *Growth As Usual*. Also, new technologies are adopted slightly faster.
- Scenario 3: *Low Investment*. Canada's appetite for new technology doesn't disappear, but it abates somewhat. Demand continues to grow, at about the rate exhibited in Scenario 1, but networks, operators and even consumers are unable or unwilling to invest in infrastructure and technology at the rate projected in *Growth As Usual*. New licences and release of spectrum are somewhat slower to be introduced than in *Growth As Usual*.

Scenario 2 (*Wire-Free World)* is designed to assess the likely demand for spectrum, if demand, services and technologies develop faster than in Scenario 1. It is somewhat of a "high-spectrum demand scenario".

In contrast, Scenario 3 (*Low Investment)* is focused on what might happen if investment slows down. It is not particularly focused on generating high or low[9] cases for spectrum demand; it is, instead, focused on varying the level of investment.

Taken together, the three scenarios cover the range of outcomes that can be considered sensible, for planning purposes, i.e. they include both a "most likely" trajectory, plus a "high-spectrum demand trajectory".

5 Assumptions for Forecasting Demand

In addition to the factors mentioned in the preceding sections of the report, the major assumptions used to determine the demand for services and spectrum are identified in each of the relevant sections of the services covered.

6 Key Findings and Spectrum Demand Forecast

6.1 Cellular Services

6.1.1 Overview

The Canadian cellular industry has significantly grown since the mid-1990s with the introduction of personal communications, advanced digital networks and consumer devices with a wide range of smartphones and data-rich services and features. As of early 2011, the Canadian cellular market served close to 25 million users with a penetration of 74%. It is estimated that one or more mobile operators serve 99% of the population, with the coverage concentrated mainly along the southern land area of Canada.

To date, the three large incumbents support more than 95% of the subscriber base. Some regional operators and several new entrants have won spectrum at the 2008 Advanced Wireless Service (AWS) auction. They are currently gaining some traction by adding new subscribers.

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9 A Scenario built around "lower spectrum demand than the central projections of Scenario 1" was considered and discarded as unlikely to generate useful insights.

Since 1985, Industry Canada has licenced a total of 270 MHz for cellular services (50 MHz in 800 MHz cellular band; 130 MHz in the 1900 MHz PCS band and 90 MHz in the 1700/2100 MHz AWS band). In general, Canada follows the lead of the U.S. in releasing new frequency bands within 18-24 months. In addition to the 270 MHz of spectrum outlined, the U.S. has released 60 MHz of commercial mobile in the 700 MHz band and 200 MHz in the 2500 MHz (BRS) band.

The three largest cellular operators with the regional operators retain approximately 85% of the licenced spectrum (240 MHz of the 270 MHz available). The new entrants in the AWS band have 40 MHz of the 270 MHz of spectrum licenced across Canada, and some of the new entrants have 10 MHz to 20 MHz in the four largest cities.

Industry Canada has held consultations to release new spectrum for commercial broadband mobile service in the 700 MHz (up to 84 MHz) and has re-farmed the band 2500-2696 MHz (196 MHz) to Broadband Radio Service (BRS), including high-mobility broadband applications. The addition of up to 270 MHz would double the amount of spectrum available to commercial cellular operators for a total of 540 MHz.

The Canadian cellular industry has been undergoing a rather rapid transformation with the rollout of HSPA/HSPA+ technology supporting 21/42 Mbps throughput and significant capability to handle IP data services, multimedia, video streaming and other high-speed services. The phenomenal adoption of social networks, the capability of advanced smartphones, computing power of tablets, use of aircards for laptops and netbooks, and the tens of thousands of mobile applications (apps) is driving mobile data traffic at exponential growth rates since 2009. Recent HSPA+ networks and the new 4G (LTE and WiMAX) networks just being introduced are likely to experience an exceedingly high data traffic growth rate and relative spectrum demand. This section will study the cellular service growth and spectrum demand for the current time on up to 2015.

6.1.2 Spectrum Inventory and Spectrum Utilization

Industry Canada's Inventory Report, in Section 1.0, provides important information on the distribution of spectrum amongst the various operators, the number of cell sites, frequencies and other information. For example, the spectrum holdings for the operators in large cities are presented in Figure 6.1.1, below (Inventory Report, Figure 1.3).

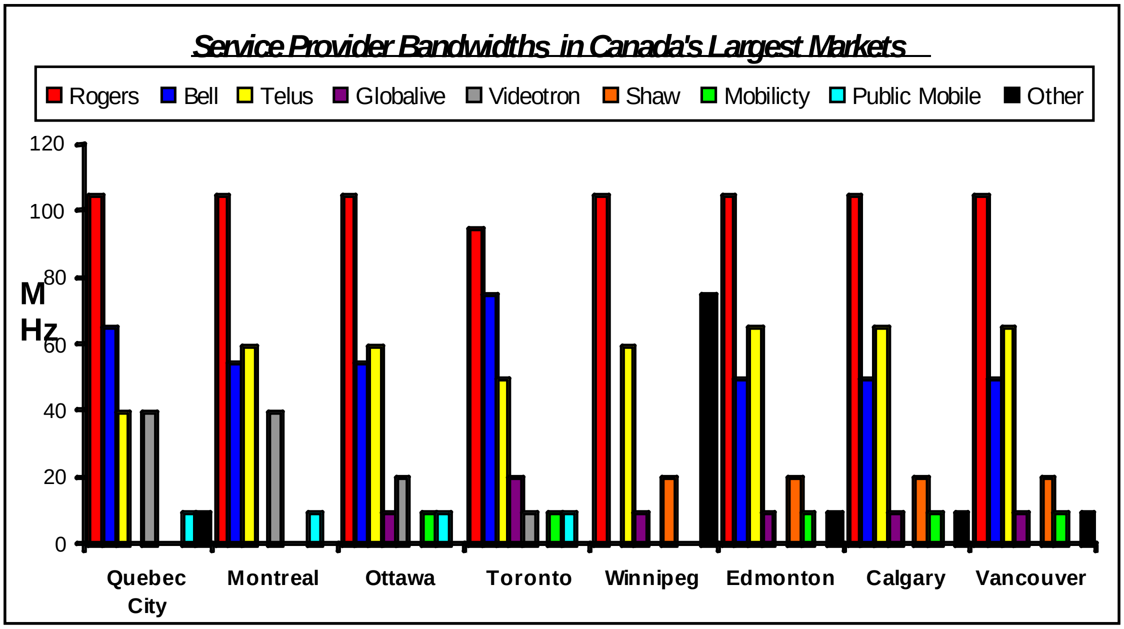

Figure 6.1.1 — Spectrum holdings by operators in large cities (*Source: Inventory Report, Figure 1.3*)

The 700 MHz Consultation process has summarized the overall spectrum-population holdings of each wireless carrier and Industry Canada (spectrum for auction), including the 700 MHz and 2500 MHz spectrum, as can be seen in Figure 6.1.2, below. The figure assumes that 84 MHz of commercial spectrum in the 700 MHz band is available.

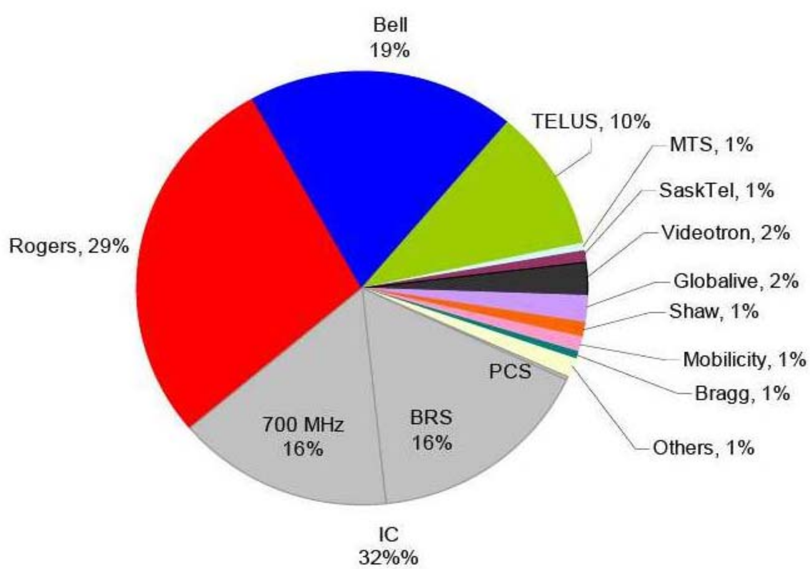

Figure 6.1.2 — Cellular, PCS, AWS, BRS and 700 MHz spectrum *(Source: Industry Canada)* (Total: 544 MHz weighted by population)

Note: The 700 MHz band is based on a maximum of 84 MHz of spectrum available. The ESMR spectrum, at 800 MHz, is not studied as part of this section and not addressed in Figure 6.1.2.

Spectrum Utilization

Preliminary analysis of spectrum utilization in urban core areas is developed from a number of sources, including the 2009 CRTC CMR Report, Spectrum Holding record (Figure 6.1.1, above) and demographic data. This is illustrated in Table 6.1.1, below.

The Table raises some interesting information about the cellular spectrum usage in the three largest markets: Toronto-Hamilton, Greater Vancouver Area and Montréal.

First, the population density and potential cellular market in the Toronto-Hamilton area is relatively higher than Vancouver and Montreal. According to the market share estimate by the three largest cellular operators and their spectrum holdings, it is seen in the last column that in Toronto, each operator has relatively the same density of subscribers per MHz (23.2 K to 28.7K per MHz), but in Montreal and Vancouver, some operators have twice the subscribers per MHz than others.

The Table, below, shows that spectrum holdings per each operator in large cities are not necessarily proportional to their market shares (density of subscribers per MHz), and different spectrum pressures may exist among cellular operators.

Table 6.1.1 — Projection of a typical profile of Canada's three largest carriers' operations in key urban centres (*Source: CRTC CMR Report and Red Mobile Analysis*)

Province (Percent of Market share, from 2009 CRTC-CMR)	Bell Group	TELUS	Rogers	Others	Cell penetration, by Province	City Pop., areas sq. km., and spectrum holdings (Fig. 6.1.1)	Calc. of subs/MHz Van., Toronto and Montreal [100% pen. In peak period]
British Columbia	16%	41%	42%	0%	75% penetration	Vancouver 2.0 M pop. 1176 sq. km. 1748 pop./sq. km. Bell: 50 MHz TELUS: 65 MHz Rogers: 105 MHz	Bell = 6.4 K subs/MHz TELUS = 12.6K subs/MHz Rogers = 8.0 K subs/MHz
Ontario	32%	20%	47%	1%	70% penetration	Toronto-Hamilton 5.8 M pop. 2279 sq. km. 2540 pop./sq. km. Bell: 70 MHz TELUS: 50 MHz Rogers: 95 MHz	Bell = 26.5 K subs/MHz TELUS = 23.2 K subs/MHz Rogers = 28.7 K subs/MHz
Quebec	39%	26%	33%	2%	55% penetration	Montreal 3.4 M pop. 1676 sq. km. 2005 pop./sq. km. Bell: 50 MHz TELUS: 60 MHz Rogers: 105 MHz	Bell = 26.5 K subs/MHz TELUS = 14.7 K subs/MHz Rogers = 10.7 K subs/MHz

Total Subscribers **Canada (1Q/2010)**	6. 9 M	6.5 M	8.5 M	1.0 M	22.971 M		

6.1.3 Stakeholder Input and Research Analysis

As part of the research, several industry participants, including operators and vendors, were surveyed for their input and perspectives. As well, the submissions made by several parties to the 700 MHz Consultation were reviewed.

The input received is not being shared in this document to protect contributor information. However, the input provided by various sources has been taken into consideration, as part of the overall approach to evaluating the growth of subscribers, services and traffic, and impact on spectrum. Where numbers are shown, these numbers are not the exact figures and projections shared by various parties, but rather what was determined based on analysis. The analysis was based on in-house expertise and assessment of the factors that influence growth, alongside information provided by all parties, as well as secondary research.

6.1.4 Service and Spectrum Demand

In this section, the projections for subscribers and traffic, the assumptions used to convert them into a demand for spectrum, and the results for alternative scenarios and the sensitivity analysis using alternative definitions of spectrum demand are presented.

Service Demand: Market Analysis

In developing the projections for service demand, Red Mobile used a combination of in-house expertise and primary research, and then reviewed this against several sources of reputable secondary research. While the initial analysis took place at YE 2010, the projections were revised several times over the course of the year, as new sources of current information became available. This included data from operators on actual consumption, as well as from other sources that monitor traffic. While the revisions meant several iterations of the models for service demand, which results in further iterations of spectrum demand, the exercise proved to be both necessary and highly valuable.

When the initial projections were made for YE 2010 and reviewed against industry input and secondary research, the projections aligned well with several reputable secondary sources, as well as with long-term market trends. However, over the course of 2011, a marked increase in data consumption was noted that was greater than what many had projected in the industry and constituted unusually high-percentage growth rates, when compared with the preceding two decades. As a result, projections were revised to be more reflective of the Canadian consumers' appetite for data services.

Several factors have led to this:

1. The rapid growth in adoption of high-end smartphones has continued to grow, despite any presumed economic pressures;
2. There has been a greater uptake of tablets and netbooks as they become more affordable;
3. The enhanced network throughput and improved overall user experience for data services through better devices, engaging applications, etc. has propelled data usage;
4. Canadian tariff rates for data have become significantly more attractive over the last two years, and consumers have responded to this.

A top-down analysis was conducted to determine consumer-driven demand over the next five years. The analysis included determining growth of subscriptions, changing the mix of the types of devices (i.e. feature phones to different types of smartphones, connected broadband devices/dongles, etc.), traffic-growth based on device type and mix of traffic (i.e. voice, SMS, email, web browsing, etc.), among other factors.

Overall, Red Mobile predicts that, with the growth in the variety and capability of device types, the insatiable appetite of users, and the evolving ability of networks to support higher data rates, the annual growth rates of traffic will remain extremely high in the short term.

Another factor, while not explicitly shown in this Study, but considered as part of the overall data growth, is the growth of Machine-to-Machine (M2M) communications. While M2M communications involves many devices, the aggregate traffic per connection is nominal, compared to that of the high-end broadband devices. While M2M devices are not counted as part of the overall subscriptions shown in this Study, the traffic generated by such devices as part of the overall offered traffic calculations has been accommodated.

The charts below summarize the projections for subscribers, data traffic and total traffic.

Figure 6.1.3 shows the number of subscriptions growing from 25 M at the start of 2011 to more than 34.6 M by 2015, translating to a penetration rate of a little more than 96%.

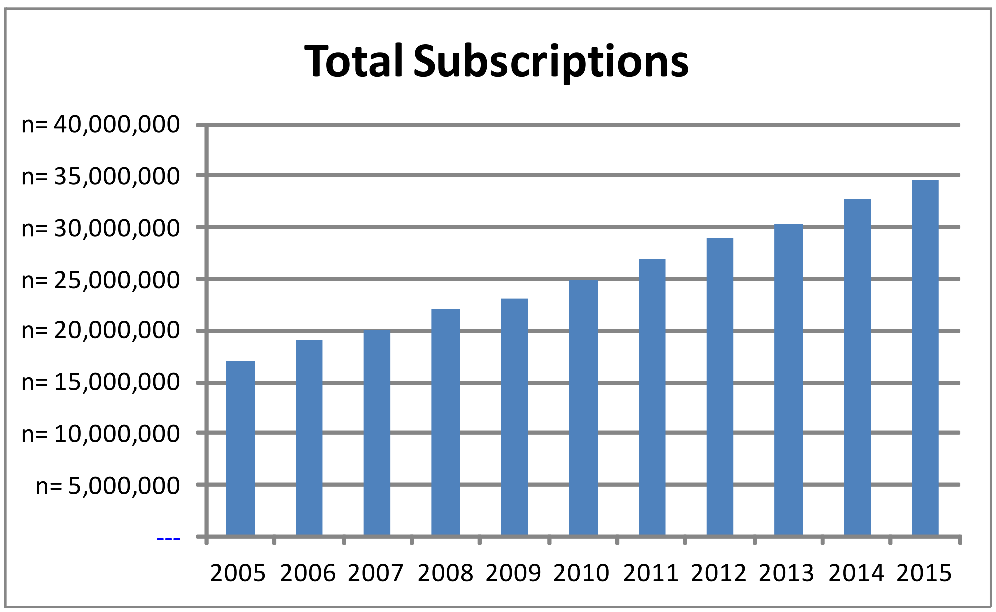

Figure 6.1.3 — Growth of cellular subscriptions (*Source: Red Mobile Analysis and Projections)*

Canadians typically replace their devices every couple of years, and a growing number have been upgrading to smartphones. It is estimated that, by the end of 2015, 60% of devices will be mobile-broadband devices, consisting of smartphones, dongles and mobile-capable tablets and netbooks. This represents a growth in mobile-broadband devices of 2.7 times over the period from the end of 2010 to 2015.

As can be noted in Figure 6.1.4, according to projections, the number of high-end smartphones will surpass the number of entry-level smartphones by the end of 2015. There will also be a marked increase in the number of mobile-enabled tablets over this period, as they become more affordable, with a large variety of them available in the sub-$300 range. By yearend 2015, it's estimated that close to 57% of all non-smartphone mobile-broadband devices will be tablets or an equivalent type of device. In the figure below, these devices are differentiated from the remainder of non-smartphone mobile-broadband devices, which include netbooks, dongles, etc.

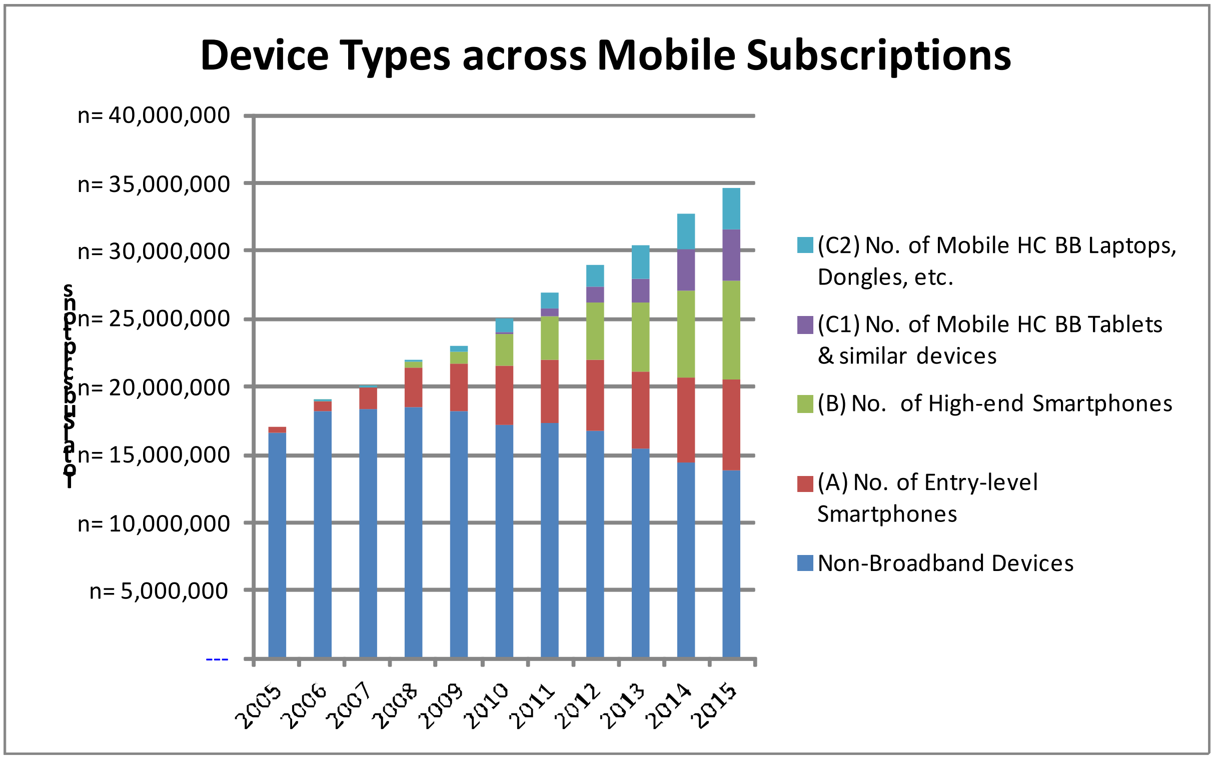

Figure 6.1.4 — Distribution of device types (*Source: Red Mobile Analysis and Projections*)

In determining the projections for data traffic, Red Mobile analyzed the growth in usage of each type of application, taking into account evolution towards convergence of multiple services in a given application; the evolving mix of the types of devices; and the average consumption of data per device type. In addition, the inherent improvement in capability within a device class was also considered. That is to say that, 2015's entry-level smartphones will likely perform at the levels close to those of 2010's high-end smartphones. Likewise, the high-end smartphones will continue to grow in capability with dual-core processing power. Also noted in the figure is that 2015's feature phones will be far more sophisticated than those of today and may, in fact, see the data usage that entry-level smartphones had experienced in 2010.

Four main sources of traffic were treated separately:

Voice: While voice usage has been declining slightly over time, incoming and outgoing calls combined were estimated to remain, on average, between 300 and 400 MoU (Minutes of Use) monthly per subscription. For the purpose of the modelling, it was estimated that this would remain flat at 400 MoU per subscriber.

Messaging and IM: Different forms of messaging — including SMS, IM, and MMS — were assessed for traffic. Converged applications, using messaging, social media, and forms of community-based communications, including RIM's BBM and Apple's iMessage services, are all seen as drivers for this medium of communication. The data usage for long messages, such as MMS, was arrived at separately from that of short messages, and the overall impact on traffic was calculated. As a result of the ongoing evolution of this space, messaging traffic has been projected to grow to 1 MB/month per subscription by YE2015.

Video, Web browsing, downloading, emails, content sharing: There has been rapid growth in the popularity of high-end smartphones and connected devices, including cost-effective tablets and netbooks. This has been a major catalyst in the uptake of data services in Canada. Extensive cellular operator investments in networks to support 3.5G (HSPA/HSPA+) and the recent start of 4G (LTE) deployments means that the majority of Canadians have access to networks that support broadband mobile communications, which, when combined with the high-end devices, have fuelled the insatiable appetite for data. As a result of the significantly lower cost to deliver data over 3.5G+ networks versus their predecessors, and growing competition in the market, consumers now enjoy lower data tariffs than in the past.

All of these factors have resulted in Canada experiencing one of the fastest rates of data growth in the developed world. Our projections show a growth rate of 140% year over year (YoY) at YE2011.

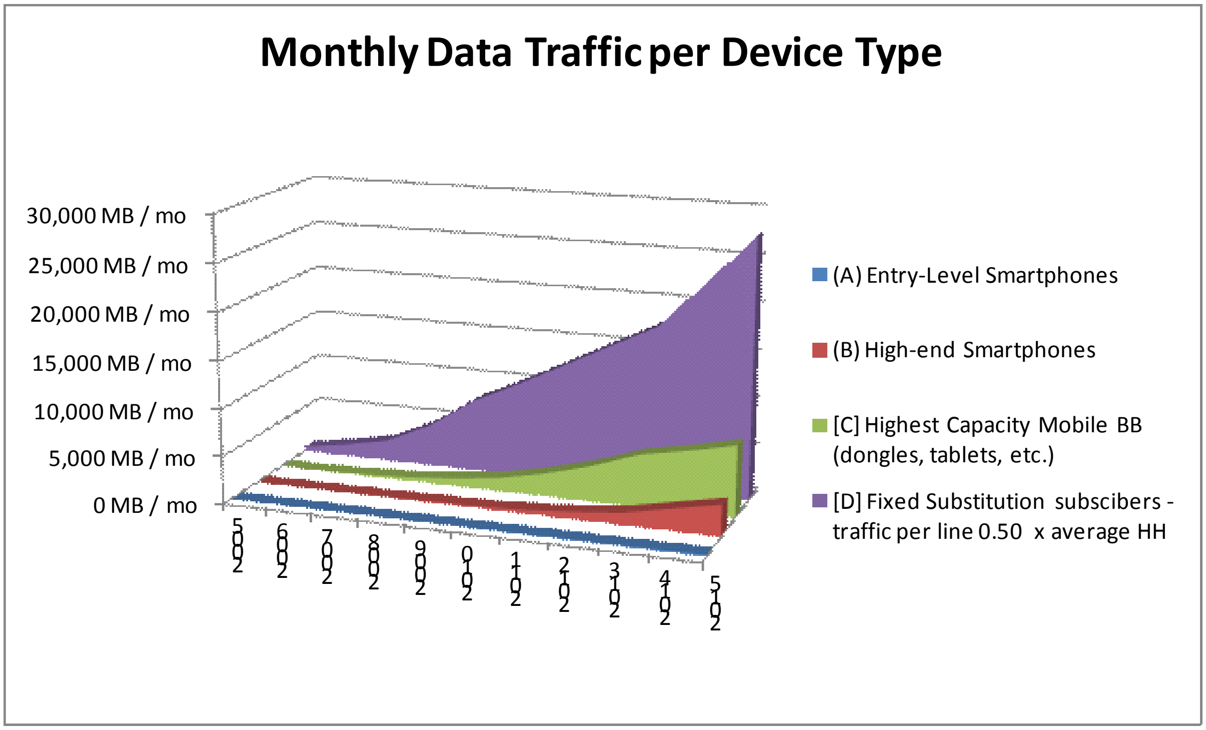

Figure 6.1.5 — Average monthly traffic generated by each device type (*Source: Red Mobile Analysis and Projections*)

Fixed Mobile Substitution (FMS) for broadband: In some cases, subscribers may use cellular for access to broadband Internet services. While broadband data usage via FMS represents a very small percentage of overall subscriptions, the usage per subscription is very high.

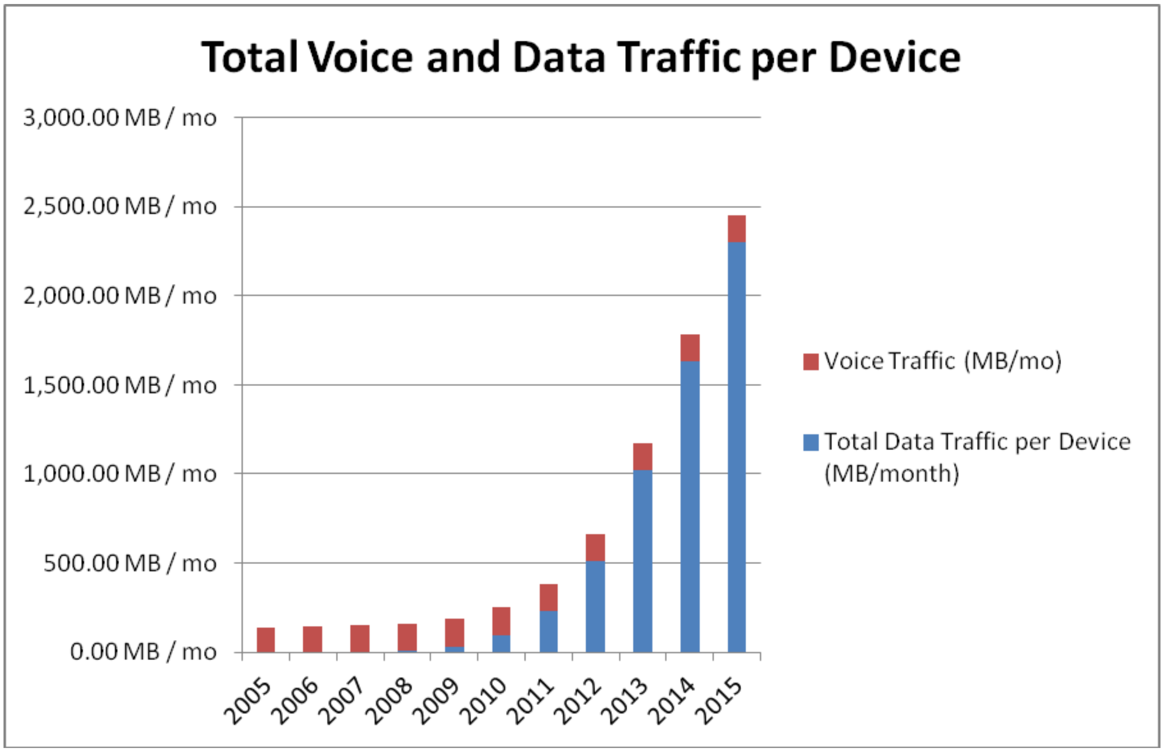

Figure 6.1.6 — Total monthly traffic per device (*Source: Red Mobile Analysis and Projections*)

In historical terms, the projections shown in Figure 6.1.6 represent a relatively strong growth scenario over the next five years, with an approximate doubling of data traffic per year, as Canada's cellular traffic grows to take advantage of improving technologies, devices and tariffs.

The total data traffic by 2015 is 30 times the 2010 level, as can be noted in Figure 6.1.7, below.

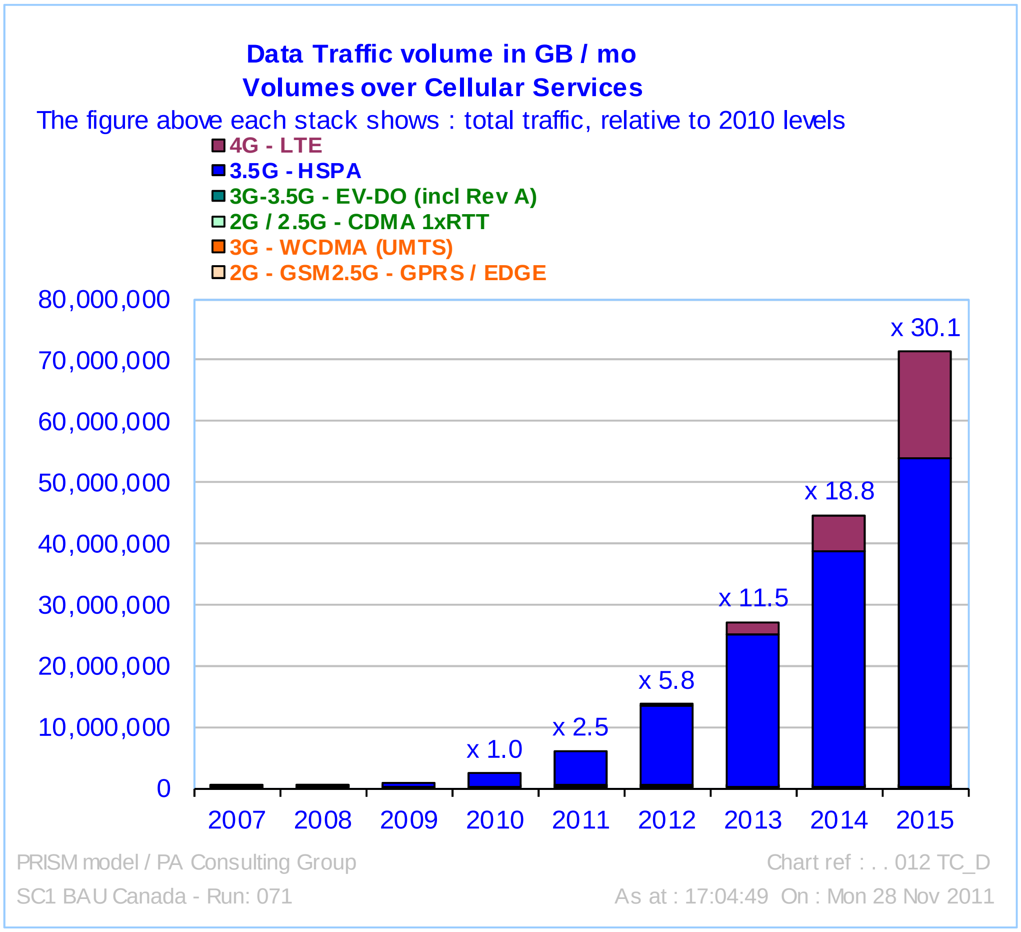

Figure 6.1.7 — Total monthly traffic growth for data, only (*Source: Red Mobile Analysis and Projections*)

It can be noted that Canadian operators have invested heavily in evolving their networks to embrace the latest technologies. In addition, Canadian consumers were quick to adopt newer smartphones and broadband devices using the latest HSPA networks. In fact, the Canadian smartphone uptake has been one of the highest in the world. Figure 6.1.8, below, shows the total traffic across all services (voice and data).

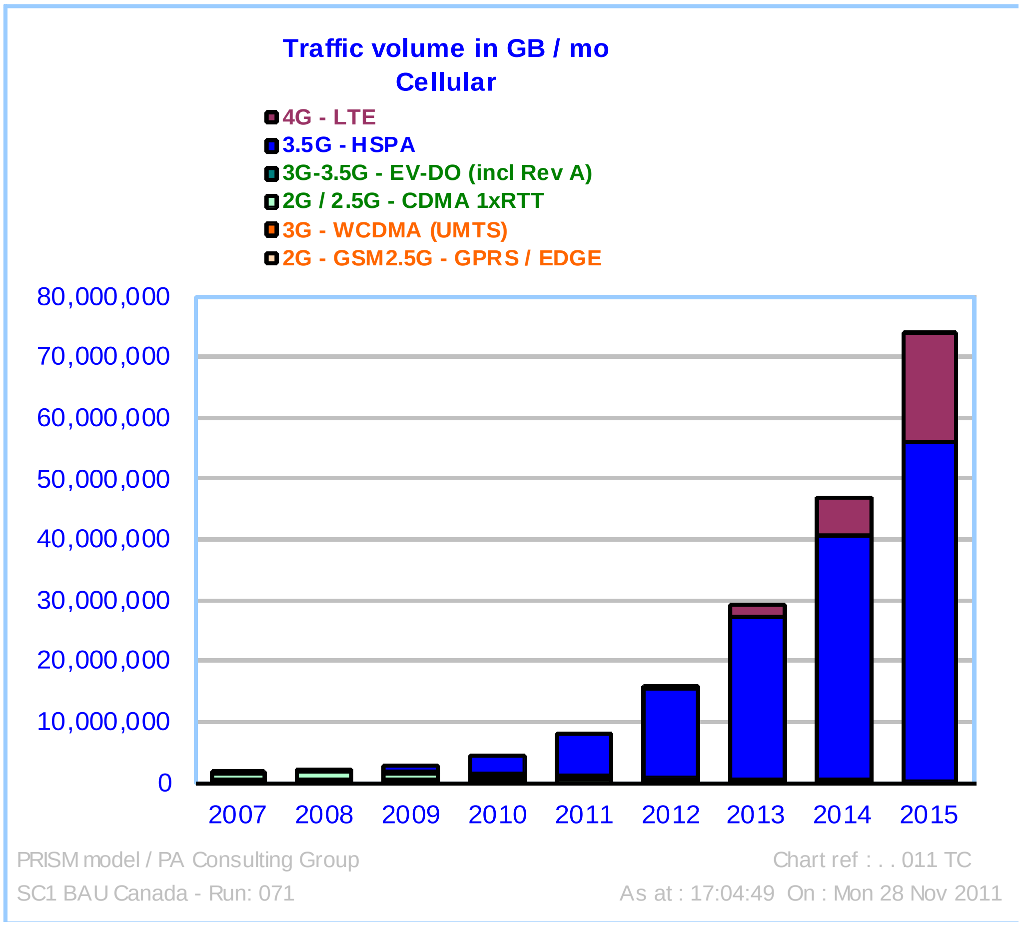

Figure 6.1.8 — Cellular traffic: Total traffic, all applications (GB/mo equivalent) (*Source: Red Mobile Analysis and Projections)*

As can be noted in Figure 6.1.9, the majority of the traffic (most of which is data traffic) is carried over HSPA networks today, and this trend is expected to continue to extend to LTE.

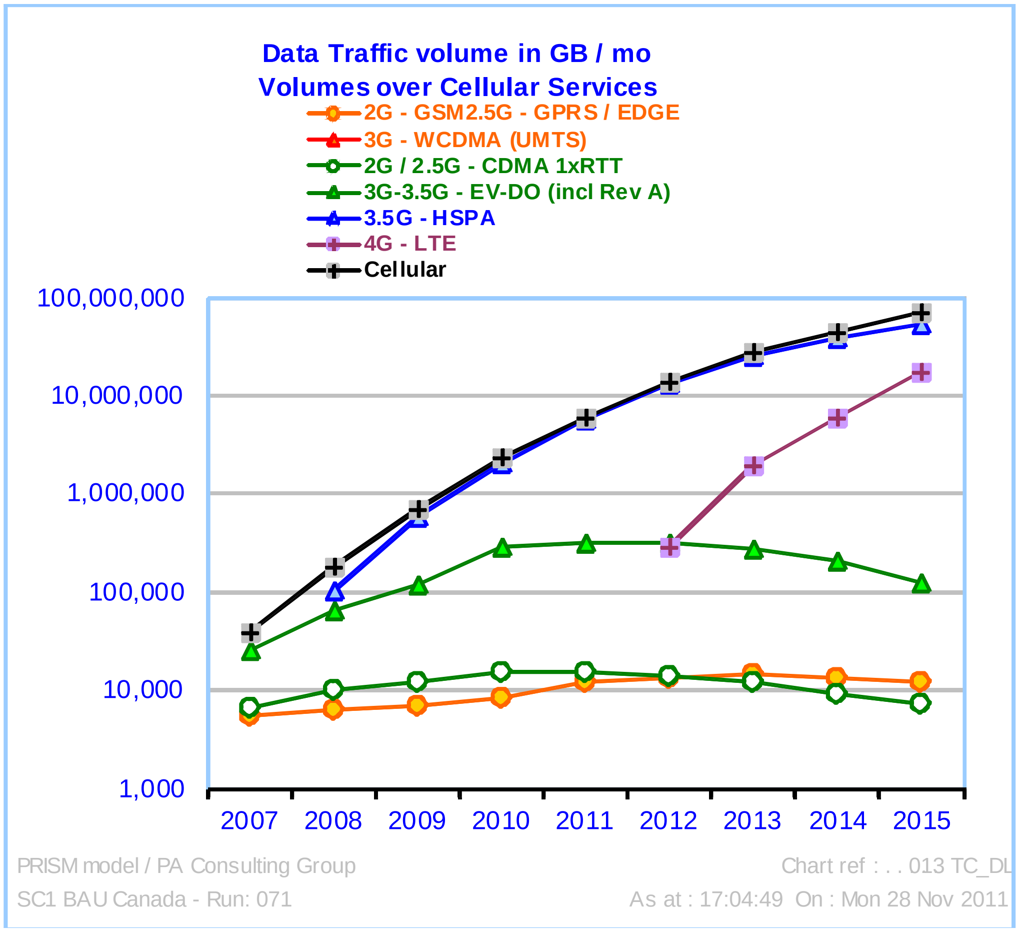

Figure 6.1.9 – Distribution of traffic across network technologies *(note: in log scale)*
(*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling)*

Notes and Other Assumptions Regarding Traffic Projections

1. Each year, approximately one-third of the subscriber base (existing subscribers and new addition) acquires new devices.

2. Voice MoU (Minutes of Use – monthly per subscriber) will stay broadly constant over the next five years at 400 MoU.

3. Smartphone projections: based on survey and validated by Q series paper for Canada and U.S. in 2014 - 5 yr = CAGR of 18.6%. Estimates indicate a 16% CAGR over six years, which seems well aligned with the Study's estimates.

4. Based on input from stakeholders, uptake of HSPA devices has been significantly more than initially expected. Also, a significantly larger percentage of data traffic is carried over the HSPA networks than initially anticipated.

5. Smartphone-to-other-mobile-device breakdown: According to CWTA[10], mobile broadband subscriptions in Canada comprised 5.68 M as of June 2010, which represents 24% of total wireless subscriptions. Of the total mobile broadband subscribers, 86% were subscribers with a smartphone voice/data plan, and 14% were subscribers of data plans exclusively with a mobile Internet stick.

6. Smartphone data usage: Based on secondary sources and various papers, six-year projections (2010-2015) of smartphone data usage show an average CAGR of approximately 47%. Red Mobile's projections were conducted separately for entry level versus high-end smartphones and indicate a six-year (2010-2015) CAGR for data usage of 34% for entry-level smartphones and a 75% CAGR for high-end smartphones. These align with an average CAGR of 47% across all types of smartphones.

As a sense-check of these growth rates, a brief comparison was conducted of the Study's forecasts for growth of cellular traffic against those published by other parties in the industry, including Cisco (VNI), the GSMA, FCC, stakeholder input and submissions made to Industry Canada for the 700 MHz Consultation. From this review, it can be concluded that, while, the growth rate used here could be viewed as being on the high side, there are good arguments for assuming a high rate of traffic growth over the period through to 2015, and the projections are greatly out of line with those used in other sets of forecasts[11].

Key Assumptions and Relationship between Service and Spectrum Demand

In this section, the main assumptions used in analyzing how subscribers and traffic changes translate into changes in the demand for cellular spectrum are summarized below.

- **Spectral Efficiency of Cellular Technologies**. There are major gains in spectral efficiency as networks move from older technologies, such as GSM, to newer ones, such as HSPA and LTE. There are also some gains over time as technologies make incremental improvements in their spectral efficiency of the deployed networks.

The table below shows the assumptions made regarding the spectral efficiency and frequency reuse of the various technologies over the time period of the Study. The spectral efficiencies are per sector.

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10 CWTA, Facts and Figures: http://www.cwta.ca/CWTASite/english/industryfacts.html

11 Three examples: (1) Cisco: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf - a 93% CAGR for global mobile data 2010-15, with some suggestion that this will be higher in emerging markets than in North America
(2) UMTS forum: Trade association view, May 2011, reported here: http://www.totaltele.com/view.aspx?ID=464665&mail=513 and http://www.3gamericas.org/index.cfm?fuseaction=pressreleasedisplay&pressreleaseid=3156&printfriendly=1 33x growth in total traffic 2010–2020, which is equivalent to a 40%-45% per-annum compound growth rate.
(3) Projections that the University of Surrey developed for PA Consulting for a similar UK study for Ofcom in 2008-09 [average growth rates for data, 2008-2025: varying from 30% to 80% pa compounded across the six scenarios studied.]

Table 6.1.2 — Spectral efficiency and frequency reuse of the various technologies over the time period (*Source: PA Consulting Group*)

Technology	Frequency Reuse Factor	Combined effect of (i) Frequency Reuse and (ii) Link Spectral Efficiency in Bits / Sec / Hz								
		2007	2008	2009	2010	2011	2012	2013	2014	2015
2G - GSM	9	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2.5G - GPRS / EDGE	9	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
3G - WCDMA (UMTS)	1	0.17	0.17	0.17	0.3	0.42	0.55	0.67	0.8	0.92
3.5G - HSPA	1	0.5	0.5	0.58	0.68	0.76	0.82	0.86	0.93	1.01
4G - LTE	1	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.35	1.4
2G - CDMA	1	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
2.5G - CDMA 1xRTT	1	0.29	0.29	0.31	0.34	0.36	0.37	0.38	0.4	0.41
3G-3.5G - EV-DO (incl. Rev. A)	1	0.5	0.5	0.58	0.68	0.76	0.82	0.86	0.93	1.01

- **Numbers of sites and growth.** Site and sector counts assumptions have been obtained by comparing a wide range of data sources, including online sources (Industry Canada's TAFL data, the Loxcell and Ertyu Web sites), as well as highly confidential discussions with the operators themselves. By the end of 2010, it is assumed that, in general, the operators were approximately midway through their rollout of HSPA networks. For the projections, the Study assumes that this rollout will be completed in all areas of medium and high demand by 2015. And that the headline site counts of each operator will continue to grow at 5%-10% per annum, as has occurred over the last 5-10 years, and that LTE achieves a level of rollout similar to that of HSPA in 2010 cell/sector counts are not disclosed, as doing so by technology would identify confidential operator information.
- **Offload of traffic to Wi-Fi.** Much recent interest has been shown in offloading cellular traffic to Wi-Fi, with some operators internationally reporting 20% to 40% of the traffic in certain areas being offloaded. It can be assumed that, by 2015, approximately 8% of the projected cellular data traffic is offloaded by the operators (not offloaded directly by the users) to Wi-Fi and other short-range wireless technologies. This does not include any "offload instigated by the end user." For example, if a subscriber has a 1GB cap on their mobile data allowance, and they are close to that cap, they may elect to instead use the same device to generate traffic over Wi-Fi and other short-range technologies. This is counted as end-user demand for the Wi-Fi service, but it is not counted toward the projections of traffic or subscribers for cellular services.
- **Dimensioning of Networks, and, hence, the required capacity and spectrum, for the busy hour.** It is assumed that spectrum is required to be able to carry the traffic offered in the busy hour, and that this traffic is 3.5 times that of the average hour (24x365).
- **Dimensioning of networks and spectrum requirements to provide the required quality of service.** Simply dimensioning the spectrum for the busy hour is not sufficient. Additional spectrum is required, in order to handle variation in the traffic, for example:
    - Subscribers and traffic are not evenly spread across sites and sectors.
    - A certain amount of overhead may be required in order to provide high burst rates for individual subscribers when required, e.g. downloading a file or browsing a Web page.

  Therefore, the required capacity of the networks and, hence, the demand for spectrum is scaled-up by a further factor, typically 1.75, to allow for this variation in demand over space and over short-term (i.e. seconds, rather than over the course of a day or week) timescales.

- **Spectrum pairing.** It is assumed that all cellular traffic is carried over paired spectrum across the Study period, rather than assuming that, for example, LTE will be making significant use of unpaired spectrum by 2015 to reduce the spectrum requirements of the networks.
- **Current approximate mix/routing of cellular traffic to technologies.** General evidence available for Canada, alongside that from comparable markets, has been used to calibrate the current routing of cellular traffic to GSM/HSPA/CDMA. It has been assumed that, by mid 2011, the vast majority of data traffic was being routed over HSPA.
- **Downlink/Uplink mix of traffic.** For Cellular data traffic, changes in the ratio of Uplink to Downlink traffic are assumed.
  - For 2010, the assumption is that Downlink traffic is 87% of the total, i.e. a UL:DL ratio of approximately 1:7.
  - For 2015, as user-generated content and file sharing become more prevalent over time, the assumption is that downlink traffic is 80% of the total, i.e. a UL:DL ratio of 1:4.
- **Allocation of cellular demand to neighbourhood types, and allocation of sites and sectors to neighbourhood types.** The modelling includes an assessment of the differences between seven different types of local areas, according to the density of demand and population (daytime and nighttime), and makes some assumptions regarding where the cell sites are relative to where the traffic is. Broadly, the analysis assumes that deployment of sites and sectors follow traffic needs in urban areas and in dense rural areas. Additional sites, often with just one sector each, are deployed in rural areas in order to provide coverage.

The modelling has been informed by the evidence available, regarding the distribution of cellular sites and sectors across Canada, based, in particular, on the central (most dense) areas of major cities, such as the Greater Toronto Area (GTA) and Greater Vancouver Area (GVA).

This evidence confirms that, in Canada, areas where there is a high density of population and cellular traffic, operators install a higher density of sites and sectors to provide additional capacity. This relationship appears to be close to pro-rata across the areas where 95% of Canadians live and work, i.e. downtown areas of major cities, urban areas, including suburbs, and the most densely populated rural areas.

In the lower density rural areas, cell sites are mainly required to provide coverage, rather than capacity, and the demand for spectrum in these areas is somewhat less than it is in the urban areas.

Finally, in the sparse rural areas of the lowest population density, cellular coverage may be patchy, and the level of traffic is lower. Demand for spectrum is reduced still further.

The model uses assumptions that reflect these findings. It makes allowances for orders-of-magnitude differences in population density across the neighbourhood types, and, for urban areas, it uses a distribution of sites and sectors that is largely (but not wholly) driven by population density.

The model also makes allowance for the movement of subscribers between the neighbourhood types during the day and week, which further inflates the demand for spectrum, as downtown cells have heavier loads during the working day, and suburban cell sites have heavier loads in the evenings. The assumption is that this tidal flow scales up the spectrum requirement by a further factor of 1.2.

The foregoing assumptions are broadly consistent with those used for the UK study for Ofcom (looking at the demand for spectrum 2010-25) and with similar studies undertaken for other clients in Europe, Africa and Asia.

Demand for Spectrum

The main impact of the calculations is to convert the growth in traffic and subscribers into the growth in demand for spectrum as follows:

- Over the period between 2010 and 2015, there is a 30-fold growth in data traffic per device.
- The continuing shift of traffic from GSM and CDMA to HSPA and LTE gives a large improvement in spectral efficiency. GSM and CDMA require 3-16 MHz/Mbps/sector; whereas HSPA and LTE require only require 0.7-1.0 MHz/Mbps/sector.
- Some other factors have a modest mitigating effect on the demand for spectrum; for example, increases in number of sites and sectors, and some offload of traffic to Wi-Fi, and a slight reduction in the ratio of downlink-to-uplink data traffic.

The chart below shows the growth in the demand for spectrum[12] for cellular, over the 2007-15 period.

The substantial growth in traffic that is forecast for the period of 2010-15 translates into considerable growth in the demand for spectrum — from 55 MHz in 2010, to 190 MHz in 2015.

[12] For a discussion of the approach taken to defining "demand for spectrum", and for the primary definition of it as used throughout this Report (i.e. MHz required to serve the Offered Traffic) for all High-Value Services, the reader is referred to the Section 3, and, in particular, to the final pages where the topic is discussed and the definition used is set out in detail.

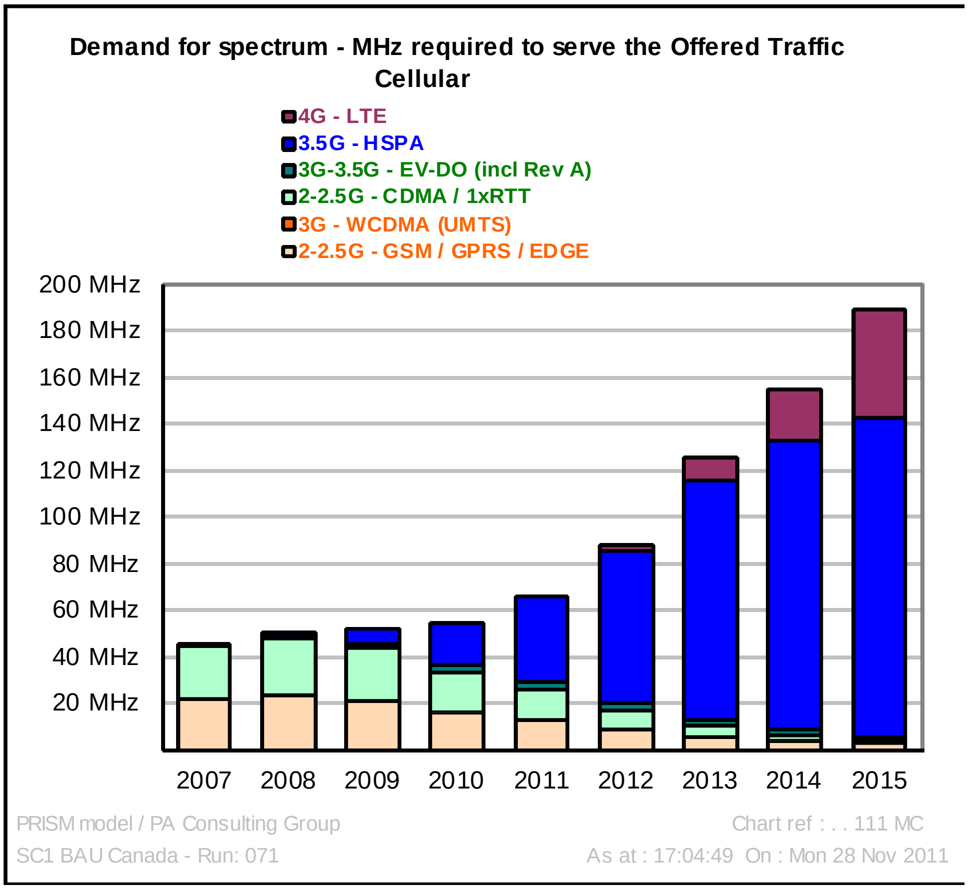

Figure 6.1.10 — Cellular demand for spectrum, by technology (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

The demand for spectrum to carry cellular traffic over the period of 2010-15 is projected to be quite volatile as networks and customer devices migrate from the widely deployed 2G-2.5G technologies to 3.5G (HSPA), and, by 2013-2015, they begin to migrate to 4G (LTE).

The high growth in cellular traffic, with data traffic doubling every 12-15 months, does not simply translate into a pro-rata increase in the demand for spectrum.

A main reason for this occurrence is that the newer technologies offer greater spectral efficiencies than the legacy ones.

The secondary reasons include:

- Rollout of HSPA is completed;
- There are some modest increases in the number of base stations and sectors, in areas of high-spectrum demand. Micro-, femto- and picocell deployments pick up momentum.
- There is some offload of cellular device traffic to Wi-Fi hot spots/short-range wireless.

This result — i.e. a significant growth in data traffic, that causes some growth in spectrum demand, albeit slower than the growth in data traffic — warrants some consideration of the true drivers at work.

One important part of the picture is that, over the last five years, network operators have invested in the capability to handle this growth. Taken together with a migration to LTE, and some continuing trends, such as offload to Wi-Fi, and a reasonable growth in the number of sites, the networks have invested to ensure that they are well placed to serve the growing demands placed on them by end users.

Assessment of Alternative Scenarios

The projections given above are for Scenario 1 (*Business as Usual* (BAU)), which constitutes the central scenario considered for the Study. However, two other scenarios have also been modelled to give an indication of some of the possible alternatives:

- Scenario 2 – *Wire-Free World* (WFW)
- Scenario 3 – *Low Investment* (LI)

The two figures below compare the three scenarios. The first chart shows the assumptions regarding traffic growth, and the second chart shows the projections for spectrum demand.

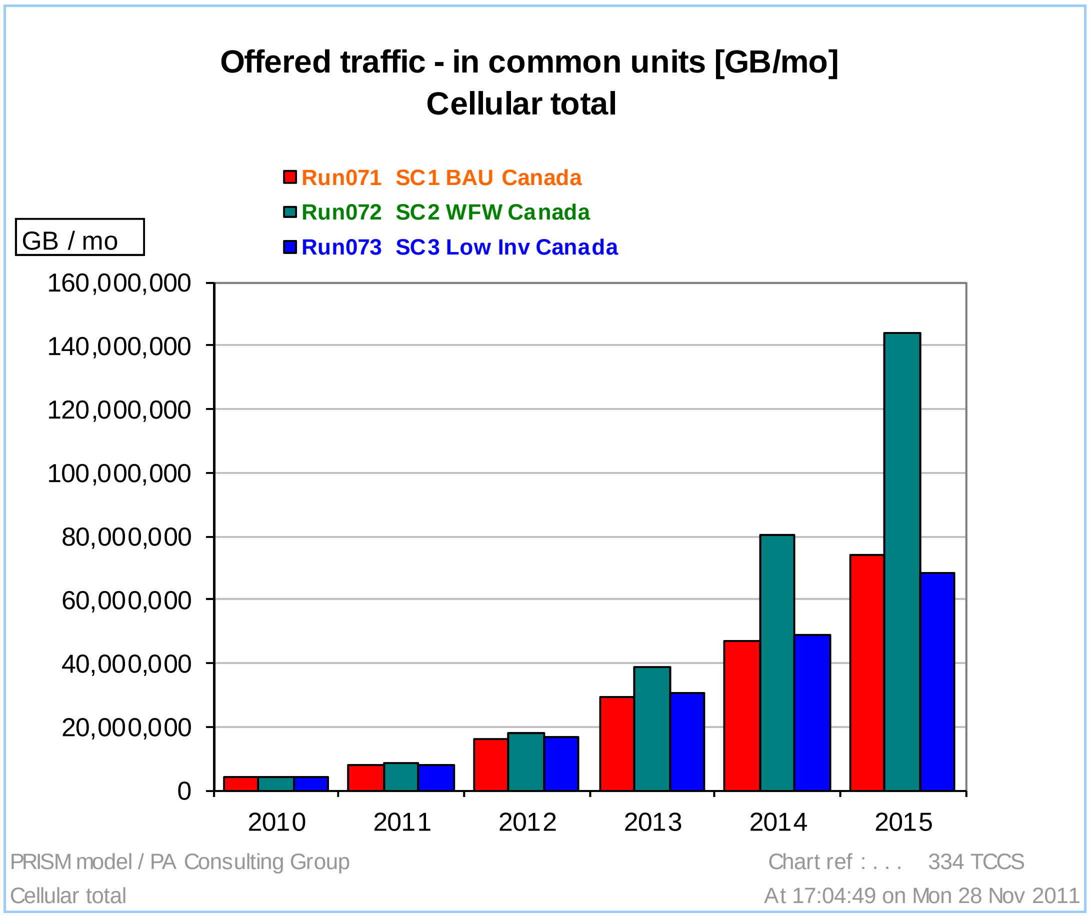

Figure 6.1.11 — Cellular demand (traffic), by Scenario (*Source: based on Red Mobile and PA Analysis and PA PRISM Modelling*)

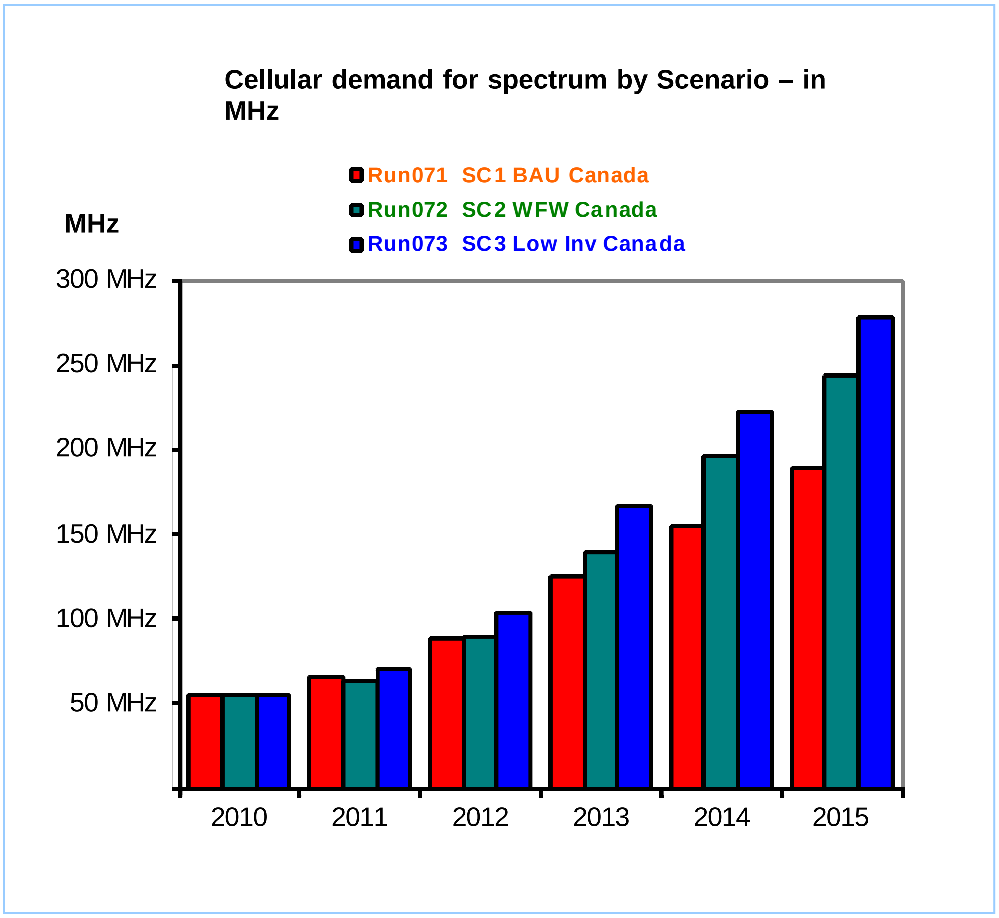

Figure 6.1.12 — Cellular demand for spectrum, by Scenario (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

In Scenario 2, *Wire-Free World*, traffic in 2015 is projected to be roughly twice what it is in Scenario 1.

