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Traffic forecasts and estimated spectrum requirements for future development of the mobile-satellite service in the range 4-16 GHz

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

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REPORT ITU-R M.2218

Traffic forecasts and estimated spectrum requirements for future development of the mobile-satellite service in the range 4-16 GHz

(2011)

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1 Introduction

Future spectrum requirements for mobile-satellite service (MSS) systems as contained in this Report are estimated on the basis of broadband MSS market forecasts.

Assessment of the spectrum requirements for the MSS, i.e., the satellite component of IMT in the 1-6 GHz range, was carried out prior to WRC-07 and is contained in Report ITU-R M.2077.

For the year 2020, the shortfall in spectrum requirements is between 19 and 90 MHz in the uplink direction and between 144 and 257 MHz in the downlink direction, including the distribution applications. These requirements are indicated as being required in the 1-6 GHz range on the basis that high mobility applications would not be feasible in frequency bands above 6 GHz.

The MSS applications envisaged in Report ITU-R M.2077 are appropriate to small, typically handheld, portable devices. The highest data rate considered is 144 kbit/s. By current standards, this is quite modest. Current terrestrial mobile systems using 3G technologies (such as HSDPA) are providing data rates of up to 7.2 Mbit/s (download) to a user. Higher data rates are likely to be introduced in the future, particularly when terrestrial IMT-Advanced systems are deployed. The use of such high data rate applications in terrestrial mobile networks is likely to be a driver for demand of higher data rate services in the MSS. In this respect the maximum 144 kbit/s assumption in Report ITU-R M.2077 may be considered very conservative.

The provision of data rates of above about 100 kbit/s in the MSS will probably require the use of directional antennas. Currently in the 1-3 GHz ranges MESs are able to provide data rates of between about 64 kbit/s and 500 kbit/s using directional antennas between about 15 cm and 80 cm in diameter.

However, the demand for MSS terminals with relatively high data rates (above 144 kbit/s) is not currently addressed in Report ITU-R M.2077 as well as MSS requirements in the frequency range between 6-16 GHz.

A further category of MSS applications which is not addressed in Report ITU-R M.2077 is for the provision of backhaul for terrestrial mobile systems. For example, terrestrial mobile base stations and wireless Internet hubs can be operated in remote locations with the backhaul provided using an MSS system. Such systems are currently being deployed to provide mobile service (mobile phone and WiFi) to passengers on planes and to passengers and crew on ships. This is a relatively new type of use but one with potential for high growth. Similar systems are also used for land-based applications, for example for provision of cellular mobile base stations in disaster-hit areas.

Studies have been conducted to estimate the spectrum requirements for broadband MSS systems and the details are given below.

For this reason the spectrum requirements for new broadband MSS applications contained below in this Report should be considered as the aggregate requirements for MSS in the 4 to 16 GHz range, including the requirements in Report ITU-R M.2077 for the 4-6 GHz range.

Some administrations do not see a need for additional spectrum for future MSS growth beyond that already allocated for the MSS in the Radio Regulations, believing instead that existing MSS spectrum allocations are sufficient. For this reason, some administrations do not believe the estimates for user density and typical usage is appropriate for their administration, and expect the estimates to be much lower.

2 Study 1 – Spectrum requirements in the context of WRC-12 Agenda item 1.25 (4-16 GHz range)

2.1 MSS – Evolution towards broadband

MSS high data rate (HDR) delivers in-fill connectivity and/or convenience/effectiveness compared to terrestrial solutions. Applications include broadband Internet access, videoconference, voice backhauling, broadband security and safety, broadband corporate network, real-time satellite news gathering (SNG), telemedicine, tele-education.

TABLE 1

Categories of MSS high data rate in the 1-16 GHz range

Application name	Category	Market	Segment	Addressable market
Passenger voice coms	HDR	Aero, maritime	Commercial, governmental	Boats, planes
BB Internet access	HDR	Land, maritime, aero	Commercial, governmental	Boats, planes, individuals
Video conference	HDR	Land, maritime	Commercial, governmental	Boats, individuals
BB security and safety	HDR	Land, maritime	Commercial, governmental	Boats, monitored sites
BB corporate network	HDR	Land	Commercial, governmental	Corporate sites
Real-time SNG	HDR	Land	Commercial	TV teams ...
Telemedicine	HDR	Land, maritime	Commercial, governmental	Boats, remote sites, remote hospitals, ...
Tele-education	HDR	Land	Governmental	Number of remote schools

This estimation of the spectrum requirements is based on the assumed applications provided in Table 1. It is recognized that some of the applications and markets identified in this Table may be addressed by FSS systems. For example, earth stations on-board vessels (ESV) provide broadband satellite communications to some ships using FSS satellite networks.

Regarding data requirements, data rate requirements of several Mbits/s have been considered in the traffic forecast for broadband MSS. Considering that data rates provided by MSS systems have increased over time with the emergence of new technologies and new applications, whereby MSS is currently providing data rates of the order of 492 Kbits/s, further considering the evolution of data rates in terrestrial systems, it seems reasonable to consider that data rates forecasted to be provided by MSS by 2020 are of several Mbits/s.

Regarding the number of subscribers, study 1 has considered the current number of subscribers of broadband MSS in the world, and in forecasting the evolution of each MSS application envisaged, assumed an overall growth for the number of subscribers of about 6% per year until 2020. According to the industry’s experience, this assumption for the number of subscribers is considered reasonable.

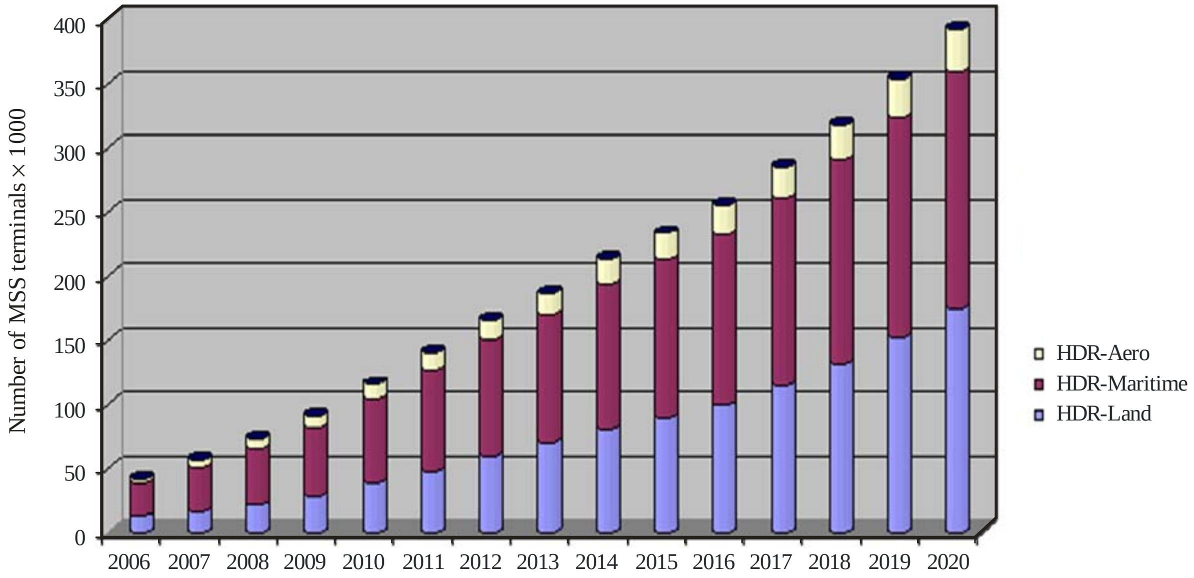
2.2 Market forecasts in the 1-16 GHz range

MSS can currently deliver high data rate connectivity at speeds ranging from 56 kbit/s up to 492 kbit/s. The continuation of the growth in this market requires the availability of real broadband (between 492 kbit/s and 4 Mbit/s) products, capable of providing multi Mbit/s connectivity. Such real broadband data rates require much more spectrum than is currently available for MSS.