This translates into a further growth in spectrum demand, some 25% to 30% higher than in Scenario 1.

The effect of the traffic growth is partly offset by faster technology enhancements: greater improvements in spectral efficiency, replacement of devices, increased offloading to Wi-Fi, and further growth in base stations and sectors.

Scenario 3, *Low Investment*, uses the same set of traffic projections as in Scenario 1, but with somewhat lower levels of investment in new networks and devices.

This translates into much higher spectrum demand, with a figure for spectrum demand in 2015 that is slightly higher than that in Scenario 2 and some 50% higher than the figure from Scenario 1.

The cumulative effects of the lower degree of investment are significant even over the 2010-2015 period. The main components that impact demand are:

- Slower rollout of LTE;
- Slower growth in the number of base stations and sectors;

- Slower churning of consumer devices and technologies.

Sensitivity Analysis: Assessing Spectrum Demand Using Alternative Metrics

Throughout this Report, the primary analysis of the projections for spectrum demand uses a "Traffic" view of the demand for spectrum. In other words, it focuses on what spectrum is required, in order to carry the offered traffic over the existing (or likely future) network. It considers:

- What spectrum is required to serve the Offered Traffic;
- Dimensioning for the Busy Hour (BH), with a typical Quality of Service (QoS);
- A location of high-spectrum demand (highest of six or seven neighbourhood types, including city downtown, dense urban, suburban, dense rural, sparse rural) rather than a simple average across the country.

For cellular, two additional views of the demand for spectrum were analyzed, from the perspective of practical demand based on network operations, rather than just being based on user demand:

The two alternative definitions of "demand for spectrum" that are used in this Report are:

- **Allowance for channels**: Demand for spectrum after allowing for minimum channel widths for each network operator in each band. This is calculated using appropriate detailed assumptions, regarding the minimum channel width for each technology, and the number of operators using each technology in each band in the same local area. Assumptions regarding minimum channel widths take into account, where appropriate, the needs for larger channels if advances in spectral efficiency are to be achieved.

- **Allowance for other practical issues / timing rules:** This same demand, after allowing further headroom for some of the practical issues of network management, on the grounds that operators cannot precisely predict the timing of changes in demand, and associated shifts. Operators need sufficient spectrum to cope with fluctuations in market share or changes in demand occurring faster or slower than expected. The analysis allows a timing margin of +/- two years for the demand of spectrum for each individual technology.

These alternative views of the demand for spectrum are shown in the following two charts.

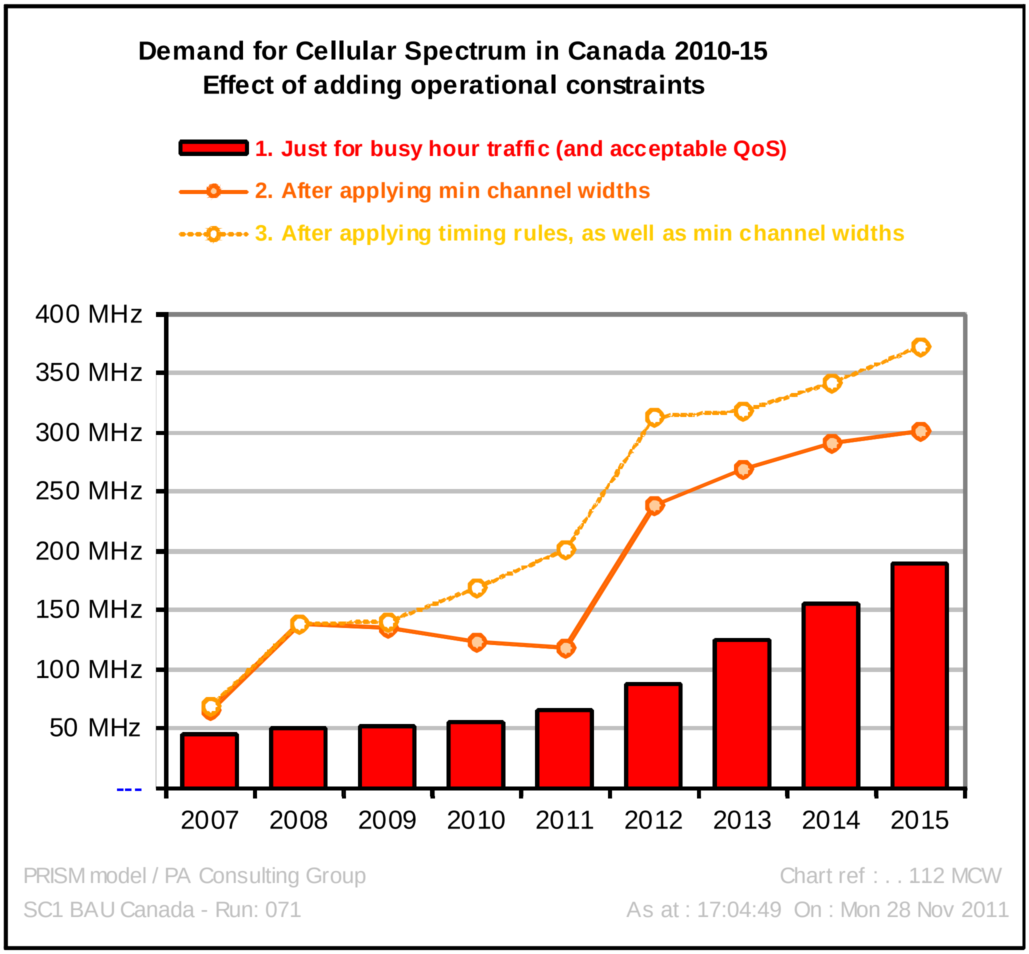

Figure 6.1.13 — Cellular demand for spectrum: Alternative metrics for "Demand" (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

The solid bars represent the primary (traffic-oriented) projections of demand, as shown previously, allowing for busy-hour traffic and for an acceptable Quality of Service.

The lines show the two alternate measures of demand: the solid line shows the demand after allowing for minimum channel widths, and the dotted line shows the demand after making an allowance for "timing rules". The alternate measures reflect a higher need for spectrum to allow for these parameters.

The driver of the large increase in 2012 is the additional deployment of LTE, with sufficient channel widths to get proper benefit from the gains in spectral efficiency that it offers.

The subsequent changes over the period 2013-15 are due to a mix of falls in the spectrum, required for older technologies, and rises in the demand for spectrum for HSPA-enabled devices use newer technologies as traffic shifts away from GSM/CDMA. There is little or no corresponding growth in the demand for spectrum for LTE, because most of, or all the, traffic can still be carried by a single 2x 10 MHz channel per operator.

The next two charts show how the demand with operational constraints looks in each of the other two scenarios.

Both scenarios have higher future projections for the primary measure of demand or spectrum.

In each scenario, the extra demand for spectrum translates additively, not multiplicatively, into higher figures for the alternative measures of spectrum demand.

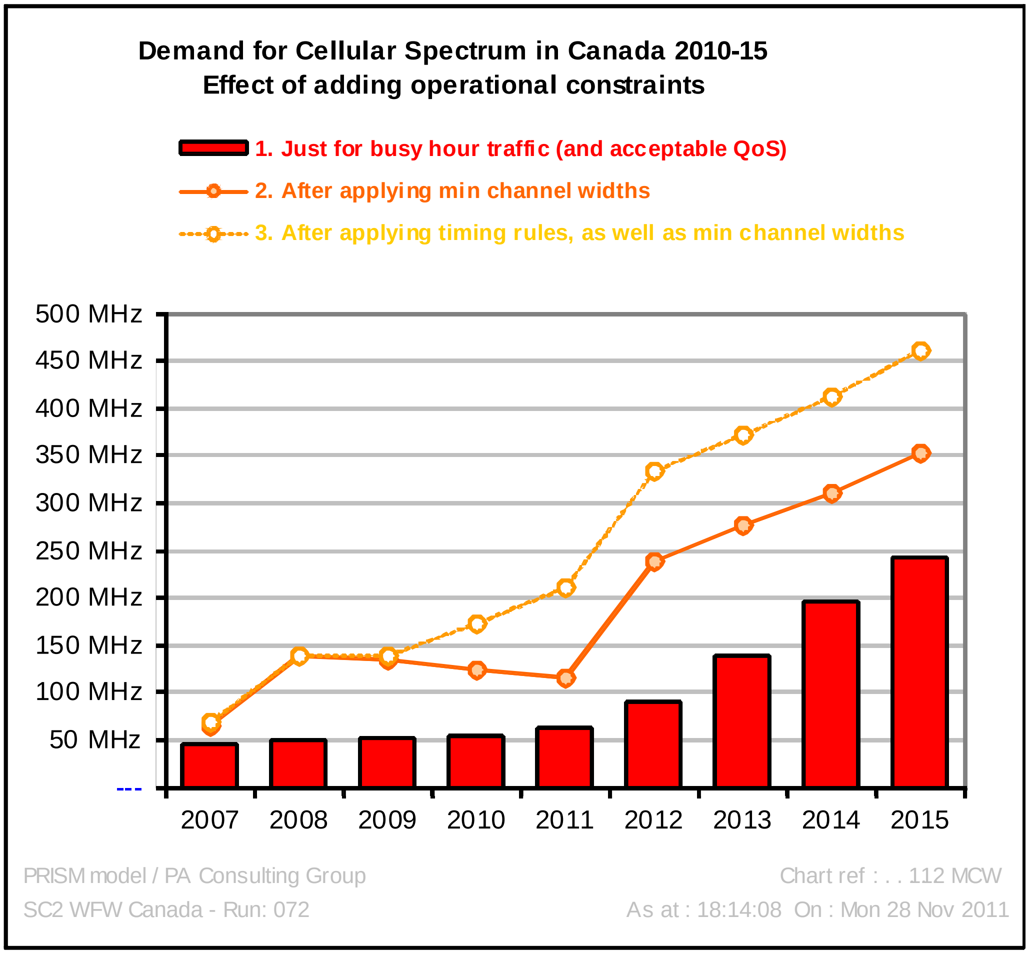

Figure 6.1.14 — Cellular demand for spectrum: Alternative metrics for "Demand": Scenario 2 (*Wire-Free World*) (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

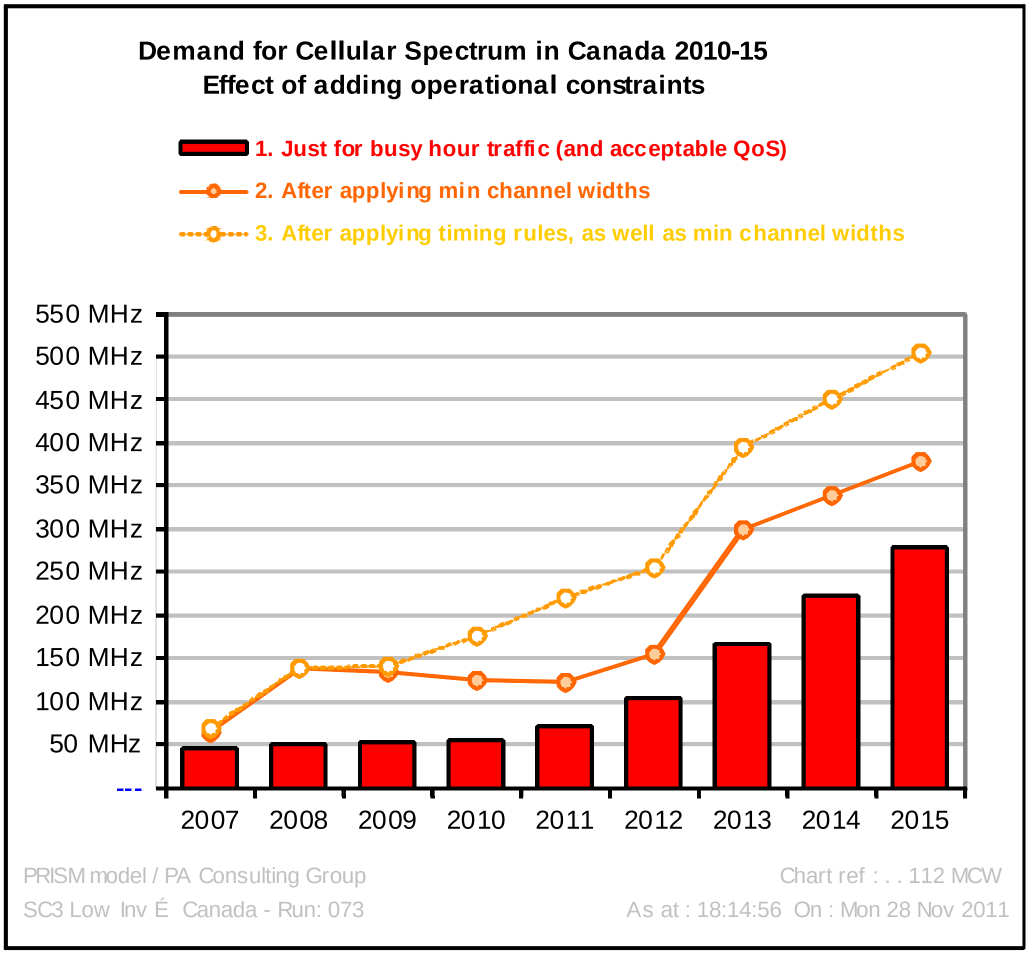

Figure 6.1.15 — Cellular demand for spectrum: Alternative metrics for "Demand": Scenario 3 (*Low Investment*) (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

6.1.5 Considerations beyond 2015

Although the time period beyond 2015 is outside the scope of this Study and demand has not been modelled, some commentary and insight is possible from extrapolating the trends for 2010-15, and considering whether the reasons for the observed growth in the demand for spectrum are likely to remain in force.

Considering the four factors that have increased the efficiency of cellular networks, namely:

- Gain in spectral efficiency from newer technology;
- Operators completing the rollout of networks based on newer technology;
- Increases in the numbers of base stations/sectors;
- Offload of some traffic to fixed Wi-Fi/short-range wireless.

It seems likely that most of these forces will continue beyond 2015; the first of these will be weaker, the others about the same or slightly stronger than they were in 2010-15. It, therefore, seems plausible that, over the time periods of 2015-2020 and 2015-2025, a considerable part of the demand growth in those time frames will translate into continued growth in the demand for cellular spectrum, as there appears to be less scope for improvements in cellular spectral efficiency moving forward, as systems are more constrained by the Shannon Limit.

It is certainly possible to construct a scenario where the demand for spectrum does not continue to grow rapidly beyond 2015 — for example, if cellular traffic growth slows down to merely doubling every two or three years, and/or if the cost of adding new base stations in congested neighbourhoods declines substantially, and/or if offload to Wi-Fi becomes routine for stationary or nomadic users, so there is less pressure for operators to exploit each site to the maximum.

However, these outcomes seem far from certain, and it seems possible that demand for spectrum beyond 2015 will continue to grow, fuelled by traffic growth, and will be only partly offset by the four factors that are improving spectral efficiency of the cellular networks.

6.1.6 Conclusion

The Study has modelled three spectrum demand scenarios: *Business as Usual*, *Wire-Free World* and *Low Investment*, as shown in Figures 6.1.13, 6.1.14 and 6.1.15. The projections for the main traffic-oriented measure of spectrum demand climb from a current level of 50-60 MHz, reaching 190 MHz by 2015, or approximately 250 MHz in the alternative scenarios.

The analysis has also quantified the additional spectrum overhead required to handle minimum channel widths, and also to allow for the challenge of forecasting exactly when and how quickly demand will grow and shift to new technologies.

This typically adds a requirement for a further 100-150 MHz of spectrum to the current demand, increasing by 150-200 MHz once LTE is launched in the 2012-2013 timeframe.

This additional spectrum overhead is an additive factor (e.g. +150 MHz) rather than a multiplicative factor (e.g. x2). It is not particularly sensitive to the traffic projections; instead, it is driven by the degree of proliferation of bands, technologies and licencees.

The Study projects that by 2015 Canada will need a total of 300 MHz to 500 MHz of cellular spectrum, including the overhead for channel widths and variance in the timing of growth in traffic and migration to new technologies to accommodate the service demand. The exact figure depends on

- which scenario unfolds;
- how much provision is made for new entrants and for infrastructure competition;
- and, of course, depending on the many other factors covered by the modelling and the assumptions, such as the rollout of additional sites and sectors and the degree to which operators make efficient use of their spectrum resources.

In reality, there is likely to be somewhat of a balancing feedback loop in the demand for spectrum;

- Large amounts of underutilized cellular spectrum tend to lead to operators adding fewer sites and sectors, and/or pricing to attract customers.
- Highly utilized spectrum tends to lead to operators adding more micro and picosites and sectors to maximize frequency reuse, more offloading of traffic, less liberal “fair use” policies, and pricing to discourage very heavy use of the networks.

So, there are good grounds to expect something analogous to Parkinson's Law[13]: i.e. that spectrum demand will expand — or contract — to fill what is available. And, this is likely to somewhat reduce any imbalance between supply and demand for spectrum, which is, in turn, likely to trade these off against other cost and benefits, such as changes to fair use limits or to data tariffs.

6.2 Fixed Wireless Access

6.2.1 Overview

Canada is one of the leading countries in Internet usage, access to broadband[14] and broadband penetration (subscriptions)[15]. An increasing number of Canadians are demanding greater access to content, including rich multimedia, audio, video and data.

In 2009, residential subscribers obtained their broadband services as follows: 54% cable modem, 39% DSL, 5% dial-up and the remaining 3% fixed wireless, satellites and other technologies[16]. Fixed wireless broadband represents a small percentage of the total broadband Internet access for the residential market.

Cost-effective technology is available for bands below 6 GHz to provide wireless broadband services. LTE is also likely to be available in instances where FWA spectrum is converted so it can be used as cellular spectrum, i.e. in the BRS band 2500-2690 MHz.

Enterprises represent 25% of the broadband Internet revenues and are served by cable modem, DSL, fibre optics, satellites and fixed wireless facilities. Broadband wireless access provides a number of conveniences not available with traditional wireline cable modem and DSL. This includes full portability to various locations within the serving areas.

Technology progress in the broadband spectrum above 20 GHz bands will enable more feasible deployments of broadband wireless facilities in those bands, and may be an alternative to cable modem and DSL facilities for enterprises and potentially for household Internet access.

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13 Parkinson's Law is most often formulated as: *"work expands to fill the time available*".

14 According to the CRTC report, in 2009, fixed broadband was available to more than 96% of households and mobile broadband (i.e., 3G or equivalent) was also available to more than 96% of households. The broadband access technologies available to a percentage of Canadian households were 85% for DSL, 80% for cable modem and 82% for fixed wireless.

15 In 2009, 62% of the Canadian households subscribed to broadband Internet services of speeds greater than 1.5 Mbps and higher, and 44% subscribed to speeds of 5 mbps and greater. Subscription to all speeds was 75% and to high speed and more was 72%. The availability of broadband to residential is 95% national, 100% in urban and 82% in rural. The average download per month per user is 12 GB and upload is 3.4 GB. Another segment of the broadband service is business customers.

16 Worth mentioning is that 99% of Canadian population had 3G mobile service available in 2009 versus slightly less in the U.S. However, the subscription to broadband services was about 9% versus about 33 % in the U.S.

6.2.2 Spectrum Inventory and Spectrum Utilization

The fixed broadband access spectrum consists of:

Below 6 GHz – Point-to-multipoint (PTM) technologies:
- 30 MHz of WCS spectrum in bands 2305-2320 MHz and 2345-2360 MHz auctioned in 2004/2005;
- 175 MHz of FWA spectrum in the 3475-3650 MHz range auctioned in 2004-2005 (three paired 25 + 25 MHz blocks and one block of 25 MHz);
- As of 2005, more than a 100 MHz of MCS and MDS spectrum has been used to developed fixed broadband wireless access in the 2500-2690 MHz range; the band 2500-2690 MHz BRS is being rearranged for mobile use, with allowance for fixed broadband use in part of the spectrum. The BRS spectrum is expected to be auctioned by the end of 2012;

Above 20 GHz – Point-to-point (PTP) technologies:

- 400 MHz of BWA spectrum at 24 GHz, 1000 MHz of LMCS spectrum at 28 GHz and 800 MHz at 38 GHz was licenced using a comparative-competitive (beauty contest) process for wireless broadband service[17]. Industry Canada has recently extended some of the licensing and has clawed back other spectrum for licensing on a first-come, first-served basis.
- Another 1000 MHz of spectrum is available for point-to-point and point-to-multipoint use in the 26 GHz range. As well, the 31 GHz band has yet to be released for future broadband wireless.

These two groups of technologies and services are quite distinct: They serve different markets, their network architectures are different, and the methods of estimating their demand for spectrum are quite distinct.

FWA Services – the differences between Point-to-multipoint and Point-to-point

1. **Point to multipoint:** Frequencies below 6 GHz

   - Rural areas of medium-low-population density;
   - Broadband for Residential and SoHo market;
   - Diverse technologies: Fixed WiMAX, FWA over Cellular technologies and Licence-exempt.

2. **Point to point:** Frequencies above 20 GHz

   - Urban areas – e.g. fringes of city downtown;
   - Most customers are Tier 2 enterprises/SMEs;
   - Technology is similar to that used for Microwave Backhaul.

This Study provides separate projections for Service and for Spectrum Demand for these two sets of technologies/markets.

Accordingly, in presenting the results for FWA, this Report considers each of these two groups of technologies (PTM and PTP) and markets separately. PTM is covered in Section 6.2.5, and PTP is covered in Section 6.2.6.

[17] Spectrum Utilization Policy, Decisions on the Band 25.25-28.35 GHz, June 2011: http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/sp25-25.pdf/$FILE/sp25-25.pdf

6.2.3 Stakeholder Input and Research Analysis

Comments from stakeholders

- A fixed wireless network carrier reported that it has more than 100 sites, covering portions of rural areas in three provinces using Motorola Canopy technology in the licence-exempt 900 MHz band.
- Another operator reported plans the use of HSPA+ in the AWS band to offer broadband in rural Quebec, supported by government broadband subsidies.
- Some stakeholders felt that the 3500 MHz band is well-suited for deployment in large urban areas, given the large amount of contiguous spectrum blocks available in Canada. Currently, WiMAX technologies are available for this band, and it is widely expected that LTE technologies will be available at this band as 3GPP defines the standards. The U.S. has recently identified 100 MHz of spectrum that could become available in this band.
- It was reported that, in Canada, two main operators provide 95% of the residential broadband services using wireline, plus, their local Telcos provide most of the wireline business customers.
- According to a stakeholder, the CRTC 2010-43 statistics stating 95% broadband coverage exists in Canada, tend to overlook that: (i) at least 700,000 Canadian households are un-served by broadband access with download speeds of at least 1.5 Mbps (with 1.5 Mbps under-delivering what Canadians increasingly need); (ii) that 1.4 million households lack access to broadband access with download speeds of at least 4 Mbps; and (iii) that all of these households are located exclusively in rural and remote areas.
- Some stakeholders reported that a significant amount of the fixed wireless spectrum that has already been licenced is held by the same companies that dominate the wireline broadband access market.
- It was reported that wireless represents a small percentage of the total broadband Internet access for the residential market. According to this respondent, the demand for wireless access technology has likely peaked, and the demand growth will likely flatten.
- A stakeholder felt that spectrum below 6 GHz has the characteristics to combine fixed and mobile service delivery. Unlicenced spectrum is used initially to meet the rural demand, but the long-term spectrum availability and reliability are not good.
- Some respondents indicated that, while the 24/28 GHz, even the 38 GHz FWA, bands are assigned for point-to-multipoint applications, they have been treated more like PTP bands, and as broadband pipes, to businesses.
- One provincial Telco reported having up to 5% of its broadband customer base using wireless access, mostly in rural areas. Customers located in extremely remote areas are using satellite-based Internet. In the future, the usage of fixed wireless access to provide voice and Internet data services may be a more economical alternative to replacement of longer spans of copper plant in rural areas.
- In total, there are indications from respondents that 6% to 10% of Canada’s population could be served efficiently using fixed broadband wireless for data and voice.
- One FWA carrier, using mostly the 24/28/38 GHz bands, reported providing several-thousand business customers in more than 40 cities with business-grade broadband and voice services. Also, this includes the provision of backhaul facilities to a number of new AWS entrants.
- It was reported that WiMAX is the technology of choice for the 3.5 GHz band. Although WiMAX is also available for the 2.5 GHz band, the LTE technology will eventually dominate.

- A respondent felt that manufacturing cost-effective equipment for the 24 GHz BWA and 28 GHz band poses challenges. The same one felt that it is unlikely to be a business case for deploying FWA systems for residential customers in these bands in the foreseeable future.
- In the opinion of a stakeholder, three main technologies will be deployed for fixed broadband wireless, namely WiMAX, DOCSIS-based wireless and proprietary OFDM equipment. WiMAX will be mostly used for the 3.5 GHz licenced band, as well as in the TDD 3.65 GHz band, which is lightly licenced. DOCSIS-based access technology has been deployed in Canada in the 3.5GHz, 5.8 GHz, 2.5 GHz band, and in the newly available Rural Remote Broadband Service (RRBS) in spectrum available from unused TV channels 2-51. There is a potential market for some amount of proprietary OFDM equipment (or Wi-Fi-based gear) in the 900 MHz unlicenced spectrum.
- A stakeholder stated that the 3.65 GHz shared licenced band (and 5 GHz unlicenced band) is providing broadband data and voice services in rural and some backhaul service to new AWS entrants.
- One respondent reported energizing the 900 MHz licence-exempt band by using Canopy technology, the 2500 MHz band by using DOCSIS (covering more than 7.5 million households, or 63% of the Canadian residential market), as well as the 3500 MHz band also by using DOCSIS. No fixed broadband technology has been deployed in the 2300 MHz band as yet.
- Respondents noted that, in the 2300 MHz WCS and 3500 MHz FWA bands, only a small portion of the licenced spectrum has been fully utilized in Canada. Many licence holders have not deployed their spectrum in any meaningful fashion.
- A stakeholder reported that equipment in the 3.5 GHz band remains limited at present. The Canadian band plan does not align with the rest of the world. The short-range coverage of typical 3.5 GHz FWA stations also imposes high-cell-density costs, making blanket deployment very expensive. However, it will likely be utilized as a dense urban overlay of the urban mobility network, whenever handset technology evolves.
- A provincial carrier plans to continue to use the 2.5 GHz band for FWA services and will replace the existing DOCSIS equipment with another wireless solution, such as LTE, for fixed wireless broadband services to rural customers who are outside the range of DSL service.
- One FWA operator reported point-to-multipoint (PTM) deployment growth of 37% and point-to-point (PTP) deployment growth of 34% over the last five years; and projects an increase of 39% for PTM and 31% for PTP from 2010 to 2015.

6.2.4 Research

Information from Spectrum 20/20 proceedings, May 2011

- According to a presentation made by Barrett, nearly 2.4 million households (HHs) could be defined as rural (less than 30 HHs per sq. km). Barrett suggested that FWA is an economical solution for rural areas with a density of between 6 and 30 HHs per sq. km. (i.e. 11% of 13.7 M HHs, which equates to 1.5 M HHs), and multimedia satellite service is an economical solution for rural areas with less than 6 HHs per sq. km. (i.e. 7% of 13.7M HHs, or 0.9M HHs). The average monthly data usage by rural subscribers was reported as approximately 16 GB.
- Two new multimedia satellites are being launched this year and should provide broadband capacity to serve the Canadian market, especially the very low-density rural areas.
- It was also commented on that Industry Canada's Tier 4 licensing of broadband mobile spectrum is not adequate to advance broadband services in rural Canada. For example, the Tier 4 area, which includes Calgary, has an area of 19,188 sq. km. and has 1 M people (est. 41,5000 HHs). 92% of the population resides in Calgary, and 8% of the population is in rural areas[18]. In order to gain access to the 700 MHz and 2500 MHz for rural broadband, or the 8 % of the population, with Tier 4, one has to pay for 92% of the urban population. (Note: The Tier 4 should be modified to

[18] IC Tier 4 for Calgary: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf05871.html

reflect rural areas to encourage broadband services. For the Calgary Tier 4, separating the rural areas would represent about 18,000 sq. km. and 80,000 people, or 33,200 HHs.)

CRTC Information published in 2010

In the 2009 CRTC Annual Report[18], it was indicated that more than 93% of the broadband subscribers were being served by wireline facilities, such as cable modem and DSL.

The average broadband usage per subscribers was reported at 15.4 GB per month (12.0 GB downstream and 3.4 GB upstream).

100% of the urban households have access to broadband wireline-based facilities. In contrast, just 82% of rural households had access to broadband facilities. The remaining 18% in the latter group is the most natural market for FWA broadband services.

CRTC Information published March 2011[19]

- On average, Canadians spent 43.5 hours/month on the Web, almost twice of worldwide average of 23.1 hours.
- Of 11 countries surveyed, Canada ranks first in the number of Web site visits per user per month at 95.2.
- The CRTC estimates that 95% of Canadian household can access broadband services using a landline.
- Satellites extend to virtually all households but have limited capacity.
- The report to the Standing Committee of Industry, Science and Technology on Feb 3, 2011, indicated that:
    - The average usage per month per subscription (residences and businesses) was 15.4 GB/month in 2009.
    - 14% of all subscriptions (9.17 M) account for 83% of the Internet traffic. This means that:
        - 14% (1.3M) of subscriptions average 91 GB per month,
        - The remaining 86% of the subscriptions (7.9 M) average 3 GB per month.

19 Canadians' Internet usage nearly double the worldwide average, The Globe And Mail, March 08, 2011: http://www.theglobeandmail.com/news/technology/tech-news/canadians-internet-usage-nearly-double-the-worldwide-average/article1934508/

Table 6.2.1 — Information derived from tables on Internet and broadband availability[20] **(*Source: CRTC CMR and Red Mobile Research*)**

	2008	2009	Growth	Comments
Revenues [$ Billions] **> Residential** **> Business** **> Wholesale** **> Other**	$6.2B $3.9B $1.1B $0.2B $1.0B	$6.6B $4.3B $1.1B $0.3B $1.0B	6.3% 9.9% 1.2% 21.5% -5.5%	>Good growth in revenues - indicative of GB traffic >Business is approximately 25% of residential, in terms of GB traffic and subscriptions
Residential subscribers [M]	9.8 M	10.1 M	2.6%	>No data on number of business subscribers is available
Broadband availability to HH, excluding satellite ➢ **National** ➢ **Urban** ➢ **Rural**	 95% 100% 82%	 95% 100% 84%		
Penetration (HHs) [%] ➢ **All speeds** ➢ **High speed** **BB > 1.5 MB** **BB > 5 MB**	 74% 69% 52% 41%	 75% 72% 62% 44%	 10.1% 7.3% 6.3% * 4.4%	>* Fig 5.3.4 of CRTC CMR estimates the number of BB connections greater than 1.5 MB to be 7.9 M subscriptions (Cable 4.5 M, DSL 3.4 M)
Avg. Monthly Subscriber Traffic [GB /month/sub] • **Download** • **Upload**	 9.1 3.2	 12.0 3.4		> Total avg. monthly traffic per subscriber was 15.4 GB; > 14% of all users (9.17 M) account for 83% of the total Internet traffic.

6.2.5 Point-to-Multipoint FWA: Services and Spectrum Demand

This section presents the projections of broadband Internet subscribers and traffic to be accommodated by Fixed Wireless Access (FWA) facilities, the assumptions used to define the FWA market, the demand for spectrum and the results for alternative scenarios.

Point-to-Multipoint FWA – Clarification Regarding Services in the 2500 MHz Band

In reporting the demand for the High-Value Services, the primary principle in this report is to show the demands according to the types of service being delivered.

Given the changes to the BRS (2500 MHz) band, there are three distinct services operating in this band in the period of this Study.

The principle is applied to these services in the same way it is to all other services. This means that those in the 2500 MHz band are treated as shown in the box below.

[20] CRTC CMR Report 2010, Section 5.3: http://www.crtc.gc.ca/eng/publications/reports/policymonitoring/2010/cmr2010.pdf

Clarification: Analysis of Services in the 2500 MHz band

1) FWA Services using Fixed WiMAX or any other non-cellular technology — mostly in mid- to low-density rural areas. This is accounted for here in the FWA Point-to-Multipoint Service, both for traffic and for demand for spectrum.

2) FWA Services using LTE/HSPA technology — mostly in mid-to-low density rural areas. This, too, is accounted for here in the FWA Point-to-Multipoint Service, both for traffic and for demand for spectrum.

3) Mobile Services using LTE/HSPA technology — in all areas, urban and rural. This is accounted for in the Cellular Services, both for traffic and for demand for spectrum.

Point-to-Multipoint FWA: Service Demand: Market Analysis

In developing the projections for service demand for FWA to deliver broadband Internet, the Study uses a combination of in-house expertise and primary research, which was reviewed against several sources of secondary research. This includes data from the CRTC Annual Report on the state of broadband subscriptions and types of facilities, number of households already passed by various access facilities, the average broadband consumption per subscriber and other information. Some operators provided information on their FWA facilities. This also included their views on broadband services and the economic opportunities for FWA and broadband satellite to address un-served or under-served rural areas.

In determining demand, the process began by reviewing the existing status of broadband Internet subscriptions in urban areas and the household broadband penetration rate. In studying the market, it is clear that there is a dominant use of wireline broadband facilities (cable/fibre with either DSL or cable modem) and limited use of FWA and broadband satellite. Furthermore, it can be noted that the situation in urban areas is, such that, close to 100% of the households (HH) and businesses are passed by wireline broadband facilities of some sort, with speeds of greater than 1.5 Mbps. With the high availability of competitive broadband wireline facilities, it was concluded that there are very limited opportunities to use FWA facilities (point to multipoint below 6 GHz) to serve urban households and small businesses. However, the need for large-capacity broadband wireless facilities (point to point at 24/38 GHz) was identified in urban and rural areas to complement broadband fibre distribution facilities.

For the FWA service, the large number of rural households and businesses were studied, especially in moderate and sparsely populated areas, which have limited or no access to broadband facilities. Broadband FWA facilities, including broadband cellular platforms, such as HSPA, will continue to play an important role in bringing broadband to un-served and underserved rural areas.

Furthermore, the role of broadband satellites was studied as suited to serve sparsely populated rural markets. It was concluded that, in moderate-to-sparsely populated rural regions, conventional wireline broadband facilities are either technically inadequate to provide high-speed services or are cost prohibitive. For many of these areas, some service providers depend on government subsidies to assist in bridging the high costs of broadband facilities.

A top-down analysis was conducted to project the growth of broadband subscriptions, which will be provided by a mix of technologies such as wireline facilities (DSL and cable modem), FWA (bands below 6 GHz and the bands 24/38 GHz), and broadband Ka-band satellites over the next five years.

The analysis included determining:

- Market share across a mix of broadband facilities;
- Subscription growth on FWA facilities (including fixed HSPA connections);
- Average monthly usage in GB per subscriber;
- Traffic mix – i.e. download/upload usage; and
- Types of (rural) markets best suited for FWA and broadband satellite.

In modelling the service demand for broadband access and FWA, the following factors have been taken into consideration.

Approximately 20% of the rural households (700,000 HHs) have no access to broadband wireline and wireless services. Multimedia Ka-band satellites provide national broadband services, but satellite service is limited in capacity, and the Internet speed and price are not competitive with terrestrial facilities, especially for the more populated rural areas, where the business case for FWA holds.
Hence, in assessing the relative demand for FWA spectrum, it is important to consider that:

- Existing FWA subscriptions are mainly in rural areas, and represent a small percentage of the total (urban-dominated) subscriptions for broadband services.
- Broadband service in urban areas is very competitive with DSL and Cable facilities already available to 100% of the households, where these services are often bundled with landlines and cellphones.
- According to stakeholder input and analysis, a percentage of rural households are still un-served, when it comes to broadband connectivity.

Point-to-Multipoint FWA: Projections of Subscribers and Traffic

The charts below summarize the projections for subscribers, data traffic, and total traffic for FWA (point-to-multipoint) below 6 GHz to households and Small-to-Mid-sized Enterprises (SMEs).
Figure 6.2.1 shows the number of subscriptions on FWA below 6 GHz, growing from 520,000 at the start of 2010 to more than 960,000 by 2015. This constitutes a near doubling of subscribers over the period from 2010-15. It also illustrates the evolution in the mix of technologies, with FWA services starting to be delivered using cellular technologies in the 2013-14 timeframe.

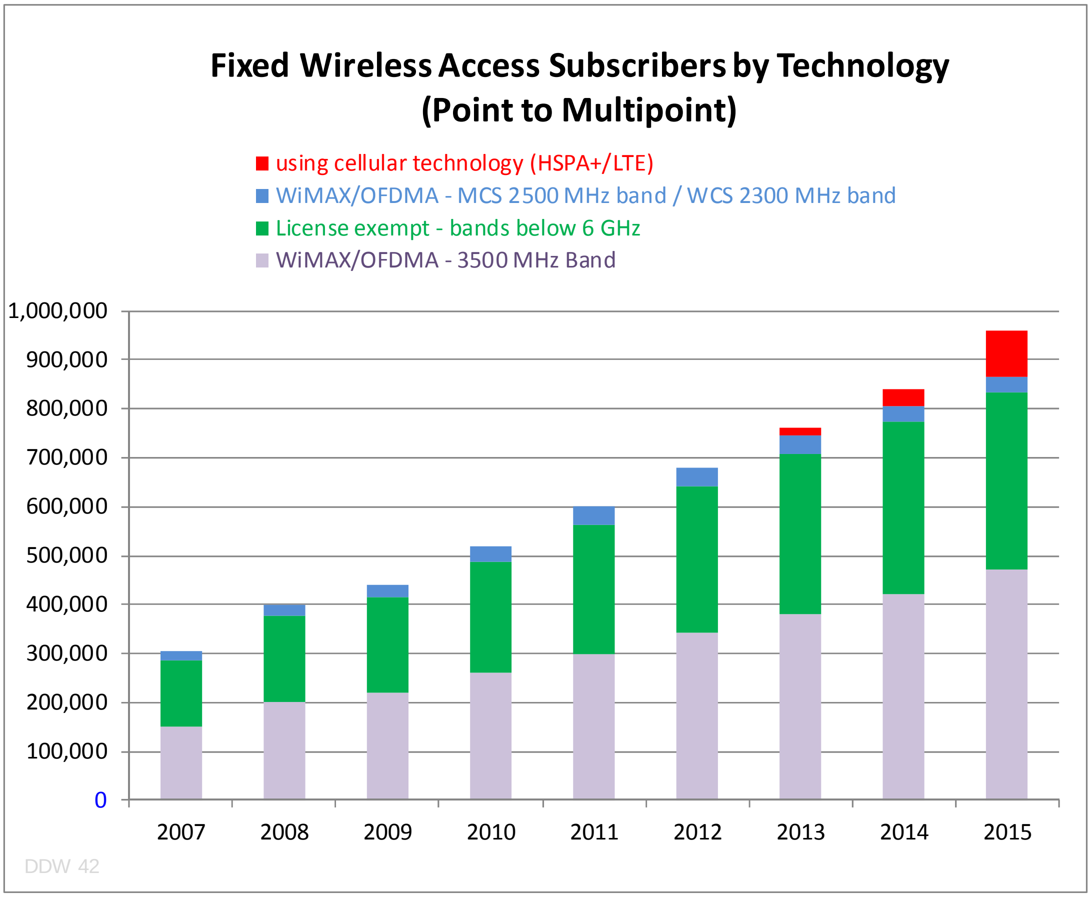

Figure 6.2.1 — Point to Multipoint, subscribers (*Source: Red Mobile Research and Projections*)

FWA has a larger potential in rural areas, where large segments of the market are under-served. As a result, in this Study, it was forecast that FWA subscriptions, as can be noted in Figure 6.2.1, would grow from 520,000 subscribers in 2010 to 960,000 in 2015.
Traffic is projected to grow from 15 GB/month/subscription to 45 GB/month/subscription during the period from 2010 to 2015.

Total traffic grows from 8 M GB/month to 44M GB/month, as shown in the chart below.

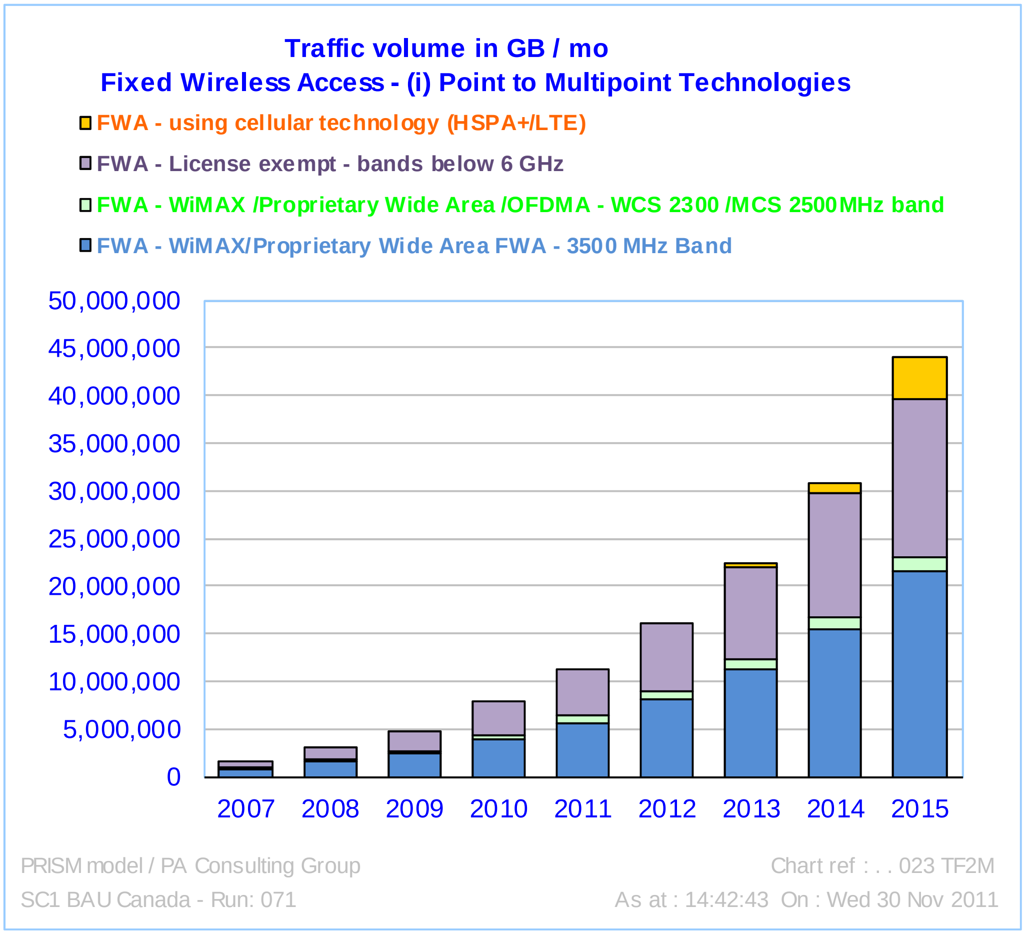

Figure 6.2.2 — Point to Multipoint, traffic per subscriber (GB/mo equivalent) (*Source: Red Mobile Projections*)

Point-to-Multipoint FWA: Key Assumptions and Relationship between Service and Spectrum Demand

The key assumptions used for this calculation are as follows.

For each of the main established rural FWA technologies, including those in licence-exempt bands:

- Assumptions are made regarding the approximate number of sites and sectors in which they have deployed and how this is likely to evolve out to 2015. The number of cells and sectors are not identified to protect the confidentiality of some of the information.
- Data traffic per rural FWA subscriber is 15 GB/mo in 2010 rising to 45 GB/mo by 2015 (80% downlink, 20% uplink).
- These FWA services are offered in areas of moderate-to-low-population density. The main market being areas with population density of between approximately 4 and 40 population per square kilometre, extending into more-densely populated rural areas. The services are not generally offered in urban areas (approximately more than 400 population per sq. km.) and are also not aimed systematically at high-density rural areas with a population of between 100 and 400. These assumptions are particularly relevant to FWA over LTE/HSPA — service offerings and take-up to 2015 are limited by the availability of LTE in areas of suitably low-population density. The

assumption is that FWA over LTE/HSPA is not offered in significant volumes in urban areas, where the traffic would consume expensive capacity and spectrum aimed at cellular services.

- Spectral efficiency is assumed to be 4.0 bits/sec/Hz for the WiMAX and licence-exempt bands, and 1.3 (rising to 1.4 by 2015) for the cellular technologies.
- Frequency reuse factors are assumed to be 4 for the WiMAX technologies and the licence-exempt bands, 1 for the cellular technologies.
- Busy-hour traffic is three times that of 24/7 average-hour traffic.
- Required capacity, to allow for burst rates for individual subscribers, is 1.75 times that of busy-hour traffic.

Point-to-Multipoint FWA: Demand for Spectrum

The considerable change in traffic growth, shown in the previous subsection, drives some demand for additional spectrum for these technologies, as shown in Figure 6.2.3, below.

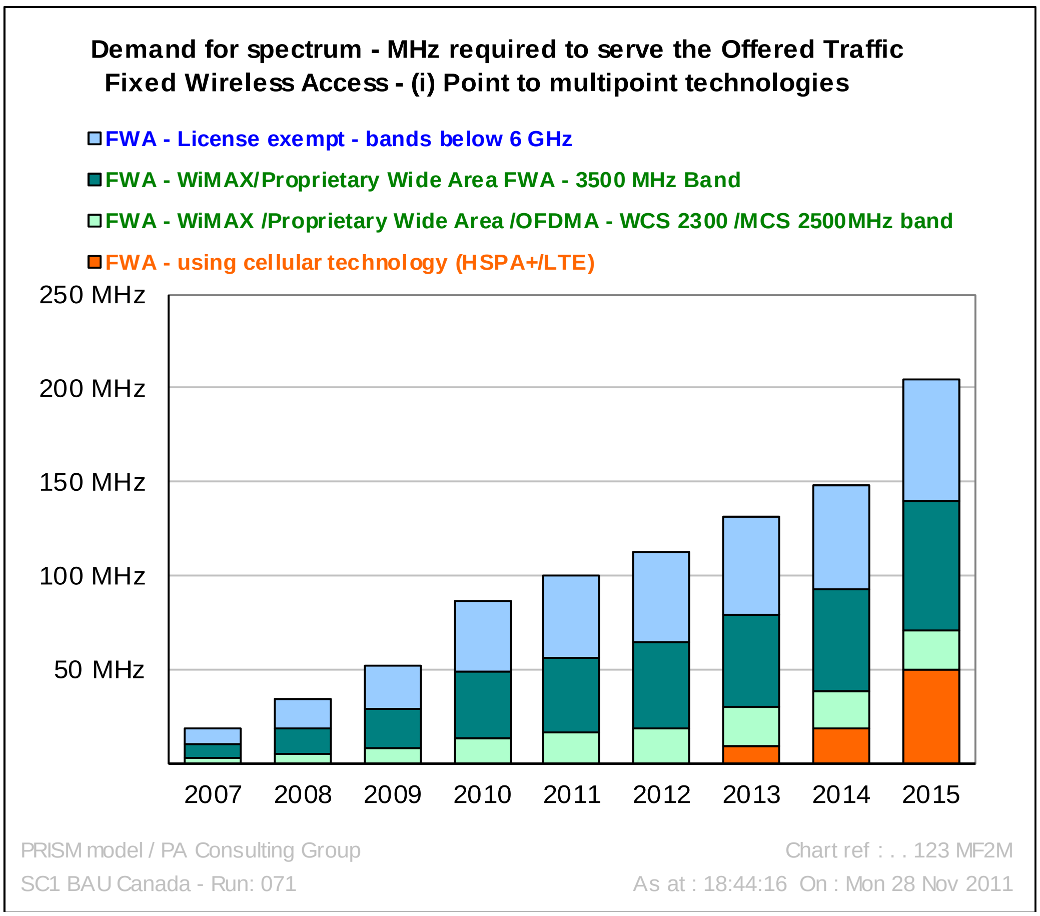

Figure 6.2.3 — Point to Multipoint, demand for spectrum (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

Growth in the demand for spectrum is slower than the growth in traffic. The main reasons for the difference are gains in spectral efficiency and an increase in the number of nodes/sites/sectors to cope with some of the growth.

The projections are, of course, sensitive to the assumptions regarding numbers of sites and sectors and how these grow over time.

Point-to-Multipoint FWA: Sensitivity analysis – Assessing Spectrum Demand Using Alternative Metrics

For point-to-multipoint FWA, the effect of including further operational constraints, further increasing the measure of the demand for spectrum, was also examined the same way as was done for cellular. The results of this analysis are shown in the next chart.

The solid bar (1) shows the demand for spectrum, on the primary measure used above: i.e. what is needed to carry the traffic at an acceptable Quality of Service, in the Busy Hour, etc.

The two higher measures of demand are shown as lines on the chart. They are calculated in the same way as was done for cellular:

- Solid line (2): including allowance for minimum channel widths per licenced operator/per technology;
- Dashed line (3): also allows for channel widths and also for the fact that timing of demand growth cannot be predicted, and, therefore, allows two years either way on the demand figures for each technology;

Including the above operational constraints inevitably increases the figures, adding a further 100-150 MHz to the figures obtained on the primary measure of demand.

As with the Cellular service, the effect of using the different metrics for the demand for spectrum is additive (+100-150 MHz), rather than multiplicative (x2-x3).

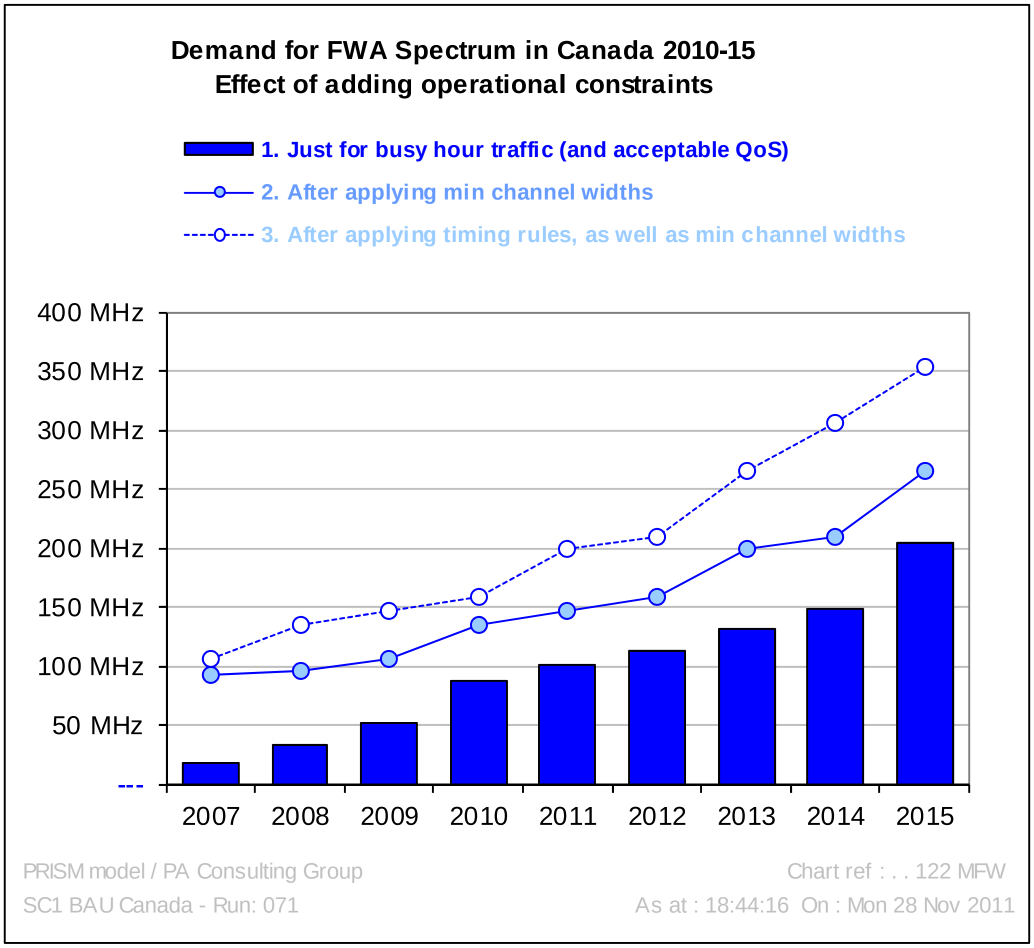

Figure 6.2.4 — Point to Multipoint, includes operational measures of spectrum demand (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

Point-to-Multipoint FWA: Assessment of Alternative Scenarios

Figure 6.2.5 below shows the projections for traffic growth in the alternative scenarios. The projections are higher in Scenario 2 (Wire-Free World), and slightly lower in Scenario 3 (Low Investment).

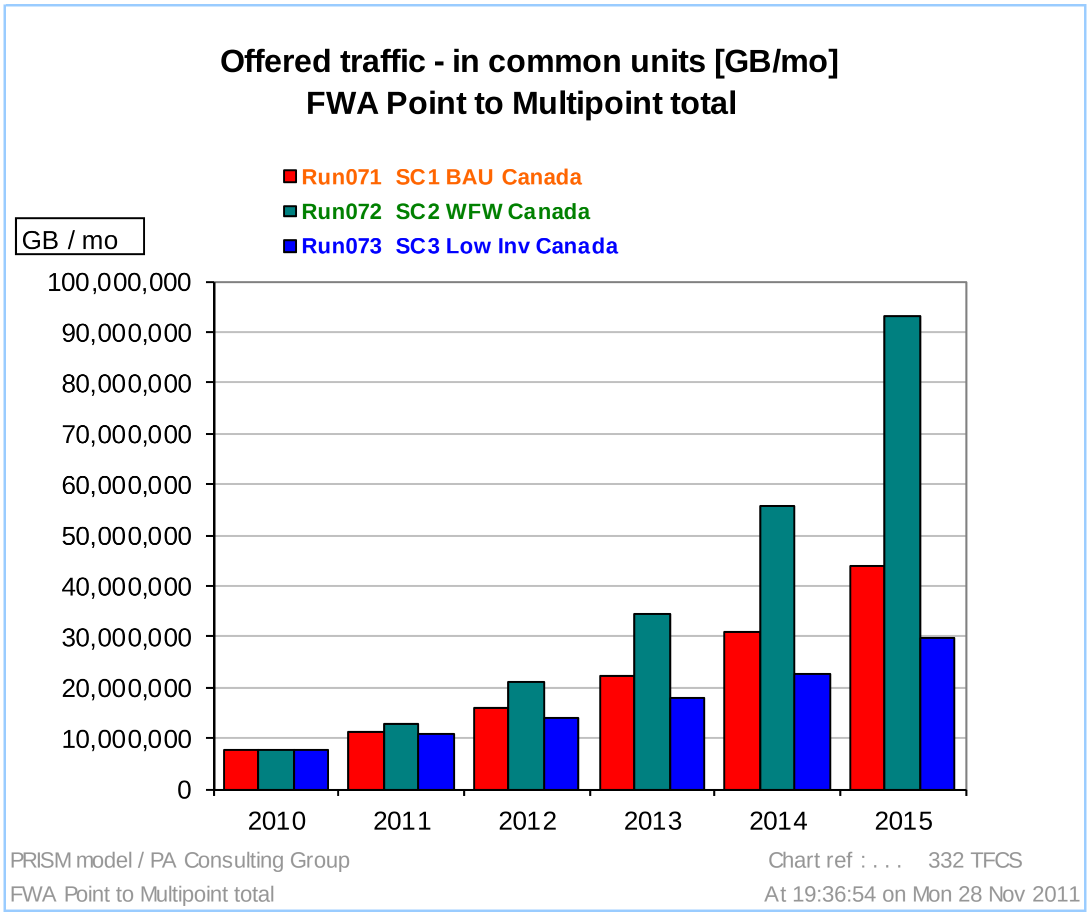

Figure 6.2.5 — Point to multipoint, traffic by scenario (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

Projections for Spectrum Demand are shown in Figure 6.2.6 below. They follow a similar pattern, but slightly less extreme. The main reason for this is the differences in the projected rates of growth in sites and sectors. In particular, in Scenario 3, the slower growth in traffic is partly counter-balanced by lower growth rates for the numbers of sites and sectors, so the changes in spectrum demand are less dramatic than the changes in traffic volumes.