Figure 1 presents forecasts in terms of number of MSS terminals up to the year 2020 for a baseline (low growth) scenario, regardless of the frequency range considered, and for three market segments considered (land, maritime, aeronautical). The HDRs considered in this period are assumed to grow linearly from 56 kbit/s in 2006 to about 4 Mbit/s in 2020.

FIGURE 1

Growth in the number of MSS terminals per market segment (low growth scenario)



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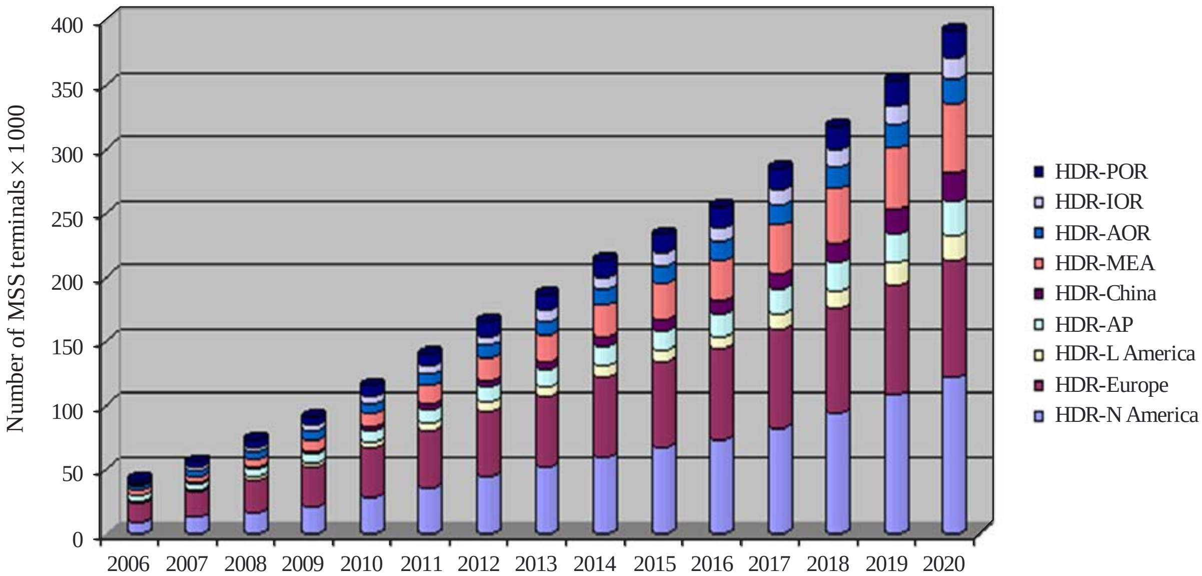
MSS is by nature global or at least multi-regional. Figure 2 presents forecasts in terms of number of MSS terminals up to the year 2020 for a baseline scenario, regardless of the frequency range considered, and for various geographical areas. New MSS spectrum allocations should be done on a global basis.

FIGURE 2

Growth in the number of MSS terminals per geographical area (low growth scenario)



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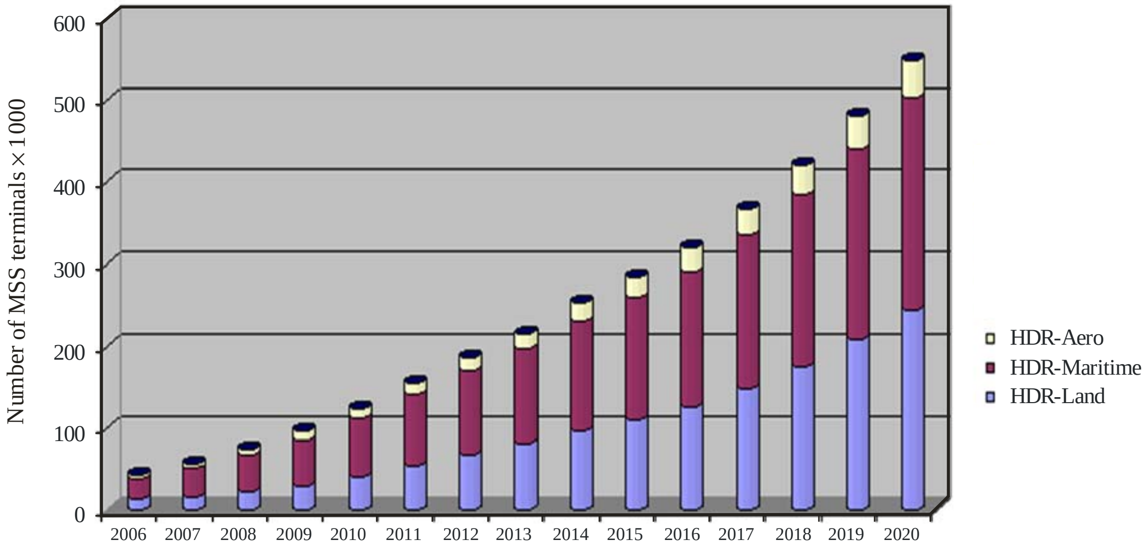
A high-quality service at moderate cost will permit a fast growth. The service quality is strongly related to the bit rate that can be commissioned per terminal and thus to the total available spectrum.

The success of the service also depends on the desirable key features of MSS: global coverage, small antenna size, terminal portability, mobility, fast deployment, no sensitivity to rain fade, etc. The number of MSS terminals is therefore estimated to be 380 000 worldwide by 2020 in the baseline traffic scenario, and 540 000 worldwide by 2020 in the high-growth scenario (see Fig. 3).

FIGURE 3

Growth in the number of MSS terminals per market segment (high growth scenario)



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2.3 Methodology

It is assumed that all traffic is carried in packet-switched mode and all services are multiplexed together on the same carriers. This is the most efficient way to carry a given amount of data over a network.

The basic equation required to calculate the spectrum requirement S (MHz) is:

$$S = \frac{N_{beams} \cdot T_{BH} \cdot 8000 \cdot B}{3600 \cdot eff \cdot R} \qquad (1)$$

where:

- N_{beams}: number of beams in a frequency reuse cluster;
- T_{BH}: busy hour traffic in one beam (Gbytes);
- B: carrier bandwidth (MHz);
- eff: efficiency factor to take into account the average loading of each carrier;
- R: average effective data rate of a carrier (Mbit/s).

Considering a traffic forecast expressed in Mbytes per month, a conversion of these forecast numbers to Mbytes in the busy hour is required. This is done through the following equation:

$$T_{BH} = \frac{T_M \cdot p_{BH} \cdot p_{HS}}{MD \cdot N_{beams}} \qquad (2)$$

where:

- T_M: forecast global traffic per month (Mbytes);
- p_{BH}: portion of the diurnal traffic that occurs in the busy hour;
- p_{HS}: geographical distribution factor, i.e., the ratio traffic in hot spot cluster to traffic in low spot cluster;
- MD: month to day conversion ratio;
- N_{beams}: number of beams in a frequency reuse cluster.

It can be noted that these equations assume that the traffic is uniformly distributed between the beams in the hot-spot cluster. This is a simplification that underestimates the spectrum requirement.

2.4 Input parameters

Traffic: The number of MSS terminals is taken from market forecasts provided in section 2.1. The average traffic per month and per user is assumed to be between 2 to 4 Gbytes. It is assumed that this is the traffic carried in the MSS network.

Spectrum reuse pattern: A four-cell reuse pattern is assumed.

Spectrum efficiency: The spectrum efficiency increases with increasing terminal size as larger antennas improve the link margin, thereby allowing the use of more efficient modulation schemes and reduced coding rates. A 1 bit/s/Hz spectrum efficiency is determined based on the assumption of a mix of terminal types, including handheld, pocket-sized, notebook-sized and briefcase-sized.

Busy hour traffic: The month-to-day conversion factor used was 25 and the day-to-busy hour factor 25%.