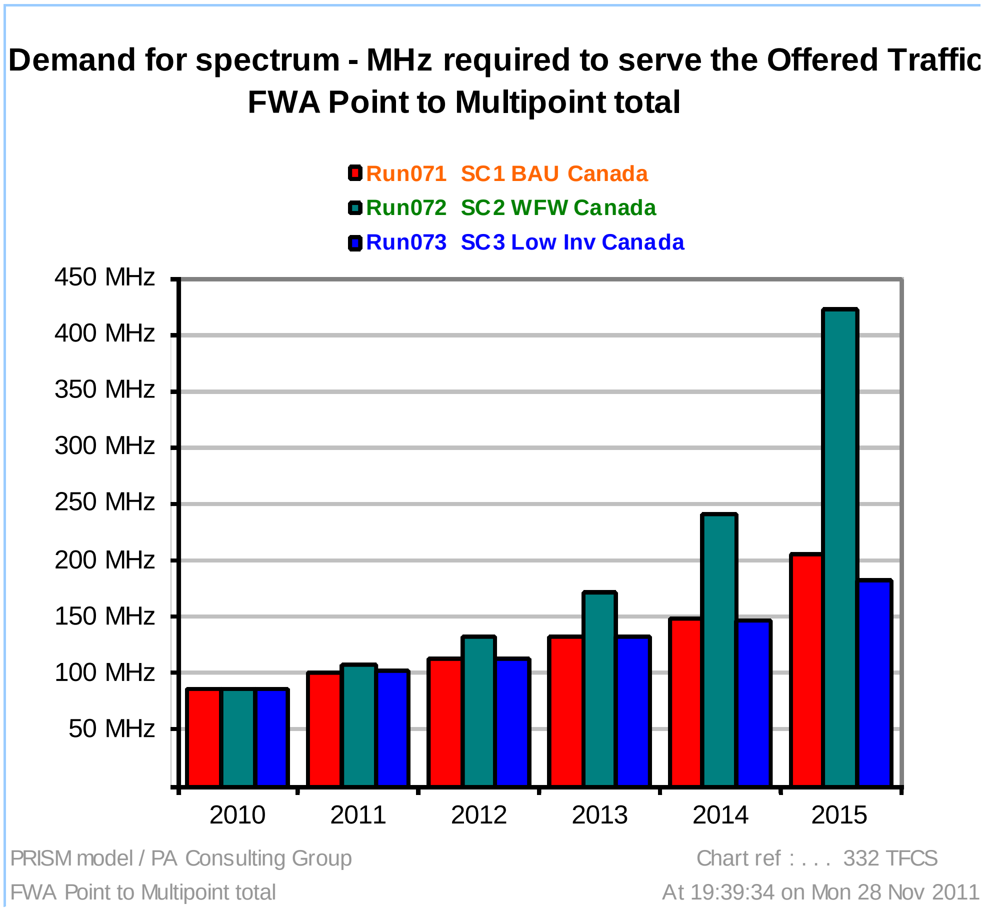

Figure 6.2.6 — Point to multipoint, spectrum demand by scenario
(*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

As with the spectrum demand for Cellular services, there is likely to be some further balancing feedback loops between available spectrum and spectrum demand.

The most evident example of this comes from considering the projections for Scenario 2 – Wire-Free World (high growth), which suggest that the demand for spectrum may grow rapidly over the period 2013-15, and this may be felt as pressure on spectrum. There are ways for operators to alleviate some of this pressure, although, in general, this comes at a cost[21] to operators and/or consumers, so, the greater the pressure on spectrum, the more these means of alleviating the pressure are likely to be deployed.

21 For example: adding more network nodes/sites; or capping or throttling some usage; migrating some usage to frequencies, technologies and frequencies above 38GHz.

6.2.6 Point-to-Point FWA: Services and Spectrum Demand

Point-to-Point FWA: Subscribers and Traffic

The FWA point-to-point part of the model does not directly use projections of traffic. Instead, it starts from assumptions, regarding the capacity required on each link. Accordingly, this Report does not provide charts for traffic projections.

In terms of the development of the market, the projections are for slow continued growth in links (on the order of up to 5%-10% pa) and a rather more-rapid growth in traffic, on the order of a threefold growth in traffic per link, from 1TB/link/month to 3 TB/link/month.

Point-to-Point FWA: Key Assumptions to Get From Traffic to Spectrum Demand

Key assumptions are as follows:

1. The point-to-point links are highly directional, and the general characteristics resemble those of microwave links much more than they resemble the other FWA technologies.
2. Current links are at up to, approximately, Ethernet speeds, with required capacity averaging 80 Mbps in 2010, rising to 200 Mbps in 2015. But, the majority of these links operate most of the time in the range of 2-20 Mbps.
3. Spectral efficiency is 4 bits/sec/Hz, frequency reuse is 6 (i.e. six frequencies are needed in order to provide channels for all links), and sufficient channels — for two independently planned networks — are needed to operate in each neighbourhood. These assumptions do not vary over the period of 2010-15.

Because of the way that the point-to-point part of the FWA model works — i.e. it starts from assumptions about the required capacity per link and applies factors for frequency reuse and the other aspects of network design — the calculations do not directly use assumptions regarding total traffic, busy-hour factors or required headroom.

Point to Point: Spectrum Demand

The growth in demand for spectrum is shown below. Growth in traffic and the resulting capacity required on the links are the drivers of increase in demand for spectrum. Changes in the number of point-to-point FWA microwave links are not a major driver of growth in spectrum demand, and so long as they do not increase the allowance that needs to be made for frequency reuse, they do not have an impact.

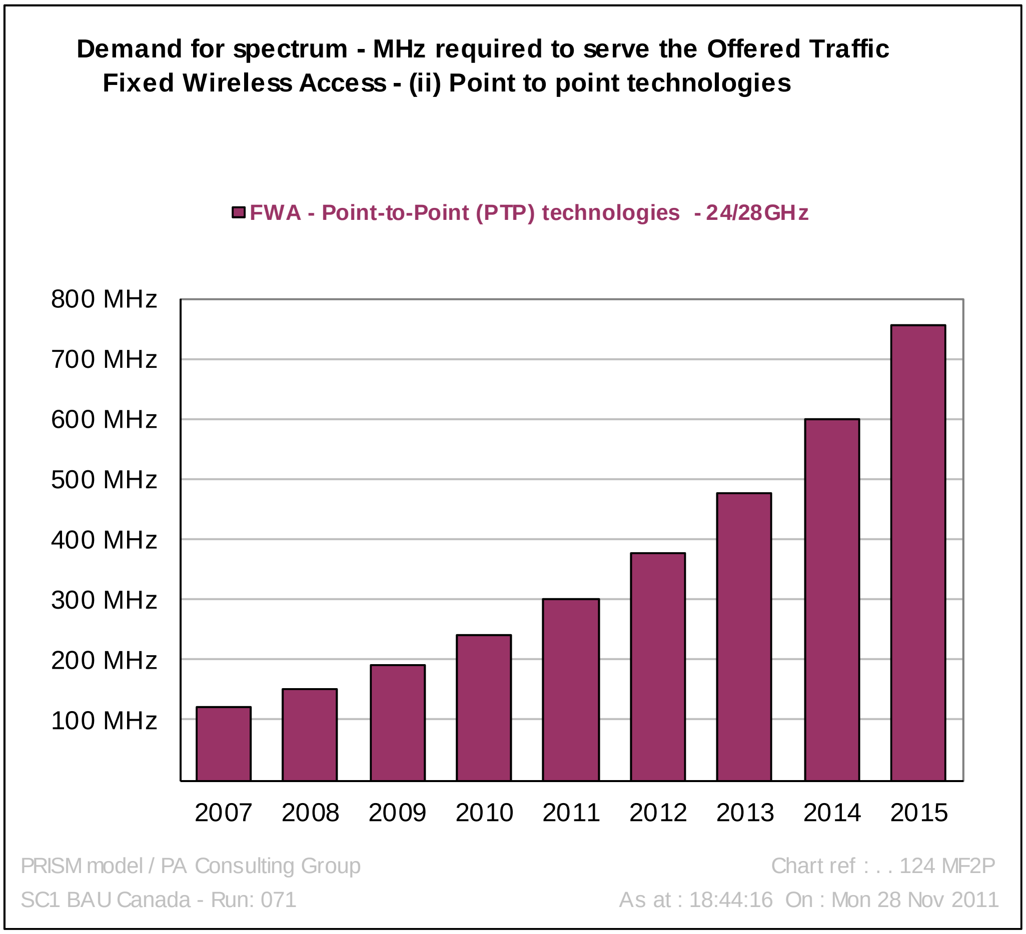

Figure 6.2.7 — Point to point, spectrum demand (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

Point to Point: Assessment of Alternative Scenarios

For point-to-point FWA, the alternative scenarios were modelled using different assumptions regarding the rate of growth in the required capacity per link.

The implied traffic growth figures for 2015 are a factor of two higher in Scenario 2 (*Wire-Free World*) and 25% lower than in Scenario 3 (*Low Investment*).

The chart below (Figure 6.2.8) shows the spectrum demand projections for the alternative scenarios.

Spectrum Demand follows a similar pattern to the implied traffic projections.

Projections for Scenario 2 — *Wire-Free World*/high growth — suggest there may be a high level of pressure on spectrum by 2015.

As with other services, there may be ways for operators to alleviate some of this pressure, including migrating traffic to frequencies above 38 GHz or substituting from microwave to high-speed fixed connections. Like cellular, this service also exhibits the presence of a balancing feedback loop between spectrum supply and demand.

The projections are sensitive to the assumptions regarding the degree of coordination between operators in the same local area. If infrastructure completion were permitted or encouraged in a way which made less-efficient use of spectrum — for example, if there were twice as many operators in each local area, each with their own set of frequencies — this would have a corresponding pro-rata impact on the amount of spectrum required.

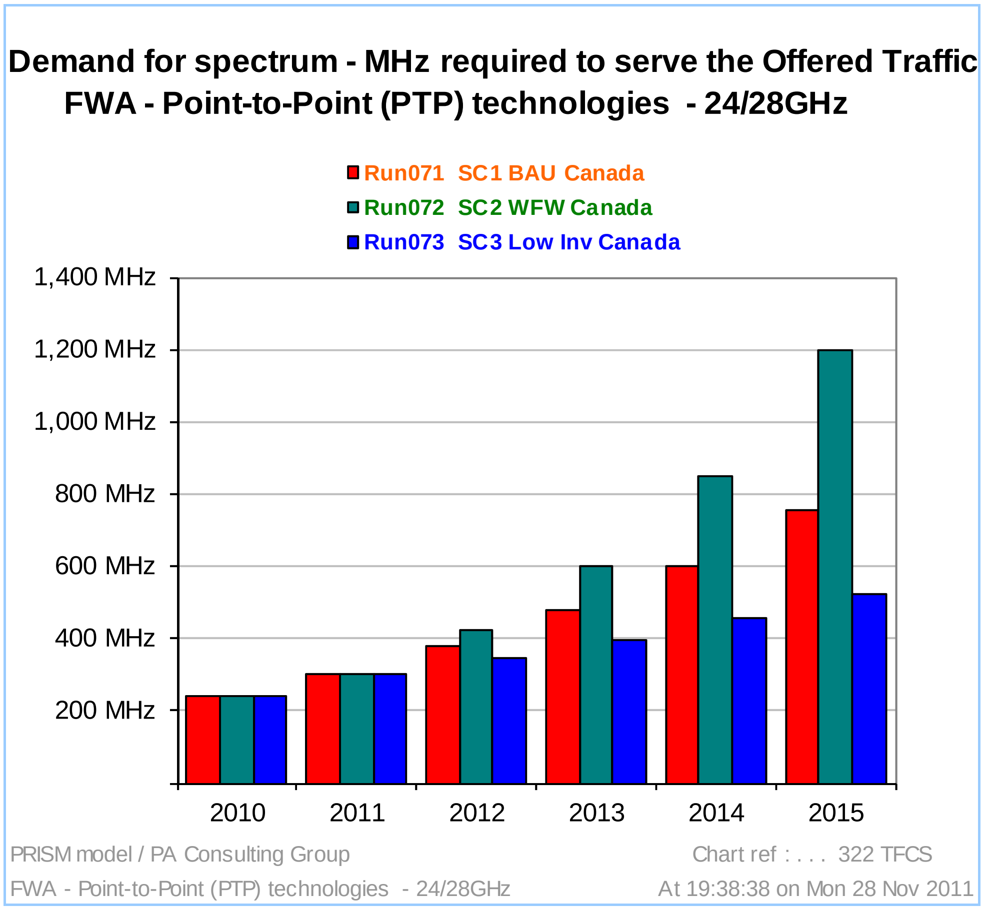

Figure 6.2.8 — Point to point, spectrum demand by scenario (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

6.2.7 Conclusions

Conclusions are given separately for Point-to-Multipoint FWA and for Point-to-Point FWA.

Point-to-multipoint FWA: Canada has one of the highest penetrations of broadband Internet access of the OECD countries. One of the opportunities for FWA growth is that more than 14% of the rural households are un-served or underserved. These are the most natural markets for growth in point-to-multipoint FWA services.

Canada has licenced greater than 200 MHz of FWA spectrum, in addition to the provision made to use licence-exempt bands and locally unused TV broadcasting channels.

FWA point-to-multipoint (PTM) technologies will play a growing role in delivering broadband to households and small businesses in rural areas. The existing networks using WiMAX and other technologies will continue to operate and grow, in terms of their traffic. Finally, HSPA/LTE cellular access will provide a further means to serve part of the rural market by 2015.

The Study forecasts a significant service and spectrum demand to serve the broadband rural market using FWA (licenced and licence-exempt) PTM facilities and advanced HSPA-LTE cellular networks. Figure 6.2.4 projects the spectrum demand to double (from 150 MHz to 300 MHz) for the 2010-15 period to meet the broadband-access service demand.

Point-to-point (PTP) FWA: The high-capacity point-to-point links are providing an effective way to serve part of the large enterprise market and other high-speed connections requirement, in addition to multiple DS-3 (SONET) fibre-optic and wireline carriers.

PTP links require extensive spectrum, as shown in Figure 6.2.8 above. By 2015, the spectrum requirement varies according to the traffic scenarios and is projected as being between 500 and 1200 MHz.

Finally, the Study has identified a likelihood of the demand for FWA spectrum being influenced by some balancing feedback loops, in the same way as seems likely for Cellular services. This balancing feedback will tend to bring the demand for spectrum into closer alignment with the supply of spectrum, for both point-to-multipoint and for point-to-point FWA.

6.3 Backhaul Microwave Facilities

6.3.1 Overview

Although backhaul microwave facilities are used for a wide range of applications, this Study will focus mainly on the demand for backhaul facilities to support the accelerated growth of cellular networks and broadband access systems at frequencies up to 28GHz. Use of microwave technologies for point-to-point access communications, and its associated demand for spectrum, is covered in the previous section under Fixed Wireless Access.

There has been a major shift in the development of backhaul microwave facilities to support public telecom networks since the mid-1980s. A number of large regional and national fibre-optic-based facilities have been built to accommodate public telephone and data networks, Internet traffic transmission, inter-city carriage of television programming to cable TV head-ends and to DTH broadcasting satellite gateways, as well as to meet other transmission requirements. The role of heavy-route, long-haul microwave radio systems in certain bands below 10 GHz, such as the 4 and 6 GHz bands, has been replaced mostly by large fibre-optic systems. These systems are able to expand their transmission capacity with the adoption of new generation optical multiplexers and repeaters, and advanced signal processing techniques.

There have been similar initiatives undertaken by incumbent telecom carriers, local cable operators and new telecom entrants to build a wide range of fibre-optic systems in urban areas and surrounding communities to complement traditional copper and coaxial distribution facilities for residential and business customers. A main reason for this was to increase the transmission capacity and quality of their broadband Internet and cable TV offerings, including the bundling of multiple services (IPTV, telephone, broadband).

As for microwave facilities, there has been considerable activity in the 1990s in rolling out point-to-point links in the 23 GHz and 38 GHz bands to serve large business customers. At that time, a significant amount of spectrum was licenced using competitive processes for point-to-multipoint broadband access in the 24/28/38 GHz bands, the 2500 band and the 2300/3500 MHz bands. Point-to-multipoint spectrum below 6 GHz has been gradually assigned for FWA broadband access. FWA to households has not been economically viable in the 24 GHz to 38 GHz range due to the historic lack of cost-effective Consumer Premise Equipment (CPEs) for residential use. However, some of the spectrum is being used effectively for short-haul backhaul links.

Therefore, while the incumbent telecom and cable operators have extensive wireline-based facilities (copper/fibre and coaxial/fibre), microwave backhaul and FWA provide them another transmission alternative. For new entrants in cellular and broadband, the use of FWA and microwave backhaul are, often, their only options.

Given the number of national and regional cellular networks with thousands of cell sites concentrated in Southern Canada, and the rapid growth of mobile traffic, the use of backhaul microwave facilities has significantly increased to link clusters of cell sites to collector points and public switching networks. Due to the relatively short distances between cell sites in urban areas, the use of microwave spectrum in the Ku- (11/14 GHz) and Ka- (18/21 GHz) bands has exceedingly been in demand for backhaul. There has also been an increased use of these bands for microwave backhaul to support broadband Internet access using FWA bands below 6 GHz.

The demand for microwave backhaul facilities and spectrum will be studied within the context of other backhaul transmission facilities, mainly fibre-optical systems and copper-based digital operators providing extensive routing of traffic of cellular and broadband Internet distribution services.

6.3.2 Spectrum Inventory and Spectrum Utilization

The Inventory Report (Section 2.0) reviews the number of frequency assignments in the fixed-service frequency bands (both point to point and point to multipoint). It considers various factors, including regional distribution and geographical concentration, metropolitan/non-metropolitan usage, growth of frequency use, and trends over the last 10 years for selected bands.

The spectrum of interest for backhaul facilities in this Study is the frequency bands above 10 GHz for two-way point-to-point microwave links. These links are in increasing demand, as a result of growth in traffic of mobile cellular networks and broadband distribution systems. Specifically, the 11 GHz, 14 GHz, 18 GHz and 23 GHz bands are of interest. These bands are experiencing the greatest demand to provide short transmission links in urban and rural areas.

The Inventory Report summarizes the number of frequency assignments for two-way microwave bands between 2 GHz to 38 GHz. A number of these bands in this spectrum range have been identified as prime bands for backhaul facilities supporting cellular and wireless broadband access networks. Both of these network types are experiencing a very high demand for backhaul facilities. Microwave bands above 10 GHz are well suited for short hops (typically less than 16 km) to link cellular and broadband sites to their respective networks directly or through other transmission facilities. Microwave bands below 10 GHz provide for much longer hops (20–50 km) and are intended for medium-to-long-haul transmission, often as provincial or inter-provincial systems. Figure 6.3.1, below, taken from Chapter 2 of the Inventory Report shows the number of frequency assignments in the various fixed point-to-point microwave bands, and the relative interest for spectrum in the 11 GHz, 14 GHz, 18 GHz and 23 GHz range for microwave backhaul facilities.

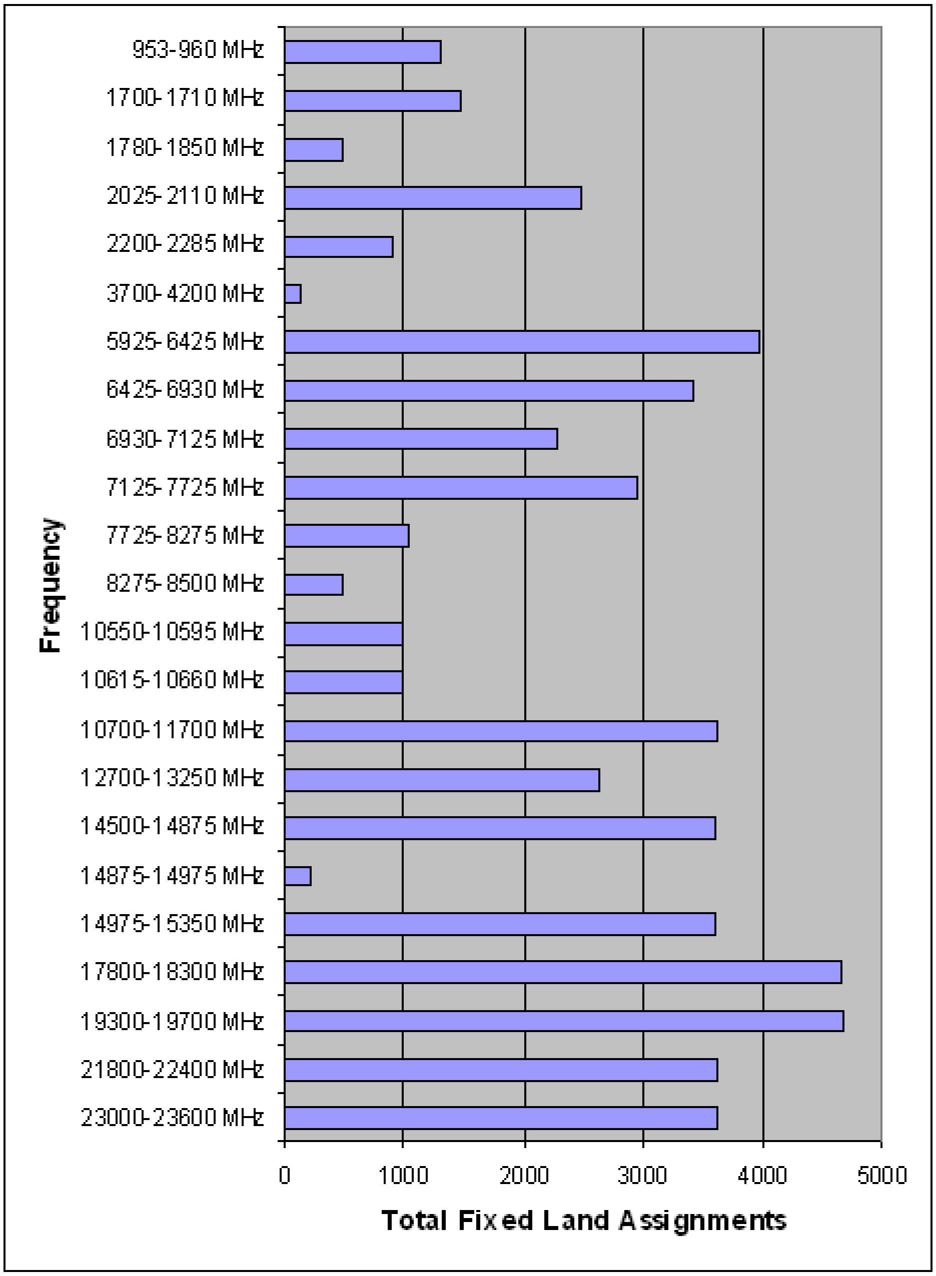

Figure 6.3.1 — Total Number of Fixed Land Station Frequencies Assigned (*Source: Inventory Report, Figure 2.1, Section 2.3.2*)

Some of the key insights in the Inventory Report that are relevant to the scope of this Study include:

- The 11 GHz, 14 GHz, 18 GHz and 23 GHz bands are experiencing an exponentially high growth of frequency assignments. This is likely being driven by increasing capacity requirements in support of cellular and broadband access networks;
- The highest number of frequency assignments across Canada are found in the 18 GHz band, with the majority of assignments in Ontario at close to 4600;

- The second-highest number of frequency assignments is in the band 5925-6425 MHz, with nearly 4000 assignments. This is likely due to the re-channellization of part of the band to support low-capacity microwave systems via a larger number of narrowband channels;
- An average of approximately 65% of all backhaul links are located in non-metropolitan areas; and
- The number of assignments in metropolitan areas tends to be greater in bands above 14 GHz, with the exception of the 6930-7125 MHz band.
- The Inventory Report identified new spectrum for backhaul below 10 GHz in the bands 7975-8025 MHz and 3700-4200 MHz; and above 10 GHz, in the bands 12.7-13.2 GHz and 28 GHz.
- We note that 600 + 600 MHz of fixed microwave spectrum has been reserved since the early 1990s in the paired bands 21.2-21.8/22.4-23.0 GHz. This band is adjacent to the popular paired spectrum in bands 21.8-22.4/23.0-23.6 GHz, where technology readily exists.
- It can also be observed that, despite the availability of suitable technology, there is unassigned spectrum in the 31 GHz range, which could provide more spectrum for backhaul microwave facilities.

6.3.3 Stakeholder Input and Research Analysis

Stakeholder Input

- Service providers highlighted the benefits of microwave backhaul facilities, including:
  - Microwave provides a cost-effective way to rapidly deploy facilities, and transport traffic from cell sites to aggregation points. This is especially important for new entrants having limited fibre-optic and wireline facilities.
  - Microwave backhaul supports broadband distribution networks. Some broadband FWA hubs have moved from 36 Mbps to 150 Mbps with further expansion planned in the near future.
  - Currently, HSPA sites use microwave backhaul links with 150 Mbps capacity. These links can support 220 Mbps capacity. When LTE sites are launched, the capacity will grow to support 530 Mbps.
  - With the aggregation of traffic in multi-hop backhaul relays, the capacity of these hops is 2 to 3 times that of an average busy site.
- Service providers also indicated their perspective on future needs as:
  - The deployment of 4G technology, for broadband services, will have dramatic demand on backhaul capacity in the next five years.
  - An incumbent local exchange carrier (ILEC) expects exponential growth in backhaul capacity needs in the coming years.
  - A wholesale microwave backhaul provider projected 20% annual growth for microwave-backhaul-capacity needs, driven by incremental bandwidth demanded by businesses.
  - Another operator, discussing highly congested areas of Toronto and Ottawa suggested that it expects its backhaul capacity needs to grow by up to 25 times over the next five years.
- Comments by some indicated that they are moving to fibre optic to save costs:
  - Meanwhile, it was also noted that, over time, multiple microwave channels will be needed per link, which are more expensive than fibre facilities. Therefore, it is expected that there will be an increase in the use of fibre-optic-based systems to backhaul.
  - A public power utility indicated that they have replaced microwave with fibre optic connections already, as a result of the long-term cost benefits for them.
  - Another major ILEC and CLEC carrier indicated that most of their heavy-transmission routes have moved from microwave to fibre. It also indicated that the majority of its light-transmission routes, that have more than two hops, will be replaced by fibre within five years. However, for the foreseeable future, it sees using microwave backhaul for switching office transport and to access remote sites, where fibre costs are prohibitive.

- In lieu of deploying heavier capacity microwave systems, a facilities service provider reported that it continued to maintain dark and leased fibre facilities to aggregate traffic and to offload over-exerted microwave links. Although this has helped alleviate short-term needs along busy corridors, it does not meet the redundancy requirements for some Canadian businesses.

- Current use of various bands was addressed by several stakeholders as follows:
  - It was noted that bands used for the types of hops are as follows:
    - Long hops: 6, 7, 8 GHz
    - Medium hops: 11, 15 GHz
    - Short hops: 18, 23 GHz
  - Some observed that, in some cases, the 24 and 28 GHz, even the 38 GHz, FWA bands for point-to-multipoint applications have been treated more like backhaul bands and as broadband pipes to enterprises.
  - As growing rural expansion requires long hops and spectrum below 10 GHz, concern was expressed about the limited available channel bandwidth of 30 MHz.
  - A provincial ILEC is using a mixture of 2, 6 and 8 GHz microwave system in rural and remote northern regions.
  - New entrants are using several bands for backhaul, including 11 GHz, 14 GHz, 18 GHz and 23 GHz bands, plus the 24 GHz and 38 GHz bands in large urban centres. Transmission capacity ranges from 30 Mbps up to 227 Mbps with channel bandwidth of 4 MHz to 10 MHz. In many cases, those without existing wireline facilities see an annual growth of 50% in the use of microwave assignments.
  - A large broadband service provider indicated using the four prime bands above 10 GHz with bandwidth ranging from 30 MHz to 50 MHz, to support up to 300 Mbps capacity, depending on the number of relay hops. The first link from a point of presence (POP), or where the link connects to the fibre backhaul facility, has the highest transmission capacity. In the near future, with 4G broadband, the minimum microwave backhaul capacity is expected to rise to 150 Mbps. Hence, the last microwave link connected to the fibre system for three to four broadband sites will require 500 Mbps capacity.
  - A national cellular operator reported primarily using the 11 and 18 GHz band for microwave backhaul. These links are mainly used in mid-urban areas, and the anticipated capacity requirement in five years is 1 Gbps, with increments expected as follows:
    - 2011: 134 Mbps;
    - 2012: 300 Mbps;
    - 2013: 500 Mbps;
    - 2014: 750 Mbps; and
    - 2015: 1 Gbps.

    Over the last five years, for medium-haul backhaul, the carrier has preferred to use fibre optic than microwave. The capacity for these microwave links has jumped from 15 Mbps up to 135 Mbps per MW hop.
  - According to a facility carrier, its microwave backhaul has reached more than 70% utilization on some hops and will require solutions in the short term to sustain the incrementing traffic load. Markets with high-spectrum utilization, such as the GTA, Montreal, Calgary and Vancouver, are expected to be at 80%-100% capacity within the next five years.

- As expected, respondents indicated that some bands are becoming congested in certain regions:
  - There is increased congestion surrounding Toronto and Ottawa in the 18 GHz and 23 GHz bands, due to new cellular operators.
  - CLEC indicated challenges in coordinating frequencies at 11 GHz in Toronto to avoid interference from other users. Examples of such areas include the Greater Toronto Area (GTA) and Greater Vancouver Area (GVA), both congested at 11 GHz.
  - The GTA, GVA, Calgary, Edmonton and Montreal also have a high level of utilization in the 18 GHz band.
  - It was suggested that 11 GHz faces very challenging congestion in Ontario, due to the 15-GHz moratorium, which is displacing many links into the 11 GHz band. In addition, LTE will put

pressure on 11 GHz in more urban areas. The 6 GHz could see issues in rural areas, as expansion continues and several long hops are required. In fact, it was noted that the upper 6 GHz is already experiencing congestion in Alberta.

- There were some exceptions for regional carriers who reported sufficient spectrum for their use:
  - o A provincial ILEC carrier uses the 2, 6, 7, 11, 18, 24 and 38 GHz bands to establish backhaul facilities for mobile and broadband traffic. The carrier does not experience any congestion, nor does it foresee any congestion in the next five years.
  - o Another regional carrier indicated using a large amount of fibre infrastructure. Microwave is used only in remote areas where deployment of fibre is too difficult and costly. In these remote areas, there are a sufficient number of channels available in the 6 and 8 GHz bands to provide capacity for the present and foreseeable future.
- Recommendations by some respondents included:
  - o Spectrum should be allocated in the 13 GHz band, which provides similar propagation characteristics as 11 GHz, and the 80 GHz band, as well, which is instrumental in supplying multiple gigabit access in dense urban areas. Both bands currently have equipment from Canadian and U.S. radio vendors.
  - o 50 MHz channels are especially preferred because they maximize the potential of the hardware. Currently, all new microwave hardware deployed is capable of supporting 50 MHz channels but is typically used only with 30 MHz channels. 40% of the radio's potential is going untapped in this scenario.
  - o Utilize Cross-polarization whenever possible to maximize capacity on a single channel.
  - o Make use of adaptive modulation (up to 256 QAM) in order to provide the highest-possible best-effort data rates.
  - o Deploy fibre where feasible, as it has better scalability.
  - o Systems in the 11 GHz band utilize high-modulation schemes up to 256 QAM, with good propagation and small channel bandwidths of 30 MHz–40 MHz; the spectral efficiency allows capacity up to 200 Mbps. In addition, the spectral efficiency is doubled by employing two independent microwave links, by using a single assigned pair on both polarities along the same path. This supports aggregated traffic upwards of 400 Mbps. With authorization to use 50 MHz of channel bandwidth, radio systems can achieve the same 400 Mbps at 256 QAM on a single radio and 800 Mbps at 256 QAM, when employing dual radio systems.

Research Analysis

As a review of trends in other markets, the U.S. market was reviewed. As can be noted, there are several parallels in the Canadian market to the U.S.

A 2009 FCC Report[22] on Mobile Wireless Competition summarizes the situation with backhaul facilities supporting cellular networks. It notes that, with growing mobile voice and data traffic, the existing backhaul facilities need to accommodate greater transmission capacity and, often, these facilities need major rebuilds. The U.S. study noted that cell-site backhaul capacity had increased four-fold between 2007 and 2011.

Three major technologies[23] are being employed for backhaul transmission, mainly digital wireline, fixed microwave and fibre-optical systems. The U.S. study estimated that, in 2009, some 71% of the

[22] 13th Annual CMRS Competition Report: http://wireless.fcc.gov/index.htm?job=cmrs_reports

[23] The 2010 CMRS Report discussed the growing need for backhaul solutions and alternatives. It is recognized by large cellular carriers, such as AT&T, that, as the mobile broadband traffic expands exponentially over their networks, a reengineering of the backhaul facilities will be needed, and wireline and fibre-digital systems will provide a large component of the backhauling, as microwave radio facilities will not be sufficient nor the most technical-economic solution. A mix of backhaul facilities will be needed where fibre will play an

backhaul traffic was carried over wireline carriers, 16.8% over fibre systems, and 12.3% using microwave transmission. In comparison to 2005, there was a decrease of 15% in the use of wireline systems, and, consequently, an increase of 11% for fibre optic and 4% for microwave systems.

Much like the U.S., it can be seen that, in Canada, several trends in the mobile market have led to the increased demands for backhaul capacity. The rapid growth of mobile computing devices incorporating video and Internet browsing has resulted in much higher bandwidth consumption than previously anticipated. As smartphone penetration accelerates, data services are becoming a dominant percentage of the overall traffic. The U.S. report noted that mobile data traffic is growing at exponential rates, and competitively priced mobile Internet services are enabling subscribers to consume more. The conditions in Canada are expected to replicate the U.S. experience.

The rollout of HSPA and HSPA+, with greater transmission speed, the availability of high-end smartphones and tablets, aircards for netbooks and laptops with an ever-increasing number of applications, will greatly increase the backhaul capacity requirements. Further, pressure will be exerted on backhaul facilities in the next year or so with the rollout of 4G mobile networks with a much higher access speed.

In Canada, Telcos have built significant fibre- and wireline-based distribution facilities in populated areas, along major highways and to many rural communities. Similarly, Cablecos have built significant fibre-distribution facilities in populated areas and between various cities. These facilities accommodate the needs of their cellular and broadband services. New-entrant operators have the challenge of rolling out their own facilities in a timely manner. Therefore, in many cases, new entrants must negotiate the use of backhaul facilities from existing carriers.

A significant number of fibre-optic facilities support many of the provincial broadband initiatives. In cities, the traffic of a cluster of three to five cell sites is often routed to a central control site by single aggregated microwave links and then routed off to fibre backhaul rings and wireline digital carriers. Cellular traffic can be typically offloaded at any of many points in a cellular network. In suburban and rural areas, microwave backhaul facilities often route mobile traffic over a few radio hops, and there is an accumulation of traffic as cell sites are added.

The Inventory Report summarizes the number of frequency assignments for two-way microwave bands between 2 GHz to 38 GHz. A number of these bands have been identified as the prime spectrum for backhaul facilities for the expanding number of cellular networks and for wireless broadband access systems. The microwave bands above 10 GHz are well suited for short hops (typically less than 16 km) to link cellular sites and broadband access hubs directly to networks or through other transmission backhaul facilities. Microwave bands below 10 GHz provide for much longer hops (20-50 km) and are most suitable for medium-to-long haul inter-city microwave transmission systems.

The Study concentrates on the microwave backhaul facilities used to carry the traffic of fixed and cellular networks. Several different backhaul technologies are deployed to meet the ever-expanding

increasing transmission role. Also, as much as 90% of the new smartphones are equipped with Wi-Fi, and companies, such as AT&T, have established more than 20,000 hot spots to permit their customers to offload to Wi-Fi. In some cases, up to 40% of the traffic is expected to be offloaded. Also, carriers will be able to route customer traffic through hot-spot installations so as to preserve capacity of the cellular networks. This will impact on backhaul requirements, as well as the access facilities.

traffic demand of cellular and broadband Internet networks. The main wireline facilities are digital-wireline carriers and fibre-system carriers.
As another wireless alternative to microwave backhaul, fixed bent-pipe satellites often provide backhaul to northern and remote communities.

This section of the Study focuses on the microwave backhaul in the 10 to 23 GHz bands. These facilities are greatly used in urban and surrounding areas. They have also been extensively deployed as short-distance links for handling cellular sites and rural fixed broadband traffic.

Result of Analysis

The distribution of cellular towers across Canada[24] has been reviewed to get a sense of the concentration of cell sites and associated backhaul microwave facilities. While not precise, however, a relatively decent estimate can be made of the backhaul requirements, assuming a mix of transmission facilities, including microwave backhaul links. This, in addition to information from the Inventory Report and other sources, was used to derive the estimates shown in the table below. The table shows an estimate of frequency assignment density per 100 square kilometres in Ontario cities.

Table 6.3.1 — An estimate of the highest frequency-assignment density areas of Canada, assuming that city area is approximately 10% cellular coverage area. (Source: Red Mobile Analysis based on Ontario cities, derived from Inventory Report Figures 2.2 and 2.3, and other sources, as discussed)

Band (BW)	Total Frequency Assignments [FA] in Canada	Percentage of FAs Assigned to Canadian Cities	Portion of Canadian City FAs Assigned to Ontario Cities	Est. of FAs for Ontario Cities	Est. Area of Ont. Cities (10% of cell coverage of 150,000 sq. km.) [sq. km.]	FA density per 100 sq. km. for Ontario Cities [FA/sq. km.]
11 GHz **500 + 500 (Now 375 + 375) MHz**	3700 FA	23% (851 FA)	45 % (i.e. 383 FAs out of 851 FAs)	383 FA	15,000	2.5
14 GHz **375 + 375 (Now 215 + 215) MHz**	7400 FA	33% (2442 FA)	47 %	1150 FA	15, 000	7.7
18 GHz **500 + 500 MHz**	9600 FA	53% (5088 FA)	45%	2290 FA	15,000	15.3
23 GHz **600 + 600 MHz**	7200 FA	75 % (5400 FA)	40 %	2160 FA	15,000	14.4

[24] Loxcell – Cell sites across Canada: http://loxcel.com/celltower

It can be noted that the Ontario Region has between 40% and 50% of all frequency assignments in Canada in the four prime bands. An assessment of the spectrum density of the Ontario cities is a good proxy of the highest frequency assignment areas of Canada.

Some additional observations based on interviews, review of research and industry participants include:

- The 11 GHz, 14 GHz, 18 GHz and 23 GHz bands are of main interest for cellular and broadband backhaul. Significant spectrum was reassigned in the 11 GHz and 14 GHz to accommodate DTH satellite and military services, of late.
- The 11 GHz and 18 GHz bands are the most popular microwave bands used by wireless carriers. In certain regions, an estimate of 20% and 35% spectrum vacancy may exist in the respective 11 GHz and 18 GHz bands, based on efficient spectrum planning. As opposed to this, in other areas, such as in London and Ottawa, there are only limited frequency assignments available in the 11 GHz band.
- There is a need for microwave links having greater than 30 MHz bandwidth (50 MHz or more) and larger capacity due to the ever-increasing mobile data growth;
- There is interest in the 4 GHz band for microwave backhaul. This band is currently under-utilized.

6.3.4 Services and Spectrum Demand

As with the other services, the projections for service demand in terms of traffic were first set out, then, based upon further review and analysis, relevant assumptions were used to convert these projections for traffic into a demand for spectrum. These were, then, modelled to develop projections for spectrum demand.

Service Demand: Market Analysis

It is estimated that there are approximately 28,000 bidirectional microwave backhaul links, with a further breakdown estimated as just more than 75% (21,500) for fixed networks and 6,500 for cellular. The fixed network backhaul links tend to be in deep rural/low-density locations; cellular backhaul links are a mix of urban and rural.

As busy links reach capacity and require upgrading, and as the economics of fibre versus microwave changes, there is a continuing offload of links and traffic from microwave to fibre-based systems.

The traffic that these links carry is estimated to increase in volume, but decline as a proportion of the total traffic carried by the fixed and cellular telecoms' networks, as follows:

- For fixed networks, the proportion of fixed network traffic carried over microwave backhaul declines from 10% to 5% over the period of 2010-15.
- For cellular, the proportion of cellular network traffic carried over microwave backhaul declines from 50% to 25% over the same period.

In both cases, this means that the volume of traffic carried over microwave backhaul continues to increase, but it increases at a slower rate than the trajectory for the total traffic over the network.

Figure 6.3.2, below, shows the projected growth in traffic over microwave backhaul. Fixed network traffic dominates, but cellular is projected to contribute to a growing proportion of the total traffic.

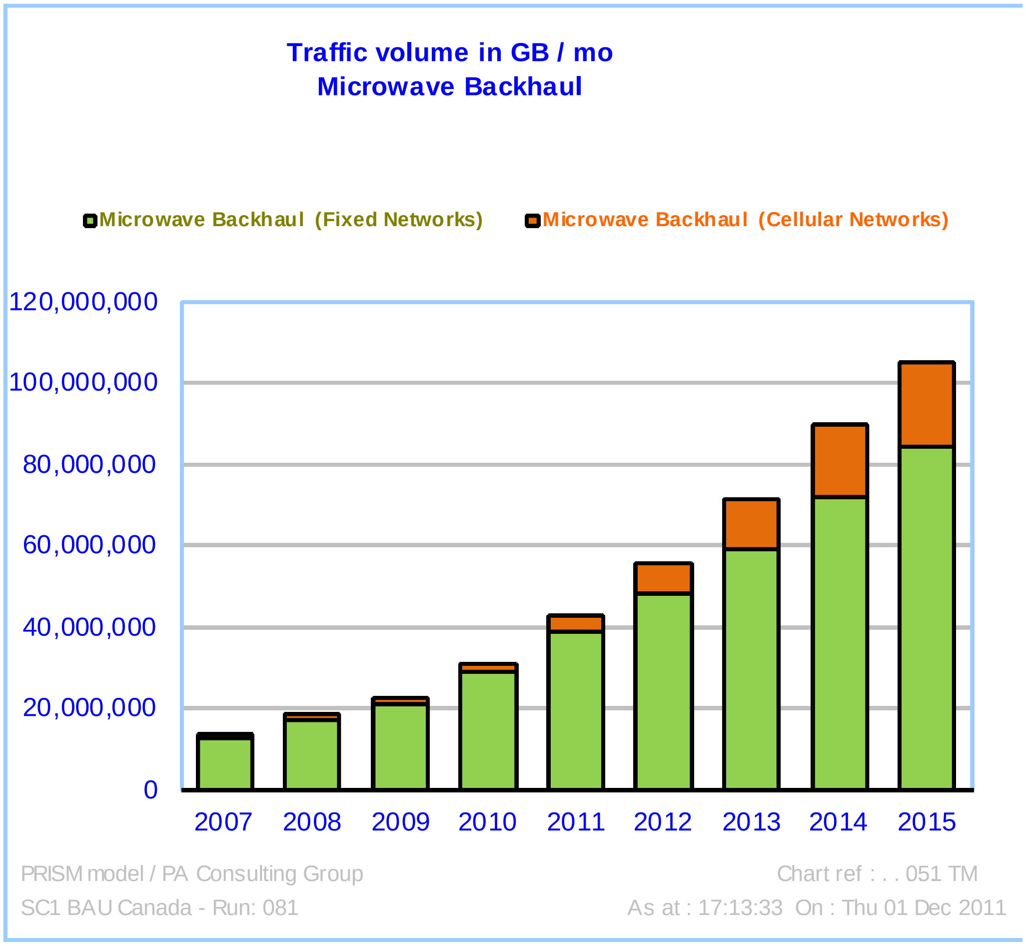

Figure 6.3.2 — Growth in traffic, Microwave backhaul (*Source: Red Mobile Projections*)

Key Assumptions and Relationship between Service and Spectrum Demand

Assumptions are given separately for Fixed and Cellular backhaul networks.

The main assumptions regarding fixed networks backhaul are as follows:

- Fixed network data traffic for residential subscribers is 15 GB/subscriber/month in 2010, rising to 90 GB in 2015.
- This traffic is scaled up by a factor of 1.6 to allow for non-residential traffic and non-data (voice) traffic.
- The number of links declines at 5% per annum;
- By 2015, 10% of the fixed network microwave backhaul traffic is routed over links operating at frequencies at or above 38 GHz. The traffic carried over these links is included in the projected traffic volumes for the microwave backhaul service, but removed before the demand for spectrum is calculated.
- Busy-hour traffic is 3.5 times that in the average hour, and required headroom (for minimizing latency, etc. and for delivering burst rates to individual users) is six times the average-hour traffic (approximately 1.7 times the busy-hour traffic).
- A factor of two is applied to allow for dual routing/ring architectures.

- A further factor of two is applied to the required capacity, to allow for some future growth in traffic without needing a further install of equipment.
- Spectral efficiency is 4 bits/sec/Hz, rising by 5% per annum.
- Backhaul links are often required to operate in series. A busy link needs to be dimensioned to carry traffic for six times the traffic on an average link.
- Where there are multiple operators in the same neighbourhood, backhaul links are licensed and implemented in a coordinated fashion across operators. A frequency reuse factor of three is sufficient to avoid interference between neighbouring/co-aligned links.
- Backhaul spectrum is all paired.
- So in total it is assumed that when a busy link (i.e. the link for the RAN site nearest to the core network) is dimensioned, it is sized to cope with the average traffic from that RAN site, scaled up as follows:
    - 6 times for busy hour and required headroom for that RAN site
    - Another 6 times for busy link, i.e. its carrying traffic for 5 other RAN sites as well
    - 3 times for ring architecture / resilience, i.e. it needs to be able to cope with a break elsewhere on the backhaul ring
    - 2 times for future - proofing

  Therefore, the Grand total is about 200 times the average hour traffic of the RAN site.

The main assumptions regarding Cellular networks backhaul are as follows:

- Cellular network voice and data traffic, for residential subscribers, is as described in the section on Cellular Services above.
- The number of links increases at 10% per annum.
- By 2015, 15% of the cellular network microwave backhaul traffic is routed over links operating at frequencies at or above 38 GHz. As with fixed backhaul, this traffic is included in the projected traffic volumes, but removed before the demand for spectrum is calculated.
- Where there are multiple operators in the same neighborhood, cellular backhaul links are licensed and implemented in a coordinated fashion across operators. A frequency reuse factor of six is sufficient to avoid interference between neighbouring/co-aligned links.
- The other assumptions — Busy hour, Required Capacity, Capacity for future growth, Spectral Efficiency, dimensioning for busy links and pairing — are all the same as for fixed networks backhaul.

Demand for Spectrum

Figure 6.3.3 shows the growth in the demand for spectrum. This demand is projected to grow by a factor of about three, slightly slower than the growth in traffic.

The drivers of this difference are: improvements in spectral efficiency and substitution to frequencies above 38 GHz.

There is also a shift in spectrum required, from fixed backhaul to cellular backhaul. This is driven by faster growth in cellular network traffic, but is offset slightly by an increase in the number of cellular backhaul links.

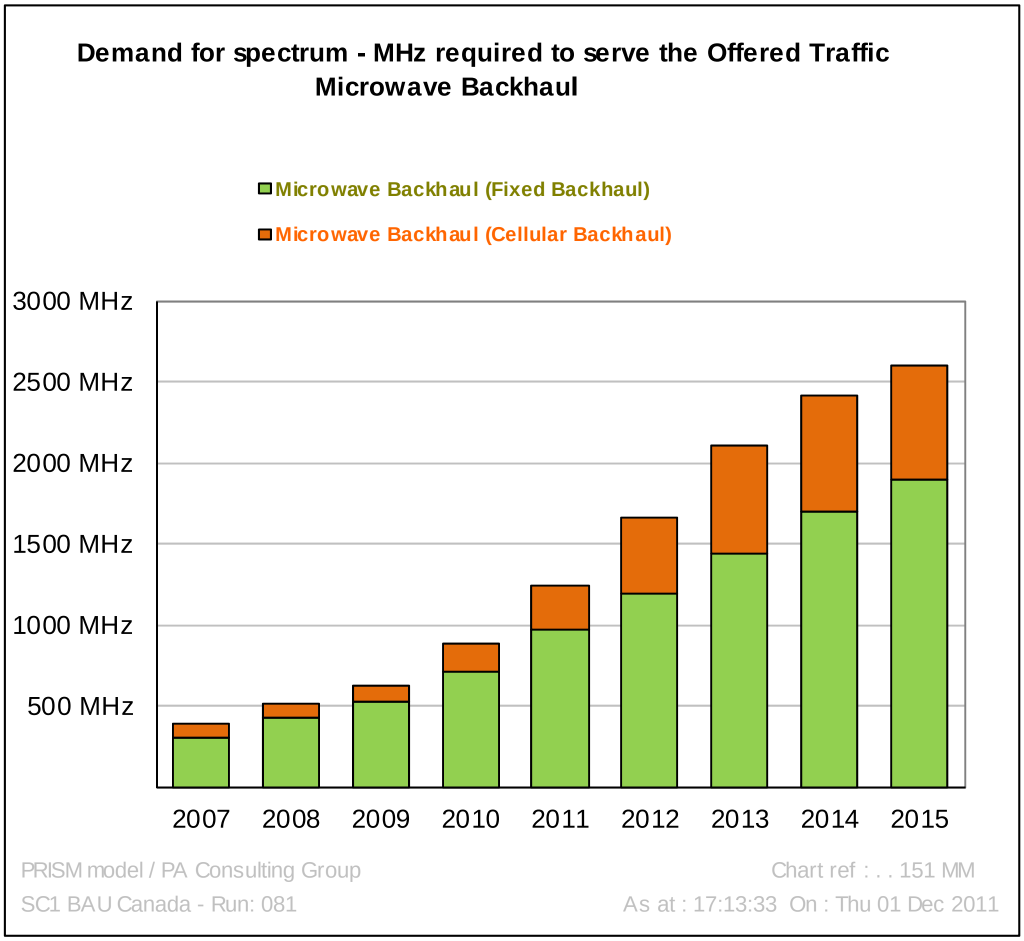

Figure 6.3.3 — Demand for Spectrum, Microwave backhaul (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

As with some of the other services, there are further factors not included in the projections (above) that are likely to create a balancing feedback loop. So, if spectrum did start to become a constraint for operators, they may have viable options for mitigating this, albeit at some cost. These options may include offloading a larger percentage of the traffic onto fibre, where possible, for high-demand areas/links; and/or greater substitution to higher frequency bands above 38 GHz, where feasible.

Assessment of Alternative Scenarios

Projections for traffic and for spectrum demand for microwave backhaul are shown in Figure 6.3.4 and Figure 6.3.5.

The primary differences between the scenarios are as follows:

Scenario 2:

- Higher traffic growth, by 2015, there is 1.5x the fixed network traffic and twice the cellular network traffic of Scenario 1.
- Share of traffic routed over microwave backhaul declines faster; by 2015, it is down to 4% of fixed network backhaul, rather than 5%.
- Take-up of frequencies above 38 GHz is twice as fast as in Scenario 1.

- Spectral efficiency improves at 7% pa, instead of 5%.

Scenario 3:

As with the other services, the underlying traffic growth on the fixed and cellular networks in Scenario 3 is the same as it is in Scenario 1. However, as there is less investment in fixed facilities for Scenario 3, therefore, more traffic goes over microwave backhaul in this case. Thus, we note a divergence in Scenario 3 mainly on the following inputs:

- Scenario 3 has less investment in fixed-network fibre backhaul, resulting in the share of traffic routed over microwave backhaul declining 30% more slowly over the period 2010-15 — reaching 7% of fixed network backhaul, rather than 5%. This results in some 50% higher volumes of traffic over microwave backhaul in Scenario 3, when compared against Scenario 1.
- This reduced investment in fibre backhaul also results in a 5% per annum (pa) growth in the number of fixed network microwave backhaul links.
- There is little or no migration to frequencies above 38 GHz.
- Spectral efficiency improves at 3% pa instead of 5%.

The net result of these differences is that Scenario 3 (*Low Investment*) has the highest level of microwave backhaul traffic in 2015.

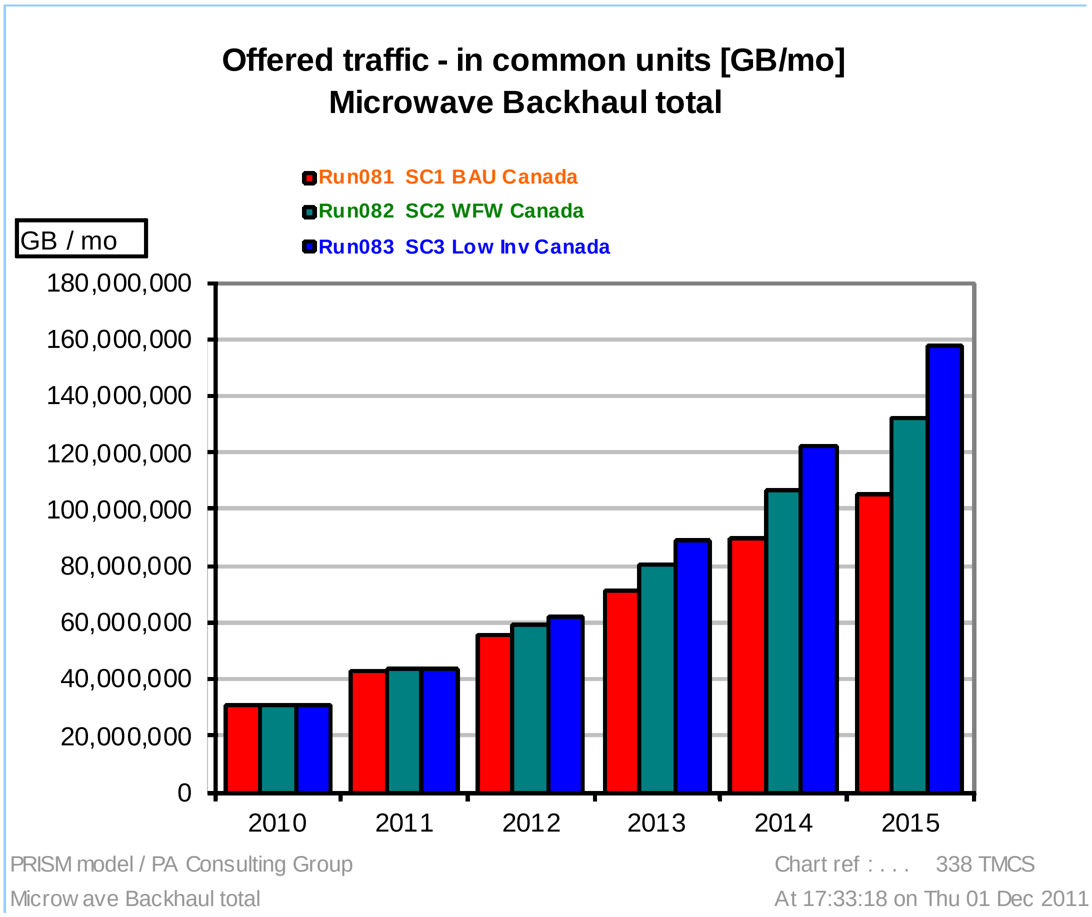

Figure 6.3.4 — Microwave Backhaul Traffic, by Scenario (*Source: Red Mobile Projections*)

When converted into a demand for spectrum, the higher traffic growth in Scenarios 2 and 3 is offset by differences in spectral efficiency, rates of growth/retention of microwave links, and offloads to frequencies above 38 GHz.

The resulting projections from spectrum demand are shown in the chart below. The net effect is that Scenarios 1 and 2 have similar demands for spectrum, and Scenario 3 has a slightly higher demand.

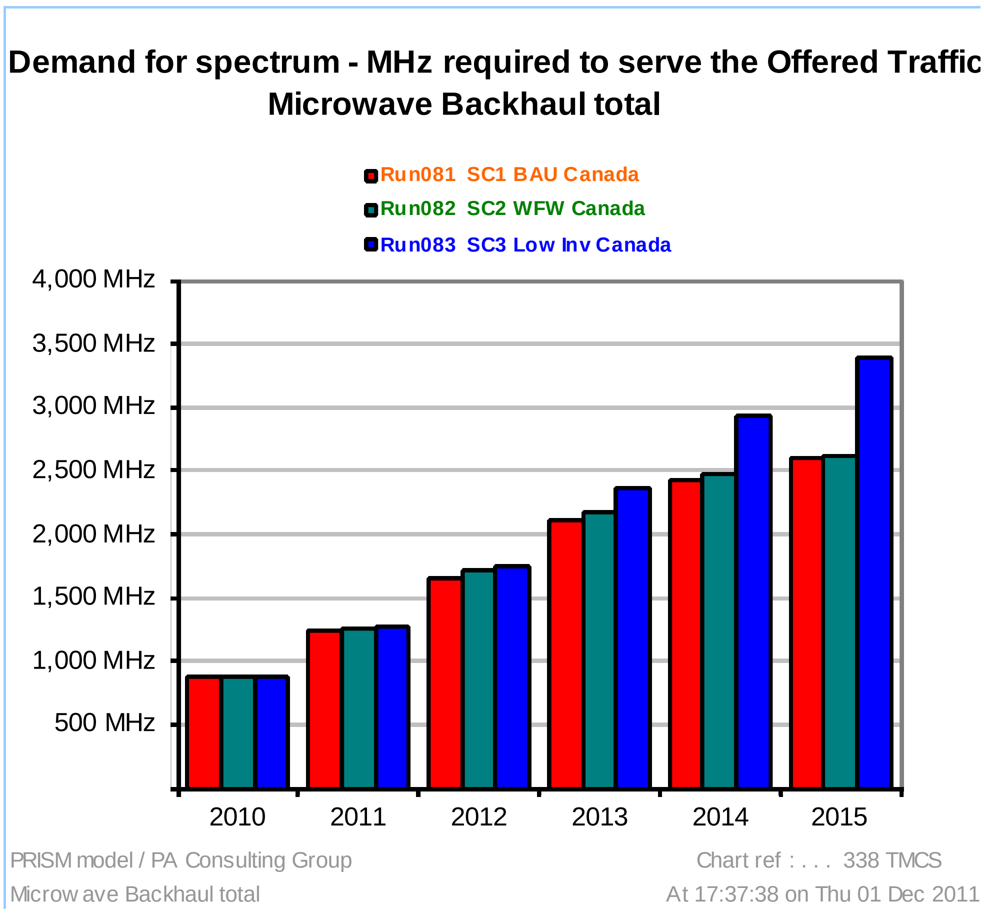

Figure 6.3.5 Microwave Backhaul – Spectrum Demand by Scenario (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

6.3.5 Conclusion

The Study has modelled the relative traffic (GB/mo) levels of the microwave backhaul facilities in the prime microwave bands (i.e. 11/14/18/23 GHz) bands, to carry cellular network and FWA broadband traffic (to collector points or concentrators) for the period 2010-2015. Then, the Study has converted these traffic levels of cellular and fixed networks to spectrum demand for the same period.

Results suggest that the prime microwave backhaul bands (i.e. 11/14/18/23 GHz) bands will see an increase in their demand for spectrum over the period of 2010-15, as HSPA and LTE networks drive growth in cellular traffic, and as fixed networks increase their appetite for high-capacity microwave backhaul links.

6.4 Broadcasting Services

6.4.1 Overview

This section covers television, FM radio and DTH Satellite.

Over-the-Air Television

Major developments are expected to continue to take place in over-the-air (OTA) television broadcasting with the transition to digital technology, from production to delivery of signals, over the next five years.