Geographical distribution factor: Ratio between traffic in a beam in the hot-spot cluster and the traffic in a low spot cluster.

Traffic loading: It was assumed that the MSS carriers are on average 90% loaded. This represents a very efficient system.

Number of beams: It is assumed that 3 systems, with 200 beams each, cover the surface of the Earth, hence 600 beams are assumed.

Frequency range: The calculations assume that the market forecasts presented in section 2.1 relate to MSS systems in the 4-16 GHz range.

2.5 Results of calculations

Table 2 shows the results of the calculations based on the methodology in § 2.3 and the input parameters in § 2.4.

TABLE 2

Spectrum requirements by 2020 in the 4-16 GHz range

	Baseline scenario			High growth scenario			Unit
Number of users in the world	380 000	380 000	380 000	540 000	540 000	540 000	
Traffic per user/month	2	3	4	2	3	4	Gbyte
Total traffic/month	760 000	1 140 000	1 520 000	1 080 000	1 620 000	2 160 000	Gbyte
Month-to-day ratio	25	25	25	25	25	25	
Day-to-busy hour ratio factor	25	25	25	25	25	25	%
Loading factor	90	90	90	90	90	90	%
Number of beams	600	600	600	600	600	600	
Geographical distribution factor	300	300	300	300	300	300	%
Required data rate in busy hour	56	84	113	80	120	160	Gbit/s
Spectrum efficiency	1	1	1	1	1	1	bit/s/Hz
Spectrum reuse pattern	4	4	4	4	4	4	
Total spectrum requirement	375	563	751	533	800	1 067	MHz
Uplink/downlink ratio	1:1	1:1	1:1	1:1	1:1	1:1	
Uplink spectrum requirement	188	281	375	267	400	533	MHz
Downlink spectrum requirement	188	281	375	267	400	533	MHz

Assuming the middle-ground value for traffic per user/month, i.e., 3 Gbytes, the results obtained for the baseline and high traffic scenario are shown in Table 3.

TABLE 3

Spectrum requirements by 2020 in the 4-16 GHz range

	Low growth scenario	High growth scenario
Uplink spectrum requirement	281	400
Downlink spectrum requirement	281	400

3 Study 2

3.1 Introduction

Spectrum requirements for the MSS, in the context of the satellite component for IMT, have been assessed in Report ITU-R M.2077. As discussed above, the requirements in Report ITU-R M.2077 cover the satellite component of IMT-2000 and systems beyond, with an assumed maximum data rate per user of 144 kbit/s. There are other MSS applications, which may or may not be part of the satellite component for IMT, which will have higher user data rate requirements. This contribution provides an estimate of those requirements. These requirements are termed “broadband MSS” and consist of requirements for MSS systems with user data rates greater than 144 kbit/s. Hence these requirements can be considered as complementary to those in Report ITU-R M.2077.

Any new allocations to the MSS under WRC-12 Agenda item 1.25 would be made in 2012 or 2013. Considering the time taken to design, build and launch new MSS satellite systems, it can be estimated that the new allocations could be brought into use around 2016 at the earliest. Considering a typical design life for an MSS satellite of around 15 years, the time-frame for use of the new allocations would be around 2016 to 2031. However, for purpose of this analysis, the reference date assumed is 2020. This is to maintain consistency with Report ITU-R M.2077 and also means that the figures in this study could be considered conservative in the context of WRC-12 Agenda item 1.25. Multicast mode of MSS communications is not considered here on the basis that these requirements are already fully identified in Report ITU-R M.2077.

It should be noted that the requirements discussed in this study are independent of frequency band insofar as it is assumed that broadband MSS systems would use directional antennas for the user terminals, and may therefore operate in a wide range of bands, at least from 4-16 GHz. Effectively, it is assumed here that there are no constraints on the available spectrum for MSS. This is on the understanding that the technical studies required to assess the feasibility of new MSS allocations is a separate step in the overall process.

There are broadly two steps to estimating the spectrum requirements: 1) to estimate the average data throughput per MSS terminals, and 2) to estimate the number of MSS terminals. Using this information and characteristics of the proposed MSS systems it is possible to derive the spectrum requirements.

3.2 Estimation of the number of broadband MSS users and data requirements

3.2.1 Land mobile MSS users

In the case of land mobile MSS services, the likely applications for broadband MSS are for the extension of terrestrial mobile services to users in geographic areas beyond the coverage of terrestrial systems. Hence the traffic requirements for a typical land broadband MSS user will tend to follow those of terrestrial mobile users. Report ITU-R M.2078 may therefore be used as a reference to estimate the traffic requirements for future broadband MSS users.

In Report ITU-R M.2078, the data rate requirements are identified for certain service categories (SC) and for certain service environments (SE). These are identified in Tables 4 and 5 below.

TABLE 4

Service categorization

Traffic class / Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	SC 1	SC 6	SC 11	SC 16
High multimedia	SC 2	SC 7	SC 12	SC 17
Medium multimedia	SC 3	SC 8	SC 13	SC 18
Low rate data and low multimedia	SC 4	SC 9	SC 14	SC 19
Very low rate data[(1)]	SC 5	SC 10	SC 15	SC 20

(1) This includes speech and SMS.

TABLE 5

Identification of service environments

<table>
<tr><th>Teledensity / Service usage pattern</th><th>Dense urban</th><th>Sub-urban</th><th>Rural</th></tr>
<tr><td>Home</td><td>SE 1</td><td>SE 4</td><td rowspan="3">SE 6</td></tr>
<tr><td>Office</td><td>SE 2</td><td rowspan="2">SE 5</td></tr>
<tr><td>Public area</td><td>SE 3</td></tr>
</table>

In the context of broadband MSS, it is assumed that service environments SE 2, SE 5 and SE 6 only are applicable. It is further assumed that all service categorizations are applicable to a representative broadband MSS user, except that it is assumed that all combinations of service categorization and service environment which require a very high data rate (greater than 2 Mbit/s) will not be carried by MSS means (i.e., that all such requirements will be carried by terrestrial means only). It may be noted that service usage patterns associated with SE 2 consist of the dense urban teledensity and the office service usage pattern, even though MESs are not typically used in the urban environment. It is effectively assumed that an MSS user has the same requirements (subject to the exception made for very HDR applications mentioned above) as a terrestrial mobile user associated with this service environment (i.e., the same requirements for applications such as high rate multimedia/videoconference, business intranet/extranet, messaging (MMS/IMS/SMS)). This fits with a typical application for MSS users which is to corporate communications to remote areas.

Using these assumptions, an assessment of the data requirements for a representative broadband MSS user can be determined by referring to Tables 32b and 32c of Report ITU-R M.2078 which contain the uplink and downlink unicast requirements for the year 2020 (low user density case). Annex 1 shows the derivation of the data requirements based on Table 32b which leads to a mean daily data requirement of 152 Mbyte/day.

This is the requirement for the uplink direction. A review of Table 32c in Report ITU-R M.2078 shows that the downlink requirements are identical to the uplink requirements. Although it might seem surprising that the uplink and downlink requirements are the same considering that traffic for web browsing applications is typically asymmetric, the assumption fits the current trend towards user generated web content, which would tend to reduce the asymmetry. It should also be noted that a common application for land MSS usage is for news journalism involving the transmission of voice and images from remote locations. These applications are dominant in the uplink direction, so also have the effect of providing some balance to other applications which are dominant in the downlink direction. Although there is some uncertainly, for the purpose of this analysis, the assumption of equal requirements in the uplink and downlink directions is acceptable. Hence the result of 152 Mbyte/day is equally applicable to the downlink. Assuming 25 days in a month, this figure is equivalent to 3.72 Gbyte/month in each direction, i.e., 7.44 Gbyte/month in total, which is taken as the average data requirements for the “high traffic scenario”. For the “low traffic scenario”, this figure is reduced by one quarter to 5.58 Gbyte/month.