The benchmark established by the CRTC for converting standard analogue OTA TV broadcasting stations to digital television (DTV) in large markets (populations more than 300,000), provincial and territory capitals and Ottawa occurred on August 31, 2011. The new DTV allotment plan provides a digital channel to each TV broadcasting station below 698 MHz or TV channel below 52. A total of 526 standard-power TV stations and 871 low-power TV (LPTV) stations operate in the VHF broadcasting band; and 231 TV stations and 476 LPTV stations operate in the UHF bands. Within the 6 MHz, which is the digital channel assigned to each broadcasting station, the broadcaster may have the flexibility to operate an HDTV program with some ancillary program services, such as mobile TV, or two standard-digital TV (SDTV) programs or other combinations, including two programs each from different broadcaster entities. In Europe and the U.S., broadcasters are pursuing the development of OTA mobile TV broadcasting, using capacity within the channel assigned to their station. In large market areas and along the U.S. border (in the vicinity of large U.S. cities, such as Detroit, Chicago, etc.), the broadcasting spectrum below 698 MHz is heavily used, thus, leaving just a few spare channels for growth in Canada.

The implementation of digital broadcasting technology brings significant spectrum efficiency and substantial capacity within the new TV allotment plan below channel 52. Digital-emission technology, with proper compression, significantly increases programming transmission and enables the use of additional allotments (in comparison to unused taboo channels prevailing with analogue), the support of higher-definition programs and other signals within a 6 MHz channel. The main consideration is how the demand for more OTA services will be accommodated within the new allotment plan. Cable TV and satellite broadcasting distribution undertakings (BDU) account for more than 90% of the household broadcasting distribution (approximately 11.3 millions) according to the CRTC CMR Report for 2009. The top four cable TV BDUs and two DTH BDUs provide 89% of all BDU subscribers in 2009. Approximately 25% of these BDU subscribers receive their services from DTH and MDS facilities. A growing number of Canadians use the Internet to watch some video programming. Although OTA TV broadcasting serves less than 10% of Canadian households, it is an important component of the broadcasting system.

FM Radio

The FM radio-broadcasting band (88-108 MHz) supports 1450 standard-power FM stations and 900 low-power FM stations across Canada. In large-market areas, the availability of allotments for new stations has reached exhaustion (e.g. Toronto) or is near exhaustion. The proximity to large U.S. cities also decreases the availability of FM allotment channels[25].

[25] To a lesser degree, similar congestion situation exists for AM broadcasting spectrum (outside the scope of this Study), which is more affected by long-reach propagation of U.S. AM stations, and coordination is required to ensure reasonable signal quality, free from harmful interference.

In the 1990s, Canada endeavoured to develop a new generation of digital audio broadcasting (DAB) technology in the L-band (1452-1492 MHz) with some other countries, but, due to lack of affordable equipment and lack of synergy with the U.S. marketplace, DAB was not realized. The U.S. adopted an in-band on-channel (IBOC) digital solution, where, initially, a digital broadcasting signal is multiplexed with the existing FM or AM signal within the existing analogue channel and then, eventually, a full digitization of the bandwidth would take place. This approach is being gradually implemented in the U.S. and will provide additional programming service capacity with the existing AM and FM broadcasting bands. The Canadian broadcasters have been given full flexibility to pursue a similar strategy for a transition to digital radio broadcasting.

Although the introduction of new OTA broadcasting services is driven, in part, by the prospect of market demand, the implementation is very much controlled by the CRTC, which oversees and authorizes any new broadcasting undertaking, often assessing against limited spare broadcasting channels and using a competitive process. The merit and benefit of new programming applications to the CRTC and the sustainability and impact of the new stations on existing OTA stations in the areas influences the service demand and spare channels allotment.

The approval of new OTA TV stations and FM station is determined by the CRTC, which bases its decision on a number of programming objectives contained in the Broadcasting Act and in a set of broadcasting regulations. Although there may be a perceived demand for new commercial or educational broadcasting stations for a particular type of programming, applications must go through a rigorous public hearing process before the CRTC renders decisions. The growth of OTA broadcasting stations is influenced by the availability and the type of subscription on Broadcasting Distribution Undertaking (BDU) and by the broadcasting objectives, and not primarily just on market demand.

DTH Satellite Broadcasting

DTH Satellite broadcasting delivers hundreds of television and radio programming services to about 2.7 million home subscribers. Close to 90% of Canadian homes (or 11.3 million homes) received their television services from cable TV and DTH satellite broadcasting distribution undertakings (BDUs). It is estimated that less than 10% of Canadian households receive their television services from OTA television stations.

Canada has been operating two DTH satellite BDUs since the late 1990s, and each operator offered hundreds of television and radio programs to their subscribers. This includes the programs of national, regional and local OTA stations; groups of specialty channels; pay-per-view and movie channels; and national and regional radio stations and other audio services. DTH satellites compress these analogue and digital programming signals, using MPEG 2 and offer various service plans in both standard-definition television (SDTV) and high-definition TV (HDTV) digital format to a home set-top box and small dish antenna.

Over the years, the two DTH satellite operators have developed their respective television program lineup and secured long-term DTH satellite facilities from independent satellite network operators. One DTH operator has secured its satellite's capacity in two orbital-spectrum resource units at 91 degrees and 85 degrees longitude west, for an equivalent capacity of 64 satellite transponders in the Ku-bands (12/17 GHz broadcasting satellite bands). The other DTH satellite operator has secured satellite capacity in the equivalent to 1.5 orbital-spectrum resource units at 111.1 degree longitude west, for an equivalent of 36 satellite transponders in the Ku-bands (11/18 GHz fixed satellite bands). An orbital-spectrum resource unit is equivalent to 500 MHz spectrum in an orbital position for downlink services to the subscribers. (It is noted that interleave transponders operating in one polarization partially overlay the adjacent transponders operating at a different polarization in the 500 MHz band. This approach permits a satellite orbital-spectrum resource to enhance the satellite capacity to up to 800 MHz of throughput operating spectrum.)

In an effort to keep similar information together regarding satellite information, the full description of satellite communication spectrum-orbital resource, the Inventory Report, the stakeholders' inputs and other analyses is contained in the Satellite Section (Section 6.5) of this Study. This includes the relevant information on DTH satellite. However, as DTH satellites are used for the broadcasting market, this Study covers DTH satellite-spectrum demand modelling within this Broadcasting Services section.

6.4.2 Spectrum Inventory and Spectrum Utilization

The Inventory Report provides the following overview of the broadcasting environment in Canada.

Over-the air (OTA) Television Broadcasting
(53 – 72 MHz, 76-88 MHz, 174 – 216 MHz, 470 – 806 MHz)

As of June 2010, there were 2079 analogue TV stations in Canada: 732 regular and 1347 low power, as shown in the table, below, from the Inventory Report.

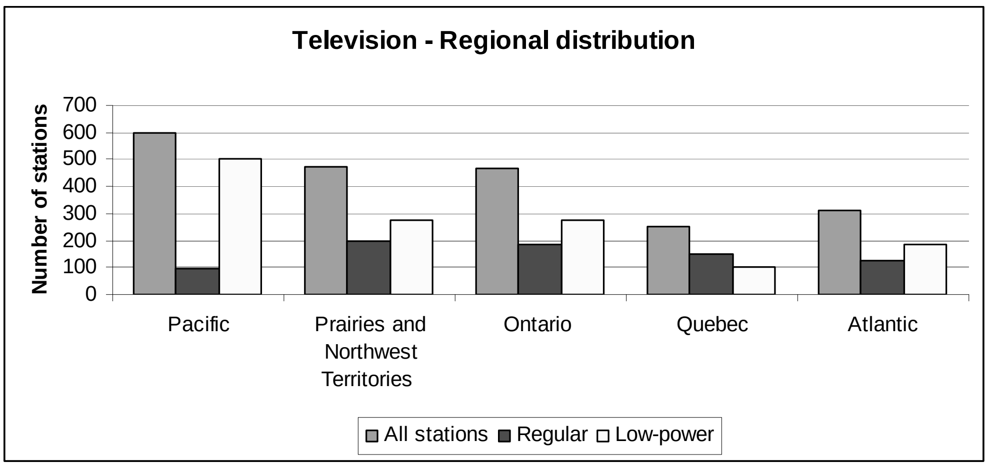

Figure 6.4.1 — Distribution of OTA TV stations, by region (*Source: Inventory Report*)

Major users include CBC/Radio-Canada (668 stations), The Ontario Educational Communications Authority (TV Ontario) (267 stations), CTV Television (122 stations), Aboriginal Peoples Television Network (94 stations) and CanWest Television (89 stations). There were 183 unique TV broadcasting station owners, 37 for regular stations only.

FM Radio (88 – 108 MHz)

A review is made of the actual FM allotments in large-market centres to determine occupancy, the progress of in-band on-channel (IBOC) digital technology by the American FM broadcasters, and any plan of Canadian broadcasters to move to digital technology. The potential of IBOC technology to increase the number of programs and ancillary services is also assessed.

As of June 2010, there were 2349 FM stations operating in Canada: 1456 regular and 893 low-power stations, as shown in the table, below, from the Inventory Report.

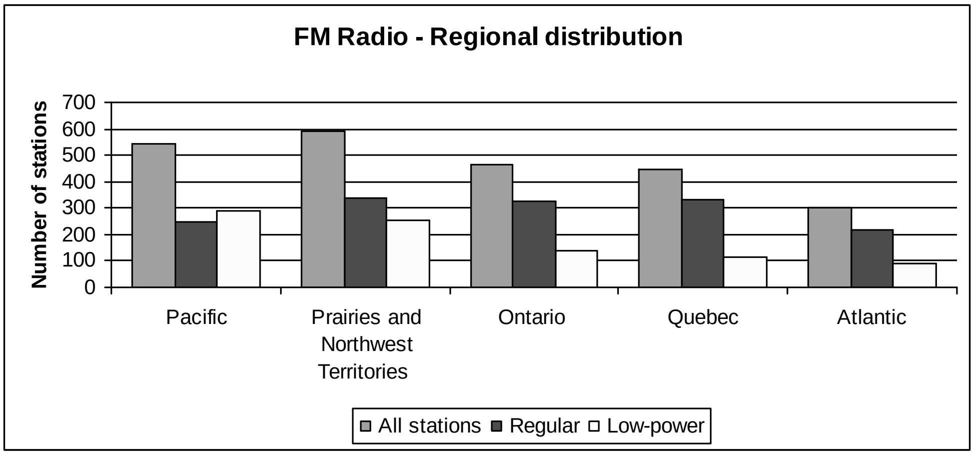

Figure 6.4.2 — Distribution of FM radio stations, by region (*Source: Inventory Report*)

Major users include CBC/Radio-Canada (560 stations), Astral Media (62 stations), Rogers Broadcasting (60 stations), Native Communications (56 stations), Newcap (51 stations) and Northern Native Broadcasting (51 stations). There were 672 unique FM broadcasting station owners, 334 for regular stations only.

6.4.3 Stakeholder Input and Research Analysis

Input from stakeholders and observations from interviews are summarized below:

- According to input from the broadcasting industry participants, in-band-on-channel (IBOC) technology in the FM band, adopted from the U.S., presents some concerns. Also, there is some ongoing debate over the power level of digital signals as compared with the analogue signal.
- Some stakeholders feel IBOC HD is likely to be the right choice for the Canadian radio industry. However, to ensure this, testing should be conducted to confirm for a smooth transition to digital of FM radio stations, while concurrently ensuring that adjacent analogue stations will not experience interference.
- One major broadcaster is planning to implement 27 DTV digital stations in mandatory markets, but does not intend to convert its remaining over-the-air television networks.
- CRTC rules for the digital transition merely provide for the minimum of OTA television stations, which must be converted to digital. It is expected that 75 to 100 OTA stations will have been converted to digital by the mandated date of August 31, 2011. As for stations in smaller markets, it is impossible to predict the period of time required to convert these OTA stations to digital.
- In Canada, a 50% conversion rate (OTA analogue to OTA digital) is realistic, given that there are no set-top box subsidies.
- OTA TV reception may not increase, as a percentage of Canadian households, given the existing dominance of cable and DTH BDUs, as well as their growing Internet services.
- According to some projections, OTA TV households will continue to slowly migrate to subscription TV services, and OTA TV will gradually decline from 10% in 2009 to 4% in 2012. However, there seems to be a renewed interest in OTA DTV. Interest in watching TV on a mobile phone is growing. In 2010, 19% of Anglophones and 14% of Francophones showed interest in watching TV on a mobile phone.
- Some broadcasters believe that there is a continued requirement for DAB channels at L-band for specialized, ethnic, community, campus, public and commercial programming. Also, they are of

the view that the L-band DAB should be licenced for wideband multimedia services, which would include a local DRB/DMB component, and the traditional broadcasting licence should be retained.

- It has been noted that, according to stakeholders' input, the radio industry would support a North American-wide reallocation of TV channels 5 and 6 (76-88 MHz) for a new, digital-only radio band.
- Radio Data System (RDS) is a communications protocol standard for embedding small amounts of digital information in conventional FM radio broadcasts. The RDS system standardizes several types of transmitted information, including time, station identification and program information.

Spectrum Utilization

Table 6.4.1 — Data compiled from Industry Canada DTV-Post Transition Allotment Plan identifies assignment for a minimum of nine OTA TV channels (*Source: Industry Canada*)

DTV (post-T)	NTSC	T-DTV	City	Station
2			Montreal	un-assigned
6			Montreal	un-assigned
10	10	59	Montreal	CFTM-TV
12	12	21	Montreal	CFCF-TV
15			Montreal	un-assigned
19	2	19	Montreal	CBFT
21	6	20	Montreal	CBMT
26	17	27	Montreal	CIVM-TV
29	29	54	Montreal	CFTU-TV
35	35	42	Montreal	CFJP-TV
36			Montreal	un-assigned
49	62	69	Montreal	CJNT-TV
51	46	51	Montreal	CKMI-TV-1
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5			Toronto	un-assigned
8			Toronto	un-assigned
9	9	40	Toronto	CFTO-TV
19	19	51	Toronto	CICA-TV
20	5	20	Toronto	CBLT
21			Toronto	un-assigned
25	25	24	Toronto	CBLFT
30			Toronto	un-assigned
40	52	66	Toronto	CKXT-TV
41	41	65	Toronto	CIII-TV-41
44	69	44	Toronto	CJMT-TV
47	47	64	Toronto	CFMT-TV
51	57	53	Toronto	CITY-TV

The Figure 6.4.3, below (Inventory Report, section 6.4), shows the growth in broadcasting stations over the last six years.

FM radio has seen increases in both regular and low-power operations during the last seven years (26.3% and 19.7%, respectively). This can be partially explained by a number of radio stations converting from AM to FM.

Television has seen increases in regular operations (2.2% analogue and 700% digital) and decreases in low-power operations (9.4%) within the last seven years. The large increase in digital television stations is due to their very low initial numbers and the beginning of the DTV transition.

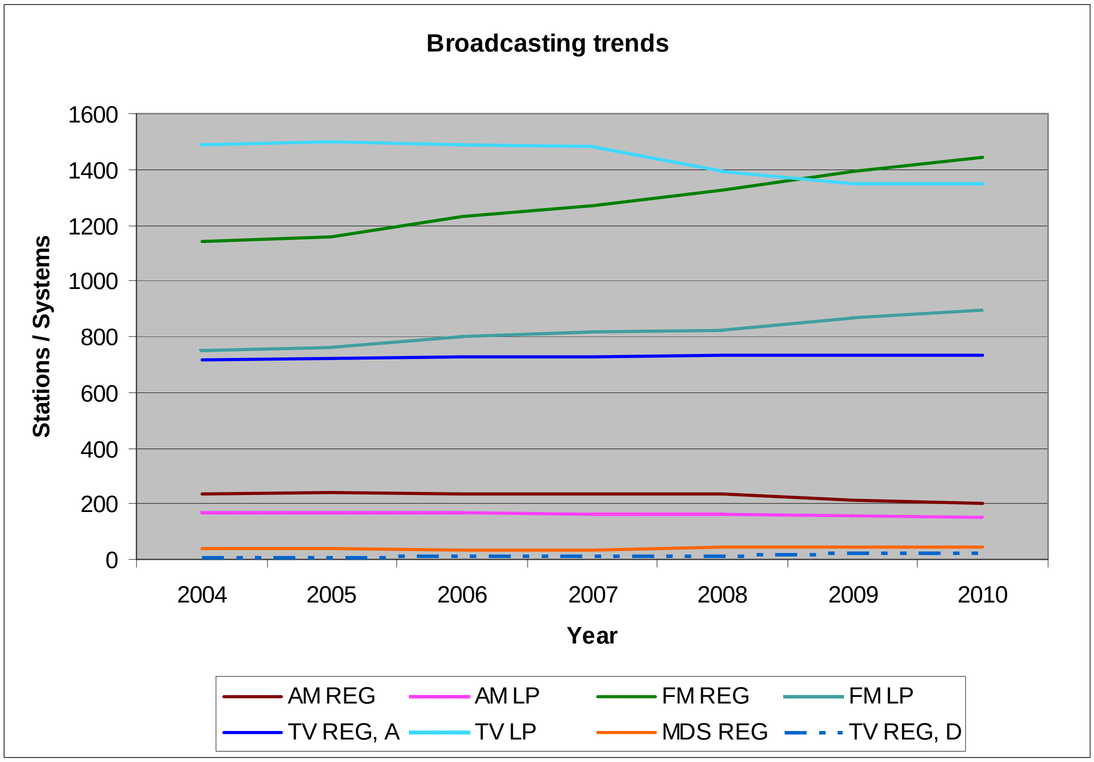


Figure 6.4.3 — Broadcasting: local and national channels, by technology, 2004-10 (*Source: Inventory Report*)

6.4.4 Services and Spectrum Demand

Service Demand: Market Analysis

When modelling the service and spectrum demand, it is important to note some key considerations in relation to OTA TV broadcasting in Canada, as highlighted below.

The model for spectrum demand under a digital broadcasting system assesses the capacity of 6 MHz channels to accommodate a range of simultaneous broadcasting offerings from HDTV, 3D-HDTV, SDTV, mobile TV and other distributive IP-based services.

As noted, more than 90% of Canadian households receive TV signals by cable or DTH satellite. However, for public policy reasons, OTA TV broadcasting will continue to be available from a number of stations.

Service demand considerations: In preparing the forecast of the demand for OTA TV spectrum, consideration needs to be given to the regulatory regime, the number of stations in operation per market and the capacity of the 6 MHz digital channel (19.3 Mbps). These are the factors that will govern TV broadcasting from 2010 to 2015. Broadcasters will want to respond to the emerging market needs to offer High-Definition TV, 3D HDTV, mobile TV, Standard-Definition TV and other service opportunities.

Regulatory-driven demand considerations: The CRTC's regulations will decide, in part, how many OTA SD, HDTV and mobile TV channels will be broadcast. The Advanced Television Standard Committee's (ATSC) current timelines for implementing digital TV for standard-power stations are: (i) major markets, provincial and territorial capital cities, (ii) areas with population more than 300,000; and, (iii) other areas where there is more than one local TV station broadcasting OTA signal. The OTA signal in these areas must be transmitting a standard-definition digital signal as of August 31, 2011.

Spectrum demand considerations: Converting a quasi-market demand for OTA TV will need to take into account the technology options, as well as the market demand and regulatory regime in place.

The North American digital standard is based on the ATSC's set of standard requirements, which provide a means for TV stations to upgrade to digital TV, including the transmission of HDTV and 3D HDTV. As such, the usual configuration is for a multiplexer to accommodate a single HDTV stream, plus one or two extra SDTV programs. Up to 6 SD (standard definition) TV programs could be accommodated by a 6 MHz OTA channel operating a 19.3 Mbps channel.

Table 6.4.2 — Capabilities of a 6 MHz channel or a 19.4 Mbps payload (*Source: Spectrum 20/20 Presentation*)

Program/digital bit rate (Mbps)	Bit rate required (Mbps)	Payload
0.4 Mbps	PSIP	-----
4-6 Mbps	2-3 mobile video	------
1-3 Mbps	SD multicast	Up to 6 SD
12 Mbps	Primary HD	1 HD and 2 SD or 1x 3D HD

Industry Canada has coordinated a comprehensive post-transition allotment plan for Canada, plus developed a detailed assignment of the allotments below channel 52 for each of the standard analogue TV stations. The Canadian TV broadcasters now have the frequency allotment resources to convert their analogue stations to digital TV broadcasting. The demand for channels (spectrum) will, therefore, depend on the number of TV channels (SD or HD) that are to be supported, and on any constraints imposed by frequency reuse across Canada and in coordination with the U.S.

The Study has considered the likely national demand for TV channels under the established DTV allotment plan in large markets, such as Toronto and Montreal, and identified the requirements, in terms of the range of potential broadcasting service offerings across Canada.

For terrestrial broadcasting — OTA Digital TV, and Analogue and Digital FM radio — there are two further important assumptions that should be borne in mind:

- A cap, or constraint, is applied to reflect the amount of available spectrum within the bands that each technology can use. For OTA TV, and for FM radio, this effectively caps the demand for spectrum at the current allocation.
- A suitable factor for frequency reuse (generally 5, for those broadcasting technologies that require frequency reuse) is then applied to get from the spectrum required to serve one local area in isolation (and ignoring cross-border interference), to get to a National figure of spectrum demand for Canada.

The Figure 6.4.4, below, shows the growth projections for the number of national-equivalent channels of each type of broadcasting services — OTA TV, FM Radio and DTH satellite (log scale). As the focus in this Report is on assessing the demand for spectrum, the figures are given in national-equivalent channels, i.e. with regional channels and licences aggregated to give a national-equivalent figure.

The projected pattern is as follows:

- Some traffic growth is observed in DTH Satellite TV services for Standard-Definition TV (SDTV) and High-Definition TV (HDTV) for the period of 2010-2015.
- For OTA radio and TV services, the view is that demand generally remains at the current level.

There are two further possibilities for OTA Broadcasting, although, in this Study, they are not projected to occur within the 2015 timeframe:

- Demand for commercial OTA TV broadcasting may be reduced, if there is a large decline in the number of households it serves. In these circumstances, the economics of serving the market may drive some operators to merge or reduce their OTA broadcasting services.
- Demand for OTA radio spectrum may alter — either an increase, if further spectrum becomes available — particularly if this becomes an international frequency plan, with corresponding economies of scale, which reduce equipment costs. Or, the demand may decrease, if users switch to streaming audio via other technologies, such as over fixed broadband, cellular or satellite.

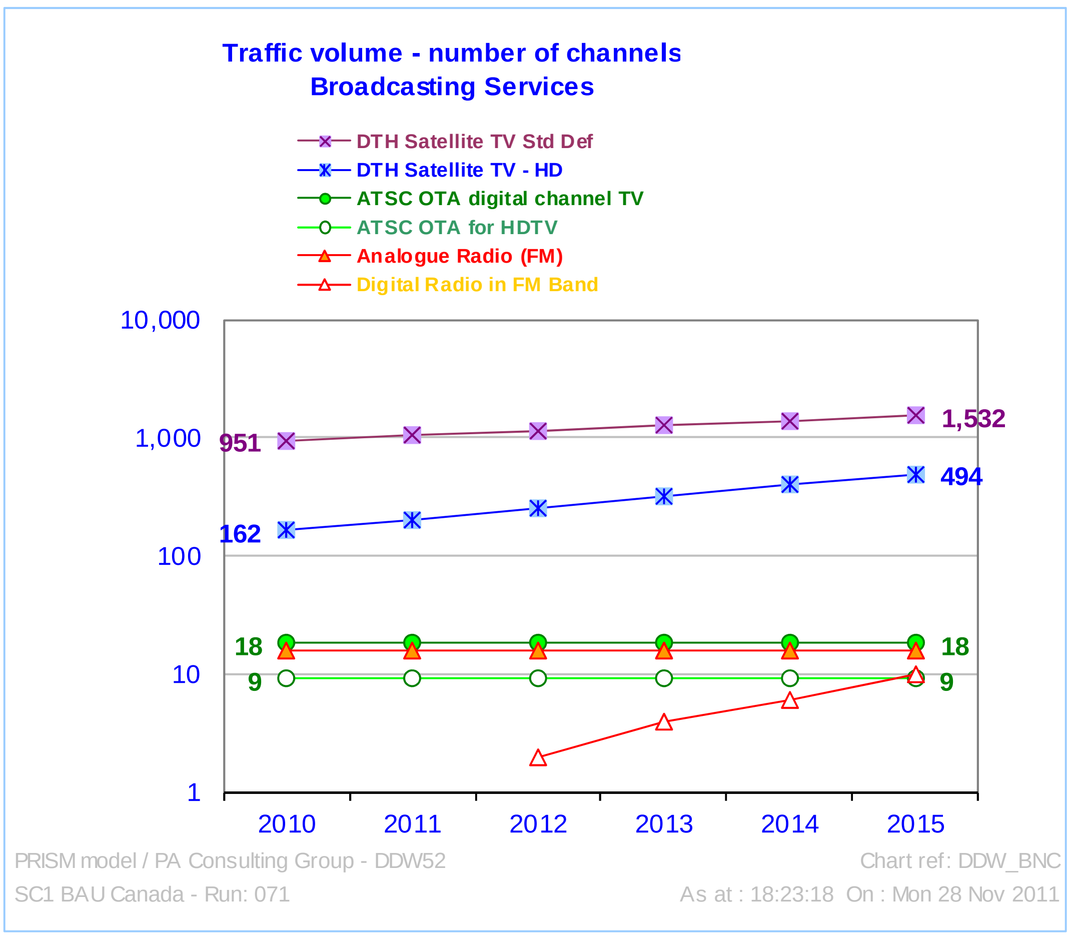


Figure 6.4.4 — Traffic volumes: Broadcasting – number of national-equivalent channels (*Source: based on Red Mobile Analysis*)

The next figure, 6.4.5, shows the traffic growth, converted into the common units of GB/month, and plotted on a log scale. Again, DTH Satellite Broadcasting shows some growth, and OTA remains constant.

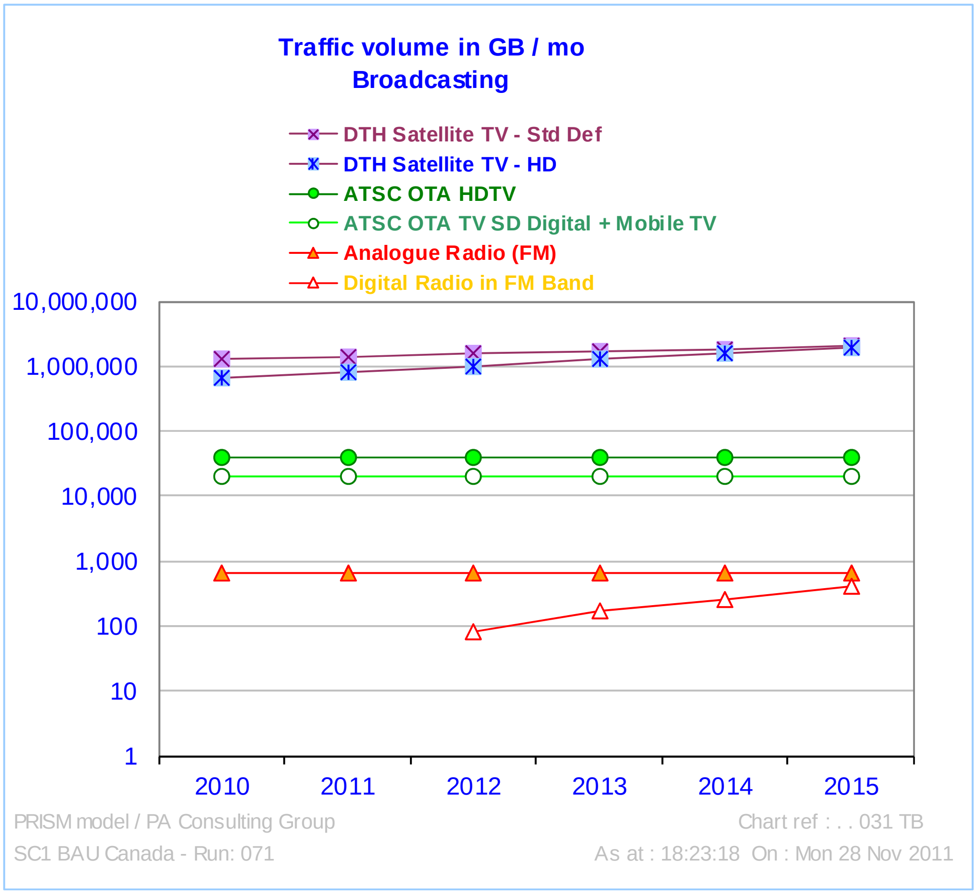


Figure 6.4.5 — Traffic volumes: Broadcasting, in GB/mo (*Source: based on Red Mobile Analysis*)

Key Assumptions and Relationship between Service and Spectrum Demand

In this Study, the preferred approach is to focus on a traffic-oriented metric that gives projections on how much spectrum the networks need to carry the traffic to serve consumers.

For Broadcasting services, there is a need to pause briefly to consider the concept of the "demand for spectrum", and to define it further: specifically, whose "demand" should be considered. For this service, unlike the other services, the approach is to project the demand for spectrum calculated from the viewpoint of the spectrum user or network operator, rather than a pure end-consumer viewpoint[26].

26 Alternatively: The approach used here simply assumes that consumer demand for the number and type of channels delivered over each technology is in line with the number and type of channels delivered by the broadcasting networks, i.e. that all of the diversity of content and delivery technology reflects consumer demand. If this assumption is broadly valid, then the approach used here for Broadcasting is in line with that used for other services.

It represents the spectrum that broadcasting networks require in order to deliver the volume of content they wish to broadcast.

For Broadcasting, there are no major changes expected over the period of 2010-2015 regarding the spectral efficiency of each of the individual technologies or networks. The likelihood of major changes in technology, such as a migration from MPEG-2 to MPEG-4, which would double the spectral efficiency of the networks, has been considered. However, MPEG-4 will not be compatible with the existing base of receivers currently in the hands of the public.

The resulting assessment is that these technological changes are likely to occur, but perhaps not in the time period of the Study, and that any gains from improved codecs or spectral efficiency would likely be absorbed by broadcasting networks migrating their content to higher resolutions and bit rates.

As a result of this, the changes in the demand for spectrum for Broadcasting are wholly driven by changes in traffic volume, and the results are less spectacular than those for the previous services in this Study.

Demand for Spectrum

The projection of the demand for OTA spectrum is shown below. Figure 6.4.6 covers OTA TV, and Figure 6.4.7 covers OTA FM radio.

Demand for spectrum for terrestrial services is projected to remain constant for both TV (270 MHz) and FM radio (20 MHz).

There will be demand for additional FM spectrum as broadcasters seek to provide digital, as well as analogue FM services, and the available spectrum is already congested. The large installed base of devices includes a significant number (i.e. in-vehicle), which cannot easily be switched to accept digital FM signals. This prolongs the requirement for analogue FM capacity to, at least, the end of the period of this study.

In addition to this, there seems to be a suppressed/pent-up demand for additional program channels from broadcasters. This suggests that there would be advantages to increasing the number of channels that FM can deliver to the installed base of devices. The main options for achieving this would seem to be converting to digital technology (noting the issues outlined above regarding the installed base), extending the band, or further reducing the channel spacing.

There are no corresponding issues for OTA TV because the digital switchover was completed in 2011, so analogue TV was excluded from the projections made in this study.

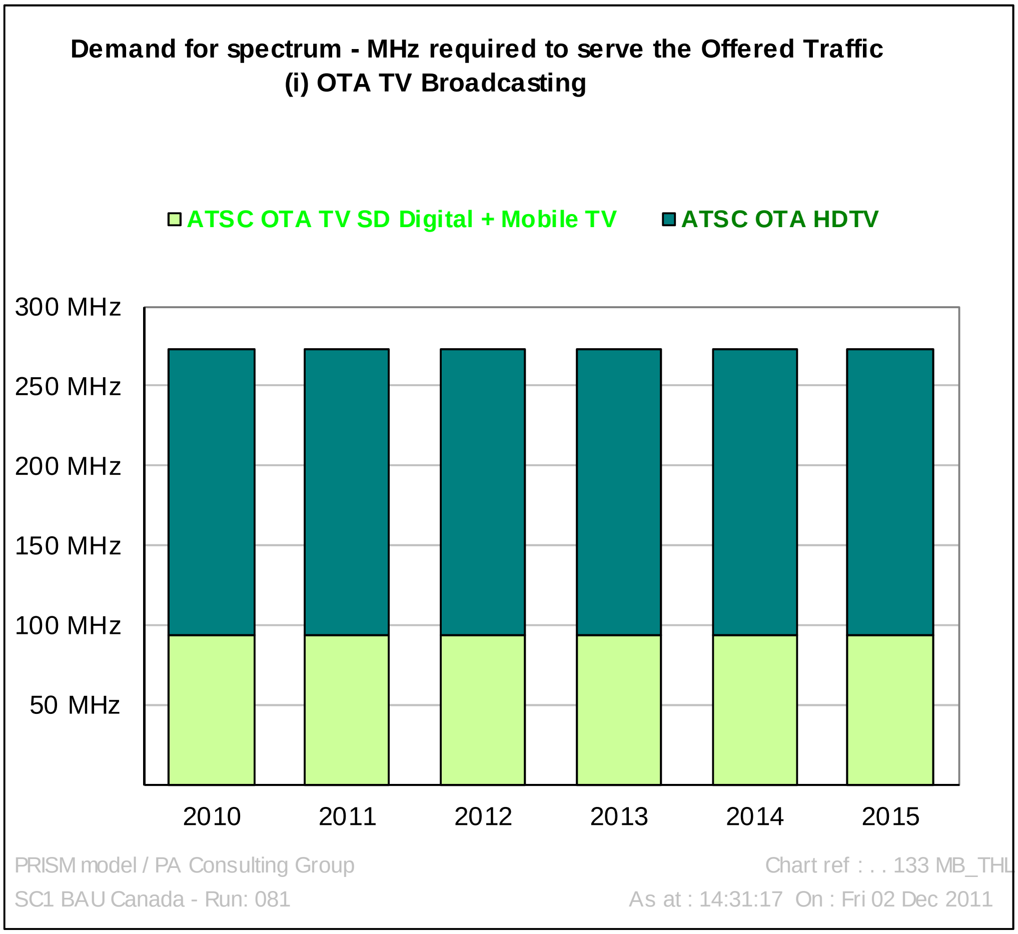


Figure 6.4.6 — Demand for Spectrum: Broadcasting – OTA TV (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

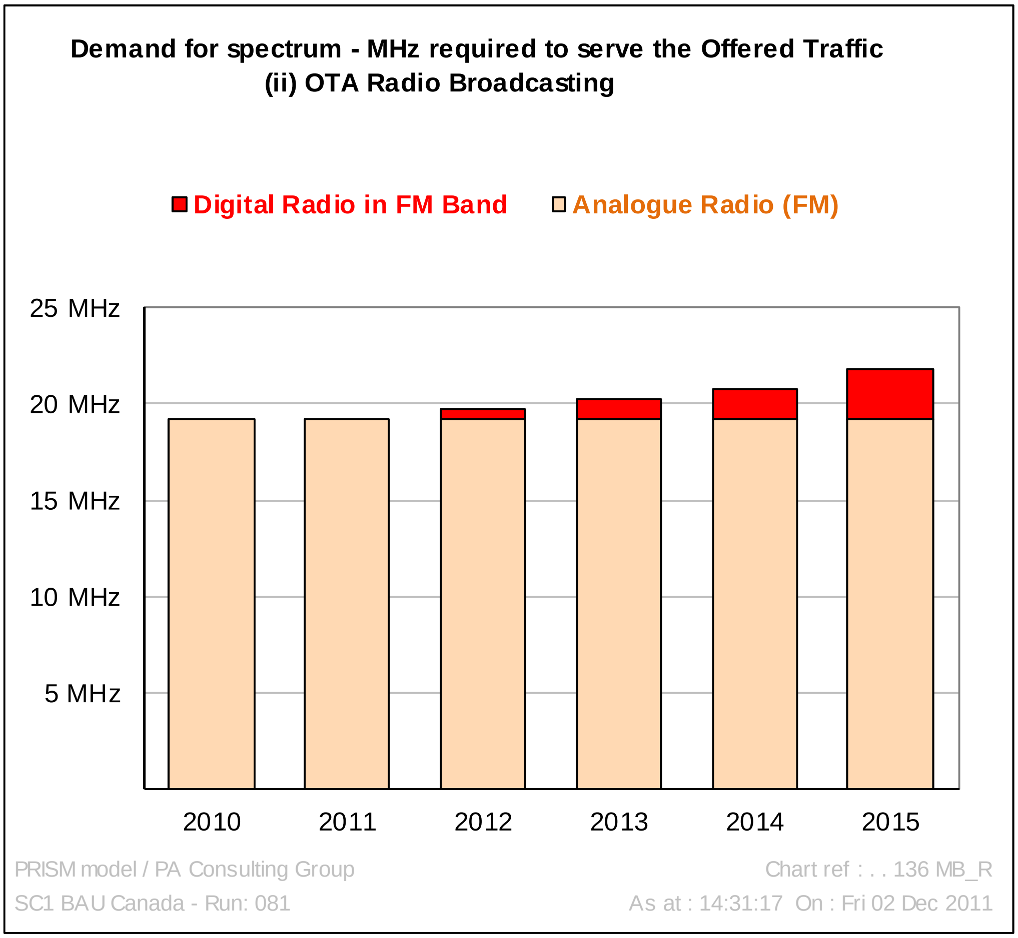


Figure 6.4.7 — Demand for Spectrum: Broadcasting – FM Radio (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

For DTH Satellite, Figure 6.4.8 shows that there is growth in demand for spectrum, as measured in the relevant units for satellite, MHz x Orbital Slots[27].

The growth in demand is largely fuelled by growth in HDTV, but is supplemented by continuing growth in the demand for a wider range of content channels for Standard-Definition TV.

27 Units are a combination of spectrum (MHz) and Geostationary Orbital Slots. So, for example, if demand were projected to reach twice the current capacity, it could be served by either a doubling of the amount of available spectrum, or a doubling of suitable and available geostationary orbital slots. (*Note that either approach would require a suitable deployment and allocation of satellites to Canada within the internationally agreed frameworks.).*

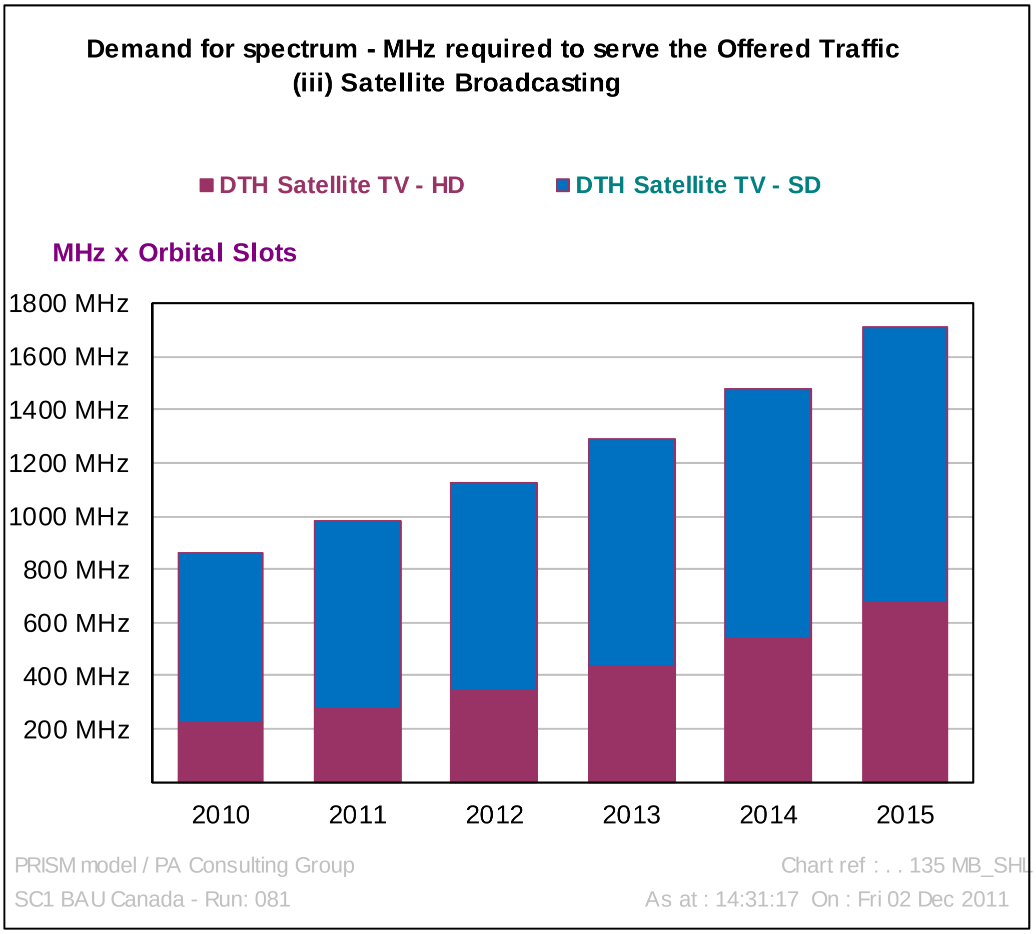


Figure 6.4.8 — Demand for Spectrum: Broadcasting, Satellite TV (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

The above projections assume no large-scale shift in encoding, from MPEG2 to MPEG4, over the period of 2010-15. If this were to occur, it could potentially reduce the demand for spectrum by a factor of 2, although it would appear likely that some or all of this would be taken up by broadcasters electing to upgrade more channels to HD (and/or to 3D), or to add more channels at SD.

Assessment of Alternative Scenarios

The projections given above are for Scenario 1, *Business as Usual* (BAU), which constitutes the central scenario considered for this Study. However, two other scenarios have also been modelled to give an indication of some of the possible alternatives:

Scenario 2 – *Wire-Free World*
Scenario 3 – *Low Investment*

The assessment of these scenarios was as follows:

- During the period of 2010-2015, OTA demand for spectrum remains the same as it is in Scenario 1, *Business as Usual* (BAU).

- In this same time span, the rate of growth in DTH satellite TV channels is likely to vary, with consequent impact on the demand for Satellite Broadcasting spectrum.

The figure below shows the spectrum-demand projections for DTH Satellite Broadcasting. There is higher growth in demand in Scenario 2 and lower growth in Scenario 3. The differences are driven by different growth rates of HDTV and SDTV channels.

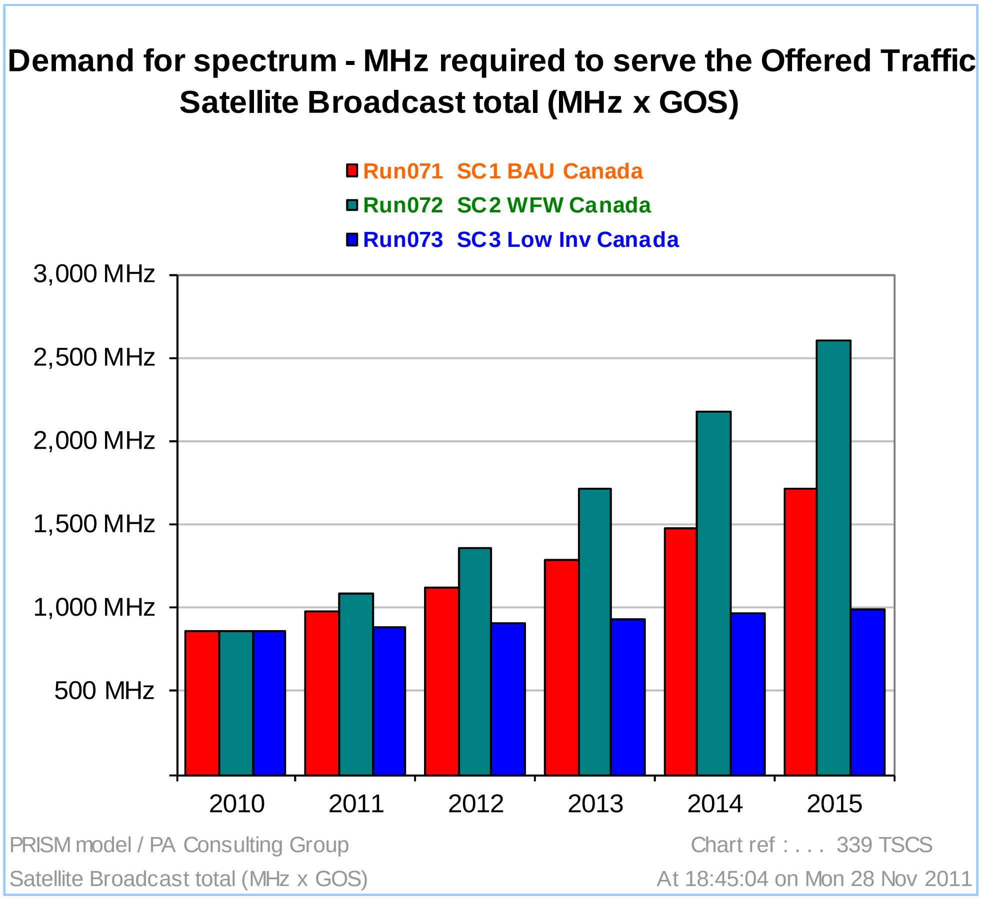


Figure 6.4.9 — DTH Satellite Broadcasting Services: demand for spectrum, by scenario (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

6.4.5 Conclusion

This Study shows that the spectrum demand for OTA Television is relatively flat. However, within the DTV Allotment plan, a small number of spare channels are available for growth (See allotment for Toronto and Montreal in Table 6.4.1). Moreover, within the ATSC digital channel of 19.3 Mbps, there are opportunities for broadcasters to offer a mix of HDTV, SDTV and mobile TV programming within an assigned 6 MHz OTA TV broadcasting channel. The demand for spectrum will remain at 270 MHz, however, service growth will occur within the allotted 6 MHz channels.

It is noted that congestion of FM Radio spectrum exists in large markets, such as the Greater Toronto Area. There will be continued pressure as AM stations aspire to convert to FM broadcasting. The use of IBOC digital broadcasting within existing FM channel allotment may offer a way forward to expand the use of the FM band. But, it is envisaged that the FM radio spectrum will remain the single most congested band of any of those assigned to the High-Value Services, over the period of the Study, and there are limited grounds for expecting this to change in the years immediately following 2015.

Three scenarios of DTH Satellite service and spectrum demand were modelled as shown in Figure 6.4.8, above. The number of SDTV is estimated to grow from 951 to 1532 programs from 2010 to 2015. Similarly, the number of HDTV grows from 162 to 494 programs. In 2010, about 800 MHz (orbital-MHz units) is needed for the equivalent of less than two DTH satellites.

However, in 2015, depending on which scenario is used, a range of 1000 MHz to 2600 MHz (orbital-MHz units) will be needed. For the *Business as Usual* scenario, the equivalent of 3.5 DTH satellites will be required. As the two DTH satellite operators have already procured the equivalent of 3.5 DTH satellites (as indicated in the Overview, Section 6.2.1), there is sufficient satellite capacity to meet the service demand. Some DTH satellite operators (See the Stakeholders' comments in the Satellite Services section (Section 6.5)) have indicated that some satellite capacity is available on new DTH satellites currently being put in service.

6.5 Satellite Services

6.5.1 Coverage of Satellite Services in this Report

This section covers all commercial communication systems using satellite technology.

The analyses and findings cover the following the following three categories of satellite communications services:

1. Mobile Satellite Service (MSS);
2. Fixed Broadband Satellite communications; and
3. Fixed (Bent-pipe) Satellite communications

This section also presents the supporting stakeholder and technical information on Satellite Broadcasting (DTH) regarding orbital slots, bands and stakeholder comments[28].

The table below summarizes the classification of satellite communications and broadcasting services used in this Report, showing where each can be found and how they map onto other classifications used for satellite services.

[28] The traffic assumptions and the spectrum demand projections for the DTH services are included with the rest of the Broadcasting Services in Section 6.4, above.

Classification and terminology used in this Report	Methodology used	Where is it analyzed?	Where is the stakeholder and technical research data?	Mapping onto BSS / MSS / FSS
Mobile Satellite Service (MSS)	PRISM model – Satellite Communications module	6.5.4 Satellite Communications	6.5 Satellite Communications	MSS
Fixed Broadband Satellite Communications	PRISM model – Satellite Communications module	6.5.4 Satellite Communications		FSS (part)
Fixed Bent-pipe Satellite Communications	High-level analysis	6.5.5 Satellite Communications		FSS (all of it other than fixed broadband)
DTH Satellite Broadcasting	PRISM model – Broadcasting module	6.4 Broadcasting services		BSS

6.5.2 Overview

Due to Canada's large landmass, satellite communication continues to play a critical role in providing telecommunications to all regions. Key examples of use include:

- Linking remote and northern communities with Southern Canada;
- Delivery of broadcasting programs to CATV cable head-ends;
- Delivery of broadcasting program networks;
- Distribution of DTH broadcasting satellite services;
- Provisioning of commercial VSAT networks;
- Enabling access to broadband Internet services in remote rural areas;
- Provisioning of specialized government communications; and
- Enabling mobile satellite services.

Four categories of satellite services are treated in this Report, namely:

- Broadband Satellite Service (modelled in this section);
- Mobile Satellite Service (modelled in this section);
- Fixed Bent-pipe Satellite Service (analyzed in this section); and
- DTH broadcasting satellite service (modelled in Section 6.4, under broadcasting).

During the past 10 years, new fleets of Canadian satellite networks have been built or authorized. These include the following:

- Fixed Broadband Satellite Communications in the Ka-Bands (19.7-20.2 GHz and 29.5-30.0 GHz);
- Fixed Bent-pipe satellite Communications in the C-bands (4/6 GHz), Ku fixed satellite bands (11/18 GHz) for a range of commercial telecom services;
- Direct-to-home (DTH) Satellite Broadcasting in the Ku broadcasting band (12.2-12.7 GHz) and the Ka broadcasting band (17.3-17.8 GHz);
- Also, new Mobile Satellite service Communications networks have been built in the L-band (1.5/1.6 GHz) and 2 GHz band to serve Canada, the U.S. and other markets.

For reference, a summary of the Canadian satellite inventory per frequency band and geostationary orbital slots is as follows:

- New Fixed Bent-pipe satellite networks are presently operating in three prime orbital slots (providing coverage in Canada and abroad) in the conventional C- and Ku-bands;
- New Fixed Broadband satellite networks are authorized in four orbital slots in the Ka-band;
- DTH Satellite Broadcasting networks are operating in five orbital slots in the Ku-bands;
- Also, DTH Satellite Broadcasting networks have been authorized in seven orbital slots in the Ka-bands, but have yet to be deployed; and
- New Mobile Satellite Broadcasting Networks are operating in the L-band and 2 GHz band.

A large percentage of the newer Canadian satellite capacity is committed to serving the U.S. market. However, this is done with condition of licence to ensure that sufficient capacity is retained to serve the Canadian broadcasting industry. This includes, in particular, Canadian DTH broadcasting satellite services and TV program carriage, which have historically used more than 60% of the Canadian fixed-satellite capacity. In addition to Canadian communications satellites, a large number of foreign satellites (more than 50 satellites) have been permitted to serve the Canadian market for telecom, broadband access and mobile services.

6.5.3 Spectrum Inventory and Spectrum Utilization

Section 7.0 of the Inventory Report contains a list of operational and authorized Canadian and foreign satellites permitted to serve the Canadian market. For simplicity, the information in Figures 7.3 to 7.8 has been summarized in Table 6.5.1, below.

Table 6.5.1 — Summary of satellite orbit-band resources (*Source: Inventory Report*)

Type of satellite (orbit-band)	Canadian satellite-operational (orbit-band)	Canadian satellite - with authorization	Foreign satellite, operational	Foreign satellite - To be implemented
Fixed Bent-pipe Sat; C-band	4	0	53	0
Fixed Bent pipe Sat; Ku-band	4	0	52	0
Fixed Bent-pipe Extended Ku	2	1	24	0
Fixed Broadband Sat; Ka-band	5	3	6	
DTH Sat; Ku-band	7	1		
DTH Sat; Ka-band	0	7		
MSS- LEO 1.6/2.4 GHz	0	0	2	
MSS- L-band; 1.5/1.6 GHz	1		4	1
MSS 2 GHz	1			1

6.5.4 Stakeholder Input and Research Analysis

Comments from stakeholders

General

- From the perspective of a satellite network carrier, there is un-met incremental satellite capacity demand to address broadcast, broadband and VSAT requirements in the Canadian market. For example, the two DTH satellite broadcasters have not secured satellite capacity for hundreds of

CRTC Category 2 licensed broadcasts (digital specialty and pay programs). There is a significant demand for un-met Ka-band broadband VSAT service and some use of U.S. and FSS satellites.

- The aforementioned carrier also believes that, given the development lead-times typical for satellite spectrum, a 10-year analysis of demand may be more useful than the current five-year analysis.
- Further, it was suggested that, given the current economics of the Canadian marketplace, it has been difficult for Canadian satellite operators to interest Canadian satellite networks in pre-committing to new growth satellite programs in the near term.
- A satellite-carrier perspective of this is that Industry Canada has awarded sufficient satellite spectrum to the two Canadian FSS/BSS satellite facility operators to meet near-term demand for satellite services.

Fixed Broadband Satellite Communications

- According to a service provider, market research shows *worldwide* demand for broadband access supply will grow by more than 38% per annum over the next 10 years. A supply of nearly 350 Gbps will be required by 2019 to cover the number of projected broadband subscribers. This is equivalent to approximately 100 satellites (at 2 Mbps per MHz) assuming that the average subscriber will require less than 100 kbps (specifically, 60-70 kbps) by 2019.
- The service provider estimates that 1 million Canadian homes and businesses will want broadband satellite in the next 10 years. These users either have no access (other than dial-up), or have only high-speed service (but not broadband, defined as 1.5 Mbps or greater).
- A broadband service provider indicated that it is securing 10%-15% broadband Ka-band capacity from two U.S.-based satellites. While this will support the service provider's near-term (three-year) plans, it will be insufficient to support its mid- to long-term needs.
- As an example, the broadband service provider indicated that ViaSat and Hughes are preparing to launch high-throughput satellites to provide low-cost Broadband services in the U.S. Both foreign operators have designed beams to cover the high-population density areas of southern Canada (at minimal incremental costs to the overall satellite program). A single Canadian service provider has procured satellite capacity on these "Canadian beams" from both foreign satellite operators. However, the consequence of this development is that the foreign operators' Canadian beams do not cover broadband services for Canadians living in rural and remote areas (including the far North).
- High-speed access to the Internet in rural and remote areas will drive demand for FSS satellite spectrum.
- Migration of VSAT and broadband services from traditional satellite payloads to high-throughput satellites using Ka-band FSS spectrum;
- Continued rollout of terrestrial and wireless technologies could reduce the demand for satellite-based broadband and wireless services in Canada's rural and remote areas.

DTH Satellite Broadcasting Service

Some of the trends envisaged by DTH satellite carriers are highlighted below:

- Ongoing demand for HD & 3D TV programming will increase demand for the FSS & BSS satellite spectrum;
- Potential migration of subscribers from cable/DTH to IPTV via wired links may negatively impact demand for FSS & BSS satellite spectrum;
- Aside from anticipating increased Internet service delivery over satellite in certain remote areas in the future, the biggest demands on satellite capacity will be for video, namely, MPEG 4, and high-definition programming;

- A satellite network operator indicated that Industry Canada has done an excellent job of securing FSS and BSS spectrum for use by Canadian satellite operators in the Canadian market and throughout the Americas. The satellite carrier has a sufficient backlog of satellite spectrum under development to meet its near-term market requirements;
- A new BSS satellite was launched in 2008, and no Canadian DTH service provider has expressed an interest in its capacity for the Canadian market.
- The Canadian DTH service providers appear satisfied with their current in-orbit capacity and limited incremental capacity under construction. However, ongoing demand for HD and 3D TV may drive demand for new spectrum in Canada over the next five to 10 years. The issue is the lack of interest from the Canadian satellite service providers in pre-committing to new-growth capacity to meet consumer, enterprise and government demand for satellite services.

Mobile Satellite Service (MSS)

- The new generation of L-band MSS satellites makes use of contiguous spectrum blocks from 1.25 to 10 MHz. This generation of satellites has been planned since the mid-1990s and should provide 10-15 years of service. The MSS L-band is shared with several operators, some of whom use first-generation MSS satellites.
- Next-generation mobile satellites will be capable of providing "cellular-like" mobile communications services to rural and remote users, and also will be able to support significant growth. Mobile satellite users will have channel bandwidths of 1.25 MHz, which is a significant jump from the 6 kHz channel bandwidth used for first-generation MSS satellites (>200 times).
- Overall demand for Canadian mobile satellite voice services is expected to increase by 10% to 15% over the next five years. Dual-mode handsets for MSS and terrestrial ATC (cellular operation) could increase the uptake of voice services by 75% over the same period, and by more than 400% over the next 10 years.
- The number of MSS devices is expected to double by 2015, and MSS data services are expected to experience a 350% growth by 2020.
- The upcoming MSS service in the X-band will provide additional capacity for services.

Research

Fixed Broadband Satellite Communications

As a first step**, t**he share of fixed broadband satellite facilities as part of the overall fixed broadband Internet market size was determined. The vast majority of Canadians are served by wireline facilities (cable modem and DSL) and FWA facilities (outlined in the FWA section).

The starting point for the estimation of traffic and subscribers was CRTC's Annual Report on the state of broadband subscriptions, types of facilities, number of households already passed by various access facilities, the average broadband consumption per subscriber, and other relevant information. In addition, input was received from some service providers on broadband satellite services used to provide broadband access, and the economic opportunities for broadband satellites to address un-served or under-served broadband rural areas.

As of 2009, wireline broadband facilities (cable modem and DSL) with capacity of 1.5 Mbps or more passed by 100% of urban households and 82% of rural households. Therefore, 18% of the rural households are considered un-served or under-served. In the FWA section, it is established that wireless FWA and broadband satellite facilities offer the best business case by serving the rural market, and wireline facilities are not a feasible approach for technical and economical reasons. Thus, in the assessment of this Study, the focus was on the number of rural households and businesses, especially in moderate and sparsely populated areas, which have little or no access to broadband facilities.

The fixed broadband satellite facilities consist of advanced Ka-band (19/29GHz bands) satellites designed with multi-beams coverage and with both feeder and service links, to provide high-speed Internet service to homes and businesses.

Mobile satellite service (MSS)

The first step is to estimate the number of subscribers in Canada presently being served by all mobile satellites. In the past decade or so, the mobile satellite industry has struggled to achieve a significant level of subscriptions. In the 2008 timeframe, The FCC estimated that a total of 1M mobile satellite subscribers accessed voice and data services via U.S. Geo-stationary Orbit (GSO), which is mobile satellites operating in the L-band (1.5/1.6 GHz) and non-GSO mobile satellites in the 1.6/2.4 GHz bands.

A new generation of multi-beam mobile satellites is being launched in the L-band and 2 GHz band. These new satellites promise to greatly improve the quality and throughput capability of mobile satellite services. Furthermore, regulatory provisions have been made to permit the development of an Ancillary Terrestrial Component (ATC) (cellular mobile overlay) using the MSS spectrum and to offer integrated MSS and ATC services. This approach would permit subscribers with dual-mode handsets to access either MSS or ATC services depending on their location and preference. This is expected to help increase the up-take of mobile satellite service over the next five years. The Study estimates the existing mobile subscription on first-generation satellites and handsets to be approximately 100,000 subscribers (10% of U.S. market).

The new generation of MSS satellite services and handsets are expected to be equivalent to 3G (cellular-like) capacity and features. Over time, most consumers and businesses are expected to replace older devices as these devices are phased out.

6.5.5 Fixed Broadband Satellite & Mobile Satellite Services: Service and Spectrum Demand

This section presents the projections of subscribers and traffic to be accommodated by fixed broadband satellite service and mobile satellite service.

It gives the assumptions used to define the share of the market for satellite broadband access and mobile satellite service, the relative demand for spectrum and the results for alternative service demand scenarios.

Note: The results for Fixed (Bent-pipe) Satellite Communications Service are given in this subsection (6.5.5), and the results for DTH Satellite Broadcasting are presented in the Broadcasting Services section, 6.4, above.

Market analysis and subscriber projections

(i) Fixed Broadband Satellite Service

Fixed broadband satellite services provide Internet broadband services to homes and workplaces, generally, in deep rural/remote areas where fixed Broadband and FWA are uneconomical.

A top-down analysis was conducted to project the growth of all broadband subscriptions, which will be served by a mix of technologies over the next five years.

In the analysis, the share of the market served by fixed broadband satellites was determined. Also assessed was the growth of subscriptions, the average monthly usage in GB per subscriber, the ratio of download to upload traffic, and the types of rural markets best suited for broadband satellite services (versus FWA service, for instance).

The charts below summarize the projections for subscribers, data traffic and total traffic for broadband satellite to households and SMEs.

Figure 6.5.1, below, shows the projected number of subscriptions on Fixed Broadband Satellites.

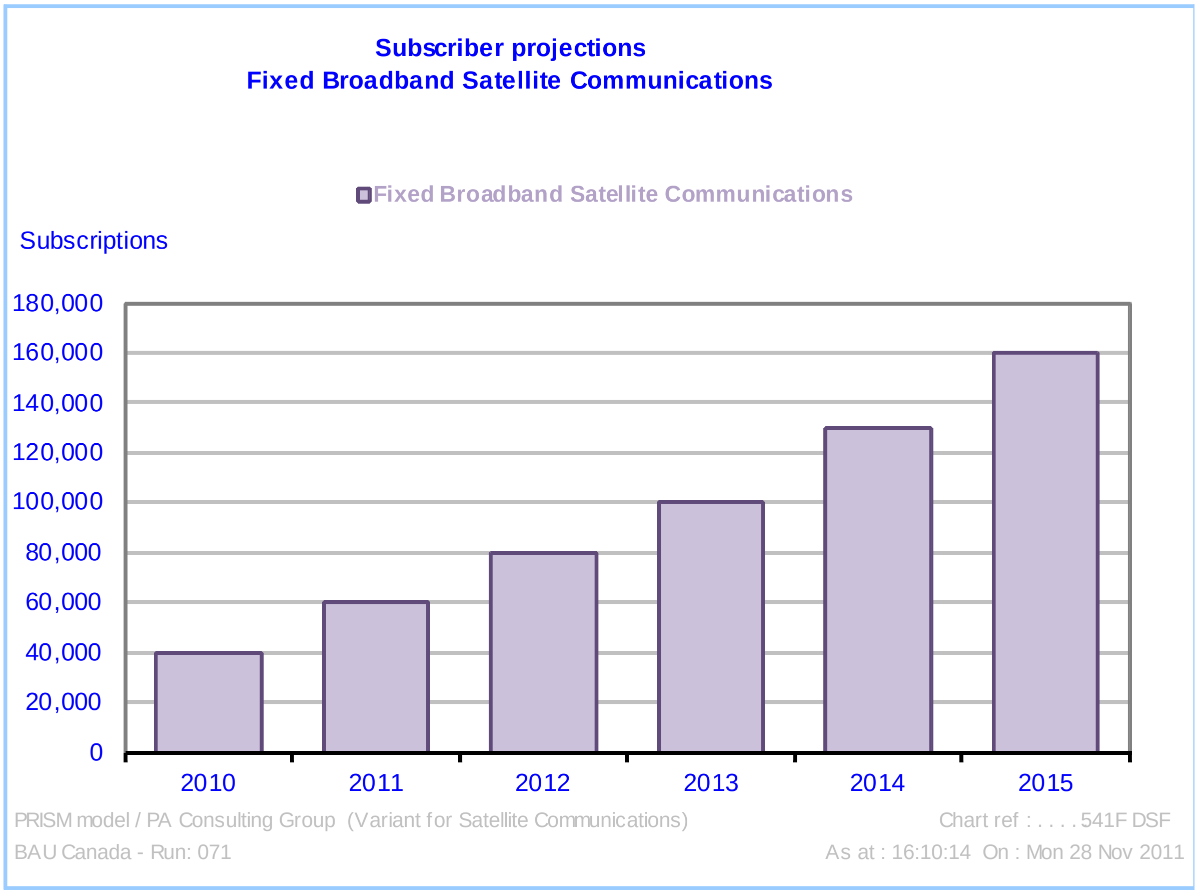


Figure 6.5.1 — Fixed Broadband Satellite subscriber projections (*Source: Red Mobile Research and Projections*)

- Data traffic per fixed broadband satellites subscriber is less than it is for FWA and xDSL/fibre subscribers, at 10 GB/mo in 2010, rising to 25GB/mo by 2015.

Market analysis and subscriber projections

(ii) Mobile Satellite Service (MSS)

Mobile satellite services will focus on the new L-band and 2 GHz satellites. In terms of market coverage, they are likely to focus on remote and deep rural areas, where cellular coverage is uneconomical.

Figure 6.5.2, below, presents the projections used for the number of subscribers for Mobile Satellite Services. They show some growth in subscribers over the period of 2010-15, coupled with a major shift from older (1G) to newer (3G) technology.

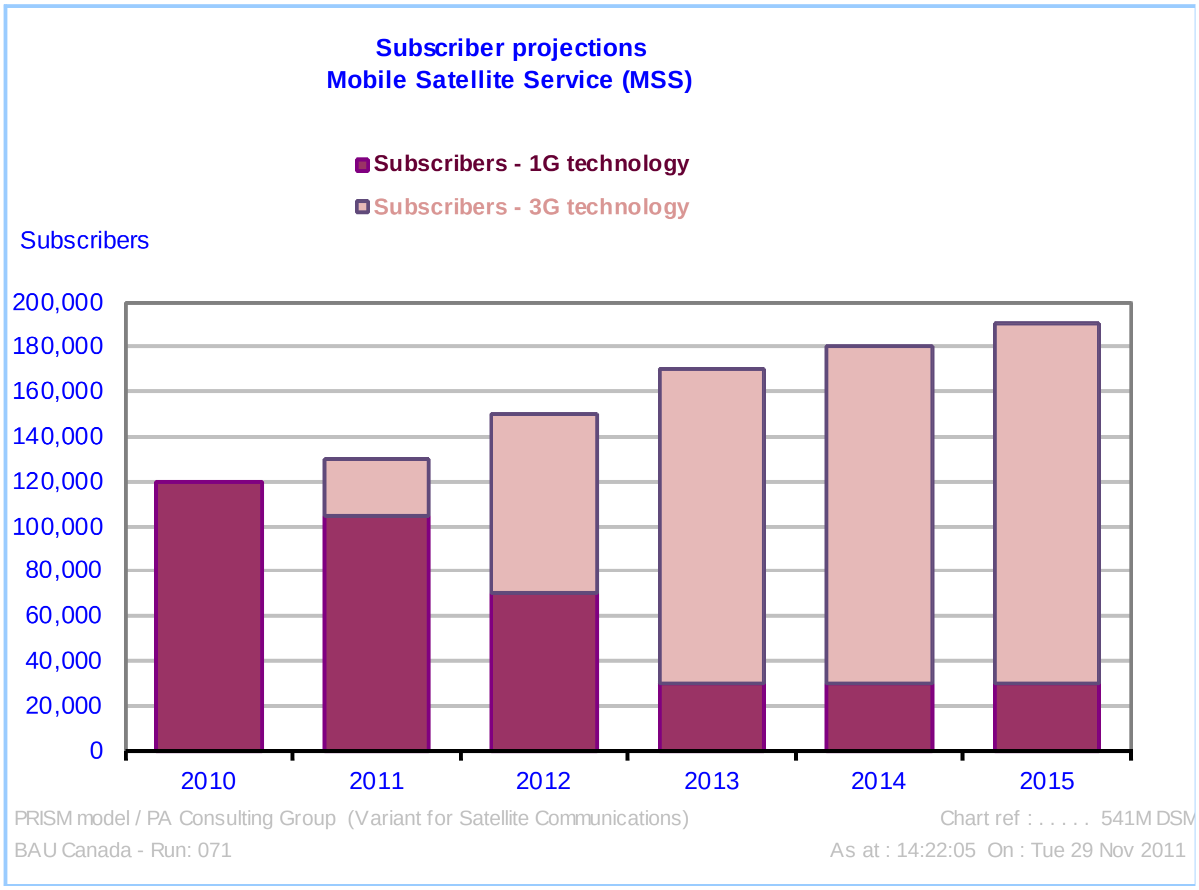


Figure 6.5.2 — Mobile satellite subscribers, by technology (*Source: Red Mobile Projections*)

- There are 120,000 Mobile Satellite Communications subscribers in 2010, growing to 190,000 by 2015;
- Mobile Satellite Communications services generate low levels of voice traffic, approximately 50-60 minutes of voice traffic per month;
- Data traffic (only for those subscribers on the newer technology) is projected to reach 40 MB per subscriber per month by 2015.

Projected Growth in Traffic

Fixed Broadband Satellite traffic is expected to grow due to a combination of increases in both the number of subscribers and the traffic per subscriber.

Mobile Satellite Services traffic remains a much lower level than FSS traffic, and the growth of MSS is largely driven by the introduction of mobile data, rather than growth in subscriber numbers.

Figure 6.5.3, below, shows the growth in traffic.

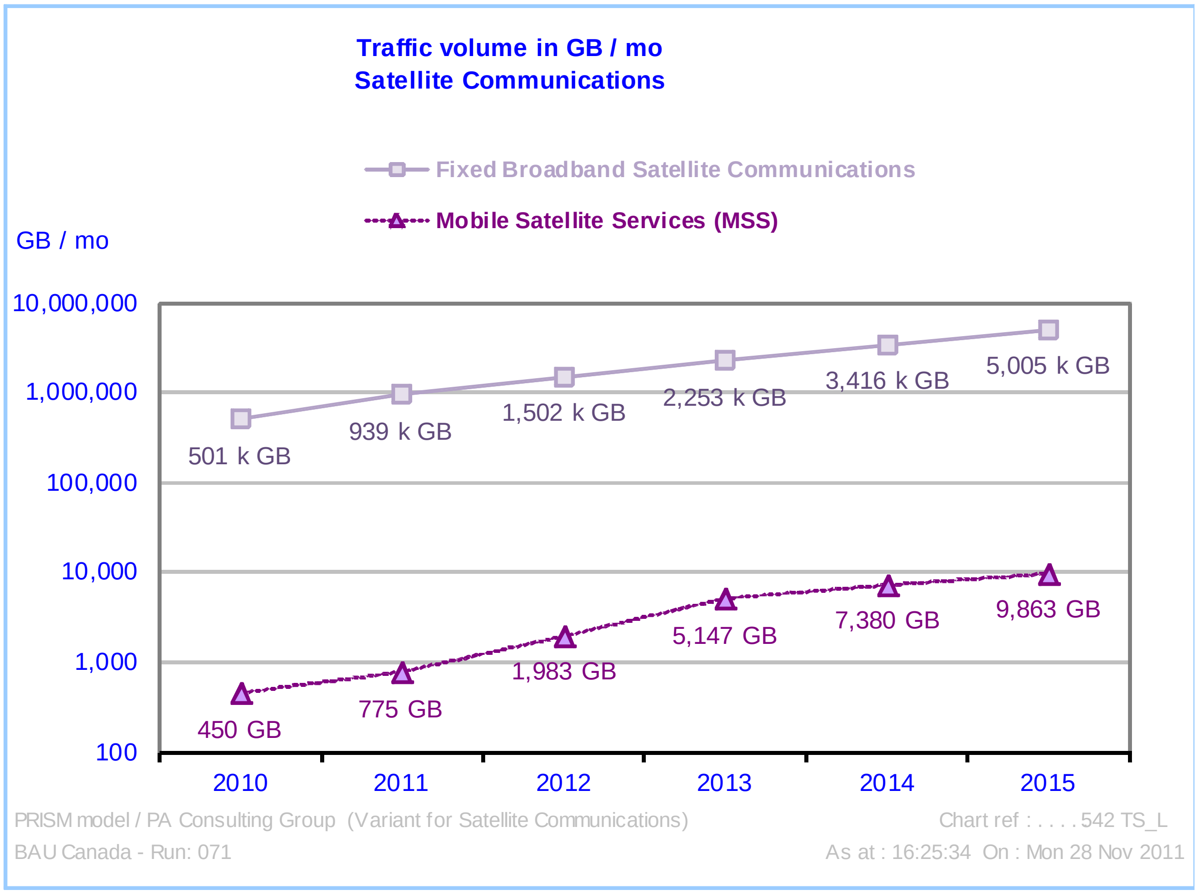


Figure 6.5.3 — Fixed broadband and mobile satellites, Traffic (*Source: Red Mobile Projections*)

Key Assumptions and Relationship between Service and Spectrum Demand (Fixed Broadband and Mobile Satellites)

The key assumptions made in going from traffic demand into spectrum demand are as follows:

- For Fixed Satellite communications, busy-hour traffic is assumed to be 2.5 times the average. For Mobile, it is assumed to be 3.5 times the average traffic;
- A further uplift of 1.5 times the traffic is assumed to accommodate Quality of Service and for short bursts in traffic demand from individual subscribers;
- Dual-polarization is implemented throughout;
- A downlink spectral efficiency of 1.5 is assumed per polarization;
- A frequency reuse factor across Canada of 4 for Fixed and 6 for Mobile is assumed
- Spot counts for Canada are assumed to be 15 for Fixed and for 1G Mobile, and 65 for 3G Mobile. Typically, each satellite is capable of offering three times this spot count, but the other two-thirds of spots are allocated to the rest of the North American market.
- Major improvements in spectral efficiency for Mobile Satellite Communications, arising from the shift from first-generation technology (delivering 0.06 bits/sec/polarization/Hz) to newer technology satellites (delivering 0.65 bits/sec/polarization/Hz).
- All the satellite communications spectrums are paired.

The assumption regarding spot-beam counts is important and warrants further clarification:

It means that the correct interpretation for the spectrum demand figures presented here is: "Canadian demand for spectrum – in MHz x Geostationary Orbital slots – assuming that Canada obtains one-third of the capacity of each orbital slot."

The effect of this aspect of the definition of spectrum demand is summarized in the box below.

Clarification of the assumptions regarding spot beams for Satellite Communications

In this Study, the assumptions regarding spot beam counts allow for the likelihood that Canada will continue to get one-third of the spot beams available in each orbital slot.

A true picture of the Canadian demand for spectrum — assuming that Canada had access to 100% of the capacity of each orbital slot — would be one-third of the figures presented in this Study.

This approach to quantifying Canadian demand for spectrum applies to both Fixed Broadband Satellite Communications and Mobile Satellite Services.

Spectrum Demand: Broadband and Mobile Satellite Communications

Figure 6.5.4, below, shows the projections for the demand for spectrum.

Note that, for this Service, the demand for spectrum is measured in MHz x Geostationary Orbital Slots.

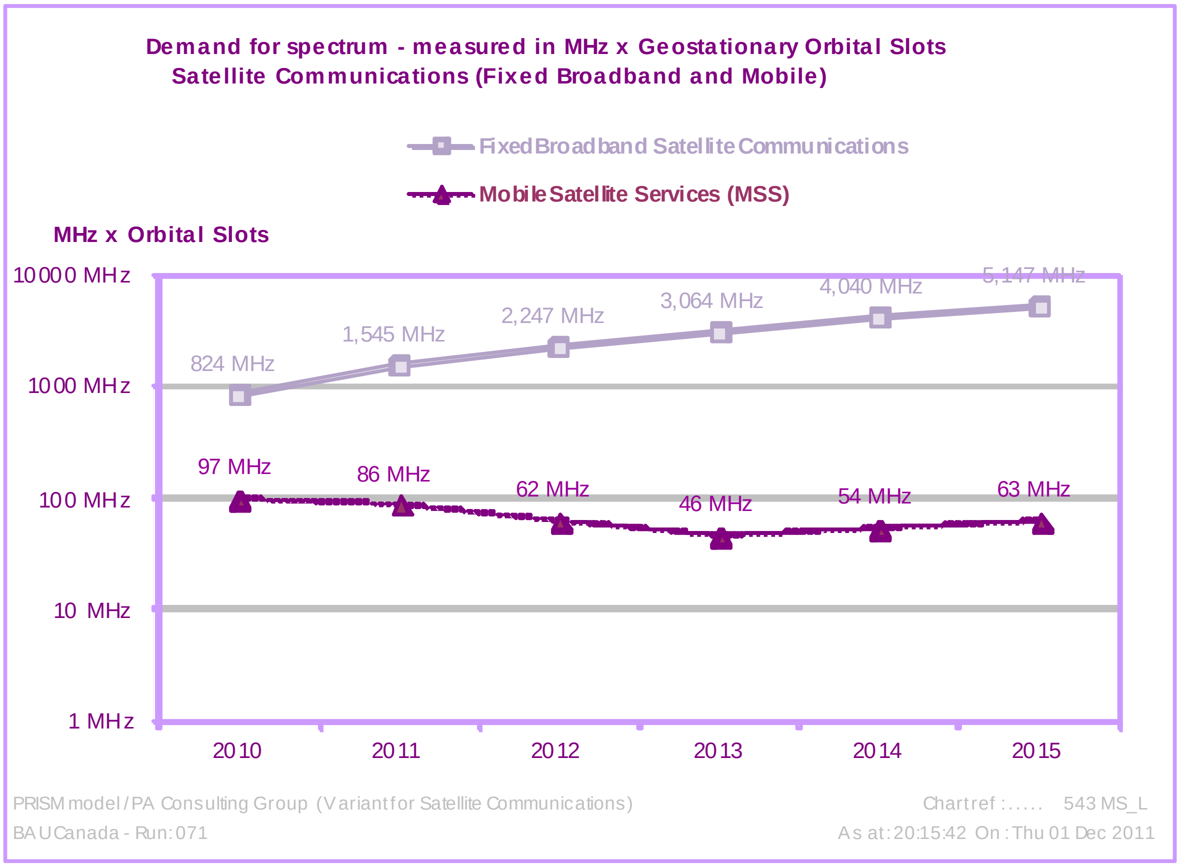


Figure 6.5.4 — Fixed broadband and mobile satellites, demand for spectrum (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

Growth in the demand for spectrum is fuelled by growth in the number of subscribers, as well as traffic per subscriber.

For Mobile Satellite Services, the shift to newer technologies brings improvements in spectral efficiency. These offset the impact of traffic growth. Overall the demand for spectrum is projected to remain comparable with, or less than, what it is in 2010.

For Fixed Broadband Satellite Communications, over the Study period, the growth in traffic translates into a pro-rata increase in the spectrum (when expressed in MHz x GOS) required to carry the traffic.

Assessment of Alternative Scenarios: Fixed Broadband Satellite and Mobile Satellite Services

The only differences between the scenarios, which have a bearing on the demand for spectrum — as measured in MHz x Geostationary Orbital slots — are in the demand projections, these are as follows:

Scenario 2:

- Fixed Broadband Satellite Subscribers grow to 185,000 by 2015 (instead of 160,000), and traffic per subscriber grows to 30 GB/mo (instead of to 25GB/mo).

- Mobile Satellite Subscribers on 1G technology decline to 22,000 by 2015 (instead of 30,000), and the number of subscribers on 3G technology grows to 250,000, instead of 160,000. Downlink data traffic per 3G-technology subscriber grows to 70 GB/mo (instead of to 40 MB/mo).

Scenario 3:

- Fixed Broadband Satellite Subscribers grow to 100,000 by 2015 (instead of 160,000), and traffic per subscriber grows to 18 GB/mo (instead of to 25GB/mo).
- Mobile Satellite Subscribers on 1G technology decline to 48,000 by 2015 (instead of 30,000), and the number on 3G technology grows to 100,000, instead of 160,000. Downlink data traffic per 3G-technology subscriber grows to 20 GB/mo (instead of to 40 MB/mo).

Scenario Comparison Results

(i) Fixed Broadband Satellite Communications

Projections for traffic and spectrum demand for Fixed Broadband Satellite Communications are shown in Figure 6.5.5 and Figure 6.5.6, respectively, below.

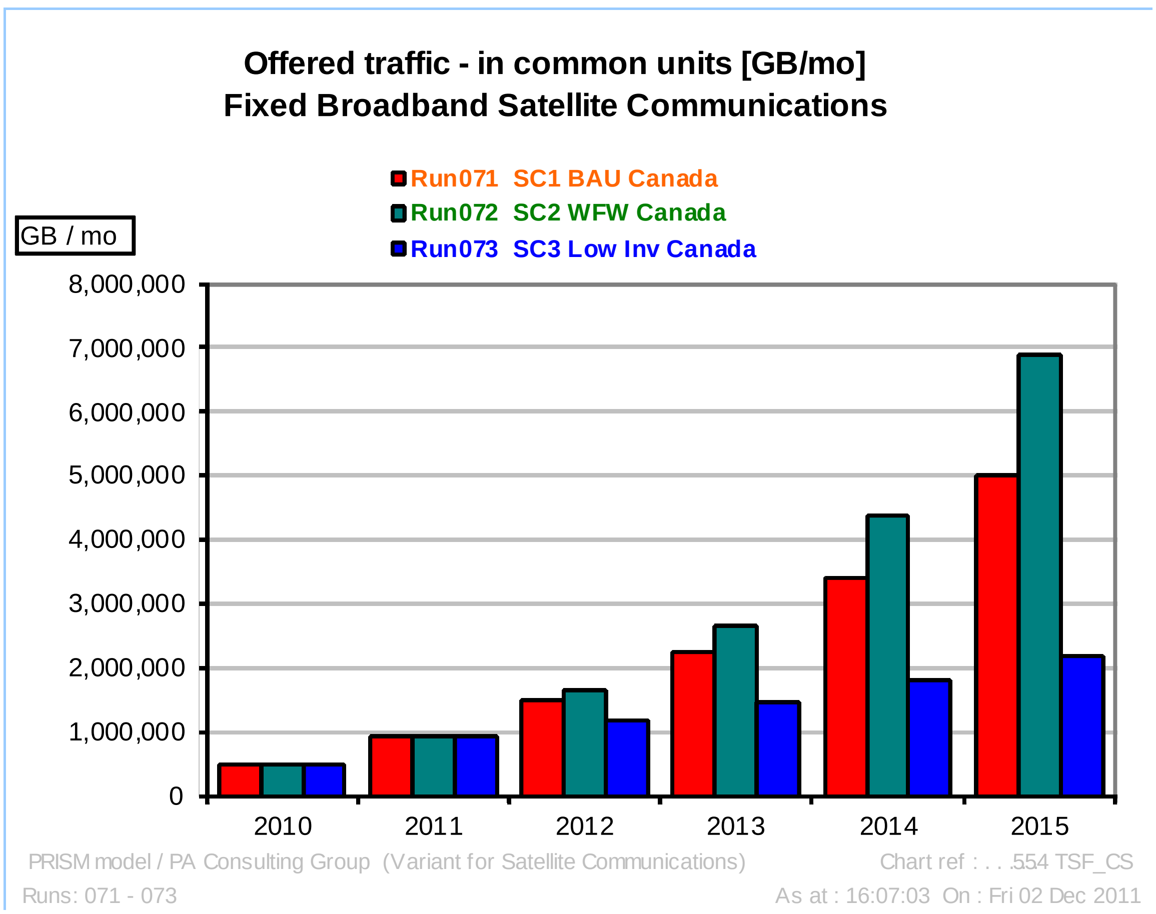


Figure 6.5.5 — Fixed Broadband Satellite Communications: Growth in Traffic, by Scenario (*Source: Red Mobile Projections*)

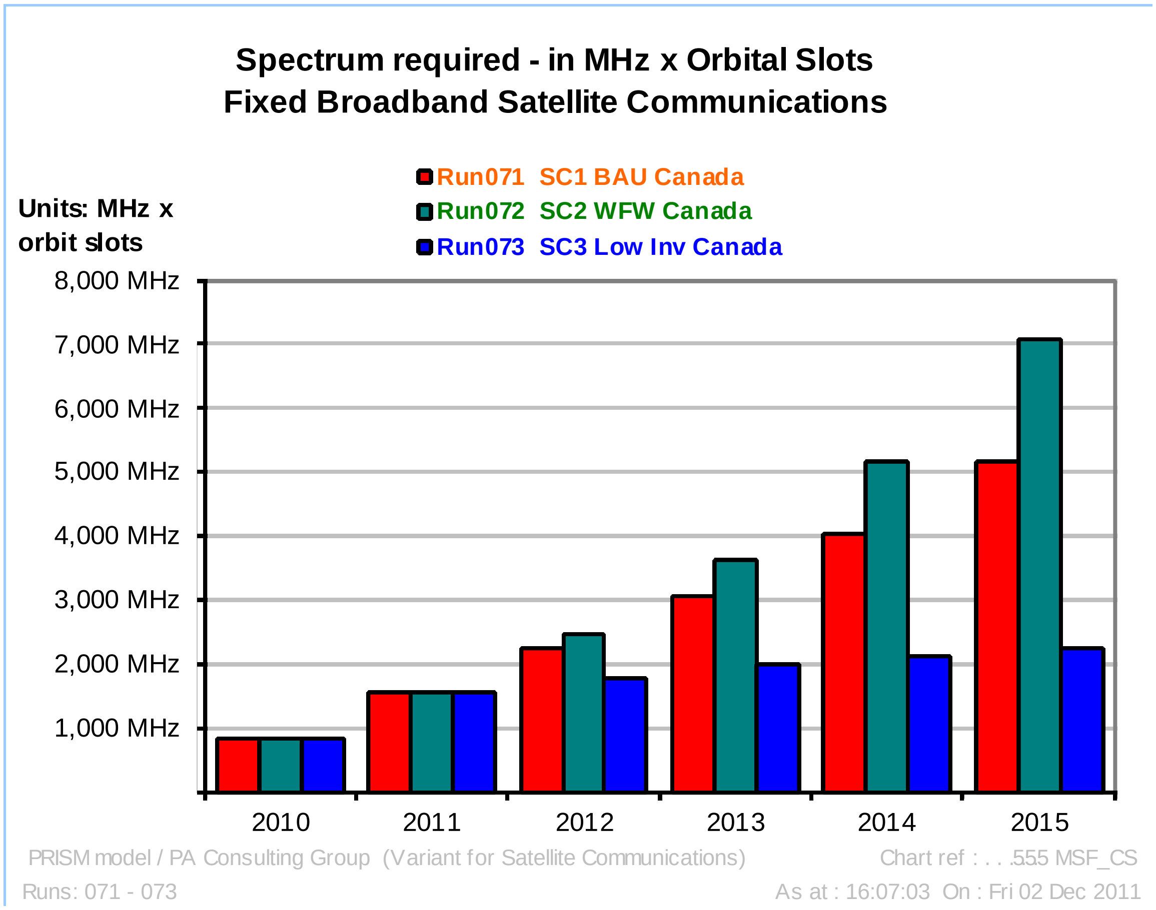


Figure 6.5.6 — Fixed Broadband Satellite Services: Spectrum Demand, by Scenario (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

The differences in traffic growth translate, proportionally, into differences in the demand for spectrum, as measured in MHz x Geostationary Orbital slots.

In practice, it is likely that these differences would translate into differences in the supply of satellite communications capacity offered to the Canadian market versus other markets, and (in the longer term) in the timing and capacity of future satellites. As with Cellular and several of the other services, there are grounds for expecting there to be somewhat of a balancing feedback loop between supply of spectrum and demand for spectrum.

Scenario Comparison Results

(ii) Mobile Satellite Services (MSS)

Projections for traffic and spectrum demand for Mobile Satellite Services are shown in Figure 6.5.7 and Figure 6.5.8, respectively, below.

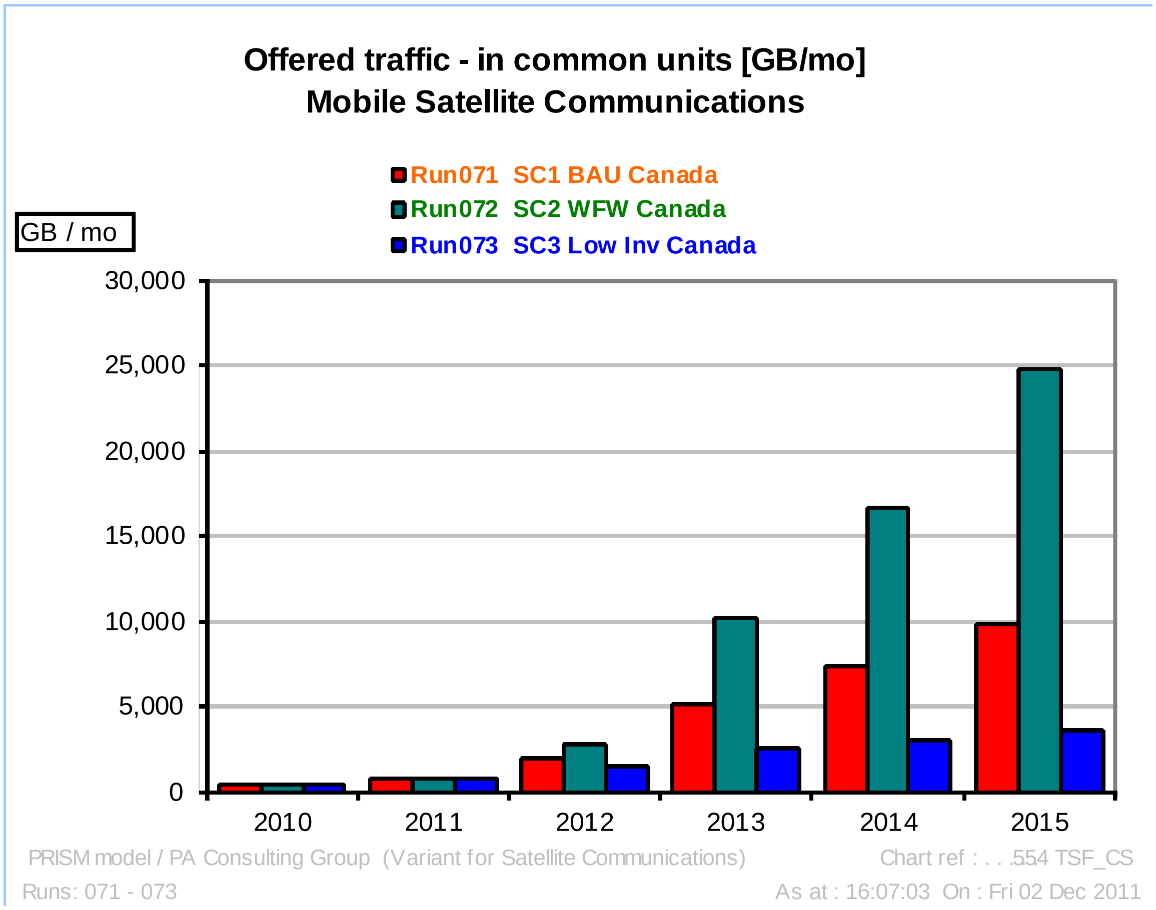


Figure 6.5.7 — Mobile Satellite Communications: Growth in Traffic, by Scenario (*Source: Red Mobile Analysis*)

The scenarios have very different projections for total traffic driven by the differences in both subscriber numbers and in traffic per subscriber, outlined above.

However, when it comes to understanding the projections for spectrum demand, the differences in traffic growth are largely offset by differences in the rate of switchover to the newer, more spectrally efficient, technology.

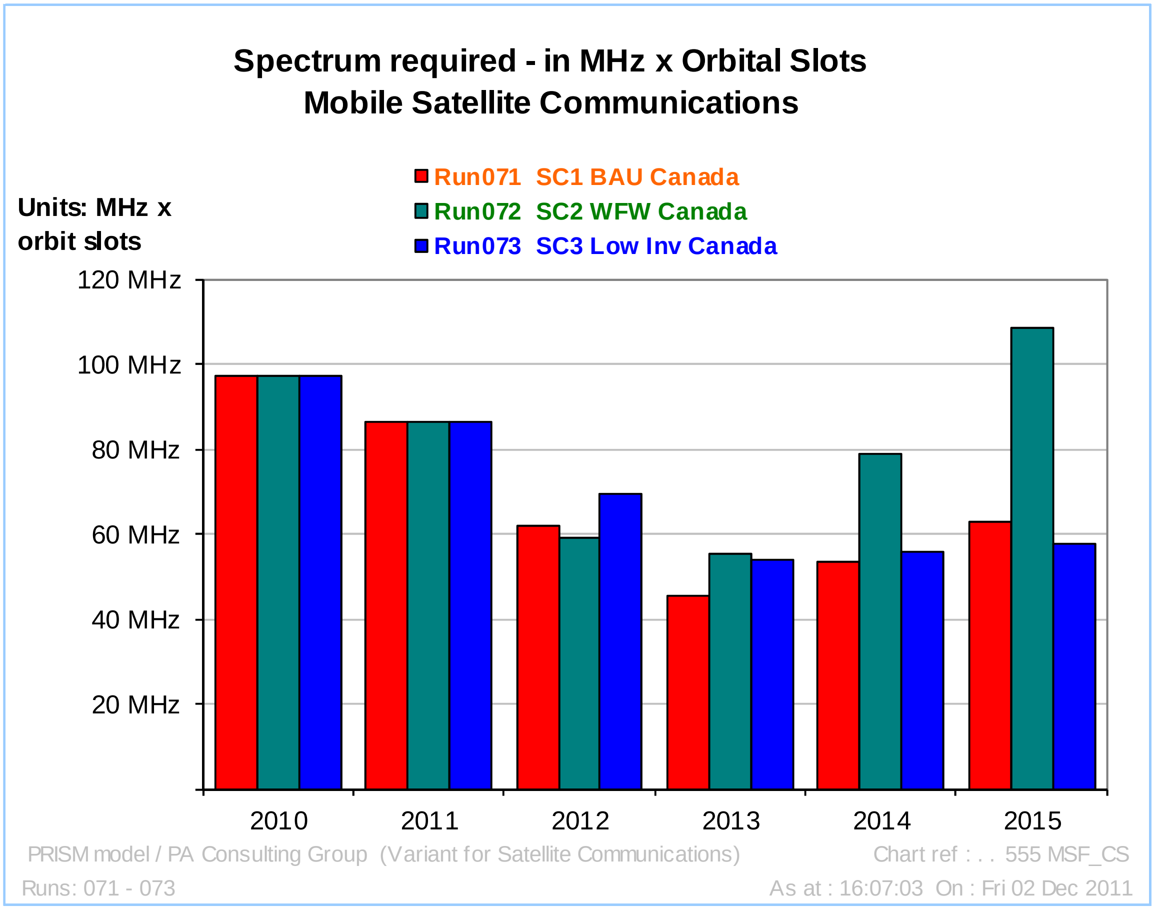


Figure 6.5.8 — Mobile Satellite Services: Spectrum Demand, by Scenario (*Source: based on Red Mobile and PA Analysis, and PA PRISM Modelling*)

The outcome is that the trajectory for spectrum demand is similar for all three scenarios over the period 2010-13, after which it grows slowly in Scenarios 1 and 3, and then grows rapidly in Scenario 2.

As with the spectrum projections for Fixed Broadband Satellite, there may to be further balancing feedback loops, which have the effect of closing any gaps between spectrum supply and spectrum demand.

6.5.6 Fixed Bent-Pipe Satellite Communications (C- and Ku-bands)

Canada has a number of commercial fixed "bent-pipe" satellites in the conventional C- and Ku-bands and a large number of foreign fixed satellites[29], approved in these bands, to serve the Canadian telecommunication market. These satellites, including Canadian satellite networks, provide services to the North American Continent and other regions. The Americas are being served by these commercial fixed satellites, which are generally staked at every 2 degrees along the geostationary arc. These satellites, located on the 70-to-130-degree-longitude-west arc would have good-to-excellent coverage

[29] Canada has a total of four Canadian and 53 foreign fixed bent-pipe satellites in the C-band, four Canadian and 52 foreign satellites in the Ku-band, and two Canadian and 24 foreign bent-pipe satellites in operation.

of Canada. This represents a large pool of spectrum-orbital resource in the C- and Ku-bands to operate a large number of fixed satellites and provide significant satellite capacity to serve the North American market, including Canada.

As such, it is hard to quantify the actual Canadian communication traffic on these many Canadian and foreign satellites serving a large marketplace. It is equally difficult to estimate the Canadian service demand of fixed "bent-pipe" satellite communications. These satellites provide a wide range of service applications to many customers and satellite resellers. These commercial communications services include:

- Carriage of public switched telecom network (PSTN) traffic across Canada, including Northern Communities;
- Internet trunking to various hubs, including remote locations;
- Specialized communication networks for enterprises and government use;
- Carriage of broadcasting programs, from production to distribution centres and to broadcasting station, including SNG (satellite news gathering);
- Support VSAT enterprise networks; and
- Use of satellite to restore terrestrial fibre and microwave radio relay systems, and other applications.

Financial analysts regularly assess the satellite service market in terms of satellite capacity (number of transponders) available and the market demand for transponders. Capacity is based on satellite service demand and projected transponders scheduled for service over the next five years. These assessments show that a good level of spare satellite capacity is available to serve the North American telecom market.

The opinions of Canadian satellite network operators on fixed "bent-pipe" satellite capacity have indicated the following:

- Business News Information made public by Telesat Canada indicated that the use of its existing satellite capacity to be as high as 80% for North America in early 2011.
- Ciel Satellite operator indicated, in a presentation at Spectrum 20/20 in 2010, that the demand for new satellites to serve North America is expected to be strong and growing steadily, and existing spectrum-orbit assigned by Canada to be adequate to meet current and future satellite demand.
- Ciel made the following estimate, in Table 6.5.2, below[30], on the availability of fixed satellite capacity (number of transponders) by Canadian satellites to serve the North American market in the C- and Ku-band.

30 Derived from Ciel's presentation to RABC Spectrum 20/20: http://www.spectrum2020.ca/Presentations/Haughian.pdf

Table 6.5.2 — Total Canadian satellite capacity (equivalent transponders), by frequency bands (*Source: Spectrum 20/20 Presentation*)

Year	C band	Ku band	Total no. of transponders
2006	60	120	180
2008	60	130	190
2010	60	140	200
2012	60	140	200
2014	60	140	200
2016	60	165	225
2018	60	190	250

The Study has provided an overview situation with fixed "bent-pipe" satellite communications and the relative capacity available from Canadian satellite networks. With more than 50 foreign fixed satellites approved in various bands to serve the Canadian market, the available transponder capacity could be a factor of 1 to 2, especially to serve Southern Canada.

6.5.7 Conclusion

In the Mobile Satellite Service, the Study projects an increase in subscribers and the introduction of some mobile data on a usable scale. These substantial increases in traffic are offset by the gain in spectral efficiency from moving from the 1G to 3G technology. The net effect is that spectrum demand for Mobile Satellite Services is projected to be fairly steady over the next five years, as subscribers upgrade to the newer technology.

In the Fixed Broadband Satellite market, a four-fold growth in subscribers, and a relatively slow (two and half times) growth in the volume of data traffic per subscriber are projected. The combined effect is a close-to-tenfold growth in traffic over the five-year period. We do not anticipate any large-scale gains in spectral efficiency for these services over the five-year period and, consequently, the demand for spectrum, as measured in MHz x orbital slots, is likely to follow the growth in traffic.

An analytic overview has been presented for the fixed "bent-pipe" satellite service. Due to the large number of Canadian and foreign satellites serving the North American market, including Canada, it is difficult to quantify demand. Furthermore, there are many types of satellite telecom services being delivered and a large number of satellite network operators, service providers and a large pool of fixed satellite users. Very little information was available to study the service and spectrum demand for this category of fixed satellites.

6.6 Land-Mobile Service

6.6.1 Overview

Land-mobile (LM) systems support a wide range of communication services, including push-to-talk voice dispatch, paging, telemetry and low-speed data. Land-mobile systems consist of base stations, repeaters, portables and mobiles.

A wide range of licensees make use of land-mobile spectrum. These licensees include commercial licensees (voice and data dispatch, paging and voice/data); government licensees (communications supporting public safety and government operations, etc.); and private licensees (communications for private companies). Land-mobile service accommodates special communication requirements, closed user groups, service functionalities and operation needs that may not be supported by public wireless networks. Public safety agencies, such as police, fire and emergency medical services, extensively utilize the general land-mobile bands for mission critical communications. The next section, 6.7, on Public Safety (PS) service, will address the spectrum requirements within the general land-mobile bands and the dedicated bands to public safety.

A number LM frequency bands have been providing the bulk of mobile communications services for various users across Canada. The prime LM bands are the 150 MHz (VHF) band, 450 MHz (UHF) band, 800 MHz, and 900 MHz bands. Of late, some additional spectrum was added in the 220 MHz and 900 MHz bands. Both the 150 MHz and 450 MHz bands are used extensively for mobile operation due to their superior coverage and economics. There are more than 300,000 frequency assignments in the 150 MHz band and more than 120,000 assignments in the 450 MHz band. The use of 800 and 900 MHz bands is based on deploying trunking systems, which include the advanced ESMR cellular technology.

In densely populated areas, such as Southern Ontario’s Golden Horseshoe Area (GHA), Montreal and the Greater Vancouver Area (GVA), the use of all four prime bands (150, 450, 800 and 900 MHz) is intense, and special spectrum management measures are used to release limited frequencies for new radio licences. These measures include the use of trunking and narrowband technology[31], terminal-loading requirements, and spectrum monitoring aimed at ensuring efficient use of the limited spectrum. In some situations, frequencies are clawed back to be reassigned to more urgent or pressing services.

For many users, private land mobile represents a unique economic solution to meet particular communications needs. LM communications allow the best means of securing service, coverage and functionality critical to their operations. The 900 MHz trunking band is moderately used, and the 220 MHz is lightly used. There is the prospect of further re-farming spectrum in the 150 and 450 MHz bands to narrowband technology using 6.25/7.5 KHz channels (Phase II of the redeployment plan).

[31] RDP 100-500 MHz: Redeployment Plan for Spectrum Efficient Land-Mobile Equipment in the Frequency Range 100-500 MHz (http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01654.html): Two phases for narrowband technology adoption: Phase I uses 12.5/15-kHz-equivalent channel BW technology, and Phase II uses 6.25/7.5-kHz-equivalent channel BW technology. The adoption of Phase I technology is underway, where required, in the 150/450 MHz bands in Canada. Phase II is awaiting suitable technology.

6.6.2 Spectrum Inventory and Utilization

The Inventory Report[32] provides the band plans and general spectrum usage in the four main land-mobile bands, 150, 450, 800 and 900 MHz, as outlined in the figures below (Figures 6.6.1, 6.6.3, 6.6.5 and 6.6.7).

The largest concentrations of frequency assignments are in large urban centres, as shown in the charts below.

150 MHz VHF and 450 MHz UHF Land-Mobile Bands

A total of 32 MHz of spectrum is available in the 150 MHz band, which is subject to Canada-U.S. sharing arrangements along the border. Montreal, Vancouver, Toronto and Victoria have the greatest concentration of subscribers that use this frequency band, as shown in Figure 6.6.2, below.

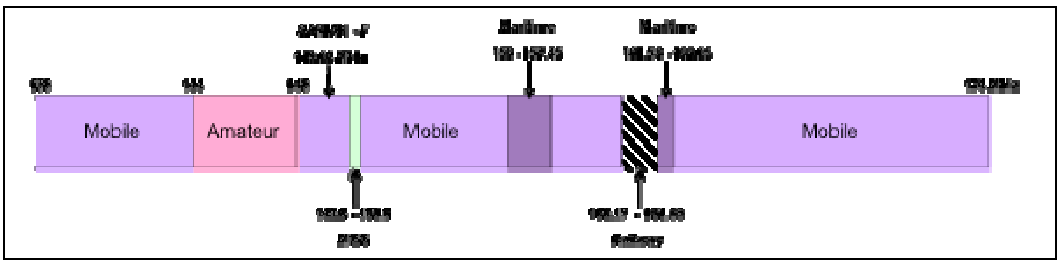


Figure 6.6.1 — The 150 MHz VHF Band Plan for Land-Mobile Service (*Source: Inventory Report*)

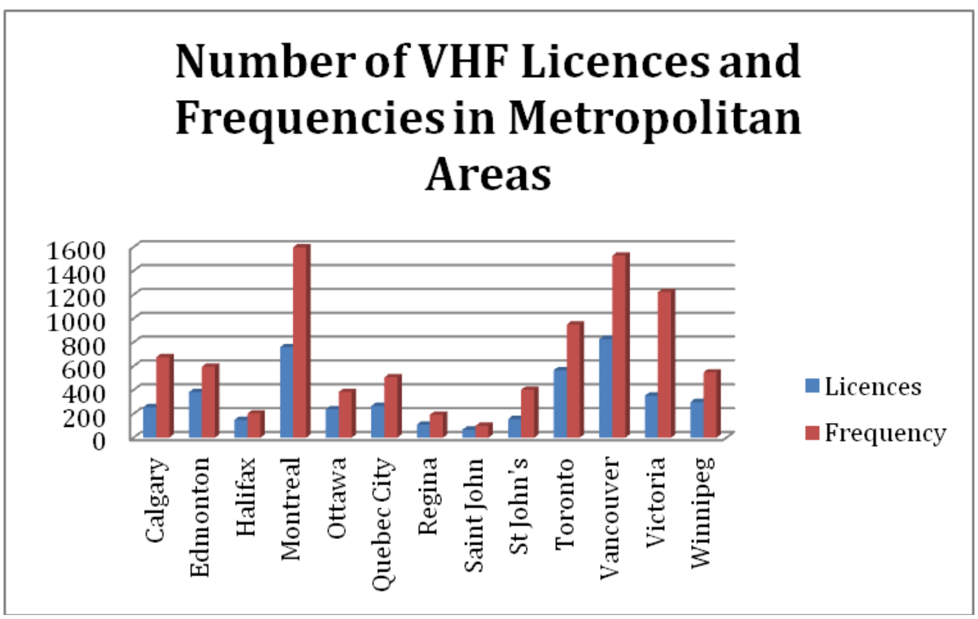


Figure 6.6.2 — The 150 MHz VHF Major Metropolitan Distribution (*Source: Inventory Report*)

A total of 44 MHz of spectrum is available in the 450 MHz band, which is subject to the Canada-U.S. sharing arrangements along the border.

32 Radio Spectrum Inventory: A 2010 Snapshot – Canada: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10023.html

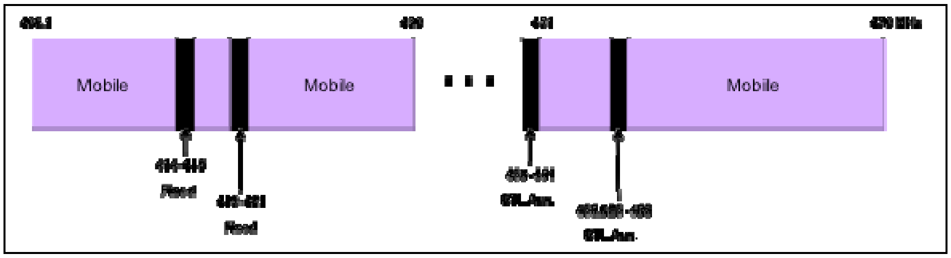


Figure 6.6.3 — The 450 MHz UHF Band Plan for Land-Mobile Service (*Source: Inventory Report*)

Montreal and Toronto have the greatest concentration of licenced frequencies, as can be seen in Figure 6.6.4.

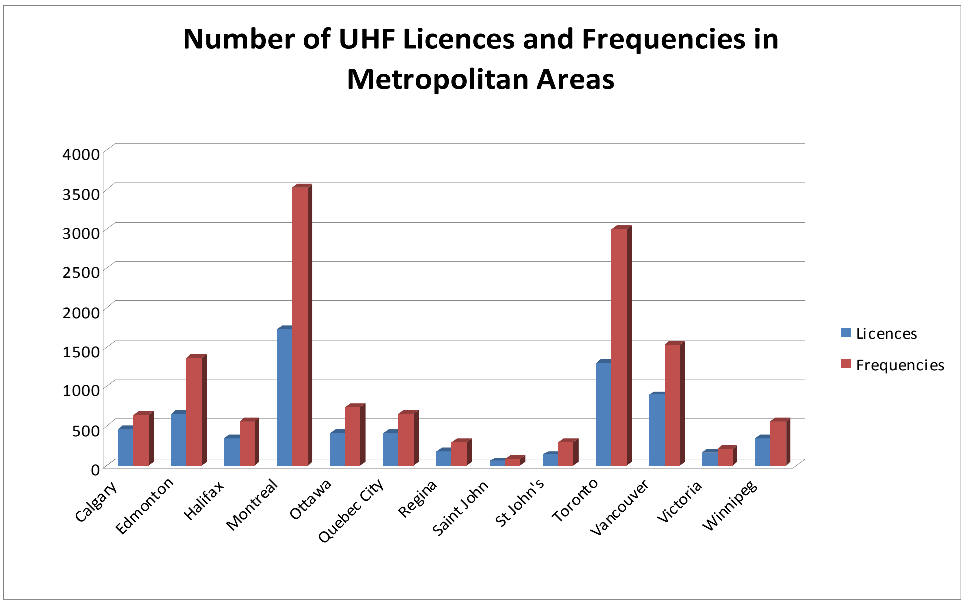


Figure 6.6.4 — UHF Major Metropolitan Distribution (*Source: Inventory Report*)

800 MHz and 900 MHz UHF Land-Mobile Bands

A total of 28 MHz are assigned for general LM use in the 800 MHz band. Toronto and Montreal have the greatest concentration of 800 MHz users, as can be seen in Figure 6.6.6. A part of the 800 MHz band supports ESMR (iDEN-based cellular-like) service.

It is noted that the U.S. has realigned its 800 MHz land-mobile band plan. The changes include a shift of the 3 + 3 MHz public safety spectrum and a rearrangement of the trunking mobile and ESMR spectrum. As a result, part of the Canadian 800 MHz land-mobile band plan is no longer aligned with the U.S.

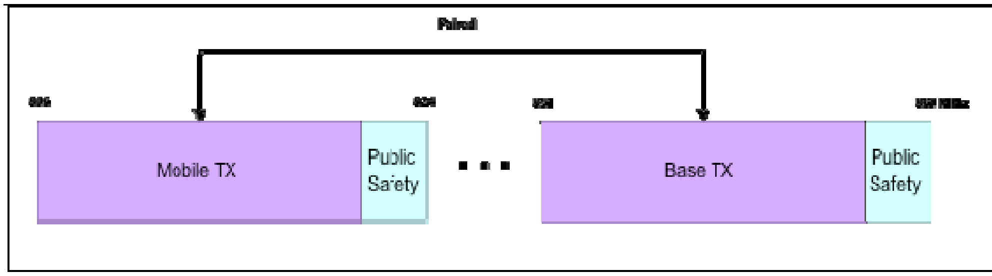


Figure 6.6.5 — The 800 MHz Band for Land-Mobile Service (*Source: Inventory Report*)

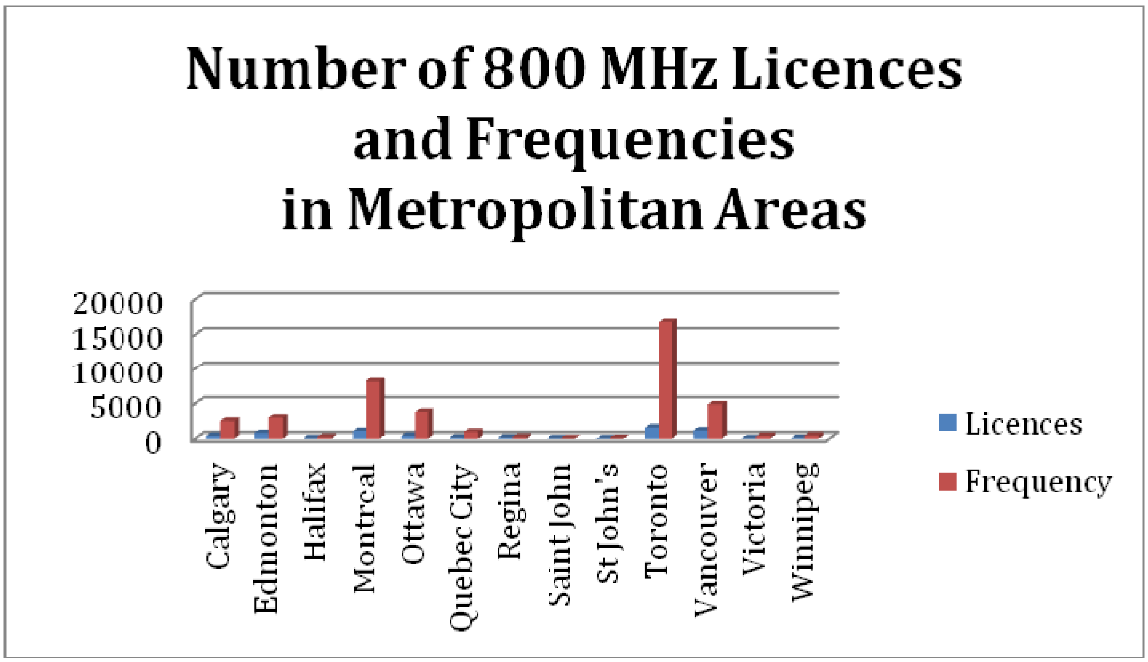


Figure 6.6.6 — 800 MHz Major Metropolitan Distribution (*Source: Inventory Report*)

A total of 15 MHz is assigned in the 900 MHz band for LM services. The largest concentration of subscribers that uses the 900 MHz band resides in the Greater Toronto Area (GTA), as shown in Figure 6.6.8, after Figure 6.6.7. The 900 MHz band is lighly used, as compared to other land-mobile frequency bands.

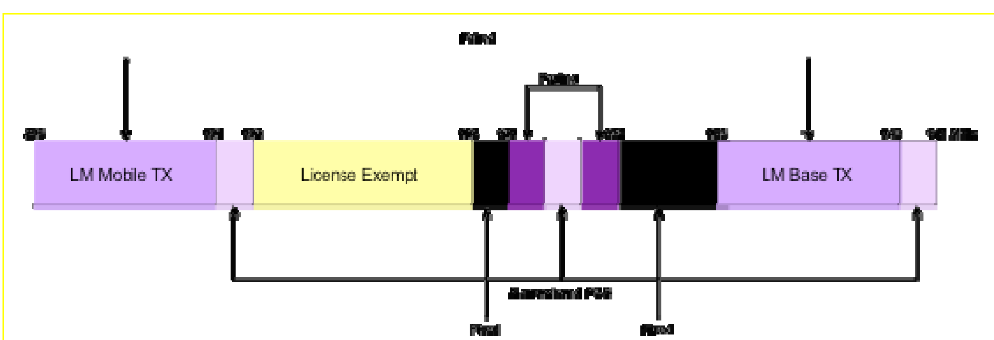


Figure 6.6.7 — The 900 MHz Band Plan for Land-Mobile service (*Source: Inventory Report*)
Note: In the figure above, kindly note that 901-902/940-941 MHz is land mobile and no longer NBPCS, as shown in this figure from the Inventory Report.

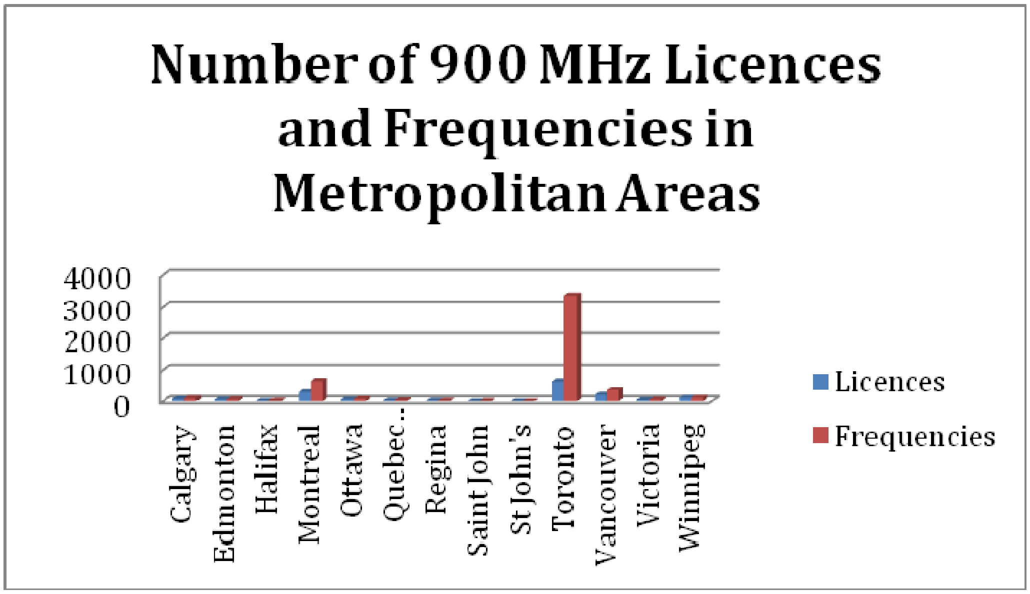


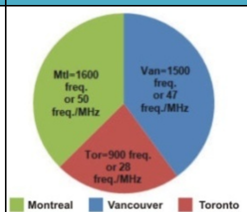
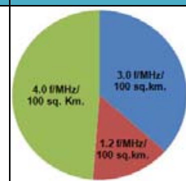
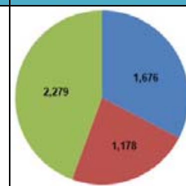
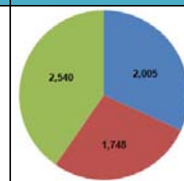
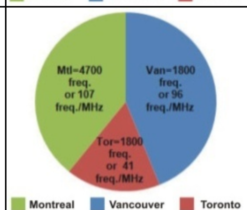
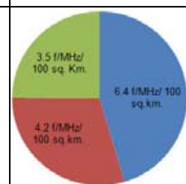
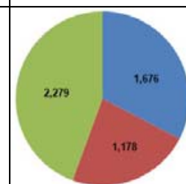
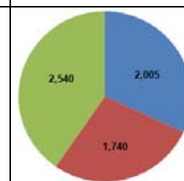
Figure 6.6.8 — 900 MHz Major Metropolitan Distribution (*Source: Inventory Report*)

Spectrum Utilization

- There is approximately 173 MHz of spectrum designated for land-mobile systems (27-941 MHz range), as shown in Table 3.1 of the Inventory Report. A total of 152 MHz is designated for general land-mobile users, and 22 MHz is designated exclusively for public safety (800 and 700 MHz). The four most popular bands (150, 450, 800 and 900 MHz) represent approximately 120 MHz, or 82% of the general land-mobile spectrum designations. However, due to the Canada-U.S. sharing arrangements, a portion of the 150 and 450 MHz spectrum is not usable in Canada along the U.S. border.
- Canada has been implementing Phase I narrowband technology (equivalent of 15/12.5 kHz channelling) at 150 and 450 MHz for a few years. This is especially true as it relates to new systems in high-usage areas, such as in large cities, where additional licensees may not be accommodatable without moving to 12.5 kHz. To benefit from the spectrum efficiency of narrowband technology, coordination is needed with the U.S. along the border for similar technology implementation.
- Narrowband systems are based on advanced digital technology, such as trunking systems using TDMA. New technologies, such as TETRAPOL, Software Defined (SDR) and multiband radios, promise to further increase spectrum efficiency for land-mobile bands. The next step in narrowband technology is the implementation of Phase II, which is based on the equivalent of 7.5/6.25 KHz channelling. Phase II implementation is anticipated to begin within two years.
- Table 6.6.1, below, shows the frequency assignments per MHz for each band and the frequency usage for the four mobile bands. It also shows the frequency density in the 150/450 bands for the three largest cities.
- In summary:
    - **Overall**: The 150 MHz band has approximately three times more assignments per MHz than the 450/800 MHz bands, which speaks to its popular use across Canada. The table also shows that the 900 MHz band is underutilized, with the 800 MHz band having almost five times more assignments per MHz.
    - **High-density areas:** In the 150 MHz band, Vancouver and Montreal have a concentration of frequencies 2.5 to 3.25 times more than in Toronto, based on an area of 100 square kilometers.
    - In the 450 MHz band, Montreal has a much higher frequency density than Toronto and Vancouver.
    - The difference may be explained by the actual number of frequencies available in Toronto for

use due to the Canada-U.S. sharing arrangement.
- o In general, the 220 MHz and 900 MHz bands are lightly used.

Table 6.6.1 — Overall frequency assignments per band and per MHz; and frequency density for large cities (Freq./MHz/100 sq. km.) (*Source: Inventory Report and Red Mobile Analysis*)

Band MHz	Total frequency assign-ment per band	BW (MHz)	Freq. Assign. Per MHz	Density of frequency assignments per MHz (Freq./MHz) Montreal, Toronto, Vancouver	Freq. /MHz/ 100 sq. km.	Total Area in Sq. km.	Pop./Sq. Km. (average)
150 VHF	302,000	32	9438				
450 UHF	121,000	44	2750				
800 UHF	99,000	30	3300	Congested in large cities			
900 UHF	11,000	15	733	Lightly utilized			
Total	533, 000	121	4405				

The licensing trends for the four land-mobile bands, in terms of number of clients, licences and frequencies over the past 10 years, are outlined in figures 3.18 to 3.22 of the Inventory Report. The Inventory Report summarizes the trends as follows:

- Assignments have been somewhat declining in the VHF band, increasing in the 800 MHz and 900 MHz bands, and they have remained steady in the UHF band.
- VHF and UHF bands are heavily used, with a large number of clients in each band.
- Overall, frequency assignments, the number of licences and users, are relatively stable in the land-mobile bands.
- Commercial operators, with a large client base, use the 800 MHz band heavily.
- The 900 MHz band is not heavily used.

6.6.3 Stakeholder Input and Research Analysis

The following information has been gathered through various sources of primary and secondary research. This includes input from the Department of National Defence (DND), regional telecom carriers and other sources. Use of general land-mobile bands for public safety, including the RCMP input, is covered in the public service section, 6.7.

Comments from Stakeholders

- Based on comments from several regional carriers and stakeholders, it is noted that the use of land-mobile spectrum varies significantly depending on the location and region. In large urban centres (i.e. GTA, GVA, Montreal, etc.) and along certain corridors, portions of the spectrum are heavily used. In contrast, LM spectrum is lightly used in many rural and low-density urban regions. Moderate congestion is observed in some of the medium-sized urban cities (i.e. Regina, Saskatoon, etc.).
- The DND noted that its Combat Net Radio (IRIS network) operates in the 30-108 MHz range, using sets of frequencies with frequency-hopping technology that can coexist with other users in the same spectrum. The Combat Radio system is expected to continue using the same range of spectrum, even when modernized. Also, some use of the VHF land-mobile band is made at the Canadian Forces bases for less-critical communications. Spectrum is lightly used at military bases, and only moderate growth is expected over the next five years.
- Over the years, there has been a slow migration of private land-mobile users to commercial systems. The 220 MHz is a suitable alternative to traditional VHF solutions, but acceptance depends significantly on product availability and pricing. According to comments from a major operator, the 900 MHz band does not appear to be a suitable alternative to 700 and 800 MHz, due to performance and option of equipment available.
- It was noted by a large operator that it is turning down its private mobile services at 150 MHz and 450 MHz bands and migrating users onto commercial mobile (cellular) services in densely populated areas. For the foreseeable future, the operator will continue to utilize the 150 MHz band for private mobile in geographic areas where cellular coverage is not sufficient to meet operational requirements.
- In areas of low-population density, it has been noted that at least one regional operator plans to utilize the 150 MHz and 450 MHz bands to provide subscribers telephone services for the next five years. The fixed wireless service offerings will move to 3G cellular services as infrastructure is introduced.
- Paging in the VHF band remains a desired service, but the market is not growing. Cellular services address many of the requirements in densely populated regions. VHF paging solutions enjoy high allegiance in rural areas, for volunteer firefighting and EMS applications. Stakeholders noted that no substantial spectrum demand growth is anticipated over the next five years for the traditional paging applications.
- While at least one regional operator anticipates that commercial mobile networks will be the preferred substitute for government agency users in the land-mobile service in the coming years, most wireless commercial operators generally hold this view. Some operators, therefore, have the view that enterprise and private use of land-mobile spectrum is expected to decline significantly as users migrate to commercial mobile services over the next five years.
- Similarly, operators believe that commercial mobile networks will be the standard for broadband data communications for enterprise and private mobile users.

Research and Analysis of the Spectrum Management Environment

- The prime land-mobile bands are at 150MHz, 450 MHz, 800 MHz and 900 MHz and are assigned to a wide range of users from government, commercial and private licensees. An intensive usage of these bands, with the exception of the 900 MHz, has been deployed in large urban areas, such as Toronto, Montreal, Calgary, Vancouver and Victoria. Moreover, the 150 MHz and 450 MHz bands are heavily used in a number of regions across Canada.
- The licensing of land-mobile systems in VHF is based on a first-come, first-served basis. Portions of 400 MHz are coordinated on an Inter-leaved or block & zone basis. 700, 800 and 900 MHz are coordinated as block and zone. This involves significant spectrum management activity in the planning of frequency assignments, coordination of installations and monitoring of spectrum for efficient use.
- Land-mobile service is unlike commercial cellular where the continuous rollout of advanced technology and spectrum-efficient systems are driven by new service offerings, competition and market forces. The implementation of advanced and spectrum-efficient technology in land-mobile bands is often driven by the spectrum regulator in order to accommodate the greatest number of users and service growth within a limited amount of spectrum.

- To achieve greater spectrum efficiency, several spectrum-management measures have been adopted. These include (especially for high-usage service areas) the maximization of mobile units per assigned frequencies, use of narrowband and advanced technology, the monitoring of spectrum usage/traffic and the clawback of lightly used frequencies.
- These spectrum measures have allowed for the possibility of further use of the limited land-mobile spectrum over the years. The continued application of best practices in spectrum management within the existing spectrum resource should ensure that reasonable land-mobile frequencies are available for assignment to meet the growing or changing needs of users over the next five years. This assumes that a portion of the users and traffic continues to migrate onto commercial mobile networks, where possible, and preferred by the users.
- Public Safety represents a very large user group of the traditional 150, 450 and 800 MHz land-mobile bands, in addition to its use of exclusive public safety spectrum (3 + 3 MHz at 800 MHz and 12 + 12 MHz at 700 MHz).
- Some provincial and municipal public safety systems, such as the Province of Quebec and Montreal Police, extensively use the 150 MHz band. Other provincial public safety systems, such as Saskatchewan, use the 450 MHz band. In addition, large public safety systems (GVA's E-COMM, Toronto) extensively use the 800 MHz band. In general, for wide coverage in rural and remote areas, there is compelling reason to secure frequency assignments in the 150 MHz and/or the 450 MHz bands. This is especially true for areas, such as for southwestern British Columbia and northeastern Alberta and the Northern Territories.
- The spectrum coordination arrangement with the U.S. in the 150/450 MHz bands and the rollout of narrowband digital technology — such as TDMA, system trunking, and APCO-25 based on Phase I re-farming (15/12.5 KHz channel equivalent) — are having a significant impact on the availability of spectrum and its efficient uses.
- The prospect of further narrowband technology under Phase II re-farming (7.5/6.25 KHz channel equivalent) in the 150/450 MHz bands, promises a more efficient use of spectrum. Furthermore, the availability of software-defined-radios (SDR), multi-band radios and the efficiency of TETRAPOL trunking systems is expected to extend spectrum availability.
- The significant portion of the 800 MHz band has been occupied by Enhanced System Mobile Radio (ESMR-iDEN), providing high-mobility cellular-like service, particularly in large urban areas. While the ESMR service is preferred by existing subscribers for its Push-to-Talk (PTT) capability, many have been gradually moving to advanced cellular networks over the last few years.

6.6.4 Service and Spectrum Demand

Approach in Forecasting Future Demand for Services and Spectrum

The aforementioned information and analyses, contained in sections 6.6.2 and 6.6.3, provide a good information base to assist in projecting future service and spectrum demand in land mobile. Also, the information related to the use of mobile spectrum, as presented in Section 6.7 for Public Safety, has to be reconciled as part of the demand for land-mobile bands.

The information considered in estimating the demand for service and spectrum includes:

- The use of key land-mobile bands (including public safety);
- Past trends and anticipated usage and user plans;
- Industry stakeholder perspectives, dynamics, challenges and plans;
- Technology and regulatory impacts;
- The level of frequency concentration in high-density urban centres;
- The use of land mobile for public safety and key issues related to that use;
- Industry Canada policy and operation provisions and measures influencing spectrum availability.

The approach to project the future demand for service and spectrum in the land-mobile bands is based on information gathered through the various sources mentioned.

Service Demand: Market Analysis

Land-mobile spectrum accommodates a wide range of mobile, paging and fixed applications utilized by a large variety of users, including the private sector, public safety and government agencies. Extensive coordination has to take place in congested urban centres to licence a modest number of new frequencies being released. Through various measures, spectrum managers have been able to modestly accommodate clients thus far. However, dense urban cities and certain corridors are experiencing pressure on spectrum available in some of the most popular bands (e.g. 150/450 MHz).

Land-Mobile Service Demand: Existing and Emerging Service Drivers

Public and private land-mobile services support a wide range of applications, including:

- **Mobile voice:** voice messaging and dispatch, group calling, voice paging, etc.
- **Mobile data:** low-speed data transmission, with a growing need for high-bandwidth data applications.
- **Specialized service applications:** fixed links for tele-control (SCADA), telemetry, monitoring, alarms, machine-to-machine.

Industry trends are expected to improve usage as a result of spectrum efficiency improvements and enhancements in system performance. Some of these trends include:

- A steadily accelerating degree of migration of some land-mobile users, including enterprise, government, and some PS to advanced commercial mobile (HSPA+ and LTE) networks that meet their features and functionality needs;
- Newer technologies and standards, such as narrowband TDMA, SDR, multi-band radio, APCO-25, and TETRA will increase the efficiency of land-mobile bands. A better use of the underutilized 900MHz and 220 MHz bands should also occur. Automatic Meter Reading (AMR) systems have many options, including new systems in the 220 MHz and 1400 MHz bands. In some cases, the actual market deployment of these technologies and market penetration of devices capable of fully utilizing these new technologies will take several more years, and, therefore, the net benefit of these developments will be somewhat limited in the near term and may start to have more significant an impact in the later portion of the Study’s timeframe;
- The growing use of cellular for M2M communications is occurring for a range of meter reading and control requirements including water meters and smart meters;
- Continued monitoring of frequency channel traffic loading and clawback of underutilized frequencies for reassignment.

For many years now, land-mobile services have grown in four main mobile bands (150, 450, 800 and 900 MHz bands) with some 533,000 frequencies presently licenced. These frequency assignments are spread across some 120 MHz of spectrum. The main groups of licensees are commercial and various levels of government users (federal, provincial, municipal and foreign governments), which includes public safety. The distribution of frequencies by groups of users and band is shown in the table below.

Table 6.6.2 — Distribution of frequencies, clients and bands (*Source: Inventory Report and Red Mobile Analysis*)

Band/ users	150 MHz (freq.)	450 MHz (freq.)	800 MHz (freq.)	900 MHz (freq.)	Total (freq.)
Commercial	179,000	91,000	62,000	7,000	362,000 (65%)
Federal Gov.	22,000	8,000	2,000	-	33,000 (6%)
Municipal Gov.	45,000	13,000	31,000	1,000	95,000 (17%)
Provincial Gov.	34,000	8,000	3,000	-	46,000 (8%)
Foreign Gov.	20,000	1,000	-	3,000	25,000 (4%)
Total (frequencies)	300,000 (56%)	121,000 (23%)	98,000 (18%)	11,000 (2%)	533,000 (100%)
MHz available	32 MHz	44 MHz	30 MHz	15 MHz	121 MHz
Total freq. in largest, high-density cities	Freq.	22,500 Freq.	38, 600 freq.	4,650 freq.	74,600 Freq.

From Table 6.6.2, notice that:

- Commercial licensees are the largest user group with about 64% use of the frequency assignments (FA). Commercial users represent a very diverse group, ranging from commercial wireless carriers, enterprises, public utilities, industrial, manufacturing and production companies, and resource companies (oil, gas, logging, etc.). Some of these commercial licensees also provide services to local governments.
- Government represents the second-largest group, based on the number of frequency assignments. Municipalities have the higher assignments in this category, with close to 17%, followed by Provincial governments at 8% FA, and then the Federal Government at 6% of the assignments. A large portion of frequency used by the three levels of government is for public safety, under the multiple categories of PS users. This category of PS users includes mission-critical PS needs of first responders (fire, police and emergency medical services) at all levels of government; municipal operations, including transportation, traffic control, public works, etc.; provincial departments, such as natural resources, public works and others; and federal departments, such as parks, transport, environment, public works and natural resources.
- The ESMR-iDEN service in the 800 MHz trunk mobile band has been historically popular, especially for its PTT capability that has been unrivalled by alternative cellular systems. However, users have been migrating to cellular systems over the last few years, and it is expected that this trend will continue to some extent, especially as iDEN technology approaches sunset. Service at this band has also been preferred by many users for its historically better in-building RF performance.
- Users prefer using the 150/45 MHz bands for their better coverage, especially in-building coverage.

The degree of demand for land-mobile service will influence the amount of spectrum required. With the proliferation of smartphones and tablets, growth of vertical-focused mobile applications (apps), the inherent nature of LM users being mobile, and the need for users to streamline costs, the trend has been to migrate to commercial cellular services, where possible. This should take place at a steadily increasingly pace, especially as communication requirements move towards integrated services using multimedia and high-speed data in the private and, to some degree, government sectors.

Although, the numbers of land-mobile users, that use existing LM services, are still expected to grow over this period, resulting in both an increase in voice traffic and mobile units, a growing segment of LM users will have some of their communication needs met by public cellular networks. It is estimated, from the Public Safety section in this Report that the demand for land-mobile frequencies in the 150 and 450 MHz bands will continue for most of the public service systems and may increase, in some cases. In large cities, it is envisaged that the exclusive PS frequencies at 700 MHz for narrowband/wideband service may not be enough, and a continued high demand for 800 MHz will prevail well until 2015.

Table 6.6.3 — Service demand projections (*Source: Red Mobile Analysis*)

Spectrum	Voice (dispatch, paging)	Data services
Now	> Extensive use of land-mobile (150, 450, 800 MHz) bands in large cities and 150/450 MHz in certain regions; > Significant spectrum used by PS for voice > Modest use of 900 MHz band.	> Use of land mobile for telemetry, monitoring, especially in rural areas > High use of commercial cellular for data services (including PS data needs)
2015	> Continued extensive use of 150/450 MHz land-mobile bands by PS, and other users; > Increased use of cellular for voice by certain users. > The new 700 MHz band is unlikely to meet all the voice growth needs of PS in certain urban areas, and growth may occur in the 800 MHz band. > Greater rollout of advanced narrowband technology (Phase I/II) and systems based on TDMA, SDR, multi-band radio, APCO-25, and TETRA trunking will improve spectrum efficiency and use of these systems.	> Substantial use for fixed broadband at 5 GHz; > Use of commercial mobile broadband (HSPA+ and LTE) by PS. > The 220 MHz band, as well as new spectrum at 1400 MHz, will continue to accommodate Automatic Meter Reading (AMR) requirements.

Spectrum Demand

In general, the Study envisages that a modest number of land-mobile frequencies will be released over the next three to five years, due to spectrum efficiency and some migration to commercial cellular service. However, these will quickly be taken up by demand, especially in dense urban areas in the case of the most popular bands. Some of the new public safety systems being built in the 700 MHz band will complement existing systems in the land-mobile band. Advanced commercial mobile networks are expected to accommodate some of the broadband mobile data services and functionality of government and commercial land-mobile users. However, the recently released 700 MHz PS spectrum designated for narrowband/wideband services may not be enough to accommodate growth for mission-critical voice traffic of some public safety systems, and continued use of frequencies in the 800 MHz band will be required for the foreseeable future.

There will always be a high demand for land-mobile service in the 150/450 MHz, due to the inherent economic advantage and wide area coverage. As frequencies are released, they will be assigned to existing systems or new systems.

- **High Demand:** The 150, 450, and 800 MHz bands are of high demand for land-mobile service. The 150 and 450 MHz bands will continue to be congested in many regions of the country. The 800 MHz has been heavily used in large cities, but declining ESMR usage is expected to continue over the near term.

- **Moderate Demand:** The 220 and 900 MHz bands are expected to have moderate levels of demand until more cost-effective and higher-performing equipment is available.

Pressure Points:

- Of the 152 MHz of general land-mobile spectrum, 104 MHz (68%) resides in three high-demand bands (150/450/800 MHz). The 150/450 MHz bands are fully occupied in large cities and certain regions (PS, large users), and the 800 MHz band is fully occupied in large cities (due to ESMR, public safety and other usage). However, the number of subscribers on the commercial (iDEN-based) ESMR system has been steadily declining with the gradual migration of users to advanced cellular networks.
- The exclusive 800 MHz band (3 + 3), for public safety, is fully occupied in cities and certain areas.

6.6.5 Conclusion

For many years now, land-mobile services have been managed in an environment of very high congestions for the 150, 450 and 800 MHz bands. While spectrum for particular applications may not be readily available in the preferred band(s), users have been accommodated or offered alternative spectrum in less-encumbered bands (900 MHz, 220 MHz or others). Public records have shown that the demand for VHF, UHF and 800 MHz frequencies have exceeded spectrum availability in certain large cities and areas of the country. Industry Canada has used a number of spectrum-management measures to ensure the most efficient use of the limited resource and has encouraged a greater use of the underutilized bands.

In conclusion, while regulatory measures, alongside industry trends, may help in releasing frequencies in congested land-mobile bands, any released frequencies are expected to address pent-up, or ongoing, demand in these bands. Also, some of the technology enhancements will start to make a more significant difference in the later part of the Study period. Therefore, despite the migration of users, technology enhancements and regulatory measures, little net-change is expected in the overall demand for spectrum in the bands already seeing pressure, with some increased usage of the currently underutilized bands over the 2010-2015 period.

6.7 Public Safety Service

6.7.1 Overview

The availability of spectrum for effective public safety operation is an important spectrum-management objective. An operating principle has been to give public safety agencies preference to access frequency assignments in the land-mobile bands, and to designate spectrum exclusively for public safety radio systems, where possible. It is recognized that other government agencies may be involved in activities related to the preservation of life and the protection of property, and therefore may also have a need for similar spectrum access for their radio systems. In general, a hierarchy of spectrum access and licensing priority for public safety spectrum is used as follows:

- Category 1: police, fire and emergency medical services;
- Category 2: forestry, public works, public transit, dangerous chemical cleanup, customs and other agencies contributing to public safety; and
- Category 3: other government agencies and selected supervisory personnel of certain non-government agencies (i.e. hydro and gas utilities).

The 150 MHz, 450 MHz, 800 MHz, and 900 MHz land-mobile bands have been extensively used, over the years, by public safety agencies. As discussed in Section 6.6, above, these bands are shared with a wide range of users, often in highly congested spectrum. The adoption of narrowband technology, terminal loading, advanced digital trunking systems, and spectrum monitoring have assisted Industry Canada in continually releasing some frequencies for licensing in the land-mobile bands. This detailed management of the spectrum is of particular importance to enable Industry Canada to accommodate the most pressing needs in congested urban areas and vicinities. A main issue of concern with public safety systems has been the large number of incompatible systems in operation by distinct agencies of municipal, provincial and federal jurisdictions, and the lack of interoperability. The problem was underscored with first responders' inability to communicate following the 9/11 attacks in the U.S. For new PS systems, the first-responder communities in the U.S. and Canada have diligently worked with their regulators to arrive at common system standards and interoperability specifications. Radio Policy (RP)-25, released in 2009, provides the principles to facilitate and enable radio interoperability.

Through a series of policy and technical standard proceedings[33] during the 2004-2010 timeframe, Industry Canada allocated and designated the bands 764-776 MHz and 794-806 MHz (12 + 12 MHz) for public safety use. Furthermore, a rearrangement of the band plan was made in the 2009-2010 timeframe, in which the sub-bands 768-776 MHz and 798-806 MHz (8 + 8 MHz) were designated to narrowband/broadband PS systems. The release of the remaining sub-bands 764-768 MHz and 794-798 MHz (4 + 4 MHz) is subject to future spectrum proceedings. Since then, a number of public safety agencies have either received approvals for, or have submitted applications to begin, developing modern public safety systems with full interoperability, in the new 700 MHz spectrum. At this early phase of implementation, a significant amount of the 700 MHz spectrum remains available for new PS systems across Canada.

6.7.2 Spectrum Inventory and Utilization

The Inventory Report outlines the frequency bands dedicated to public safety in 800 MHz and the upper 700 MHz bands, as shown in Figure 6.7.1, below.

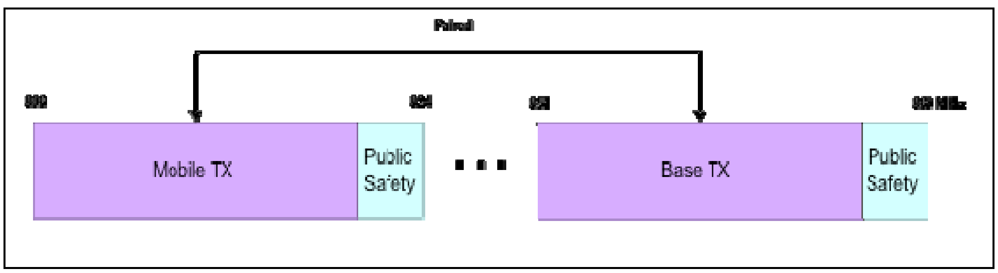
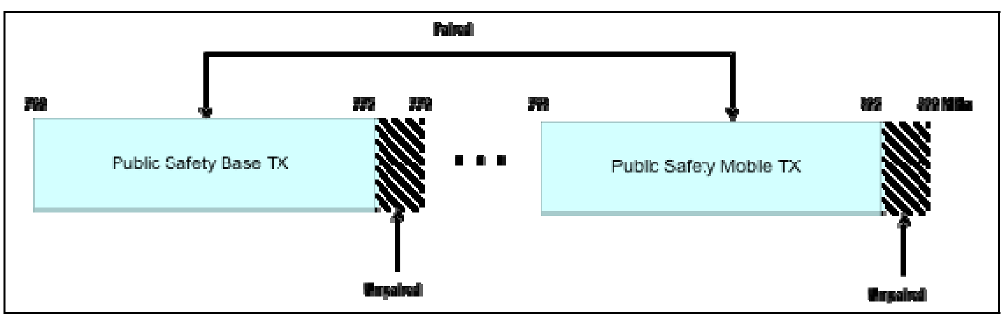


Figure 6.7.1 — 800 MHz public safety band plan (3 + 3 MHz), exclusively to PS (*Source: Inventory Report*)



[33] SRSP-511 Technical Requirements for Land Mobile Radio Services Operating in the Bands 764-770 MHz and 794-800 MHz: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08697.html; RP-06; and SP-768 Narrowband and Wideband Public Safety Radiocommunication Systems in the Bands 768-776 MHz and 798-806 MHz: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09553.html

Figure 6.7.2 — 700 MHz public safety band plan (8 + 8 MHz opened for PS, according to SRSP-511[34]) (*Source: Inventory Report*)

The new 700 MHz public safety spectrum (8 + 8 MHz) was assigned to narrowband and wideband applications in 2009. This provides important dedicated spectrum for the development of new systems and to augment or replace existing systems.

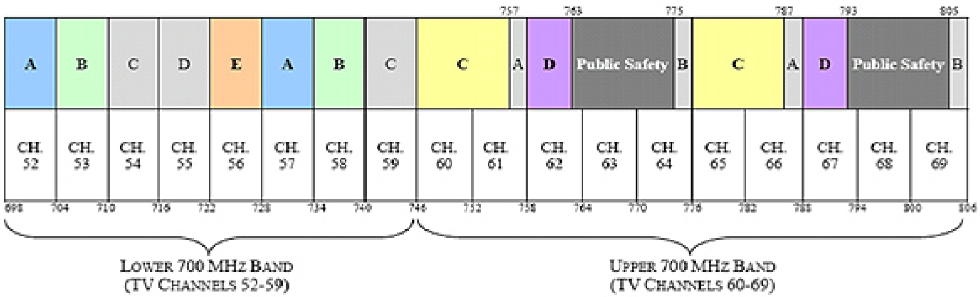
In late 2010, Industry Canada carried out further public consultation for the remaining spectrum in the 700 MHz range (in ranges 698-768 MHz and 776-798 MHz) for commercial broadband mobile service and broadband use for public safety[35].

A significant number of comments were received from federal, provincial and municipal public safety users with strong support for the allocation of continuous 10 + 10 MHz blocks for broadband public safety applications.

There is unanimous support to align the Canadian band plan with the U.S. band plan, according to the scheme in Figure 6.7.3, below.

The PS community has proposed that a total of 10 + 10 MHz be assigned to broadband PS applications. This spectrum would be made up of paired blocks D (5 + 5 MHz) and the adjacent 5 + 5 MHz of spectrum, of which 4 + 4 MHz is already allocated to public safety spectrum. Some other respondents to the 700 MHz Consultation have suggested that, given the extensive use of advanced cellular networks to support much of the broadband traffic needs of PS, only 5 + 5 MHz is sufficient for PS use.

35 Industry Canada, Spectrum Management and Telecommunications, Standard Radio System Plan, Technical Requirements for Land Mobile Radio Services Operating in the Bands 768-776 MHz and 798-806 MHz: http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/srsp511.pdf/$FILE/srsp511.pdf
SMSE-018-10 – Consultation on a Policy and Technical Framework for the 700 MHz Band and Aspects Related to Commercial Mobile Spectrum: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09947.html



Block	Frequencies (MHz)	Bandwidth	Pairing	Area Type	Licenses
A	698-704, 728-734	12 MHz	2 x 6 MHz	EA	176
B	704-710, 734-740	12 MHz	2 x 6 MHz	CMA	734
C	710-716, 740-746	12 MHz	2 x 6 MHz	CMA	734
D	716-722	6 MHz	unpaired	EAG	6
E	722-728	6 MHz	unpaired	EA	176
C	746-757, 776-787	22 MHz	2 x 11 MHz	REAG	12
A	757-758, 787-788	2 MHz	2 x 1 MHz	MEA	52
D	758-763, 788-793	10 MHz	2 x 5 MHz	Nationwide	1 *
B	775-776, 805-806	2 MHz	2 x 1 MHz	MEA	52

* Subject to conditions respecting a public/private partnership.

Figure 6.7.3 — U.S. Band plan for the 700 MHz band proposed for Canada (paired D blocks 5 + 5 MHz for broadband PS spectrum)

Industry Canada released 50 MHz of spectrum for public safety to accommodate broadband access systems in the band 4940-4990 MHz in 2006[36]. The 50 MHz has the prospect of greatly improving the communications, data access and coordination of the operation of various public service agencies from urban centres to small communities (during normal operation and during emergency situations).
Although some broadband systems have been implemented by public safety agencies, the deployments are still at an early stage, and a significant amount of unused spectrum remains available.

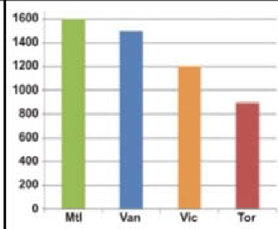
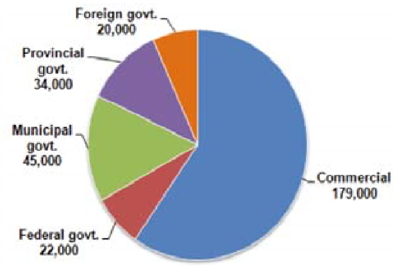
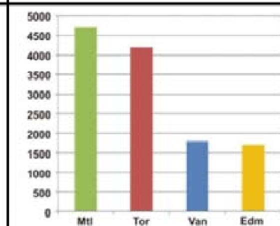
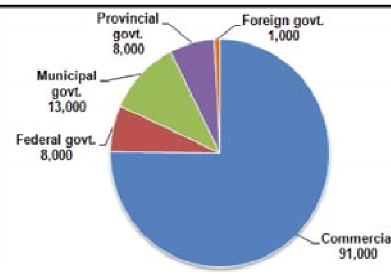
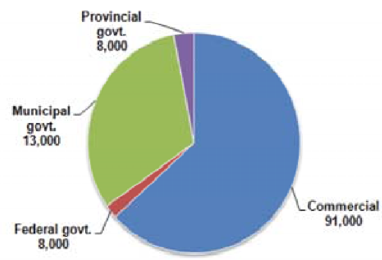
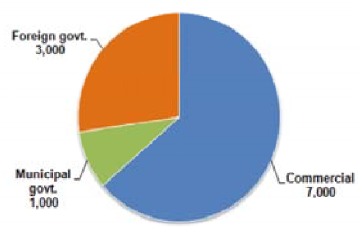
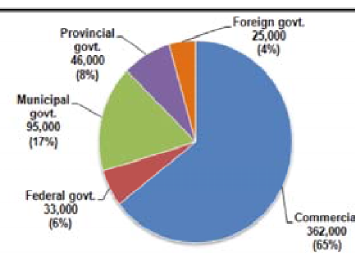
In addition to the exclusive spectrum assigned to PS agencies, public safety makes extensive use of the traditional land-mobile bands (described in Section 6.6.2, above). These LM bands are shared with thousands of other users. For example, some radio systems are in operation in the 150, 450 and 800 MHz bands and used by the police, fire and emergency services in many of Canada's large cities.

36 SP 4940 MHz — Spectrum Utilization Policy, Technical and Licensing Requirements for Broadband Public Safety in the Band 4940-4990 MHz: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08667.html

Spectrum Utilization

From the Inventory Report, the land-mobile frequencies assigned to government users are summarized in Table 6.7.1, shown below. From this information, we obtain a general understanding of the level of frequency assignments that support government requirements, of which public safety is a large and critical component.

Table 6.7.1 — Total frequency assigned in each bands, cities and governments (*Source: Inventory Report and Red Mobile Analysis*)

<table>
<tr><th>Band</th><th>Frequency Assignments (FA) across Canada</th><th>Bandwidth (BW) [MHz] FA/BW [Freq/MHz]</th><th>Largest concentration of Frequency Assignments</th><th>Frequency Assignments used by all levels of Government (Canada-wide)</th></tr>
<tr><td>150 VHF</td><td>300,000</td><td>32 MHz
9375
FA/MHz</td><td>
</td><td>
</td></tr>
<tr><td>450 UHF</td><td>121,000</td><td>44 MHz
2750
FA/MHz</td><td>
</td><td>
</td></tr>
<tr><td>800 UHF</td><td>100,000</td><td>28 MHz
3571
FA/MHz</td><td>N/A</td><td>
</td></tr>
<tr><td>900 UHF</td><td>11,000</td><td>15 MHz
733
FA/MHz</td><td>N/A</td><td>
</td></tr>
<tr><td>Total</td><td>533, 000</td><td>120 MHz</td><td></td><td>
</td></tr>
</table>

The government is a large user of the land-mobile bands. An important and large portion of the government frequency assignments is for service within the three categories of public safety discussed earlier. Municipal governments are the largest government users in the 150 and 450 MHz bands, and a sizable amount of that spectrum is for public safety first responders, including police, fire, ambulance and emergency services (category 1). Provincial and federal governments are the second-largest government users of the 150 and 450 MHz bands, which consist of a sizable amount of spectrum used for first public safety networks.

6.7.3 Stakeholder Input and Research Analysis

The following information has been gathered through various sources of primary and secondary research, including:

- RCMP (Royal Canadian Mounted Police);
- Some regional telecom carriers;
- Some comments from public safety community on new broadband spectrum at 700 MHz.

Highlight of RCMP Comments

In its submission, the RCMP provided a unique account of the major public safety communication activities across Canada. The RCMP provides federal and provincial/municipal policing to eight provinces (with the exception of Ontario and Quebec), the three territories, three international airports, 184 Aboriginal communities and to more than 190 Municipalities[37].

A synopsis of RCMP's input is as follows:

- The RCMP suggested that, in order to obtain the full benefit for broadband public service communications, and to adequately deploy LTE, at least 10 + 10 MHz is needed in the 700 MHz band.
- The RCMP noted that there will be a gradual rollout of 700 MHz narrowband spectrum for new PS systems. Some areas have relatively new communications systems and may not implement 700 MHz over the next five years.
- New communication systems to be deployed within the next five years are expected to use the new 700 MHz PS band. Depending on the type of system installed, this may release some spectrum in land-mobile bands over time as users migrate and older systems are taken offline.
- In the view of the RCMP, if the modernization of the Maritime PS network goes ahead, VHF spectrum is expected to be released over time, as services are moved to 700 MHz band, and older systems are no longer operational. Likewise, some of the 800 MHz spectrum may also be released over time.
- A new Alberta system would be a hybrid of the 700 MHz and VHF system to accommodate multi-users. Some spectrum could be reused, exchanged or returned, depending on how many other users will be part of the provincial system.
- In Ontario, the RCMP is in the early planning stages of revamping its communications system. The 400 and 700 MHz bands are being considered, based on a 12.5 KHz P25 Trunking system. There will be a requirement for more UHF spectrum with the 700 MHz to improve coverage and to provide better in-building coverage in dense urban areas.
- There is a lack of interoperability for channels at VHF and 450 MHz, domestically and along the border.
- A new communications system has recently been installed in the province of Saskatchewan for multi-users using P25 trunking technology in the VHF band. 450 MHz and 900 MHz bands are used for point-to-point links.
- In B.C., there are considerations to establish a 700 MHz infrastructure in a number of urban centres. Currently, there is a multi-cell 800 MHz EDACS trunked radio system, which is due for a technology refresh in 2014. It could be expected that the new system will operate in the public safety 700 MHz band. It could be anticipated that a great deal of the 800 MHz spectrum will be released as the

[37] Posted 700 MHz comments on Industry Canada Web site: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09997.html

EDACS system is decommissioned. The RCMP currently uses commercial service providers for most of its mobile data requirements, and it expects this trend to continue.

- The RCMP in British Columbia is currently a large user of the VHF spectrum, mainly at 150 MHz. Although the VHF band is congested, and it is difficult to get new assignments, this frequency band is better suited than 700 MHz for many of the operations outside of the urban core. The RCMP expects to continue to fully utilize any available spectrum in this band.
- The Manitoba Fleetnet system, which operates in the 800 MHz band, supports a multi-user environment. The demand for new spectrum in Manitoba will be modest. The RCMP will make use of new 3G/4G technology, but it will not replace the current land-mobile systems.

Comments from Telecom Carriers

- According to input from carriers, their view is that several public safety requirements could be met through secure or dedicated service arrangements, with commercial service providers using 3.5/4G networks. However, the current land-mobile assignments to public safety will not necessarily be vacated soon for the 700 MHz spectrum.
- Their view was that existing trunked radio solutions are very inefficient in their use of spectrum. The modernization of public safety mobile systems will free up spectrum for commercial and private use.
- A gradual migration is anticipated from existing PS systems in land-mobile bands to a dedicated 700 MHz PS spectrum.

Some Comments on Potential New Broadband Spectrum at 700 MHz for Public Safety

In the recent 700 MHz band Consultation, Industry Canada sought comments on potentially assigning broadband spectrum (5 + 5 MHz block D) for Public Safety. PS users have encouraged Industry Canada in their public comments to assign as much as 10 + 10 MHz of 700 MHz broadband spectrum for a range of applications. The PS community's argument for new spectrum is based on a range of new broadband data service applications and operation requirements rather than the growth of traditional narrowband voice services.

Several studies and papers are available to support a range of different views on the approach to accommodate broadband public safety at 700 MHz. The opinions of these studies vary on the best approach to be taken. Without bias towards any specific submission, we summarize the findings of three studies herein to provide a background to some of the viewpoints, and to enable us to summarize some of the anticipated service demand, based on analysis of some industry players. The reader is strongly urged to also review the responses to the 700 MHz Consultation for a more detailed and complete review.

1. A study done by Defence Research and Development Canada (DRDC) for the public safety community[38] on the 700 MHz broadband Consultation has established the aggregate data for day-to-day operations and for an extreme event, such as a large riot. Their analysis is for a multi-user system's requirement over the course of 10 years and is illustrated in Figure 6.7.4, below:

[38] Submission to Industry Canada's 700 MHz Consultation: http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/smse-018-10-public-safety-sub2.pdf/$FILE/smse-018-10-public-safety-sub2.pdf

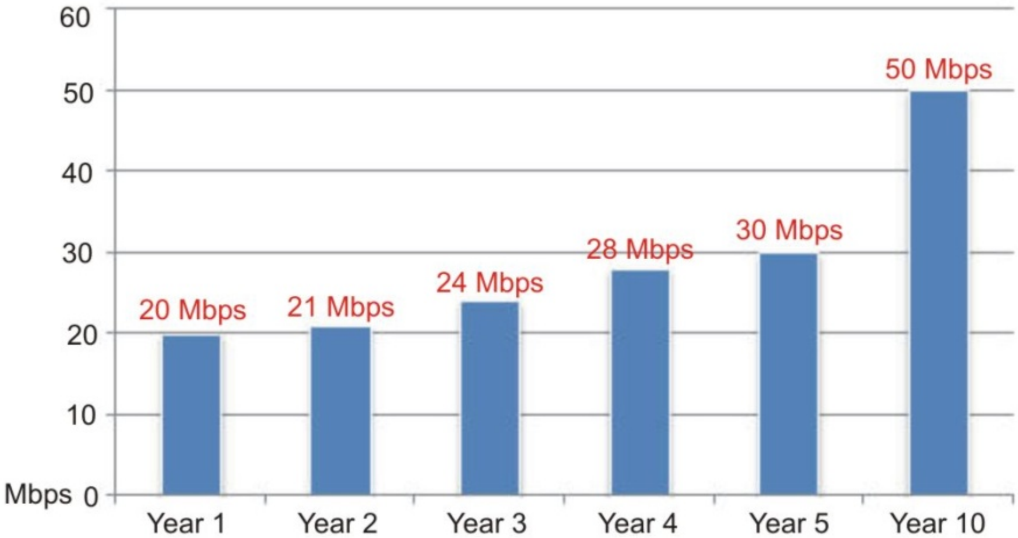


Figure 6.7.4 — Aggregate data demand (downlink and uplink)
(*Source: based on information taken from Figure 3.6, page 23, of DRDC Submission*[38])

Some conclusions of the DRDC study list are as follows:

- 10 + 10 MHz may be insufficient bandwidth to support public safety in the 10-15-year horizon;
- However, they also note that, improved spectral efficiency will likely outpace public safety demand for data, and, as a consequence, the required spectrum should decrease beyond year 10 (penetration of LTE devices among public safety users is expected to saturate).
- Despite the rapid pace of technology innovation, the ability to meet PS requirements with 10 + 10 MHz in the distant future, i.e. beyond 15 years, is not evident.

2. Another study of interest is by Motorola, titled, "Barricaded Suspect Incident Analysis: Enhancing critical incident response with public safety using Long Term Evolution (LTE) technology"[39].

The study analyzes the cumulative broadband traffic as various components of public safety activity are added to a safety crisis situation along the action timeline. The study shows the broadband data capacity usage for downlink and uplink transmission. From the examples presented, it can be determined how the average cell-sector capacity would accommodate the various data usage scenarios with an LTE system using either 5 + 5 MHz channels or 10 + 10 MHz channels. The scenarios show a cumulative data utilization of 16,000 MB for downlink data, and 10,000 MB for uplink data, transmitted for a period of 250 minutes. The average sector capacity of an LTE 5 + 5 MHz channel is 8 Mbps downlink and 3.5 Mbps uplink. That of a 10 + 10 MHz channel is 16.7 Mbps and 8.4 Mbps, respectively.

3. Lastly, an FCC whitepaper[40] focuses on the use of 5 + 5 MHz spectrum, and describes the scope and merit of the recommendations of the National Broadband Plan (NBP) on the deployment of a nationwide interoperable public safety broadband wireless network, based on LTE technology at 700 MHz. The NBP recommends, among other things, the development of a broadband public safety network based on

[39] Barricaded suspect incident analysis: http://www.motorola.com/web/Business/_Documents/Application%20Briefs/Static%20Files/Motorola_Barricaded_Suspect_Analysis.pdf

[40] The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity, Performance and Cost" (June 2010): http://transition.fcc.gov/pshs/docs/releases/DOC-298799A1.pdf

10 MHz (block D) leveraging a partnership with commercial carriers. Under the recommended Plan, the PS community would hold full right to the spectrum and the infrastructure, which will be shared between public safety and commercial entities, to improve economics and efficiency. The Plan would provide capacity for all day-to-day operations and for serious emergency scenarios. Surge capacity for emergency would be provided through priority access onto commercial LTE networks.

At this time, the FCC has decided that new public safety broadband networks in the 700 MHz band will need to use LTE technology to ensure synergy and compatibility with LTE commercial networks. At the time of authoring this document, the FCC had not yet decided on the approach for developing a nationwide PS broadband infrastructure or whether to adopt the NBP recommendations, in part or in whole.

Analysis of the Spectrum Management Environment of Public Safety

- Public safety is a large user group of the 150, 450 and 800 MHz land-mobile bands. In addition, public safety users have exclusive access to public safety spectrum in the 800 MHz (3 + 3 MHz) and 700 MHz (12 + 12 MHz) bands. Many of the government radio systems are used for some form of public safety and protection services.
- Public safety is afforded some priority access for shared land-mobile bands.
- The public safety band at 800 MHz is extensively used in large urban centres across the country. As the U.S. has rearranged the band plan at 800 MHz for public safety and some of the trunk mobile/ESMR spectrum, these portions of the band are no longer aligned in the common use for public safety operation along the border.
- Several spectrum management measures are being adopted to achieve greater spectrum efficiency and system interoperability. These include, in high-usage service areas, the maximization of mobile units per assigned frequencies, use of narrowband and advanced technologies, the monitoring of spectrum usage/traffic and clawback of lightly used frequencies. Furthermore, this includes the development of common systems at 700 MHz to be shared by several public safety users (police, fire and emergency first respondents).
- The continued application of these best practices should ensure that reasonable land-mobile frequencies, in conjunction with the new 700 MHz band, meet the evolving needs of public safety service over the next five years.
- Some provincial and municipal public safety systems, i.e. Province of Quebec and Montreal, make extensive use of the 150 MHz band. Other provincial public safety systems, such as Saskatchewan, use the 450 MHz band. In addition, the 800 MHz band is extensively used for large public safety systems, i.e. the Greater Vancouver Area (E-COMM) and Toronto. In general, for wide coverage in rural and remote areas, there is a high demand for the 150 MHz and 450 MHz bands
- There is considerable interest in developing common public safety systems at 700 MHz for police, fire and ambulance. Some of these new 700 MHz systems are being integrated as hybrid to existing systems. As examples, narrowband 700 MHz systems are proposed in Greater Vancouver Area with the existing 800 MHz ECOMM system, and in Alberta, with the existing province-wide 150 MHz system.
- The prospect of further implementation of narrowband technology, under Phase II re-farming (7.5/6.25 KHz channel equivalent) in the 150/450 MHz bands, may help to increase the number of equivalent frequency assignments over the next few years. Furthermore, the availability of software-defined-radio (SDR), multi-band radio and the efficiency of TETRAPOL trunking systems could greatly improve the more efficient use of spectrum.
- Advanced commercial cellular networks, using HSPA and LTE, may also accommodate some of the public safety data requirements.

6.7.4 Services and Spectrum Demand

Approach in Forecasting Future Demand for Public Safety Service and Spectrum

The foregoing information and analysis, contained in sections 6.7.2 and 6.7.3, were used to assess future service and spectrum demand for public safety. Also, some information presented in the land-mobile service, Section 6.6, is relevant to public safety. In determining the service and spectrum demand environment, the following was considered:

- The exclusive PS assignment at 800 and 700 MHz bands;
- Past trends and anticipated usage;
- Stakeholder perspectives, dynamics, challenges and plans;
- Technology and policy provisions for new PS systems;
- Level of frequency concentration in high-density urban centres;
- The PS use of land mobile for public safety and key issues related to that use;
- The prospect of broadband public safety network in the 700 MHz band.

Service Demand: Market Analysis

Public safety systems support specialized radio applications with features and functionality often different from traditional commercial mobile services. The use of the spectrum is based on having dedicated and reliable communications, which are often time-critical in nature.

The demand for services will continue to grow, with an accelerated move towards high-speed data and broadband communications for public safety applications. In general, the common elements of change in this sector, based on stakeholder input and research include growth in the following applications:

- Voice traffic: voice dispatch; group calling; 9-1-1 calls;
- Broadband data: multitude of broadband applications;
- Messaging: SMS, MMS, email;
- Database access and record upload: Map info, building plans, still images, biometric data, traffic advisories, etc.;
- Monitoring: i.e. vehicle location, tracking resources, telemetry;
- Video applications: surveillance, tactical support, ambulance-patient monitoring, public transit, etc.

The degree of demand for these applications varies on a day-to-day basis. Also, with public safety, one needs to account for extraordinary events, in which case, there can be a significant spike in usage and, hence, in demand.

As highlighted in Table 6.7.4, below, over the next several years to 2015, government land-mobile users and PS service agencies are expected to make greater use of advanced cellular networks, such as HSPA+ and LTE, for data-rich applications. This is considered especially true where the combination of high data rates, mobility and large coverage areas come into play.

While the use of 4.9 GHz spectrum is still limited, it is felt that its use for metropolitan area broadband wireless communications will increasingly play an important role for access and some point-to-point connectivity between sites.

The potential of future broadband PS spectrum at 700 MHz would accommodate a range of public safety needs for high-speed data communications. LTE technology for new broadband PS networks at 700 MHz would provide a common air-interface between public safety and commercial broadband networks.

Table 6.7.4 — General quantification of service and spectrum demand (*Source: Red Mobile Analysis*)

Public Safety	Service needs & plans	Solutions & installation base	Spectrum usage & needs
Past	PS began to implement: ▪ Multi-user systems and interoperability; ▪ Broadband RLAN for day-to-day operation of fire, police and EMS in 4940 MHz; ▪ 700 MHz networks.		
Now (2011)	▪ Major modernizations underway in PS systems in various locations, using 700 MHz (as described by RCMP). ▪ Continued PS use of Land-mobile bands for voice services	▪ Large number of municipal frequency assignments are used for PS ▪ Other government frequency assignments are also used for PS-related services.	▪ PS is large user of land mobile; ▪ Only limited land-mobile frequencies available for growth in certain areas.
Future (to 2015)	▪ High growth of new broadband PS applications, i.e. first respondents, emergency; ▪ Continued growth of voice and low-data communications	▪ A large number of narrowband PS assignments in 700 MHz; ▪ A considerable number of broadband systems in the fixed 4940 MHz band ▪ Use of some commercial HSPA+ and LTE commercial systems for broadband PS communications.	▪ Extensive use of 700 MHz and continued use of land-mobile bands for voice growth. ▪ Increase use of commercial HSPA+ and LTE for PS broadband data applications ▪ PS broadband network, at 700 MHz, may begin accommodating broadband applications

Spectrum Demand

Public safety services have been assigned a total of 22 MHz of public safety spectrum for narrowband/wideband mobile applications and 50 MHz of spectrum for broadband applications. The following spectrum has been exclusively assigned for PS use:

- 800 MHz band (3 + 3 MHz);
- 700 MHz band (8 + 8 MHz); and
- 4940 MHz band (50 MHz for broadband).

Industry Canada is considering the assignment of additional spectrum in the 700 MHz band for broadband PS use.

The demand for spectrum in this band is influenced by a number of dynamics including organic growth of users and traffic on existing LM bands, rapid growth as a result of data-rich multimedia applications, the migration of some services onto cellular networks and the evolution of PS systems on new spectrum.

In assessing the level of impact, it is important to note the key areas of pressure, as described below.

Pressure Points:

- The 150, 450 and 800 MHz land-mobile bands are fully occupied in large cities and certain regions with few frequencies available to be assigned.
- Generally, groups of frequencies are not available in the 150, 450 MHz and 800 bands to expand public safety systems or to establish critical mobile communications along the border.
- The exclusive PS spectrum in the 800 MHz band (3 + 3) is fully occupied in the largest cities.

Clearly, the prime LM bands used by PS for communications are either highly congested or quickly approaching congestion for large urban cities. As a result of the rollout of new 700 MHz systems; the sharing of common system among PS agencies; and more spectrally efficient technologies in use, it is envisaged that a small portion of contiguous land mobile frequency assignments may be released overtime, and likely closer to the 2014-15 timeframe. However, we believe that, in many situations, these dynamics may not be entirely enough to fulfill the organically growing need for narrowband communications, and any released spectrum will likely be utilized to service this demand. This is because it will take time for new systems to be implemented and for users to migrate. In addition, legacy systems will continue to be used in conjunction to the new systems well beyond the 2015 timeframe.

In terms of addressing the need for broadband communications, it is noted that the existing 4.9 GHz spectrum is underutilized, and its use will continue to grow for metropolitan-area use. However, for larger coverage areas, and where better coverage is needed in-building, the allocation of 700 MHz spectrum for mobile broadband use would provide opportunities for PS to have high-speed data capabilities for a wide range of data-rich services and applications.

6.7.5 Conclusion

In summary, groups of 150/450/800 MHz land-mobile frequencies are not available for new PS systems, especially in border areas and dense urban cities. Despite developments including use of newer, more spectrally efficient technologies; narrowbanding; use of 700 MHz spectrum; and use of cellular networks for some PS applications, it is expected that any released frequency assignments will be used up to serve existing demand.

In terms of PS communications, interoperability is crucial between first responders from different PS agencies, and new deployments in the 700 MHz band are expected to facilitate this.

Despite the new 700 MHz spectrum, it is expected that the 800 MHz land-mobile spectrum used by PS will continue to grow at current rates in large urban areas over the Study period.

6.8 Amateur Radio

6.8.1 Overview

The amateur radio service is used by individuals for communication between amateur stations, radio transmission for non-commercial exchange of messages, disaster relief communications, and training, etc. There are several bands allocated to the amateur service, and many of these are on a shared basis.

A number of frequency bands have been allocated internationally to amateur services. These include the:

- 160, 80, 40, 30, 20, 16, and 10 meter bands at HF;
- 6 and 2 meter bands and the band 222-225 MHz at VHF; and
- A number of bands across the UHF and SHF ranges are for primary and secondary services.

Regulatory bodies may assign a number of these bands as primary or secondary to amateur service, in accordance with their domestic spectrum priorities. The Canadian amateur radio community participates actively at ITU-WRC conferences to advance the interest of its members.

The amateur community is well recognized as providing valuable communications assistance during times of disaster and emergency, in particular, when traditional wireline and wireless communications have failed. Spectrum regulators have often approved the use of secondary service allocations for temporary amateur communications during these hardship situations.

6.8.2 Spectrum Inventory and Utilization

The Inventory Report (Section 4.2.1) indicates that there is more than 23 GHz of spectrum allocated to the amateur service; approximately 20% of this is allocated on a primary basis, and 80% is allocated on a secondary basis. Given that this Study is limited to between 52 MHz and 38 GHz, there is approximately 57 MHz of spectrum allocated on a primary and exclusive basis to the amateur service in this range.

Amateur stations are not licenced in Canada. Amateur station operators require an Amateur Radio Operator Certificate with the Basic Qualification and Call Sign. With this certificate, an amateur operator may operate within any of the amateur service frequency bands in accordance with the operator's qualifications identified for the specified band.

In general, the amateur service bands are aligned with the U.S. and internationally. There are currently more than 60,000 amateur radio operator certificates across Canada. The Inventory Report (Figure 4.1, Section 4.4) shows the total number of amateur certificates active by fiscal year in Canada.

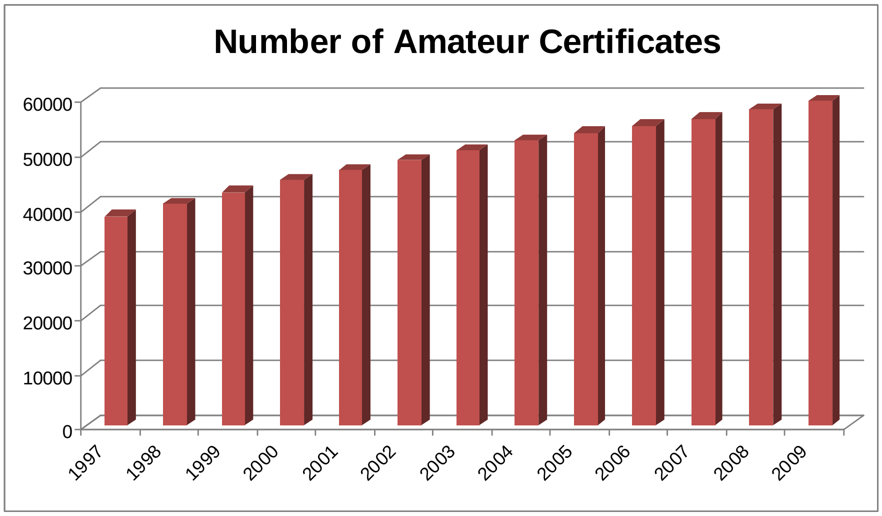


Figure 6.8.1 — Total of Amateur Certificates, by years (*Source: Radio Amateurs of Canada*)

As the Amateur radio stations are not licenced, the best source of information on the general spectrum utilization is from the Radio Amateurs of Canada. The Amateur Association provides an overview of the current spectrum utilization and the specific communications activities in certain bands, as discussed below.

6.8.3 Stakeholder Input and Research Analysis

Canadian Amateur Association

- The types of activities carried out by amateurs vary widely, but the most popular activity continues to be the use of VHF and UHF FM voice communications between amateurs using hand-held and mobile radios. The most popular bands for this purpose are 144-148 MHz and 430-450 MHz. Indeed, this strong use of the VHF and UHF bands has been augmented by amateurs embracing Internet technology as a means of inter-connecting repeaters into a worldwide network. Furthermore, amateurs are now adopting digital voice technology and mobile Internet connectivity, which puts further demand on amateur spectrum at 144-148 MHz, 430-450 MHz and 1240-1300 MHz.
- It is difficult to estimate numbers of amateur stations in use at any time. In general, amateur frequencies are neither assigned nor channellized. Amateurs use communications modes that occupy a wide variety of bandwidths, ranging from a few tens of Hz for Morse code (A1A) communications to several MHz for two-way amateur television. The main exception to this non-channellized and unassigned mode of operation is the use of voice repeaters for FM communications at VHF and UHF. In order to avoid interference between repeaters, there is a system of voluntary frequency coordination in place for these voice repeaters. In large urban areas, there are virtually no unused repeater frequencies available in the band 144-148 MHz, and the congestion of repeaters in the band 430-450 MHz is also a problem in these areas. The total number of coordinated repeater assignments is approximately 1200 in the band 144-148 MHz, 640 assignments at 430-450 MHz, 120 assignments at 222-225 MHz and 120 assignments at 50-54 MHz.
- FM voice communications may be used in the bands 50-54 MHz, 144-148 MHz, 222-225 MHz, 430-450 MHz, 902-928 MHz, 1240-1300 MHz and 2300-2450 MHz. The majority of FM voice is in the bands 144-148 MHz and 430-450 MHz, with lower levels of activity at 50-54 MHz, 902-928 MHz and 1240-1300 MHz. Digital voice and data repeaters interlinked via the Internet are now being deployed in major Canadian urban areas, with operation in the bands 144-148 MHz, 430-450 MHz and 1240-1300 MHz. In some Canadian urban areas, wideband amateur fast-scan video activity is presently occupying 6 MHz wide channels; this may include cross-band video repeaters in the band 430-450 MHz and in the band 902-928 and/or the band 1240-1300 MHz. It is becoming a challenge

to assign spectrum space for these new applications as the technology envelope continues to increase.

- Weak signal communications, including Earth-Moon-Earth (moon bounce) communications, are concentrated near 144.2 MHz, 222 MHz, 432 MHz, 903 MHz, 1296 MHz, 2304 MHz, 3400 MHz, 5760 MHz, 10.36 GHz and 24.19 GHz. These frequencies are also used for terrestrial communications, using such propagation methods as Sporadic E-layer, tropospheric, meteor scatter, auroral and rainstorm scatter propagation. In the amateur satellite service, frequencies in the 144-146 MHz, 435-438 MHz, 1260-1270 MHz and 2400-2450 MHz bands are currently used by international operational satellites.

6.8.4 Services and Spectrum Demand

Approach in Projecting Future Demand for Amateur Radio Spectrum

The foregoing information, contained in sections 6.8.2 and 6.8.3, provides the information base to assist in projecting future demand for amateur radio. The information utilized includes:

- The wide range of frequency bands (primary and secondary allocations) in the Inventory Report (section 4.2.1);
- The amateur certificates and the submission by the Canadian Amateur Association on their activities, most popular services/bands more difficult to coordinate repeater (voluntary coordination of repeaters by amateurs) stations and projected amateur certificate growths.

Service Demand: Market Analysis

Amateur services are for private recreation use of operating radio transmission, for non-commercial exchange of messages, for experimentation, self-training and to assist in providing emergency communications.

Services are most often used as follows:

- By individual operators, to provide communications between amateur radio stations over regional or worldwide radio links using terrestrial and satellite facilities;
- Amateur communications to interconnect with public networks, such as the PSTN, public packet data networks (PPDN) and the Internet;
- Amateur radio operators use various modes of transmission to communicate. Voice transmissions are most common, in addition to high-quality FM audio, and other more reliable communications, often over long distances.
- For voice communications, using various technologies, such as AM, FM and DSB-SC.
- For image transmission of amateur TV (fast or slow scan) and facsimile
- For text and data, using continuous wave, packet radio, phase-shift keying and to spread spectrum.

The size and growth of amateur membership is a good proxy of the interest in amateur radio service and the continued demand for spectrum. As of mid-1999, there were approximately 46,000 licenced amateur operators and approximately 60,000 in early 2011. The number of new licenced amateur operators during 2008-2010 grew by 1,500 per year. An estimate of amateur service growth is for this trend of 1,500 new members per year to continue over the next five years.

As there is no record on spectrum usage on the wide range of frequency band available, it is only practical to estimate the areas of high occupancy, based on the popularity of the certain amateur service applications.

Table 6.8.1 — Summary of service types and growth (*Source: Red Mobile Analysis*)

Spectrum	Voice and Internet	Image, text and data	Comments
Up to 2011	▪ Majority of voice and Internet links are in 144-148 MHz and 430-450 MHz bands; ▪ Congested number of voice and data repeaters in 144-148 MHz band and 430-450 MHz bands certain cities; ▪ Fewer voice/data repeaters in 222-225 and 50-54 MHz bands; ▪ Also, 1240-1300 MHz band is used.	▪ Due to BW, the 420-450 MHz band supports amateur television: ▪ Also cross-band repeaters in 902-928 MHz and 1240-1300 MHz as video repeaters.	▪ Some difficulty in coordinating frequencies in the 144/430 MHz bands for voice/data repeaters in certain cities. ▪ Note: This is a voluntary coordination process among amateurs.
2015	▪ Continued growth of voice/Internet traffic will have to be accommodated in other bands, then the 144/430 MHz bands.	▪ Wide range of frequency available to accommodate these service applications.	▪ With continued interest in amateur radio and membership, the existing allocated spectrum to amateurs will be increasingly used.

Spectrum Demand

The amateur 144-148 and 430-450 MHz bands are the most utilized spectrum for voice communications. Frequencies for new repeaters are often hard to find and coordinate by the amateurs in large cities. The total number of coordinated repeater assignments is approximately 1,200 in the bands: 144-148 MHz, 640 at 430-450 MHz, 120 at 222-225 MHz and 120 at 50-54 MHz.

FM voice communications may be used in the bands 50-54 MHz, 144-148 MHz, 222-225 MHz, 430-450 MHz, 902-928 MHz, 1240-1300 MHz and 2300-2450 MHz. The majority of FM voice is in the bands 144-148 MHz and 430-450 MHz, with lower levels of activity at 50-54 MHz, 902-928 MHz and 1240-1300 MHz.

Wideband amateur fast-scan video activity is presently occupying 6 MHz wide channels in some cities and is using cross-band video repeaters in the band 430-450 MHz and in the band 902-928 and/or the band 1240-1300 MHz. It is becoming difficult to assign spectrum for these new applications as the bandwidth of new technology continues to increase.

Usage trends indicate:

- High demand for repeater frequencies in urban areas, in the bands 144-148 MHz and 430-450 MHz.
- The total number of voluntary coordinated repeater assignments by amateurs is approximately 1,200 at 144-148 MHz, 640 at 430-450 MHz, 120 at 222-225 MHz and 120 at 50-54 MHz.

- The majority of FM voice is in the bands 144-148 MHz and 430-450 MHz, with lower levels of activity at 50-54 MHz, 902-928 MHz and 1240-1300 MHz.

6.8.5 Conclusion

While demand has been steady for the most part, there is some pressure on bands, including 144-148/430-450 MHz Band. Some of this pressure may be alleviated by the use of other bands for voice, i.e. 50-54, 222-225, 902-928, 1240-1300 and 2300-2450 MHz. The range of frequency bands available should ease some of the repeater operation congestion experienced in the 144/430 MHz bands in some urban areas.

In some cities, wideband amateur fast-scan video activity is presently occupying 6 MHz wide channels using cross-band video repeaters in the bands 430-450 MHz, 902-928 and/or 1240-1300 MHz. It is becoming difficult to assign spectrum for these new applications in these cities.

However, despite the occurrence of high usage for certain amateur services in particular bands, there is no additional demand for spectrum identified for this sector in the 2010-2015 time frame.

6.9 Aeronautical Services

6.9.1 Overview

Civil and military aviation are both supported by a wide range of radionavigation, communications, and radiolocation systems and applications. These systems are implemented worldwide, and aeronautical frequency allocations are international in nature. The majority of the aeronautical bands are, either directly or indirectly, part of the air navigation and air-traffic management systems. Canada is bound, by international treaty, to designate certain radio frequencies for aeronautical services and, to the greatest extent possible, keep those frequencies free from harmful interference.

The aeronautical regulatory requirements for radiocommunications are generally established by International bodies, such as the International Telecommunications Union (ITU) and the International Civil Aviation Organization (ICAO), due to the global aspects of the various aeronautical applications. The aeronautical requirements are adopted by administrations and domestic Civil Aviation agencies. In Canada, Transport Canada regulates the implementation and operation of aeronautical systems, and NAV CANADA is the agency responsible for the operation of air traffic control including the oversight of a number of civil aeronautical navigational systems. Canadian airport authorities are responsible for implementing certain radiodetermination systems, such as airport surveillance systems and operation communications. The technical requirements for universal aeronautical navigation systems are developed either by the ICAO or various regional technical groups. Industry Canada oversees the overall spectrum management of aeronautical frequency allocation, spectrum utilizations (service designations), licensing and enforcement.

A number of frequencies have been assigned by Industry Canada for VHF radionavigation, specific to the operation of mobile stations in the aeronautical service[41]. Industry Canada's spectrum and technical standard RBR-1 includes VHF frequencies for such applications as marker beacons, instrument landing systems, general aviation communication, air traffic control, as well as aeronautical operation control communications. Also, miscellaneous frequencies are available for emergency search-and-rescue use.

[41] RBR-1: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09738.html

A large number of bands are assigned for aeronautical radionavigation in the UHF/SHF range from 960 to 15,700 MHz, for a multitude of critical aeronautical systems, such as distance/bearing measuring equipment, transponders, GNSS (GPS, GLONASS) — primarily radar, mobile satellite surveillance radar (AMS(R)S), airborne radar altimeters, wind-shear radar, airborne radar and Doppler navigation. In addition, the military, some aircraft manufacturers and public safety agencies make extensive use of mobile aeronautical telemetry spectrum in the 2360-2400 MHz band.

In the case of an aircraft flying from one location to another, multiple bands are used simultaneously during the flight, from takeoff to landing, plus taxiing at the airport. It is, therefore, necessary to consider the relationship between aeronautical bands when evaluating their utilization. Aeronautical allocations are internationally harmonized. In particular, Canada and the U.S. are fully harmonized.

6.9.2 Spectrum Inventory and Utilization

According to the Inventory Report**,** there is a common trend for various applications that overlay the Air Navigation System (ANS)**.** The ANS ensures the safety of all flights, whether domestic, international, civilian or military. Domestically, the responsibility of this system is shared by Transport Canada and NAV CANADA. In the military domain, DND is the responsible department. To meet these responsibilities, an agreement for the selection and coordination of the aeronautical bands, as shown in Table 6.9.1, below (Inventory Report Table 9.1), exists between Industry Canada (IC) and NAV CANADA.

Table 6.9.1 — Bands relevant to frequency selection and coordination between IC and NAV CANADA (*Source: Inventory Report*)

Frequency bands	Applications
74.8-75.2 MHz	ILS, Marker Beacons
108.000-121.9875 MHz	VOR, ILS, ATSC, VHF Communication
123.5875-128.8125 MHz	VHF Communication
132.0125-136.4875 MHz	VHF Communication
328.6-335.4 MHz	ILS Glide Slope
960-1215 MHz	DME, TACAN, TCAS, SSR
5030-5091 MHz	MLS

Table 6.9.2 — Other related aeronautical bands (*Source: Inventory Report, Table 9.3*)

Frequency bands	Applications	Major users
335-399.9 MHz	Military applications	DND
1300-1370 MHz	Primary radars	DND, NAVCAN
2700-2900 MHz	Airport surveillance Radars	DND
4200-4400 MHz	Radio altimeters	Radio altimeters are installed on aircrafts and are not domestically licensed
5350-5460 MHz	Airborne and ship radars	DND, ship radars Not domestically licensed.
8750-8850 MHz	Radar applications	DND, Coast Guard Canada
9000-9500 MHz	Radar applications	DND, Coast Guard Canada

13.25-13.4 GHz	Airborne radar applications	DND
15.4-15.7 GHz	Airborne radar applications	DND

Spectrum Utilization

- The aeronautical community heavily uses the major aeronautical bands (108-137 and 960-1164 MHz), which are part of the air navigation system (ANS). In particular, the two major air navigation system operators are the DND and NAV CANADA.
- In the 108-111.95 MHz, the ILS localizer frequencies tend to be congested around major airports.
- The selection of optimal channel frequency is difficult as it is channel-paired with Glidepath (328-335 MHz) and DME (960-1215 MHz) through international global standards.
- A large number of aeronautical services operate in the bands from 960 MHz to 15.7 GHz. Congestion may exist in the 960-1215 MHz band, where multiple services are deployed in a sharing scenario, including DND services.
- Several critical aeronautical systems operate in multiple bands, providing different safety services, whether collision avoidance, terrain avoidance, onboard weather radar, radar altimeters, SATCOM, navigation, etc.
- Most of these systems operate in accordance to global international standards within the allocated and available spectrum.
- The existing 2300 MHz MATS/AMT spectrum is shared between military, public safety agencies and aircraft manufacturers, and it is difficult to operate simultaneously with other users in same area. Flight-test programs for new and old aircrafts use MATS/AMT spectrum to provide dynamic real-time downlinking of several hundred data parameters.

6.9.3 Stakeholders Input and Research Analysis

The stakeholders who provided input included the DND, Transport Canada, NAV CANADA and manufacturers.

1. Aeronautical Services in the 108-137 and 328-335 MHz Bands

Transport Canada:

- All aeronautical services in the bands 108-137 MHz and 328-335 MHz are expected to experience further constraint or congestion.
- In the band 108-111.975 MHz, the availability of ILS Localizer frequencies is lacking particularly in dense urban areas. The selection of an optimal ILS Localizer channel frequency is very difficult as it is channel-paired with Glidepath (328-335 MHz) and DME (960-1215 MHz) through international global standards. Cross-border coordination also applies.
- Congestion exists in the VHF communication band 117.975-137 MHz used at all airports, as well as for the approach, landing and en-route phases of flights. International standards and cross-border frequency coordination applies.
- However, these services do not experience growth, as they are constrained within the limitations of allocated spectrum. Additional spectrum is not available to expand these services to relieve frequency congestion, and there is no immediate solution. In the end, an internationally coordinated migration to digital technologies may alleviate some of the congestion. However, any migration to other technologies has to take into account aircraft fitment and certification in large fleets. The global migration to other technologies or equipment could take 15 to 25 years

NAV CANADA:

- Based on arrangements with Industry Canada, NAV CANADA is responsible for implementing aeronautical navigation services in a number of bands or frequencies assigned to aeronautical service, as outlined in RBR-1 - Technical Requirements for the Operation of Mobile Stations in the Aeronautical Service.
- NAV CANADA forecasts some growth over the next five years in the radionavigation sub-bands VHF 108-137 MHz and 328-335 MHz, including areas where the spectrum is already saturated.
- For VHF aeronautical service, NAV CANADA forecasts the following growth in frequency assignments (FA) for 2010-2015:
  - Band 108.0-111.975 MHz: Instrument landing system (ILS) - No new FA anticipated are projected over the 2010 to 2015 period;
  - Band 121.9875-123.5875 MHz: General Aviation Communication (GAC) - there are 400 FAs in 2010, a growth of 25 FA per year is projected over the 2010 to 2015 period;
  - Band 123.5875-128.8125 MHz: Air Traffic Control (ATC) Services - From a base of 400 FAs in 2010, a growth of 30 assignments per year is projected over the 2010 to 2015 period; and
  - Band 132.0125-136.4875 MHz: Air Traffic Control (ATC) Services - Growth of 10 FAs per year is projected over the 2010 to 2015 period.
- NAV CANADA indicated that the VHF Air Traffic Control bands 117.975 to 121.9875, 123.5875 to 128.8125 and 132.0125 to 136.0 MHz have been essentially saturated in certain areas of Canada (such as along the Toronto to Montreal corridor) for the past 20 years or more. This is due to the fact that this band experienced very rapid growth in the past, more so in the U.S. than in Canada. And airborne transmissions at relatively high altitudes in the U.S., on a frequency within that band, prevent the use of that frequency in Canada for several hundred nautical miles. Therefore, the frequency congestion being experienced is a result of the proximity to the United States.

DND:

- The DND does not expect major service growth in the UHF/SHF Aeronautical Bands and does not anticipate additional demand of spectrum.

2. Spectrum in the 960 MHz to 15.7 GHz Range to Support Civil and Military Aviations

Manufacturer:

- MATS/AMT spectrum is utilized for the Flight Test Telemetry Program using frequency diversity technique in the upper part of the band 2360-2400 MHz. It is difficult to access spectrum in cases where more than one user (other than DND) exists in an area.

Transport Canada:

- A large number of aeronautical services operate in the bands from 960 MHz to 15.7 GHz. Congestion already exists in the 960-1215 MHz band, where multiple services are deployed in a complex sharing scenario, including DND services.
- Flight-test telemetry programs are complex, costly and involve dynamic real-time downlinking of several hundred data parameters using avionics and antenna design, optimized for a specific frequency range. Currently aeronautical mobile telemetry spectrum is in the 2360-2400 MHz band.
- Several critical aeronautical systems operate in multiple bands providing different safety services, whether collision avoidance, terrain avoidance, onboard weather radar, radar altimeters, SATCOM, navigation, etc.
- Many of these systems operate in accordance with global international standards within the allocated and available spectrum. Continued growth in the aviation industry places increasing demand on the continued availability of these systems. The service provided by these systems must be continually available and must operate within the constraints of the allocated spectrum.
- The aviation industry is very unique in how it uses spectrum and, as such, it cannot be compared to

how other industries use spectrum. For example, one commercial passenger aircraft flying from Toronto to Ottawa will use VHF communications and navigation frequencies, UHF DME, SSR transponder frequencies, onboard weather radar and radar altimeter, ground proximity warning frequencies, GPS L-Band frequencies, etc. All of these systems are used simultaneously and not in isolation by a single system or frequency. Multiply this one example by the total number of aircraft operating at any given moment in time in Canadian airspace, including international over-flights.

NAV CANADA:

- In the UHF/SHF bands (960-5150 MHz) used to support civil and military aviation (various sources), the following growth in frequency assignments is envisaged for 2010 to 2015:
  - Band 992-1213 MHz: Distance Measuring Equipment (DME) and Aircraft Transponders - 10 new FAs;
  - Band 1051-1231 MHz: GPS L5 - An increased use of GPS L5 is anticipated when it is widely available;
  - Band 1030-1090 MHz: Secondary Surveillance Radar 15 FAs per year;
  - Band 1240-1350 MHz: Aeronautical Radio Navigation (primary Radar) There have been a stable 24 primary surveillance radar and 96 FAs for past 20 years, and change to this is not anticipated;
  - Band 4200-4400 MHz: Airborne Radar Altimeters DND makes extensive use and this is expected to continue over the period; and
  - Band 5000-5150 MHz: Aircraft to satellite communications; MLS, AM(R)S, aeronautical mobile, wireless networks - Service implemented by NAV CANADA. WRC-07 allocation provision for AMT service in band 5091-5150 MHz was entered in the Canadian Table of Allocation, and its utilization will be subject to spectrum policy.

DND:

- DND believes that there is insufficient spectrum allocated to meet the needs of MATS/AMT.
- Minor growth is expected in the Unpiloted Aerial Vehicles (UAVs) area.

Manufacturer:

- The existing MATS/AMT band 2360-2400 MHz is shared among military, public safety agencies and aircraft manufacturers. Non-military MATS/AMT operation is permitted in the top 10 MHz. It is difficult to operate simultaneously with other users in the same area within this small amount of spectrum.

Research Analysis

1. A U.S. NTIA study[42] on future U.S. Government radiocommunications makes projections on the trends in the radionavigation service and the radionavigation-satellite service as follows:
   i. GPS is the main radionavigation service throughout the world. The increased use of GPS should promote long-term reductions in the use of traditional radionavigation systems. Such systems as ILS, VOR, and MLS are expected to be replaced by GPS-based systems.
   ii. Trends toward more-accurate and reliable satellite-based technologies are making some older systems obsolete, reducing the current and future spectrum needs in several frequency bands.

Despite the projected trends of the aforementioned study, it is believed that the existing radionavigation systems (i.e. MLS, etc.) will continue to operate in Canada, as they do today, well into 2015 and beyond. With the increased use of Global Navigation Satellite Service (GNSS), such as GPS, in providing and supplementing aeronautical navigation operations, there is some concern that terrestrial use of mobile satellite spectrum in the L-band adjacent to the GPS allocations could significantly limit or interfere with

[42] Spectrum Management for the 21st Century; The President's Spectrum Policy Initiative; Federal Strategic Spectrum Plan; March 2008

the operation of GPS navigation operation around major airports. Industry Canada made provisions[43] to ensure that ATC rollout and operation will not cause harmful interference to GPS navigation systems at airports, in its spectrum policy for the future operation of ancillary terrestrial component (ATC) or terrestrial cellular service as an integral part of the mobile satellite service within the L-band, The cellular ATC operation is secondary in status to primary services, such as GPS. Nevertheless, concerns have been raised of late in the U.S. regarding potential interference to GPS applications with the full implementation of cellular ATC service.

2. Industry Canada has begun the public process of considering increasing the amount of spectrum available for aeronautical mobile telemetry (MATS/AMT) as follows:

   i. In its Consultation on revising the Canadian Table of Frequency Allocations in 2009, Industry Canada made proposed revisions to the band 5091-5150 MHz with the entry of AERONAUTICAL MOBILE as primary service and footnote 5.444B. At that time, it was indicated that: *"Industry Canada plans to hold public consultations in the near future to develop spectrum utilization policies to address the spectrum requirements of the aeronautical community and AMT in Particular"*[44]. It has been reported that some AMT equipment is being developed in this new band.
   ii. Furthermore, in its Consultation on the Spectrum Allocations and Spectrum Utilization Policies for the Frequency Range 1435-1525 MHz (L-Band) - December 2009[45], Industry Canada indicated its intention as follows:

"Industry Canada will review the policy regarding the band 2360-2400 MHz in a forthcoming consultation that will also consider the new bands identified for AMT at the 2007 World Radiocommunication Conference (WRC-07) in Geneva. The new bands identified for AMT at WRC-07 may address long-term spectrum requirements, for which equipment could become available in several years. In the meantime, Industry Canada has received some requests to accommodate the immediate and mid-term requirements of the aeronautical industry in the 1.4 GHz band, considering the capabilities of the industry's test equipment."

6.9.4 Services and Spectrum Demand

Approach in Forecasting Future Demand for Service and Spectrum

The foregoing information and analyses, contained in sections 6.9.2 and 6.9.3, provide the information base to assist in projecting future service and spectrum demand for aeronautical service. The information used includes:

- The frequency bands allocated to aeronautical service and assigned to NAV CANADA for coordination from the Inventory Report, the number of systems in various bands;
- Input from stakeholders and reporting from NAVCAN on the frequencies assigned and forecasted in various bands under its coordination; and
- Input from various users of aeronautical services.

[43] See RP-023 — Spectrum and Licensing Policy to Permit Ancillary Terrestrial Mobile Services as Part of Mobile-Satellite Service Offerings; May 2004: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08174.html

[44] Proposed Revisions to the Canadian Table of Frequency Allocations (2009 Edition): http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09230.html

[45] Consultation on the Spectrum Allocations and Spectrum Policies for the Frequency Range 1435-1525 MHz (L-Band): http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09751.html

For this sector, the users' views are important in projecting the demand for spectrum for particular applications and the evolution of aeronautical services. The forecast for demand is based on these sources of information.

Service Demand: Market Analysis

Civil and military aviations are supported by a wide range of radionavigation, communications and radiolocation systems and applications. The majority of the aeronautical bands are, either directly or indirectly, part of the air navigation and air-traffic management systems.

We note that a five-year trend analysis, based on the numbers of Frequency Assignments (FAs), would not be representative of the aeronautical services' spectrum usage. Once the systems are deployed, either at airports or in aircrafts' avionics systems, their lifespan is some decades. We address the pressure points and spectrum needs in the following section, based on input from stakeholders. However, it should also be noted that:

- Global navigation satellite services, such as GPS, will play an increasing role in supplementing existing radionavigation system and may reduce the reliance on traditional systems such as ILS, VOR and MLS (see findings of NTIA studying section 6.9.3, above);
- While it has been indicated by a stakeholder that the bands 74.8-75.2 MHz and 5000–5150 MHz are underutilized, other usages in these bands may not have been considered by the stakeholder, such as the use of the band 5000-5150 MHz for airport radar surface applications by airport authorities.

Spectrum Demand

There are areas that experience a higher degree of usage and some congestion, as noted below:

Pressure Points:

- There is high usage in bands 108-137 MHz and 328-335 MHz in certain areas where spectrum has started to experience some congestion for all services. This is the case for the Toronto-Montreal cross-section, where the spectrum is saturated due to the close vicinity to the Northeastern U.S. aviation corridor;
- The band 108-11.975 MHz, available for ILS localizer frequencies, is lacking particularly in dense cities;
- Congestion in VHF communications band 117.975-137 MHz used at all airports;
- The need for additional MATS/AMT spectrum to supplement the 40 MHz in the band 2360-2400 MHz was raised by two users. Industry Canada has initiated public processes, as outlined in section 6.9.3, to consider additional spectrum for MATS/AMT;
- Systems and applications in the 960-5150 MHz range needing additional frequencies are:
  - Distance-measurement equipment (DME) in the band 992-1024 MHz;
  - Secondary-surveillance radars in the band 1030-1090 MHz; and
  - New generation of surveillance systems in the band 5000-5150 MHz.

6.9.5 Conclusion

Aeronautical services use international frequency allocations, internationally set and followed standards and technologies based on ITU and ICAO requirements. Sometimes it can take from 15 to 25 years to migrate legacy technology systems to new digital installations.

It has been reported that all aeronautical services in the band 108-137 MHz and 328-335 MHz have been experiencing further constraint and congestion. In particular the band 108-111.975 MHz assigned to ILS localizer is lacking frequencies in dense urban areas. Also congestion exists for VHF communications at all airports.

In order to meet the growing service demand, several bands in VHF, UHF and SHF will require additional frequency assignments in the period to 2015.

6.10 Maritime Mobile Service

6.10.1 Overview

The maritime mobile service is defined as: "A mobile service between coast stations and ship stations, or between ship stations, or between associated onboard communications stations; survivor craft stations and emergency position-indicating radio-beacons may also participate in this service." Maritime mobile service provides a wide range of communication services to vessels operating in international waters, coastal areas, and inland lakes and waterways. It includes communications with coast-guard ships, aircrafts, and shore facilities for search and rescue, security and sovereignty. Maritime mobile services provide a means of communications for the day-to-day activities of the maritime community, as well as providing the critical safety link for the protection of life and property at sea.

Because safety of life on water is an international concern, compatibility among stations authorized by all nations is preferable. Therefore, many of the maritime standards are established by international agreements administered by the ITU and the International Maritime Organization (IMO). The ITU and IMO regulations are the basis for the regulations established by Industry Canada and Transport Canada with the participation of the Canadian Coast Guards. One example of an international requirement is the Global Maritime Distress and Safety System (GMDSS) and the international provisions for Safety of Life at Sea (SOLAS) communication facility requirement on vessels 300 gross tons and above.

This Study will address only the VHF maritime mobile communication band.

Today, most of the maritime mobile services use analogue technologies to communicate. However, with the emergence of new digital technologies (discussions at the ITU, as well as the International Maritime Organization (IMO), and the International Association of Aids to Navigation and Lighthouse Authorities (IALA)) the maritime community would benefit from the switch to digital. The revision of frequencies and channel arrangements of the International Radio Regulations has begun, in order to allow the implementation of new digital technologies for maritime mobile service.

The VHF mobile maritime band plan in the band 156-162.5 MHz has more than 100 frequency channels carefully designated to a wide range of maritime applications and to particular regional operations (see Industry Canada RBR-2[46]).

The main maritime communication operations (nature of service and type of traffic) provided accesses to the maritime frequencies are:

- Inter-ship
- Ship-to-shore
- Commercial
- Non-commercial
- Safety
- Ship movement
- Public correspondence
- Automatic Ship Identification and Surveillance System.
- Vessel Traffic Services

[46] Document RBR-2 contains a series of elaborate schedules of the spectrum assigned for various types of maritime service applications. Approximately 100 channels are assigned for specific uses among the maritime spectrum in the VHF mobile band 156-162.5 MHz.

6.10.2 Spectrum Inventory and Utilization

The Canadian Table of Frequency Allocations has a number of bands allocated for maritime mobile and maritime radionavigation services, as shown below (Inventory Report Table 10.1, section 10.2.1 and RBR-2).

Table 6.10.1 — Frequency bands allocated to maritime services (*Source: Inventory Report*)

Frequency Band (MHz)
.415 – .525
2.000 – 2.495
2.505 – 2.850
4.000 – 4.438
5.73 – 5.90
6.200 – 6.525
8.100 – 8.815
12.230 – 13.200
16.36 – 17.41
18.78 – 18.90
19.68 – 19.80
22.000 – 22.855
25.07 – 25.21
26.100 – 26.175
156-162.5
216 – 220
2850 – 3100
5470 – 5650
8850 – 9000
9200 – 9500

Allocations to the maritime mobile service are in the MF-HF bands (300-3000 kHz and 3-30 MHz) for long haul, over-the-horizon communications of ship at high seas and the VHF bands (156-162.5 MHz and 216-220 MHz ranges).

In the VHF maritime mobile bands, there are more than 200 frequencies assigned for various maritime operations and in different areas of the countries. The nature and type of traffic are: for inter-ship communications, ship/shore/commercial ships, non-commercial ships, safety, ship movement, public correspondence, automatic ship identification and surveillance systems and vessel traffic services. The areas of operations and present number of assigned frequencies are shown in Figure 6.10.2 (Industry Canada RBR-2), below.

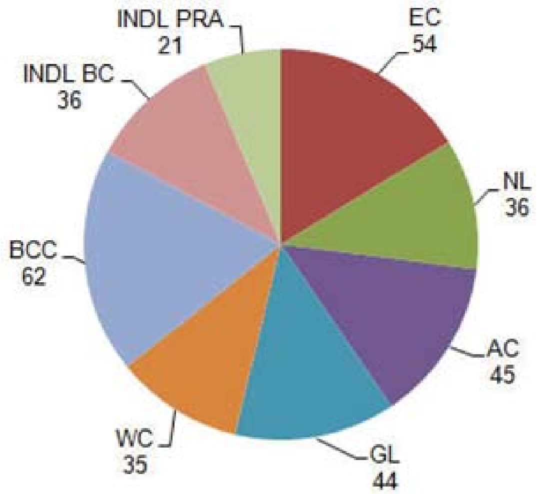


Figure 6.10.2 — Number of frequencies assigned to maritime mobile service, by areas (*Source: Industry Canada RBR-2 and Red Mobile Analysis*)

Legend

All Areas (AA), as represented below, add to 225 frequency assignments:

- East Coast (EC): NL, AC, GL and Eastern Arctic areas
- NL: Newfoundland and Labrador
- AC: Atlantic Coast, Gulf and St. Lawrence River, up to and including Montréal
- GL: Great Lakes (including St. Lawrence above Montréal)
- WC (West Coast): BCC, Western Arctic and Athabasca-Mackenzie Watershed areas
- BCC: British Columbia Coast (Pacific Coast)
- INLD BC: Inland Waters of BC and the Yukon
- INLD PRA: Inland Waters of MB, SK, and AB

The major maritime users are Fisheries And Oceans Canada (incl. Coast Guard), commercial fishing fleets, commercial vessels and pleasure crafts. The maritime mobile service applications are for emergency, weather channels, automatic ship identification and surveillance (AIS), port operation and other uses.

The Canadian maritime mobile service has a distribution of coast stations, according to the maritime ship activities. Industry Canada RBR-2 provides information on the use of maritime mobile services (number of licences for coastal stations and vessels stations). Due to the limited information on licences and assignments in Canada, spectrum trends based on the numbers of assignments are not representative of this type of service. The maritime community, with the involvement of several international organizations, has been implementing new digital technologies. However, since this is a worldwide endeavour, the changes are slow.

6.10.3 Stakeholder Input and Research Analysis

As comments were not received on the VHF maritime mobile services from stakeholders, the information below is a summary of the research conducted from secondary sources.

- The U.S. NTIA Report forecasts a continuing need for maritime mobile communications in the band 156-162 MHz for, at least, the next 10 years. Narrowbanding the entire band to 12.5 kHz channels would provide additional channels. However, the implementation of narrowband maritime mobile must accommodate international interoperability requirements, as maritime services are global in nature. Thus, maritime services used by large commercial vessels operating at high seas, coastline ports and waterways may consist of a multitude of radio systems. These may include maritime mobile stations, marine radars for surveillance and collision avoidance, satellite radionavigation (such as GPS), mobile satellite communications, HF and MF over-the horizon communications.

- It has been noted, as an example, that during the search-and-rescue operation of the Swiss Air disaster (September 1998) off the coast of Nova Scotia, there was a shortage of public safety and maritime mobile frequency to accommodate the wide range of activities among first respondents and civilian fishing boats. The development of communication plans for emergency situations along coastal waters would improve the availability of adequate frequency contingency.
- Although not originally developed to provide maritime mobile service, cellphones are becoming the communications tool of choice (in-land waterways, along coastal waters), especially for small boat owners not required to carry a VHF maritime mobile radio. A mobile satellite provides full-service coverage and is extensively used by large vessels, cruise ships and large ocean pleasure crafts.

6.10.4 Services and Spectrum Demand

Approach in Assessing Future Demand for Maritime Spectrum

The foregoing information and analyses, contained in sections 6.10.2 and 6.10.3, provide limited information to assist in projecting future demand for maritime spectrum. The information used includes:

- The frequency bands allocated to maritime mobile service and other maritime services;
- Industry Canada RBR-2 on VHF maritime mobile assignments and service applications.

The approach was to identify any shortage of spectrum for maritime service, based on these limited sources of information. Fisheries And Oceans Canada and the Canadian Coast Guard had been invited to comment on maritime service and spectrum needs.

Service Demand: Market Analysis

The observations and findings are based on the Inventory Report and research. Maritime services are specialized radio applications, which are based on international requirements for mobile and radionavigation systems to ensure safe operation of maritime transportation and industry, military vessels and pleasure crafts. The use of spectrum is based on the organizations responsible for the installations and operation of major coastal communications and radionavigation systems for their own use and that of the maritime industry. The Canadian maritime mobile service has a distribution of coast stations according to the maritime ship activities.

Maritime mobile service uses international frequency allocations, universal standards and technology, based on ITU and IMO requirements. It takes a long period to migrate old technology system to new digital installations.

Spectrum Demand

Although some shipping ports' communications and operations heavily use the VHF maritime band, no apparent shortage of maritime spectrum has been identified in the VHF maritime mobile bands.

- On occasion, cases of interference were identified on channels assigned for pleasure craft communications.
- Communication plans should be developed for sudden demand of frequencies during large-scale disasters.
- DND indicated no congestion expected with marine radars bands.

6.10.5 Conclusion

This Study's research does not identify any additional spectrum requirements in the 2010 to 2015 period.

However, in certain areas due to extensive maritime activities, particular VHF maritime communication frequencies will experience heavy usage and saturation.

It is expected that Canada will continue to follow international standards, allocation plans and particular maritime mobile frequency designations should continue. Over time, more spectrum-efficient maritime mobile technology should increase the communications capacity of the assigned spectrum.

6.11 Military Services

6.11.1 Overview

The Department of National Defence (DND) is responsible for ensuring the security and sovereignty of Canada, for engaging in peace, conflict and war missions in various regions of the world; for supporting missions with NATO allies (North Atlantic Treaty Organization), for protecting North America, alongside the U.S. Department of Defense (DoD), under the North American Aerospace Defense Command (NORAD) alliance. Canadian spectrum allocations support critical military operation needs, while keeping in mind the importance of certain bands for commercial services.

The DND uses a wide range of radio communications systems, some built mainly for civil use, such as aeronautical and maritime systems, commercial satellites facilities, and others are specialized military systems to provide enhanced aeronautical and maritime services, communications and radionavigation satellites and unique radiodetermination service applications (radiolocation and radionavigation) for mission-critical operations.

The DND is assigned a total of 175 MHz of critical exclusive spectrum to manage on its own in the range 225-400 MHz (harmonized with NATO military operation) for various operations. Some mobile satellite spectrum in the 7/8 GHz and Ka-bands provide for military satellites used by the NATO members, including the DND.

Maritime radio-navigational systems and met aid satellites are based on the availability of spectrum, which is based on international frequency allocations. A few years ago, spectrum was designated for the DND's tactical mobile aeronautical services in the 14 and 15 GHz bands, which also provided for un-manned aeronautical vehicle (UAV). Spectrum for mobile aeronautical telemetry systems (MATS/AMT) in band 2360-2400 MHz was also assigned to the DND, of which part of the band is shared with the aerospace industry and public safety.

The DND shares several fixed and mobile frequency bands with civil and government users. Spectrum is needed for maritime military training operations conducted with Allies along coastal Canadian waters. Furthermore, when land military bases require additional spectrum for training operations, frequency assignments are made readily available for these major land and sea operations.

6.11.2 Spectrum Inventory and Utilization

The Industry Canada Inventory Report does not summarize spectrum used by the military. However, a number of frequency allocation provisions are made in the Canadian Table of Frequency Allocations, which give spectrum priority access to the Canadian Government, and, in part, for the DND military operation. The spectrum access priority is made through Canadian footnotes, such as C12, C15, C16A, C25, C27, C49 and C50. Also, a number of bands are assigned to maritime services, aeronautical services, radiodetermination, radionavigation, space science and other specialized services, which include DND military operations.

Information extracted from a presentation made at the Spectrum Conference 20/20 in 2010[47] provides a good overview of spectrum assigned to DND and the Government, either as a dedicated or a shared resource. We summarize this here:

Spectrum Exclusively for Government Users:

- **52-300 MHz range:** 75 MHz harmonized with NATO;
- **300-960 MHz range:** 100 MHz harmonized with NATO; and
- **10-18 GHz range**: Radiolocation (20% of spectrum) – Airborne radar (military) and aeronautical radionavigation (mostly for military use).

Spectrum Shared Between Government and Private Users:

- **52-300 MHz range**: 12% of this spectrum is used for aeronautical services by civil and military users, specifically for voice, ILS and VHF Navigation Aids.
- **960-3000 MHz range**: 32% of spectrum is used for aeronautical services
  - Band 960-1215 MHz is used for secondary surveillance radar, distance/bearing measuring equipment;
  - Band 2700-2900 MHz is used for radionavigation.
- **3-10 GHz range**: 37% of this spectrum range is used for radiolocation
  - Band 4200-4400 MHz is used for aircraft altimeters;
  - Band 5600-5650 MHz is used for weather radar;
  - Band 8.5-10.5 GHz is used for coastal radar and airports; and
  - Band 8025-8400 MHz is used for RADARSAT
- **10-18 GHz range**: 9.4% of this spectrum is used for radiolocation
  - Band 10-10.5 GHz is used for speed measuring radar and earth exploration;
  - Band 10.6-10.7 GHz is used for meteorological; and
  - Band 13.25-13.75 GHz is used for passive and active sensors
- **18-38 GHz range**: 23% of spectrum has shared government use
  - Bands 18 GHz, 23 GHz, and 31 GHz is used for earth exploration, meteorological and passive sensors; and
  - Band 25.5-27 GHz is used for data links

A collaborative approach exists between Industry Canada and the defence department to address military spectrum needs and to re-farm some government spectrum for commercial and private use. For example, in recent years, some government allocations and spectrum-sharing arrangements have been made for the mutual benefit of all users. This was the case for:

- Designating new spectrum for medical telemetry devices in the band 1395-1400 MHz already occupied by radiodetermination (radar) systems;
- Designating new licence-exempt spectrum at 5400 MHz for consumer devices shared with radiodetermination;
- Assignment of WCS wireless service and SDAR radio satellites in the lower 2300 MHz band; and
- Relocation of the military MATS/AMT operation.

On the other hand, National Defence was assigned spectrum in the 14/15 GHz bands to support tactical data links on aircraft for land deployments and maritime coastal patrol. Other bands were assigned to the military, such as the 902-928 MHz for their ship-borne radars and protection of the 3400-3475 MHz as a NORAD radar band. The military uses many frequency bands assigned for general use, such as fixed

[47] Information extracted from a presentation given by Industry Canada on the use of spectrum amongst various users for the frequency range 52 MHz to 38 GHz.

and mobile services. A number of allocations and assignments, such as MATS/AMT, radiodetermination and radionavigation, are used for both civil and government applications.

6.11.3 Stakeholder Input and Research Analysis

Comments received from the Department of National Defence are summarized below:

- Some of the bands critical for military operations are:
    - The band 225-400 MHz is exclusively used by military for Air/Ground/Air communications and tactical radio relay and is a critical band for NATO and NORAD operation;
    - The band 2360-2400 MHz is designated for mobile aeronautical telemetry (MATS/AMT) and assigned to DND with sharing of upper 10 MHz with public safety and aerospace manufacturers (under coordination with DND);
    - The band 4400-4940 MHz is used by air and land forces;
    - The newly assigned 14/15 GHz band is used to support the tactical data links in major domestic deployments and maritime coastal patrol aircraft.
- DND does not see immediate congestion in the 2300 MHz MATS/AMT band, although sharing with other users is becoming difficult;
- Spectrum assigned to existing radiocommunication military equipment assets can be reused in the modernization of similar equipment assets, such as new fleets of aircraft, frigates, combat mobile radios, etc. Major changes in military equipment assets with the same radiocommunication applications will not entail large-scale changes in spectrum resources.

The DND has commented separately on a number of other services important to its operations, namely: space sciences, radiodetermination, aeronautical and maritime services, backhaul microwave, land mobile and satellite. The DND's comments are considered separately as part of those services. For example, the spectrum need for mobile aeronautical telemetry service is discussed with other users under the Aeronautical Services section.

6.11.4 Services and Spectrum Demand

Approach in Assessing Spectrum Demand for Military Service

The foregoing information, contained in sections 6.11.2 and 6.11.3, provides information to assist in assessing spectrum demand for military service. The information includes:

- Frequency bands assigned for military critical missions and NATO and NORAD obligations;
- Allocation provisions for government/military needs;
- The multiplicity of radio services; and
- DND comments on its operations and spectrum needs (including DND's comments in other service sections of this Report).

Service Demand: Market Analysis

Military radio systems provide specialized radio applications, which are grounded on national requirements to ensure national security and sovereignty and to meet international military obligations. The use of spectrum by military is not driven by commercial demand of particular services and products, but by certain radiocommunication applications and operations for critical missions.

In addition, some of the many radio systems critical to the military operations are:

- National aeronautical radionavigation systems used by civilian and military aviation in the 74/108/328/960/5030 bands;
- Army combat net radio in the 30-108 MHz VHF range;
- Ship radars (902-928 MHz);
- Airborne surveillance radars (2700-2800 MHz);
- Radio altimeter (4200-4400 MHz);
- Airborne and ship radars (5350-5460 MHz);
- Radar applications: DND and Coast Guard (9000-9500 MHz);
- Airborne radar applications (13.25-13.4 and 15.4-15.7 GHz);
- Airborne tactical data links to support the major domestic deployments and maritime coastal patrol aircraft (sub-bands at 14/15 GHz).

Over the years, Industry Canada has planned the spectrum for military services to effectively meet Canada's security and sovereignty objectives and missions. Industry Canada has been able to balance the spectrum needs of the military and maximize the commercial/private requirements and benefits.

Some spectrum-management best practices expected to be maintained are as follows:

- To identify new military spectrum requirements for five to 10 years in advance;
- To minimize the assignment of exclusive spectrum to government services (including military) and maximize the sharing of band between civil/government applications; and
- To encourage the modernization of military systems within the existing bands with more spectrum-efficient technology.

Spectrum Demand

For all, but the aeronautical mobile telemetry, it is anticipated that the existing spectrum will accommodate the service and system operation demands of all the military operations in the next five years. Some of the pressure points are identified below:

Pressure Points:

- There is increasing demand for a small amount of spectrum designated for MATS/AMT in the band 2360-2400 MHz by DND, the aerospace manufacturing industry and public safety. The existing MATS/AMT spectrum will not accommodate all the needs over the next five years;
- Demand for spectrum, which supports obstacle collision-avoidance systems for towers and windmills, is expected to increase in the 1240-1340 MHz band. However, the low-power operation of these collision-warning systems will not likely impact the primary use of this band for radiodetermination service;
- Radar systems (weather and military) will be modernized within existing bands. However, these new radar systems will be more sensitive to radio services operating in adjacent bands;
- No additional spectrum need has been identified for UAV for the 2010-2015 period.

The vast range of radiocommunication applications to support military assets and operations requires long-term investments. Complex military radio systems can have operating lives of 10 to 20 years or more. In most cases, especially for radar facilities, these systems are modernized in the same spectrum. However, the military's demand for spectrum for some of these services and systems is projected as follows:

- Continue to grow for Air/Ground/Air communications and tactical radio relay to meet more complex missions in the exclusive military band 225-400 MHz (harmonized with NATO);
- High for aeronautical mobile telemetry in band 2360-2400 MHz;
- High for national aeronautical radionavigation services in the 108/328 MHz bands; and

- Extensive in the civil/military band 960-1370 MHz for radionavigation and aeronautical radionavigation services and satellite positioning (GPS), radars and other systems.

Any growth of service and modernization of radar systems, radionavigation systems and others is foreseen to be accommodated within the existing assigned spectrum. For example, the modernization of the Canadian frigate ship radar and communications; the electronics for the new F-35; and aeronautical telemetry links with UAV drones, all can be done within existing spectrum designations.

6.11.5 Conclusion

In many instances, the identification of new spectrum for major military systems tends to be a collaboration within the NATO countries and the NORAD organization. New spectrum requirements are identified several years in advance, and requirements are negotiated at appropriate ITU committees and WRC conferences to gain appropriate International Allocations and regulatory status in the ITU Table of Frequency Allocations.

The military is expected to continue to modernize its assets within the existing spectrum assigned, to share some of the spectrum with government and civil users and to collaborate to ensure that spectrum is used efficiently and meets the highest needs.

It is expected that additional spectrum will be needed for AMT service, while taking into account the availability of equipment. Other than for AMT services, additional demand for new spectrum has not been identified for the 2010-2015 period.

6.12 Radiodetermination Services

6.12.1 Overview

Radiodetermination services include a range of radionavigation and radiolocation systems. These systems provide a variety of service applications critical to military operation, civil aviation and maritime transportation, monitoring weather and many other services. These systems include radionavigation on ships and aircraft, weather (wind shear) radar networks, military surveillance and weaponry radars.

Frequency allocations for radiodetermination services (radionavigation and radiolocation) are assigned worldwide. Many systems operating under these services, such as weather radar networks and radar used for navigation of ships and aircraft, are critical to the safety of life and property. Different frequency ranges are necessary for the radiolocation service to satisfy particular mission requirements, and the current allocations reflect the variety of objectives for these systems. Canada’s radiodetermination bands and systems are closely aligned with those of the U.S. and the international community.

In the frequency range from 52 MHz to 38 GHz, the radionavigation service has 3210 MHz (8.4%) of primary allocated spectrum. Radiolocation service has 8671 MHz (22.8%) of primary allocated spectrum. Some frequency bands (i.e. 2300-2500 MHz, 24 050-24 250 MHz) that are allocated to the radiolocation service have been rearranged in the past 10 years to accommodate other services. As technology advances, other services may be able to take advantage of the geographical concentrations of radiolocation systems and share spectrum in certain areas.

6.12.2 Spectrum Inventory and Utilization

The Inventory Report (section 11) lists the spectrum allocations for radionavigation and radiolocation as listed in Table 6.12.1, below.

In general, the numbers of assignments for radio-determination in most of the bands has been relatively stable over the past 12 years (Figure 6.12.1, below).

However, as these systems become more sensitive and sophisticated, they may require more bandwidth.

Table 6.12.1 — Spectrum allocation for radionavigation and radiolocation in Canada (*Source: Inventory Report, Section 11.2.1*)

Radionavigation	Radiolocation
1300-1350 MHz 2900-3100 MHz 5460-5470 MHz 9300-9800 MHz 15700-16200 MHz 24250-24650 MHz 31800-33400 MHz	430-450 MHz 902-928 MHz 1215-1390 MHz 2300-2500 MHz 2900-3500 MHz 3100-3450 MHz 5250-5850 MHz 8500-10550 MHz 13400-14000 MHz 15700-17300 MHz 24050-24250 MHz 33400-36000 MHz

The forthcoming WRC 2012 Conference will consider a potential primary allocation of radiolocation service in the band 15.4-15.7 GHz.

Table 6.12.2 — Number of assignments and area of operation (*Source: Inventory Report, Section 11.3.2*)

Service	Band (MHz)	Location	No. of Frequency Assignments
Radiolocation	430-450	Mostly rural	> 4000
Radiolocation	902-928	Limited to coastline	0 (ships not licensed)
Radiolocation and radionavigation	1215-1390	East/West Coast Northern Canada	99 radionavigation 1430 radiolocation
Radiolocation	2700-2900	Airborne commercial and military	9
Radionavigation	2900-3100	Across Canada	128
Radionavigation	5250-5850	Across Canada	35 Environment Canada weather radar, 9 other
Radiolocation Radionavigation	8500-10550 9300-9800	Across Canada	Heavily used and some growth > 500 radiolocation 1 weather radar > 1000 aircraft
Radiolocation	13400-14000	Limited use in Canada	> 400 aircraft station 1 radiolocation
Radiolocation Radionavigation	15700-17300 15700-16200	Across Canada	21 aircraft 400 low power
Radiolocation	33400-36000	Across Canada	60

Figure 6.12.1, below, illustrates the historic trends in the relevant bands.

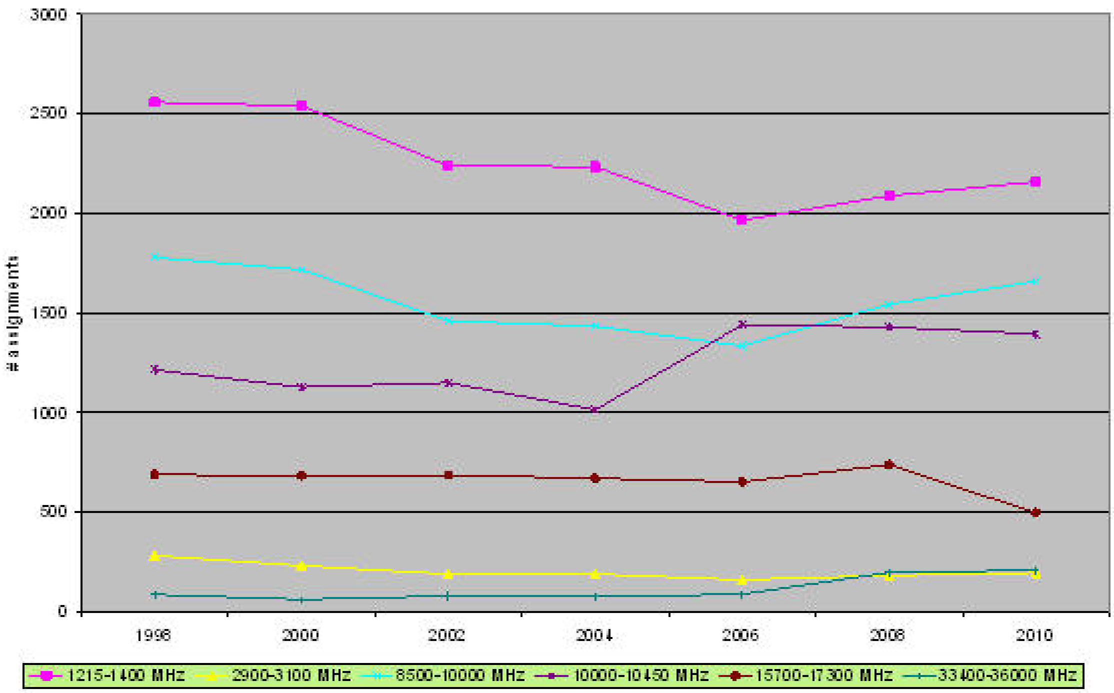


Figure 6.12.1 — Trends for frequency bands during the period of 1998 to 2010 (*Source: Inventory Report*)

Spectrum Utilization

In a 2010 Spectrum 20/20 Industry Canada's presentation[48], the following distribution of radiodetermination spectrum assignment was summarized:

Exclusive Spectrum Assignments for Radiodetermination
- **10-18 GHz range:** 20% of the spectrum is used for radiolocation, such as airborne radar (military); and 5.6% of the spectrum is used for aeronautical radionavigation.

Shared Spectrum
- **960-3000 MHz range:** 32% of spectrum is used for aeronautical; band 960-1215 MHz for secondary surveillance radar, distance/bearing measuring equipment; band 2700-2900 MHz is used for radionavigation;
- **3-10 GHz range:** 37% of the spectrum is used for radiolocation; band 5600-5650 MHz for weather radar; band 8.5-10.5 GHz for coastal radar and airports.
- **10-18 GHz range:** band 10-10.5 GHz for radiolocation speed-measuring radar.

Section 11.3.1 of the Inventory Report provides a detail spectrum utilization of the various radionavigation and radiolocation bands listed in Table 6.12.1, above. For most of the bands, information is provided on the major users and radiodetermination applications; this includes map/location of the radar installations across Canada for the Northern Warning System (1215-1390 MHz) and the weather radar systems (5600-5650 MHz).

[48] Dupuis' presentation given at Spectrum 20/20, 2010

Some examples are:

- The aeronautical radionavigation services tend to operate across the country, such as the band 1300-1350 MHz for radionavigation stations located in Southern Canada.
- Terrestrial radionavigation in the band 9300-9800 MHz supports maritime radionavigation along coastal waters and in-land waterways, which are operated by the Canadian Coast Guard (CCG) and Department of Fisheries and Oceans Canada (DFO) to monitor vessel traffic.
- The 9300 MHz radionavigation band accommodates the air traffic control operations.
- Many of the radiolocation (radar) bands are used for critical military operations and by other government users, such as the CCG, DFO and Environment Canada. Terrestrial radiolocation or radar installations tend to operate in specific areas of the country to achieve specific missions. These include NORAD's Early Warning Radar System in Northern Canada and the Eastern Seaboard in the 1215-1390 MHz range; ship-borne radar in coastal waters, and high sea and navigational waterways at 902-928 MHz; and weather radars near airports across Canada in the 5600-5650 MHz band. The 9300-9800 MHz band is also used by commercial ship-borne radar on ships, ranging from pleasure craft to large carrier vessels. In general, the band 8500-10550 MHz is heavily used for several radar applications.

6.12.3 Stakeholder Input and Research Analysis

Comments were received from Environment Canada, DND, Transport Canada and NAV CANADA. The highlights of these comments are as follows:

Environment Canada (EC)

- The timely warning of impending natural and environmental disasters, accurate climate prediction and detailed understanding of the status of global water resources are all critically important everyday issues for the global community.
- National Meteorological and Hydrological Services (NMHS) around the world, such as the Meteorological Service of Canada (MSC) of Environment Canada (EC), are responsible for providing this information.
- Radio-frequencies represent key resources used by NMHS to measure and collect the observation data upon which analyses and predictions are produced and disseminated.
- Meteorological radars and wind-profiler radars are important surface-based installations in the meteorological observation processes. There are currently about one hundred wind-profiler radars, and several hundreds of meteorological radars worldwide that perform precipitation, wind measurements and immediate meteorological and hydrological alert processes. The Canadian national meteorological radar network consists of 31 meteorological Doppler radars spread across Canada (30 C-band (5600-5650 MHz) and one S-band (2700-2900 MHz)). C-band continues to be the optimum solution for the Canadian climate however EC is planning to add S-band (~2700-3000 MHz) and X-band (~9300-9800 MHz) radars into the Canadian meteorological radar network in the next three to five to 10 years.
- In addition, EC uses data from the three McGill X-band radars (9300-9400 MHz) for operational and research purposes, operates a number of X-band research radars itself (9200-9700 MHz), and has plans for dual polarization X-band Doppler radars in Iqaluit and at the Centre for Atmospheric Research Experiments (CARE) in Egbert.
- Three wind profilers owned by EC operate at the 915 MHz band, and EC has been supporting the development of the O-QNet (Ontario-Quebec Network) of Canadian wind profilers in 40-55 MHz.
- EC operates the Canadian Ice Service (CIS), and, as such, is the primary user of RADARSAT data (RADARSAT I (currently 5255-5350 MHz) and RADARSAT II (currently 5350-5460 MHz) for snow, ice and sea ice mapping and classification, to locate excessive wet/dry areas, and for soil-moisture mapping. Also a "Side-Looking-Airborne-Radar" (SLAR) operating in the band 2300-2450 MHz aboard a Dash-7 aircraft is used for Arctic ice reconnaissance.
- EC developed, deployed and operates the Precipitation Occurrence Sensor System (POSS) in a

network of about 95 automatic weather stations across Canada. The POSS is a low-power vertically pointing radar, centred at 10.525 GHz complying with IC RSS-210.

- EC uses data from space-borne EESS active systems in research or operational mode.
- Depending on research projects, EC Science and Technology temporally uses radars from other organizations in the S-, C-, X-, K-, Ka- or W-band[49].
- Meteorological Aids, mainly radiosondes, are the main source of atmospheric in-situ measurements with high vertical resolution to provide real-time vertical atmospheric profiles that are, and will remain, essential for operational meteorology, including weather analysis, prediction and warnings, as well as for climate monitoring. In addition, these in-situ measurements are essential for calibrating space-borne remote sensing, in particular, passive.
- The radiosonde network is the backbone of the Canadian Upper Air Program and consists of 31 regular radiosonde stations spread throughout Canada, maintained and operated by EC with balloon launches twice daily. There are also six units, to be used in the event of an environmental emergency, and the occasional upper-air observations that are carried out at various bases and on ships by the Department of National Defence (DND).
- EC operates its national network of radiosondes (weather balloons) in the MetAids service in the band 401-406 MHz.
- The radiosonde network of the Canadian Upper Air Program is transitioning over to digital GPS.

NAV CANADA

- A number of frequency bands, to support various radiodetermination applications critical for the operation and safety of aviation transportation, are used by NAV CANADA:
    - Bands 1030-1090 MHz and 1030-1090 MHz are used for secondary surveillance radar and multilateration systems (MLAT);
    - Band 1240-1350 MHz is used as primary radar for surveillance of airborne aircraft near major airports;
    - Band 9300-9800 MHz are used for airport surface surveillance (ASDE) for terrestrial movement surveillance at major airports.
- The band 1030-1090 MHz (Secondary Surveillance Radar, MLAT and ADS-B) paired with GPS signals will start to be heavily used in the next five years.
- The band 1240-1350 MHz, for aeronautical radionavigation and radiolocation (primary radar), is used to operate 24 primary surveillance radars. There is no plan for additional radars in this band for the next five years. Obstacle Collision Avoidance Systems (OCAS) installed by non-aviation third parties, such as hydro companies and wind-farm operators for aviation safety, may increase in the southern area of the country in the band 1240-1340.
- Band 2700-3300 MHz for primary radar offers a possible alternative to the 1240-1350 MHz radars. No plan for such radar equipment in the next five-year horizon.

[49] S-band 2 to 4 GHz
C-band 4 to 8 GHz
X-band 8 to 12 GHz
Ku-band 12 to 18 GHz
K-band 18 to 26.5 GHz
Ka-band 26.5 to 40 GHz
W-band 75 to 110 GHz

Transport Canada (TC)

- TC comments are on civil aviation requirements. From the perspective of TC, radionavigation radars operating in the bands ranging from 1300 MHz to 33.4 GHz are not likely to see any significant modernization in the next five years.

- Radionavigation systems whether terrestrial or airborne provide a safety service in allocations that are given special measures of protection from harmful interference in accordance with the Radio Regulations.
- Typically, these legacy systems have a relatively long life cycle and can operate for many years. Traditionally, by design, these systems have an increased probability of target detection from increased bandwidth usage; some designs can use multiple frequency hopping techniques.
- Whether there are 20 targets or 250 targets within the range of one radionavigation radar, it does not technically change the bandwidth requirement or the need for additional spectrum for the system to perform its designed function.
- A variety of systems are used to support aeronautical safety-of-life functions. As described in the Aeronautical section, the growth in the industry, in terms of the number of flights and passengers flown, does not equate to a direct need for additional spectrum, or point to expected congestion in specific frequency bands. It is, therefore, very difficult to provide any realistic expectation of additional spectrum growth.
- Therefore, it is reasonable to say that user expectation on the availability of these safety services in specific bands would be the same as it has been in the last several years.

DND

- DND operates radars in many bands for radiodetermination service:
  - North Warning System (NWS) consists of radars located across the arctic to monitor North American airspace.
  - Radars are installed on all Canadian Forces ships and aircraft, as well a limited number of ground-based radars used by the Land Forces.
- The band of greatest use is the 9400 MHz band, but is not expecting congestion. The use of radionavigation spectrum has been stable over the past few years.
- DND does not forecast additional spectrum for radionavigation, and modernization will unlikely release currently used spectrum.
- DND does not anticipate congestion in the radiolocation bands and will not require additional spectrum for radiolocation.

Research Analysis

In addition to the aforementioned, it can be noted that the band 1240-1350 MHz is used for aeronautical radionavigation and radiolocation (primary radar) and provides for 24 primary surveillance radar installations. Aviation safety, wind-farm operations and hydro applications use Obstacle Collision Avoidance System (OCAS) in the band 1240-1340 MHz to detect approaching airplane in the area and to turn on flashing lights on towers to warn aircrafts of obstacle danger. These OCAS operate with low power, and are, therefore, manageable without any impact on the availability of spectrum for primary radar installations and future growth.

6.12.4 Services and Spectrum Demand

Approach in Assessing Future Demand for Radiodetermination Spectrum

The foregoing information and analyses, contained in sections 6.12.2 and 6.12.3, provides the information base to assist in assessing future spectrum demand for radiodetermination service. The information used includes:

- The frequency bands allocated to radionavigation and radiolocations;
- The number of assignment for installations in various bands;
- Trends and the band-by-band usage/users (Inventory Report, section 11.3.1); and
- Input from the main users.

The users' views are important in projecting the demand for spectrum for particular applications.

Service Demand: Market Analysis

Radiodetermination services include a range of radionavigation and radiolocation systems. These systems provide a wide range of service applications critical to military operation, to civil aviation and maritime transportation, to monitoring weather and for many other services. They include radionavigation on ship and aircrafts, weather radar networks, military surveillance and weaponry radars.

There is continued service demand for a wide range of radionavigation and radiolocation radar applications critical to security, safety and protection of life and properties. Among the major systems and services requiring long-term spectrum are the following:

- The Northern Warning System (series of radar stations in the1215-1390 MHz range located across Northern Canada and the East coast) provides strategic aerospace surveillance as part of North American Aerospace Defence (NORAD).
- Aeronautical radionavigation stations (sub-band 1300-1390 MHz) operate across Southern Canada provide navigation service.
- Radionavigation and radiolocation service (2900-3100 MHz) is used on government aircrafts and ships.
- Meteorological radar stations (5600-5650 MHz), located across Southern Canada, provide the detection of severe weather patterns, such as tornadoes, hurricanes, thunderstorms, wind shear and turbulence.
- Radionavigation radar stations (9300-9800 MHz) provide for air traffic control, maritime monitoring of vessel traffic, by commercial ship-borne radar (large vessels to pleasure crafts).

The Inventory Report indicates that the numbers of assignments in the radionavigation and radiolocation services have been relatively stable over the past 12 years. As these systems are modernized or replaced to be more sensitive and sophisticated in the future, existing spectrum will be used. It may result, however, in requiring more bandwidth.

The upcoming WRC 2012 Conference will consider a potential primary allocation of radiolocation service in the band 15.4-15.7 GHz.

Radiodetermination services accommodate vital installations for government and industrial operations and represent large investments for 20 years and beyond. Spectrum resource is essential for the continued operations and modernization of these important radiolocation and radionavigation systems.

As such, the demand for the wide range of radionavigation and radiodetermination applications is expected to continue and to modestly grow to meet increasing levels of service activities by the various users. The military is the large user of radar-base services.

There will be a continued reliance on weather radar, RADARSAT, Meteorological satellite and other systems by Environment Canada. In general, most radionavigation and radiodetermination service demand can be met with existing primary radar installations over the next five years.

Spectrum Demand

Figure 6.12.1 (above) shows that in general, the numbers of assignments for radiodetermination in most of the bands has been relatively stable over the past 12 years. This trend is expected to continue, with gradual modernization of select systems to support more sensitive and sophisticated operation, which may require more bandwidth.

No areas of critical shortage of spectrum were identified. Radiodetermination systems have a long operating life, and new service requirements are often met in modernizing existing installations.

Pressure Points:

- The band 5600-5650 MHz for weather radar stations across Canada must be protected (as these radar stations are modernized and become more sensitive, including to out-of-band emissions).
- Radar systems (weather and military) will be modernized within existing bands but will be more sensitive to adjacent spectrum services.

6.12.5 Conclusion

The Study's research is based mainly on stakeholder input, which outlines the wide array of radiodetermination system operations. The importance of the various systems is well documented.

Meteorological radars and wind-profiler radars are important for timely warning of impending natural and environmental disasters. Therefore, continued spectrum is required for these essential services.

We expect that radiodetermination systems will continue to be modernized within existing frequency bands.

The identification of new spectrum for radiodetermination tends to be collaboration of the needs of ITU members, and important to Canada are the needs of the NATO countries. WRC 2012 Conference will consider a potential of making a primary allocation of radiolocation service in the band 15.4-15.7 GHz.

It is believed that, with continued efficient spectrum usage, the existing frequency bands assigned to various radiodetermination services (radiolocation and radionavigation) should ensure that adequate spectrum is in place to meet the service operation of existing and new systems for the period to 2015.

6.13 Space Science Services

6.13.1 Overview

The ITU-R Table of Frequency Allocations specifies a number of bands for Earth exploration satellite, space research, space operation and radio astronomy services as co-primary with other radio services. Administrations may assign some of these bands on a permanent use or temporary basis to particular space science institutions (i.e. research institute, space agency, a university, etc.), according to the space activities in their countries.

In Canada, the Canadian Space Agency (CSA) carries out a number of space science projects, often with other space agencies, such as NASA and ESA, which may have particular spectrum requirements. A major Canadian program is the use of earth exploration satellite service (EESS) allocations to operate a Synthetic Aperture Radar (SAR) called RADARSAT. Among the various space science projects is the use of very small satellites to study the atmosphere, in collaboration with universities and the CSA. The National Research Council (NRC) is responsible for the operation of an astronomy observatory station in Penticton, B.C., where a radio-quiet zone is maintained around the site. Environment Canada is a large user of space science services, including weather radars, RADARSAT, Met Aids and constellation of meteorological satellites to predict environment changes and provide meteorological forecasts.

Canadian satellite operators have provided satellite orbital maintenance services to foreign satellite networks, such as a U.S. satellite radio network, Iridium LEO satellite constellation and others, which may use *space operation frequencies* at satellite operation and control stations at a few locations in Canada. Also, Canadian commercial satellite network operators may require certain frequencies, particularly in the 2 GHz space operation allocation, as tele-control, telemetry and command (TT&C) during the launch phase of new satellites.

Space science services covers a wide range of different radio systems, including systems for space operation, space research, earth exploration and meteorology, remote sensing, and radio astronomy, and standard frequency and time-signal services. Some of the main users of space services have provided an outline of their activities and projections of service use. In some areas, they have identified difficulty in securing frequencies for certain space missions. In other areas, they have expressed the importance of these services and the criticality of maintaining existing resources.

For some space services, the spectrum demand is driven by research in new applications and particular space missions. Space services also have an immediate and direct impact on the commercial and resource sectors; provide critical data for weather forecasting; highly critical atmospheric events; emergency events; defence; and sovereignty monitoring; and other critical oversights. Many of the activities are subject to obtaining government research and operation financing, rather than being based upon commercial demand and financing.

Unlike commercial services, space science spectrum demand is not assessed using past and future service demand projections. An assessment is best based on the aggregations of projects and missions that may identify a shortage of spectrum.

Space agencies have a wide range of projects in operation and in the planning stage, which needs to be treated as projects requiring spectrum on an ongoing or future basis. Many of these projects are developed in cooperation or in partnership with NASA, the ESA and other international space agencies. The Canadian space program, spectrum-based projects and spectrum use are summarized in the Inventory Report.

6.13.2 Spectrum Inventory and Utilization

The Inventory Report provides an expanded list of frequency allocation bands and service applications broadly interpreted as space science services. These frequency allocation bands and space activities are listed in Inventory Report (section 8.2.1, pages 104-108) and include primary and secondary frequency allocations for earth exploration satellite service (EESS), radio astronomy, space research, space operation, meteorological aids, meteorological satellite, and standard-frequency time-signal satellite. Some of the activities are operated on a secondary basis and also in bands not allocated to space science (i.e. radio astronomy). These bands are based on the ITU Table of Frequency Allocation. In general, Canada and the United States have identical frequency bands allocated to space science services.

The Inventory Report has summarized the total amount and percentage of primary spectrum for space science in the 52 MHz to 38 GHz range as follows.

Table 6.13.1 — Spectrum assigned to various space science services (*Source: Inventory Report*)

Space Science Services	Total Spectrum (MHz)
Radio Astronomy	141.7
Meteo ro logical Satellite	583.85
Meteorological Aids	837.45
Space Operation	281.4
Space Research	8 787.25
Earth Exploration Satellite	6 964
Total Spectrum	17 595.65

The Inventory Report states, “Unlike other services for which spectrum allocation is based on the most suitable propagation characteristics, spectrum allocation for space science services (except space operations) is more limited to the physical phenomenon of atmospheric gases, water, cosmic rays, etc. As a result, radio spectrum for space science applications appears almost everywhere in the entire radio spectrum”.

The Inventory Report (section 8.4.1, Figure 8.2, page 112) demonstrates the sharing of spectrum between space science services and other radio services as compared to the 1998 level. It indicates where some of the challenges are for space science.

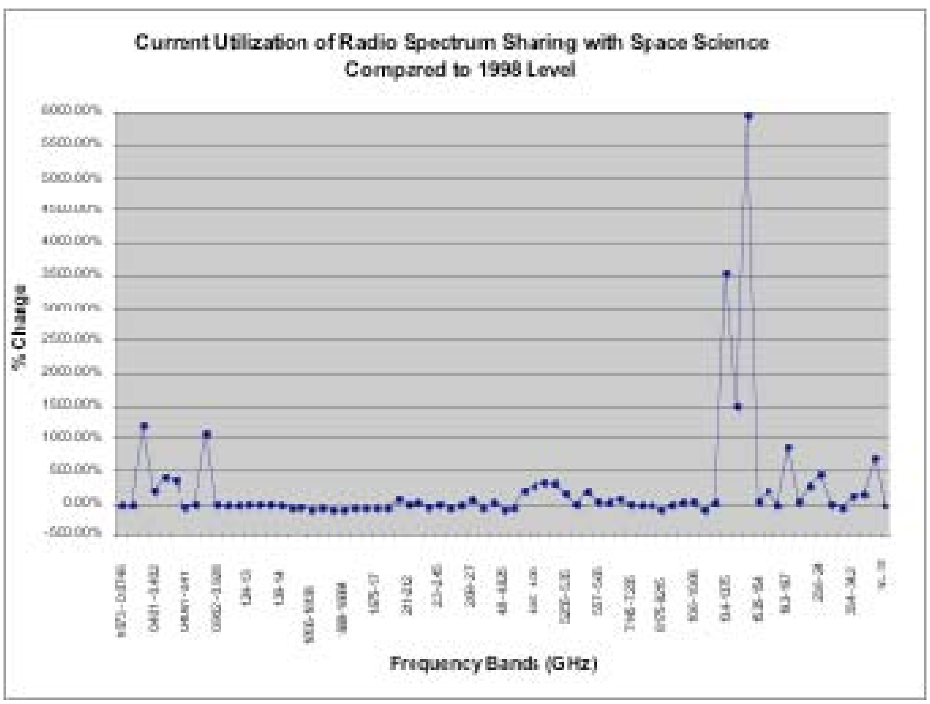


Figure 6.13.1 — Radio spectrum sharing with space science (2011 compared to 1998) (*Source: Inventory Report*)

The following groups of agencies or Institutes use the radio spectrum in space science services:

- Canadian Space Agency (CSA);
- Canadian Centre for Remote Sensing (CCRS);
- Environment Canada (EC);
- Natural Resource Canada (NRCAN);
- National Research Council Canada (NRC), including Radio Astronomy;
- Canadian universities.

In these groups of users, the CSA, EC and NRC are the major users of spectrum allocated for space science services. The NRC uses mostly the passive bands for continuum and spectral-line observations. The CSA is the major player in the EESS (RADARSAT 1 and 2). Environment Canada uses data from foreign satellites in the meteorological satellite service. Also, the DND makes use of RADARSAT data collected.

Spectrum Utilization

- Space research and earth exploration satellites use Low-Earth Orbits (LEO) in the 300-to-1000-kilometre range. A number of frequency bands are used for space operation of satellites and spacecraft, as well as data-transmission purposes.
- Existing 2 GHz bands (2025-2110 MHz as uplink and 2200-2290 MHz as downlink) are currently being used as space operation service. These bands are heavily used by fixed microwave systems. Therefore frequencies for space operation may be hard to find for earth stations located in urban centres.
- RADARSAT operation relies on the 8 GHz band for data downlink, 5 GHz band for the sensor and 2 GHz band for TT&C.
- A total of 30 wind-shear (weather) radars are in operation across Canada in the band 5600-5650 MHz. A wind profiler is in operation at 915 MHz and a number of others in the 40 MHz band.
- Data from an S-band (2700-2850 MHz) and X-band (9300 MHz) research radar is used for meteorological purposes.

6.13.3 Stakeholder Input and Research Analysis

Several stakeholders submitted input to the Study, as noted below:

Canadian Space Agency (CSA)

- An increasing number of small satellites (LEO) will require additional spectrum. Existing 2 GHz bands (2025-2110 MHz as uplink and 2200-2290 MHz as downlink) are currently being used as space operation service with a large number of fixed microwave radio systems. As a result, these bands are becoming very congested.
- For large projects, such as RADARSAT 1 and 2, there is an additional spectrum requirement to transmit broadband data requiring bandwidths in the 8 GHz frequency range in the order of 100 MHz wide or even greater bandwidth. Additional RADARSAT tasks may require greater than 200 MHz in the 8 GHz frequency band.

Environment Canada (EC)

Earth Exploration Satellite Service (EESS, passive and active)

- National Meteorological and Hydrological Services (NMHS) around the world, such as the Meteorological Service of Canada (MSC) of Environment Canada (EC), are responsible for providing this information.

- EC mission is to ensure that “Canadians are equipped to make informed decisions on changing weather, water and climate conditions” affecting their health, safety and economic efficiency. EC’s ability to fulfil its contribution to this mission critically depends on its capacity to adequately observe the earth’s surface and its atmosphere at global, regional, national and local scales.
- To be of relevance to the services provided by EC and its objective to reduce loss of life and minimize property damage, namely through high-impact hydrometeorological event detection, monitoring, forecasting and warning, the observations must be accurate, reliable and made available in a timely manner. Radio frequencies represent scarce and key resources used by NMHS to measure and collect the observation data upon which analyses and predictions, including warnings, are based or processed, and to disseminate this information to governments, policy makers, disaster management organisations, commercial interests and the general public.
- Space-borne sensing of the Earth’s surface and atmosphere has an essential and increasing importance in operational and research meteorology, in particular for mitigating the impact of weather and climate-related disasters, and in the scientific understanding, monitoring and prediction of climate change and its impacts.
- Space-borne passive sensing for meteorological applications is performed in bands allocated to the Earth exploration-satellite (passive) and meteorological satellite services.
- Space-borne active sensing, performed in particular by altimeters for ocean and ice observations, scatterometers or rain and cloud radars, provides meteorological and climatology activities with important information on the state of the ocean, land surfaces and atmospheric phenomena.
- EC uses data from space-borne EESS passive and active systems in operational and research modes.
- EC uses data generated by a multitude of space-borne sensors operating in various frequency bands. Note that after testing, evaluation and development, bands used for R&D usually transition to operations.

Meteorological Satellite Service (MetSat)

- EC mission is to ensure that “Canadians are equipped to make informed decisions on changing weather, water and climate conditions” affecting their health, safety and economic efficiency. EC’s ability to fulfil its contribution to this mission critically depends on its capacity to adequately observe the earth’s surface and its atmosphere at global, regional, national and local scales.
- To be of relevance to the services provided by EC and its objective to reduce loss of life and minimize property damage — namely through high-impact hydrometeorological event detection, monitoring, forecasting and warning — the observations must be accurate, reliable and made available in a timely manner.
- Of high importance is the availability of sufficient and well-protected Earth exploration and meteorological satellite services frequency spectrum for telemetry/telecommand as well as for satellite downlink of the collected data. It should be noted that the fixed-satellite service systems, through commercial payloads in the C-band and the Ku-band, are used globally to disseminate weather, water and climate related information, including disaster warnings to meteorological agencies and user communities.
- Various Government of Canada (GOC) departments operate satellite stations in the MetSat and EESS services for use by GOC departments to fulfill their missions, especially those departments involved in the Canadian Group on Earth Observations (see www.cgeo.gc.ca), and other key stakeholders.
- The MetSat direct broadcast service is used 24/7/365 to support EC’s mission.
- EC operates MetSat stations in the following bands:
    - 400.15-401 MHz: GOES and POES data collection platform downlinks;
    - 401-403 MHz: GOES and POES data collection platform uplinks;
    - 1675-1700 MHz: GOES GVAR direct satellite broadcast;
    - 1675-1710 MHz: NOAA POES, EUMETSAT METOP and China FY-1D, HRPT direct satellite broadcast;
    - 7750-7850 MHz: NPP satellite;
    - 8025-8175 MHz: NASA Terra satellite downlink;

  - o 8175-8215 MHz: NASA Aqua satellite downlink.
- The Canada Centre for Remote Sensing (CCRS) of NRCan operates satellite stations in the following bands (data also used by EC):
  - o 1675-1710 MHz;
  - o 2025-2110 MHz;
  - o 2200-2290 MHz;
  - o 8025-8215 MHz;
  - o 8215-8400 MHz.
- L-band direct readout broadcast is still in the planning stages for the next generation meteorological satellites to be launched in the 2020-2025 timeframe. The future generations of satellites will make more use of the X-band and K-band (e.g. 18-18.3 GHz in Region 2) for data broadcasting.

NOTE: Some of the comments of the Stakeholders summarized in this Space Science section may overlap with those presented in the Radiodetermination section or vice-versa.

6.13.4 Services and Spectrum Demand

Approach in Assessing Future Spectrum Demand for Space Science

The aforementioned information in sections 6.13.2 and 6.13.3 will assist in identifying spectrum demand for particular space science service. The information used includes:

- The Inventory Report on frequency allocations to space science;
- Band-by-band spectrum usage, users and particular spectrum activities;
- Stakeholder input on space science spectrum use and requirements; and
- Areas of growth or potential spectrum demand.

The users' views are important in assessing spectrum demand for space science.

Services Demand: Market Analysis

In general, space science encompasses the broad categories of space activities: such as earth exploration-satellite; space research; meteorological-satellite; meteorological aids; space operation; and radio astronomy. In the 50 MHz to 38 GHz range, several different bands have frequency allocation provisions to support some form of space science services.

A large number of space science projects and research activities are continually taking place in many of the frequency bands. Among the continuous use of the space science spectrum are the following projects and service applications:

- **Space research and earth exploration satellites:** space research payloads are moving from large satellites to very small and mission-focused micro-satellites with one or two scientific instruments. These satellites are operated by data links (uplinks/downlinks) for information transmission, telemetry and control (TT&C) of these satellites. The increased number of these small satellites, launched for a limited operating life, represents an increased demand for TT&C frequencies for use by these satellites in the 2 GHz range.

- **Earth exploration satellites:** earth exploration satellites are becoming more popular worldwide to provide up-to-date information on the earth geography and environment, critical imaging information during emergencies and disasters and security information (maritime surveillance and border control). For example, a use of RADARSAT I (band 5255-5350 MHz) and RADARSAT II (band 5350-5460 MHz) is to map snow, ice and sea ice, soil moisture and other important information.

- **Radio astronomy:** uses a number of radio bands, i.e. the Penticton Astronomy Observatory, which uses various frequency ranges to monitor and study space. These observatory stations use a range of well-defined astronomy bands. A quiet-radio zone must be maintained around these observatory stations, and noise from other radio operations has to be avoided.

For the most part, space science activities and projects are done in collaboration with other domestic agencies or with space agencies of other countries and use spectrum allocated on an international basis. Therefore, although there are a very large number of projects and a high level of space science activities, the ITU Table has made provisions in several frequency bands to support such services. Some of these operations are worldwide, and others are more regional.

For satellite operations, such as earth exploration and space research, the service demand can be estimated as follows:

- For the next generation of RADARSAT, there is a need for greater capability to generate higher definition imagery; hence, a larger spectrum bandwidth would be needed at 5 GHz and higher speed data links 8 GHz.
- There is an increasing number of small LEO satellites (cubesats) being planned for scientific missions with payloads to study the atmosphere. Space operation frequencies in the bands 2025-2110 MHz and 2200-2290 MHz[50] will be in greater demand as TT&C and data links.

Spectrum Demand

The areas of pressure include:

Pressure Points:

- Space operation spectrum is needed in the 2100/2200 MHz bands to provide data links and TT&C links for small research satellites and for RADARSAT operation
- Continued spectrum at 5 and 8 GHz must be protected for existing and future RADARSAT satellites.
- The opening of the Northwest Passage, due to the melting of the Arctic ice, and the Canadian Government activities in the North, will increase the demand for space science satellite missions (communication, weather report and traffic surveillance) in these remote areas.
- The decline in activities at the international space station may free some spectrum for new space science activities.

6.13.5 Conclusion

The identification of new spectrum for Space Science Services tends to be a collaboration among the member countries of the ITU forum. New space science spectrum needs will be identified and considered at future WRC conferences.

Our research has identified areas where spectrum demand may occur for Space Science in the 2010 to 2015 period. These areas include the 2 GHz band: For space operation in the 2 GHz bands to support small research satellites and RADARSAT.

For future Earth Exploration Satellite Service projects (RADARSAT equivalent), there is a potential need for additional spectrum in the 5 and 8 GHz bands.

[50] These bands are heavily used for fixed microwave systems for broadcasting electronic news gathering (ENG), including helicopter links and fixed-data links. It is hard to find temporary frequencies for satellite space operation where earth stations are located in large urban areas.

6.14 Consumer Devices

6.14.1 Overview

Consumers and businesses enjoy the convenience and benefit of a wide range of licence-exempt radio devices (referred to as “consumer devices”). In recent years, a number of bands have been opened to consumer devices. New technology protocols offer greater intelligence and frequency agility to avoid frequency collision with other devices and reduce interference. These devices operate at low power on a non-interference and non-protected basis, in relation to primary radio services in these bands and in adjacent spectrum. In addition, Industry Canada continues to assign spectrum for unprotected low-power radio devices as an under-layer to primary service operations. This is the case for a wide range of applications, such as medical applications, model aircraft, sensors, municipality traffic lights, RFID and vehicle identifications at very low power across the VHF and UHF frequency range, based on Radio System Standards (RSS) 210 (similar to FCC, Part 15).

This Study addresses only the popular frequency bands listed in Section 6.14.2, below, and assigned, in part, for consumer communications devices. Often, the low-power consumer devices must coexist with higher-power primary services retaining operation priority.

6.14.2 Spectrum Inventory and Utilization

The Inventory Report presents the number of models of consumer devices certified for distribution in Canada, according to technical requirements and applications outlined in RSS-210 for licence-exempt devices. Although, this provides general information on the certification activities in Canadian and other recognized laboratories worldwide; it does not provide direct information on the number of consumer devices distributed and sold for use in Canada. However, the Inventory Report (Section 12.4) presents interesting information on the certification of consumer devices in popular Wi-Fi-licence-exempt bands for potential distribution and sale in Canada. The report shows the increase in the number of licence-exempt device models certified in the past 10 years and the expectation of continued growth. The report estimates that 60,000 models of consumer devices have been available in the past six years, with approximately 60% of these devices operating in bands that can accommodate Wi-Fi devices.

The Inventory Report provides a number of trend charts on the number of licence-exempt devices certified with potential distribution to the Canadian market. Among the information are the licence-exempt charts in Figures 12.1, 12.2 and 12.3 in section 12.4 for the bands 900 MHz, 2400 MHz and 5800 MHz, respectively.

Also, the report indicates that, based on the 2006 census data, a typical occupied dwelling in Canada could have up to 20 consumer devices. With about 12.4 million dwellings, that indicates more than 250 million consumer devices. However, among these devices are remote controls for TV, stereo, digital box, analogue phones, FRS/GMRS, wireless play-stations, garage openers, remote switches, light sensors and others. Many of these devices use various underlay spectrum (assigned to primary services), as specified by RSS-210 for low-power ISM and consumer devices.

An area of considerable interest in this Study is the actual use of the main designated licence-exempt bands listed below for consumer devices, such as digital cordless phones, Wi-Fi routers and Wi-Fi chip-sets embedded in PCs and laptops, smartphones, Internet TVs, electronic products and others. Also, public Wi-Fi access facilities use mesh-network in urban areas, private Wi-Fi providing public Internet access, cellular network complementary hot spots and other applications. There is an ever-increasing use of licence-exempt spectrum for wireless product applications for the benefit and convenience of consumers and commercial users.

Some products in certain bands have been more popular than others, and these bands are extensively used. These products are equipped with a range of intelligent technologies, frequency agility and collision-avoidance schemes to minimize interference. The operation standards of these licence-exempt products are specified in Industry Canada RSS-210 (for low-power wireless devices) or RSS- 213 for unlicenced PCS.

Spectrum Utilization

Among the popular licence-exempt, low-power, consumer and commercial products and bands are the following:

- 44/49 MHz: range for cordless telephones;
- 462/467 MHz: range for family radio services (FRS) and general mobile radio services (GMRS);
- 151/154 MHz: five channels will be available for Multi-Use Radio Service (MURS)[51] radio communications after five years from May 2009;
- Bands 902-928 MHz, 2400-2483.5 MHz and 5725-5850 MHz: for digital phones, radio local area networks (RLAN), Wi-Fi routers, hot spots, etc.;
- Band 1920-1930 MHz: for cordless phones using DECT technology;
- Band 5150-5250 MHz and bands 5250-5350 MHz, 5470-5600 MHz, 5650-5725 MHz, and the 5725-5850 MHz: for local area networks (RLAN).

The 900 MHz and 2400 MHz bands (also support a number of ISM licence-exempt radio devices, such as sensors, microwave ovens, wireless speakers, remote controls and licenced fixed microwave systems) were among the first bands assigned to licence-exempt products. The 900 MHz and 2400 MHz bands are densely used in populated areas in comparison to the newer bands 5150-5350 MHz and 5725-5850 MHz, which were just opened in the 1990s.

The bands 5470-5600 MHz and 5650-5725 MHz were released in 2005 for licence-exempt RLAN and other devices. The spectrum policy requires that consumer devices in these new bands be equipped with intelligent technology (dynamic frequency, frequency avoidance, etc.) and meet a number of technical and operation provisions to coexist or protect a number of primary services, including radiodetermination. Also, at the same time, the band 5250-5350 MHz was upgraded to support outdoor consumer device applications. In 2005, Industry Canada provided greater flexibility for consumer products by including “mobile service” as co-primary to fixed service in the bands 5150-5250 MHz, 5250-5350 MHz, 5470-5600 MHz and 5650-5725 MHz, as provided in the Canadian Table of Frequency Allocations[52].

6.14.3 Stakeholders Input and Research Analysis

A limited number of comments were received from stakeholders and research on consumer devices (in particular, regarding the up-take of Wi-Fi capability in electronic products). A summary of this input follows below:

- The popularity of Wi-Fi devices and chip-sets used to access the Internet in homes, business locations and hot spots in the 2400 MHz band is due to lower manufacturing costs than in other bands. As a result, this band tends to be more crowded.
- Although licence-exempt spectrum is more crowded with consumer devices in populated areas, there is intense spectrum reuse of the same channels at short distances. Congestion may not be related to population density, but more site-specific situations, such as large meetings. Also, congestion of Wi-Fi bands can be more related to application, i.e. downloading video and latency limitations. Finally, some thought needs to be given to network/access-point capacity requirements where, in some cases, this may be where the bottleneck exists.
- Consumer devices will become more pervasive with Machine-to-Machine (M2M) communications,

[51] Spectrum Utilization Policy: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09543.html

[52] See C39C in Canadian Table of Frequency Allocations: http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/cane2009edition-eng.pdf/$FILE/cane2009edition-eng.pdf

sensing and using them as an integral part of the telecommunications infrastructure, i.e. "the last few feet". As air-interface throughput rate continues to increase, this will require greater bandwidth from the access point to the telecom network.

- There are a growing number of households, businesses and hot spots that are using wireless access points to deliver Internet access and other services to multiple end-user devices. In addition to laptops, netbooks and tablet computers having Wi-Fi capabilities, there are also a growing number of peripheral devices, such as cameras, printers, general household appliances and mobile phones that are enabled for Wi-Fi. The growing number of wireless access points and broadening number of Wi-Fi-enabled consumer devices will put a strain on the spectrum in these bands. Some service providers are providing customers with DSL modems and TV set-top boxes with built-in Wi-Fi functionality and, as part of an improved customer experience, are actively turning on the Wi-Fi and setting up the customers' wireless home networks.
- A growing popularity of smartphones with Wi-Fi capability (there are prospects of Wi-Fi capability on 90% of new smartphones sales) will grow to much more than 50% of the customer base. In addition, the 2.4 GHz band can be used to support Bluetooth connections between headset connections and mobile phones, as well as to peer-to-peer data transfers. Also, wireless LAN will drive some demand in these bands.

Analysis

Canadians are avid consumers of wireless electronic devices, which they use extensively at work, at home and on the move. The Inventory Report identifies a typical Canadian household having up to 20 consumer devices, according to a 2006 census report. While many of these devices (using infrared or ISM spectrum for remote control of electronic products, lights, remote garage and car door openers and others) would be outside the prime licence-exempt bands, this does show Canadians' diverse interests in a number of consumer devices. However, increasingly, more home devices use the designated spectrum of interest for a wide range of applications, such as digital phones and Wi-Fi-networking applications.

- Attraction of licence-exempt spectrum means that new technology and applications will continue to be developed. There are numerous predictions of large growth of applications for the use of licence-exempt frequencies.
- Improvements in the capabilities of smartphones and other portable devices, as well as speed enhancements of mobile networks (3G and 4G) are changing the way consumers access the Internet. Internet and data usage is changing with consumers using more and more bandwidth intensive services, such as video with exceeding growth in mobile data traffic. Some mobile operators are off-loading cellular traffic to lower-cost alternatives, such as licence-exempt Wi-Fi access points. In fact, there are now applications available for download, which require smartphones to use Wi-Fi mode.
- The most recently released bands 5470-5600 MHz and 5650-5725 MHz have a lower use of consumer devices than the other bands. However, there is an increasing number of new products being developed under more complex operating protocols.

6.14.4 Services and Spectrum Demand

Approach in Estimating the Demand

The foregoing information in sections 6.14.2 and 6.14.3 should assist in projecting demand for consumer devices in a number of assigned bands. These licence-exempt consumer products have to operate and coexist in an environment where many devices use a pool of frequencies to avoid interference. The information used includes:

- The frequency bands assigned to licence-exempt consumer devices;
- The most popular bands for particular device applications;
- Trends in number of device models certified for use in Canada;
- The phenomena of Wi-Fi applications in electronic products and most popular bands; and
- Limited input from stakeholders; and

- Research on consumer devices.

These sources of information are important to project the demand for consumer devices in popular bands and others.

Service Demand: Market Analysis

Consumer device demand has been consistently growing over the last decade, and this trend is expected to only grow. The most popular devices include digital cordless phones, Wi-Fi routers and Wi-Fi-enabled PCs and laptops, smartphones, Internet TV, electronic products and others. Of interest is the installation of public Wi-Fi access facilities using mesh-network in urban areas and Wi-Fi providing public Internet access, cellular network off-load to Wi-Fi hot spots, etc. There has been an exponential growth of wireless product applications for the benefit and convenience of consumers and commercial users.

Until now, the 2.4 GHz and 5.8 GHz bands have supported the fast adoption of Wi-Fi capability in several hundred millions of consumer devices in Canada.

The demand for wireless communications consumer devices with Wi-Fi Internet access in homes, business and public locations; for radio local area network (RLAN) and metropolitan area networks (MAN) is driven by the Internet phenomena, broadband services and a digital world, based on the full digitization of information, broadcasting and telecommunications. Also, the shift to a mobile-centric society with broadband mobile networks and broadband smartphones (richer in features and service applications) with full access to broadband Internet is an equally strong driver to consumer device demand.

The demand for wireless communication devices, based on Wi-Fi in the licence-exempt spectrum is analyzed as follows:

- **Homes:**
  - Consumers will continue to demand Wi-Fi networking with higher speeds and of better quality, and homes will eventually move to 802.11g and 802.11n products. It could be envisaged, that, at least, 40% of the more than 7.0 million Canadian households subscribing to broadband would have Wi-Fi routers to network computers and other ancillary Wi-Fi devices, including smartphones and tablets.
  - Wi-Fi data traffic in a home setting will increase by several folds and make greater use of the newly released 5 GHz bands in the next five years.

- **Business:**
  - Businesses make an extensive use of broadband Internet services. A greater use of wireless local network (RLAN/high-capacity routers) is anticipated with an increase in data traffic by several folds. Businesses are often in large office complexes with many Wi-Fi routers in close vicinity. The use of advanced technology, such as the 802.11n using dual bands and better encryption, will ensure continued reliable Internet access.
  - Also, the penetration of smartphones and tablets, and laptop computers will put greater demand on office wireless networks.
  - In the next five years, the business traffic on office broadband Wi-Fi access will increase several -old. There will be greater use of the 5 GHz bands.

- **Public Networks:**
  - There is very large number of Wi-Fi hot spots being established to access broadband Internet worldwide. In addition to being used by laptop and notebook devices, they are increasingly being used by mobile devices (smartphones, tablets). A Morgan Stanley[53] report estimates a

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[53] Morgan Stanley presentation (page 58): http://www.morganstanley.com/institutional/techresearch/pdfs/MS_Economy_Internet_Trends_102009_FINAL.pdf

total of 35 million hot spots worldwide, which can provide broadband Internet Wi-Fi access to advanced mobile phones.
- In 2010, 42% of iPhone usage was through Wi-Fi access points: Wi-Fi access speed is 10 times the speed of 3G and 70% cheaper than 3G;
- There are 862 million mobile devices equipped with Wi-Fi (less than 20% of the world cellular subscription base). For North America, the Wi-FI smartphone base would be higher than 20%.
- Adoption of dual-band Wi-Fi (2.4 GHz/5 GHz) in handsets[54] is estimated to increase from approximately 25% of all handsets in 2011 to approximately 50% of all handsets in 2012, with increasing emphasis on the 5GHz band for 3G/4G smartphones. The anticipated growth in tablet devices is also forecast to support 5 GHz, as mobile Wi-Fi chipsets for tablets increasingly adopt dual-band functionality.

- **Complementary Use to Public Wireless Networks:**
  - Wireless cellular operators have established a large number of Wi-Fi hot spots to complement their networks. Wi-Fi access will improve customer experience with data service.
  - Also, wireless operators are off-loading data traffic from their cellular network on certain hot spots so as to ensure sufficient network capacity is available to all users.
  - A number of carriers[55] have embraced Wi-Fi as part of their cellular operation plan.

The bands 902-928, 2400-2483.5 and 5725-5850 MHz have been extensively used to date for the majority of the consumer devices. In particular, the 902 and 2400 MHz bands are heavily used. These bands support an exceedingly large number of RLAN devices providing high-speed connections and accommodating broadband Internet users with large amounts of data consumption each month (10-50 GB).

As outlined above, new devices are increasingly using dual bands, which include the deployment of advanced 802.11n technology in the less-occupied bands of 5150-5250 MHz, 5250-5350 MHz and 5470-5600 MHz.

Spectrum Demand

The very local operation of Wi-Fi devices (very small coverage area) and the adaptability of a large number of devices transmitting to coexist in the same spectrum should ensure sufficient spectrum over the next five years. Advancement in smart-antenna technology and communications protocols will ensure quality and integrity of service for Wi-Fi devices.

54 5 GHz Wi-Fi front-end modules (FEMs) for handsets, smartphones and tablets: http://www.mwee.com/en/5-ghz-Wi-Fi-front-end-modules-fems-for-handsets-smartphones-and-tablets.html?cmp_id=7&news_id=222901639

55 Wi-Fi can deliver more mobile content and applications, and many wireless operators are positioning technology to improve the customer experience with data services. China Mobile plans to implement 1 million hot spots in three years. Asian operators are positioning Wi-Fi as the primary data access technology so, where the customer has a choice to connect via 3G or Wi-Fi, the device will automatically choose the Wi-Fi. AT&T has deployed more than 27,000 hot spots in the U.S. to improve customer experience and to off-load some of the data traffic after the iPhone experience. The 802.11n Wi-Fi standard is enabling the technology to address some of the technology challenges, such as Security, Handover from hot spot to hot spot and from other technologies (i.e. 3G).

Pressure Points:

- The 900 and 2400 MHz bands have the greatest number of consumer devices. The 2400 and 5800 MHz bands are exceedingly used for Wi-Fi systems, embedded chips in computers, smartphones and other consumer and medical devices.
- Congestion of Wi-Fi usage will occur in hot spots established to support large conferences, where attendees can access Internet by Wi-Fi with laptop computers, smartphones, tablets and other computing devices.

Smart technology needs evolve to other 5GHz bands (5150-5250 MHz, 5250-5350 MHz and 5470-5600 MHz) to accommodate the high growth of consumer and electronic devices. It is estimated that less than 20% of the spectrum in the defined licence-exempt bands for consumer devices is heavily occupied.

The bands 902-928, 2400-2483.5 and 5725-5850 MHz have been extensively used to date for the majority of the consumer devices. These bands support an exceedingly larger number of RLAN devices providing high-speed connections and accommodating broadband Internet users with large amounts of data consumption per month (10-50 GB). RLAN devices are evolving in the use Software Define Radio (SDR), dynamic frequency assignments, multi-bands and smart technology to co-exist with other primary services.

New RLAN technology will benefit from the less-occupied bands of 5150-5250 MHz, 5250-5350 MHz and 5470-5600 MHz. The total amount of well-defined bands below 6 GHz for licence-exempt consumer devices is approximately 560 MHz (less than 20% of the spectrum is heavily occupied). Most of these bands assigned to low-power consumer devices are used by primary radio services.

The successful introduction of Ultra-Wideband (UWB) communication devices has the potential of accommodating many of the existing Wi-Fi-networking capabilities and to bring some spectrum relief to some of the licence-exempt bands.

6.14.5 Conclusion

The Study does not show additional demand of spectrum for consumer devices to occur in the 2010 to 2015 period. However, some of the bands (960 and 2400 MHz) are heavily populated with consumer devices and can experience localized congestion in the presence of several devices operating in the area (i.e. conference centre, airport, etc.)

New technologies are increasingly using higher licence-exempt bands in the 5 GHz range. It is estimated that less than 20% of the spectrum in the new 5 GHz band (bands 5150-5250 MHz, 5250-5350 MHz and 5470-5600 MHz) is heavily occupied.

6.15 Medical Devices

6.15.1 Overview

With advances in wireless networks, new and innovative medical applications are being developed. Efficiency among hospital staff is greatly increased by utilizing these newly introduced applications and tools. Long-term patient care, remote diagnostics and support for elderly people are some of the most important issues being discussed in light of wireless networks.

Hospitals and health centres make extensive use of wireless medical communications operating as low-power and licence-exempt status. These devices operate in-building, local area setting of health centres. The devices can coexist with other primary services with relatively little harmful interference. Also, patient in-home care is a new area in the use of wireless networks and medical applications. Remote monitoring of patients and the elderly in their homes will significantly reduce costs of caregivers and also provides a non-intrusive lifestyle for its users. The non-exclusive frequency bands assigned for low-power and licence-exempt devices, which include wireless medical devices on a non-protected basis are described in Industry Canada RSS-210 or RSS-243 and listed in Section 6.15.2, below.

6.15.2 Spectrum Inventory and Utilization

Industry Canada's Inventory Report provides the number of medical telemetry device models certified for distribution in Canada according to technical requirements and applications as outlined in RSS-210 for licence-exempt devices. Although this provides general information on the certification activities of medical telemetry devices from Canadian and recognized laboratories worldwide, it does not provide tangible information on how many medical telemetry devices are shipped to Canada for use in the different bands. However, the Inventory Report (Section 12.4) presents interesting charts on the certification of consumer medical telemetry devices in Figure 12.6 for the 174-216 MHz and Figure 12.7 for the 608-614 MHz bands. New sub-bands have been opened in the 1400 MHz range for licence-exempt medical telemetry devices.

A spectrum inventory has been put together from official documents of Industry Canada on the primary frequency bands assigned to the most conventional medical devices. The non-exclusive frequency bands assigned for low-power and licence-exempt devices, which include wireless medical devices on a non-protected basis, are described in Industry Canada RSS-210 and are listed below:

- Bands 72-73 MHz, 74.6-74.8 MHz and 75.2-76 MHz: Auditory Assistance;
- Band 174-216 MHz: Medical Telemetry usage only;
- Band 216-217: Auditory Assistance and Medical Telemetry in health-care facilities only;
- Band 608-614 MHz: in part for Medical Telemetry;
- Band 401-406 MHz: for Medical Implant Communication Service (MICS) for MITS and MEDS using different parts of the band; see RSS-243;
- Band 1395-1400 MHz and 1427-1429.5 MHz: Medical Telemetry in health-care centres, not available near radar stations in Nova Scotia and Newfoundland and Labrador
- Most of these bands are assigned to low-power medical devices and are used by primary radio services.

Parts of the TV broadcasting spectrum (bands 174-216 MHz and 584-608 MHz) have been used in the past to accommodate low-power Wireless Medical Telemetry Systems (WMTS). Where local DTV stations are being implemented, it is no longer recommended to use the same spectrum for these low-power medical telemetry devices in hospital centres, due to potential interference. Medical administrations have been encouraged to retune their WMTS to other bands.

Canada has a sizable medical device market as summarized[56] in Table 6.15.1, below.

[56] Canadian Life Science Industries: http://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01706.html

Table 6.15.1 — Canadian medical device market (*Source: Industry Canada's Web site*)

Market size in 2008	Valued at $6.4 billion
Increase from 2000 to 2008	2% at CAGR (compound annual growth rate)
Exports growth from 2000 to 2009	5.5% ($1.6 billion in 2000 to $2.6 billion in 2009) at CAGR
Imports growth from 2000 to 2009	4.6% (from $1.8 billion in 2000 to $2.5 billion in 2009) at CAGR

However, it should be noted that there are very few radio-based medical products manufactured in Canada. Most of these radio-based medical devices are imported from the U.S. and other countries. Hence, the U.S. industry leads in development of new medical devices and the identification of spectrum requirements. As a rule, Industry Canada has closely followed the FCC activities in identifying and releasing appropriate spectrum to support new medical device applications to benefit Canadians.

Current RF wireless technologies working with medical telemetry devices include:[57]

- Licence-exempt devices under IC RSS-210 regulations;
- Cellular (mobile) telephones;
- Wireless handheld computers and personal digital assistants (PDAs);
- Wireless local area networks (WLAN 802.11.a/b/g);
- Wireless modems for laptop computers;
- Personal area networks, including 802.15.1 (Bluetooth), 802.153a (ultra-wideband) (UWB) and 802.15.4 (Zigbee);
- RF identification (RFID).

6.15.3 Stakeholder Input and Research Analysis

There were no comments received on the general medical service growth or spectrum demand. As a result, this section is based on secondary research.

Medical applications that are expected to see the greatest growth in the coming years are[58]:

- Remote patient monitoring (RPM) for the following conditions: Asthma, Diabetes, Chronic obstructive pulmonary disease (COPD), Congestive heart failure (CHF), Coronary Artery Disease (CAD) (devices: defibrillators, infusion pumps, blood pressure monitors, weight scales, etc.). Forrester Research estimates that the sale of U.S. chronic disease devices would have grown to $3.8 billion US in 2010 and then to $26 billion US by 2015[59].
- A Study by Nerac[60] estimates that, according to present trends, by 2020, at least 160 million Americans will be monitored and treated remotely for chronic conditions.

57 FDA Draft Guidance for Industry and FDA stuff. Radio-Frequency Wireless Technology in Medical Devices. January 2007. Downloaded from www.fda.com.

58 Taper S., Morton. E., K. Lotring. Wireless Medical Devices: Security Issues, Market Opportunities and Growth Trends | What's Your Share of the $5 Billion Medical Monitoring Market? Medical Device Marketplace Review, April 2009. Downloaded from www.nerac.com.

59 Taper S., Morton. E., K. Lotring. Wireless Medical Devices: Security Issues, Market Opportunities and Growth Trends | What's Your Share of the $5 Billion Medical Monitoring Market? Medical Device Marketplace Review, April 2009. Downloaded from www.nerac.com.

60 Nerac study on Wireless Medical devices by Scott Taper.

- Hospital bed monitoring: facilitating wireless patient monitoring, allowing greater utilization of hospital facilities (devices: smartphones, tablet PCs, PDAs, sensors).
- Laboratory automation: in-vitro diagnostics (IVD) testing can be done on an outpatient basis and in real time, decreasing the need to make repeated trips to a clinic for retesting. The total (Global) IVD market was $42 billion in 2007, and it is projected to grow at about 6.2% annually. By 2025, an additional $10 billion to $12 billion will be added to this market.
- Mobile medicine practices: provide means for treating chronic conditions on an outpatient basis, leading to fewer doctor visits and lower health-care costs.

Section 6.15.2, above, summarizes the spectrum designated for medical telemetry devices. In order to ensure the availability of medical products and innovative applications, it is important that Canada align its frequency assignments and type of applications with the larger U.S. market. Also, as many Canadians, using medical device implants travel to and vacation in the U.S., there are significant advantages in harmonizing both spectrum and standards. Canada does not necessarily harmonize with certain frequency bands available in Europe.

The significant increase in new medical device applications, which is accelerated with the integration of local and remote wireless communications (mobile, WLAN, RFID, Zigbee, and others), will drive the use of medical devices in the next five years, as outlined in Section 6.15.3, above.

As medical devices operate at very low power, using groups of frequencies, and, in some cases, using advanced-frequency collision-avoidance schemes, a large number of medical devices can coexist in the same local settings. High usage of devices is prevalent in hospital for wireless medical telemetry applications. Many of these medical devices are not communicating or may communicate or exchange data only when prompted to do so. In the past five years, Industry Canada has opened bands 1395-1400 MHz and 1427-1429.5 MHz for medical telemetry, as described in SP 1.7 GHz[61]. This spectrum is aligned with the U.S. and should accommodate a significant number of new medical devices and applications.

6.15.4 Services and Spectrum Demand

Approach in Assessing Continued Demand for Spectrum for Medical Devices

The foregoing information, contained in sections 6.15.2 and 6.15.3, above, should assist in projecting demand for medical devices. These licence-exempt medical products have to operate and coexist in an environment where many devices have a pool of frequencies. Medical telemetry devices operate in health-centre locations where greater care can be used to coordinate frequency use and avoid potential interference. The information used includes:

- The frequency bands assigned to licence-exempt medical devices (Inventory Report and RSS-210);
- The most popular bands for particular medical device applications;
- The trends in number of device models (bands 174-216 MHz and 608-614 MHz) certified for potential use in Canada;
- Research on the application of wireless devices for health care at home or other settings (particular for an aging society).

These sources of information are important to project the demand for medical devices and continued need for existing and newly assigned spectrum.

61 SP 1.7 GHz: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09543.html

Service Demand: Market Analysis

Canada has a very advanced health-care service and the use of medical devices is an important element. There is a wide range of certified medical devices available for distribution and sale to Canadian health centres and individuals. The non-exclusive frequency bands (RSS-210) assigned for low-power and licence-exempt wireless medical devices are listed in 6.15.2.

In general, Canada harmonizes its medical device bands with the U.S. rather than other regions, such as Europe, since most of the medical devices imported and distributed in Canada are from U.S. manufacturers or distributors.

From literature research, the growth of medical devices applications is forecast to be significant in the next five years and beyond, as outlined in Section 6.15.3. This will be accelerated with the integration of local and remote wireless communications (mobile, RLAN, RFID, Zigbee and others), which will drive the use of medical devices in the next five years.

Spectrum Demand

The spectrum available for use by medical devices is meeting the needs of the various applications. With the assignment of new frequency bands, of late, for various medical device applications, additional demand of spectrum has not been identified.

It should be noted that the Canadian spectrum for medical devices is harmonized with the United States, from where the majority of products are imported. This trend is expected to continue.

With proper deployment of medical devices in hospitals using appropriate frequency agile technology, there should not be serious congestion. Hospital administrators are becoming better educated in the potential of interference in operation of low-power (licence-exempt) medical devices, often in the same spectrum as primary radio services in the area. Medical telemetry will need to shift to new spectrum in the 1400 MHz band (if digital TV operates in the same broadcasting frequency in that area).

6.15.5 Conclusion

A wide range and increased use of medical devices is foreseen over this time period to 2015 and beyond, to improve delivery of health care and to better monitor an aging population. It is anticipated that a growing number of existing types of medical devices will be enhanced with wireless communication capability to support remote and tele-medicine applications.

Demand of additional spectrum for medical devices is not expected to occur in the 2010 to 2015 period, as a result of the short-range, low-power communications of many devices.

It should be noted that, the new medical telemetry band at 1400 MHz should replace the use of TV broadcasting spectrum, which is subject to more interference from over-the-air digital TV broadcasting.

A. Appendix A: The Stakeholders

Table A.1.1, below, lists the stakeholders that were approached to provide input. While most stakeholders provided highly beneficial information, some did not respond. In addition to the direct input from stakeholders, in some cases, some stakeholders were interviewed or asked more detailed questions. All stakeholder input has been treated as confidential, other than where we received permission from agencies to release their names (i.e. DND, RCMP, etc.), and, in some cases, the user is obvious. In developing the projections for service or spectrum demand, several sources of information were used and combined with stakeholder input to develop the specific input data needed for the modelling process.

Table A.6.1 — List of stakeholders approached for input; a large majority of stakeholders did provide their input.

	Stakeholder Organizations
1	Astral Media
2	Shaw Media (Canwest)
3	CBC/Radio-Canada
4	CTV Globemedia (Bell Media)
5	CIEL Satellite Group
6	OmniGlobe Networks
7	SkyTerra (Canada) Inc.
8	Telesat
9	TeraGo Networks
10	TerreStar Solutions
11	Bell Canada
12	Mobilicity
13	MTS Allstream
14	NorthWesTel
15	Rogers Communications
16	SaskTel
17	TELUS Communications
18	Videotron
19	Wind Mobile
20	Ericsson Canada
21	Motorola
22	Nokia
23	Nokia Siemens Networks
24	RIM
25	Cisco Systems
26	Barrett Xplore (Xplornet Communications)
27	EastLink
28	Radio Advisory Board of Canada (RABC)

29	Bell Helicopter Textron Canada
30	Bombardier
31	Canadian Electricity Association
32	Canadian Space Agency (CSA)
33	Department of National Defence (DND)
34	Electro-Federation Canada (EFC)
35	Environment Canada (EC)
36	Hydro One
37	NAV CANADA
38	Transport Canada (TC)
39	Royal Canadian Mounted Police (RCMP)
40	Railway Association of Canada
41	Inukshuk Wireless
42	Alcatel-Lucent
43	Canadian Wireless Telecommunications Association (CWTA)
44	Vecima Networks
45	Association of Public-Safety Communications Officials (APCO) Canada
46	Radio Amateurs of Canada
47	Tbaytel

B. Appendix B: Table of Acronyms

Following is a list of terms and their accompanying acronyms.

AMR	Automatic Meter Reading
AMS(R)S	Aeronautical Mobile Satellite (Route) Services
AMT	Aeronautical Mobile Telemetry
ANS	Air Navigation System
APCO	Associations of Public Safety Communications Officials
ARPU	Average Revenue Per User
ATC	Ancillary Terrestrial Component
ATCS	Air Traffic Control Services
ATSC	Advanced Televisions Systems Committee
AWS	Advanced Wireless Service
BDU	Broadcasting Distribution Undertaking
BH	Busy Hour
BRS	Broadcast Radio Service
BSS	Broadcasting Satellite Service (DTH Broadcasting Satellite in Report)
BWA	Broadband Wireless Access
CAGR	Compound Annual Growth Rate
CARE	Centre for Atmospheric Research Experiments
CATV	Originally Community Antenna Television; now Cable TV
CCG	Canadian Coast Guard
CCRS	Canada Centre for Remote Sensing
CDMA	Code Division Multiple Access
CIS	Canadian Ice Service
CMR	Communications Monitoring Report
CNR	Combat Net Radio
CPE	Consumer Premise Equipment
CRTC	Canadian Radio-television Telecommunications Commission
CSA	Canadian Space Agency
CTFA	Canadian Table of Frequency Allocations
CWTA	Canadian Wireless Telecommunications Association
DAB	Digital Audio Broadcasting
DECT	Digital Enhanced Cordless Telecommunications
DFO	Department of Fisheries and Oceans Canada
DL	Downlink
DMB	Digital Multimedia Broadcasting
DME	Distance-Measuring Equipment
DND	Department of National Defence
DOCSIS	Data Over Cable Service Interface Specification

DRB	Digital Radio Broadcasting
DSL	Digital Subscriber Line
DTH	Direct-to-Home
DTV	Digital Television
EC	Environment Canada
E-COMM	Emergency Communications (Metro Vancouver and parts of B.C.)
EDACS	Enhanced Digital Access Communications System
EDGE	Enhanced Data rates for GSM Evolution
EESS	Earth Exploration Satellite Service
ESMR	Enhanced System Mobile Radio
EV-DO	Evolution-Data Optimized
FA	Frequency Assignment
FCC	Federal Communications Commission
FDD	Frequency-Division Duplex
FRS	Family Radio Service
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
GB	Gigabyte
Gbps	Gigabits per second
GHz	Gigahertz
GLONASS	Global Navigation Satellite Systems
GMDSS	Global Maritime Distress and Safety System
GMRS	General Mobile Radio Services
GNSS	Global Navigation Satellite Systems
GOC	Government of Canada
GOS	Geostationary orbital slot
GPRS	General Packet Radio Service
GPS	Global Positioning Service
GSM	Global System for Mobile Communications
GSMA	Global System for Mobile Communications Association
HDTV	High-Definition Television
HF	High Frequency
HH	Household
HSPA	High-Speed Packet Access
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IBOC	In-Band On-Channel
ICAO	International Civil Aviation Organization
iDEN	Integrated Digital Enhanced Network
ILS	Instrument Landing System
IM	Instant Message
IMO	International Maritime Organization
IP	Internet Protocol

ISM	Industrial, Scientific and Medical
ITU	International Telecommunications Union
kB	Kilobyte
kbps	kilobits per second
km	Kilometre
km/s	Kilometre per second
LEO	Low-Earth Orbits
LM	Land Mobile
LMCS	Local Multipoint Communication Systems
LTE	Long Term Evolution
M	Million
M2M	Machine-to-Machine
MATS	Mobile Aeronautical Telemetry Systems
Mb	Megabit
MB	Megabyte
mbps	Megabits per second
MCS	Multipoint Communication Systems
MDS	Multipoint Distribution Services
MF	Medium Frequency
MHz	Megahertz
mi	Mile
MICS	Medical Implant Communication Service
MLS	Microwave Landing System
MMS	Multimedia Message Service
MoU	Minutes of Use
MSC	Meteorological Service of Canada
MSS	Mobile Satellite Service
MURS	Multi-Use Radio Service
MW	Microwave
NATO	North Atlantic Treaty Organization
NBP	National Broadband Plan (U.S.)
NMHS	National Meteorological and Hydrological Services
NORAD	North American Aerospace Defense Command
NRC	National Research Council (Canada)
NTIA	National Telecommunications and Information Administration
OCAS	Obstacle Collision Avoidance System
OECD	Organization for Economic Co-operation and Development
OFCOM	Office of Communications (in the UK)
OFDM	Orthogonal Frequency-Division Multiplexing
O-QNET	Ontario-Quebec Network
OTA	Over-the-air
PB	Petabyte

PCS	Personal Communications Service
PDA	Personal Digital Assistant
POP	Point of Presence
PPDN	Public Packet Data Network
PS	Public Safety
PSTN	Public Switched Telecom Network
PTM	Point-to-Multipoint
PTP	Point-to-Point
PTT	Push-to-Talk
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RCMP	Royal Canadian Mounted Police
RDS	Radio Data System
R-LAN	Radio Local Area Network
RPM	Remote Patient Monitoring
RRBS	Rural Remote Broadband Service
RSS	Radio System Standards
RTT	Radio Transmission Technology
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications
SCADA	Supervisory Control and Data Acquisition
SDR	Software-Defined Radios
SDTV	Standard-Definition Television
SLAR	Side-Looking Airborne Radar
SME	Small and Mid-sized Enterprise
SMS	Short Message Service
SNG	Satellite News Gathering
SOLAS	Safety of Life at Sea
SONET	Synchronous Optical Networking
TB	Terabyte (equal to 1,000 GB)
TC	Transport Canada
TDD	Time-Division Duplex
TDMA	Time Division Multiple Access
UAV	Unpiloted Aerial Vehicle
UHF	Ultra High Frequency
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UWB	Ultra-Wideband
VHF	Very High Frequency
VOR	Very High Frequency (VHF) Omnidirectional Range
VSAT	Very Small Aperture Terminal
WCDMA	Wideband Code Division Multiple Access

WCS	Wireless Communication Services
WiMAX	Worldwide Interoperablity for Microwave Access
WLAN	Wireless Local Area Network
WMTS	Wireless Medical Telemetry Systems
WRC	World Radio Conference
YE	Year-end
YoY	Year over year