To provide a credibility check for this figure, it is helpful to examine the amount of time per day equivalent to the above data requirements. For an MES with a data rate capability of 2 Mbit/s, the mean daily throughput equates to 8.5 minutes/day in each direction in the high traffic scenario and to 6.4 minutes/day in the low traffic scenario, which seems a reasonable estimate.

For the number of land mobile terminals, a starting point is the number of broadband MSS terminals in use today. It is estimated that in 2009 there were about 35 000 broadband (up to 0.5 Gbit/s) land mobile terminals in use in the 1.5/1.6 GHz MSS bands. For one MSS operator in the 1.5/1.6 GHz bands, the number of active broadband MSS terminals increased by about 75% between 2008 and 2009. However, assuming a more modest growth rate of 14% per year (compound) to 2015 followed by 10% per year to from 2016 to 2020, the number of terminals in operation in 2020 would be about 124 000. As a credibility check, it may be noted that there were about 1.2 m MESs in operation in the 1.5/1.6 GHz MSS bands and the 1.6/2.4 GHz MSS bands in 2009. Hence the assumed number of broadband land mobile satellite users in 2020 is about 10% of the number of all types of MSS services in operation in 2009.

3.2.2 Maritime mobile MSS users

For the maritime mobile-satellite service, the main drivers for growth in data rate requirements will come from both corporate communication requirements and personal (crew or passenger) communication requirements. As land based businesses make increased use of Internet-based communications (for example for videoconferencing), a similar requirement exists for ships. Some of the requirements have been met by 1.5/1.6 GHz MSS systems providing data rates of 432 kbit/s and some of the requirements have been met from the use of ESVs which operate in some of the FSS bands. There is also increasing use of mobile-satellite systems for provision of backhaul for terrestrial cellular systems to allow the crew and passengers on ships to use their standard mobile phones. These are mostly limited to GSM or similar applications (i.e., narrow bandwidth). However, as broadband terrestrial mobile systems become more popular, the demand will spread also to the use of similar services on ships, through a broadband MSS backhaul.

In the assumptions here, the number of broadband MSS users in 2009 was estimated at 3 000 in the MSS bands below 3 GHz and 8 000 using ESVs[1]. Based on a study by a third party market analysis company, the growth is estimated at: 24% in 2009, 28% in 2010, 25% in 2011 and 21% in 2012. From 2013 through to 2020 it is assumed a more conservative growth rate of 10% per annum. This gives a total of 45 210 broadband MSS users in the maritime sector for the year 2020. For comparison purposes, there were approximately 178 000 maritime mobile satellite users (including low bandwidth systems) in use in 2009.

For the average data requirement per user, the current average use for systems in the 1.5/1.6 GHz band is 0.8 Gbyte/month. For maritime, very small aperture terminal (VSAT) users twice this number is assumed. For the low traffic scenario, annual growth of 10% in data requirements has been assumed, which gives a requirement of 3.9 Gbyte/month in 2020. For the high traffic scenario, annual growth in the data requirements of 15% is assumed, which gives a requirement of 6.4 Gbyte/month in 2020.

3.2.3 Aeronautical mobile MSS users

For the aeronautical sector, the main driver for growth will come from the provision of in-flight communications requirement for passengers. While the provision of in-flight Internet service has had rather limited success to date, there is currently much interest in provision of GSM or similar service in the cabin, with backhaul provided by MSS systems.

While there are additional future requirements for aircraft operations and safety systems being considered (see WRC-12 Agenda item 1.7), these are not expected to be major drivers for increased bandwidth requirements in the future. The bandwidth requirements for unwanted aircraft system (UAS) may be more significant, but are being considered under WRC-12 Agenda item 1.3 and are not considered here.

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1 ESVs operate in the FSS.

There were about 300 broadband MSS terminals in use on aircraft in 2009. As this is a relatively new service, it is more difficult to predict future growth based on historical numbers but the same figures as for the maritime sector have been used (24% in 2009, 28% in 2010, 25% in 2011, 21% in 2012 and 10% thereafter). This gives a total for the year 2020 of 1 233.

The current average data requirement for broadband MSS users on aircraft is about 0.5 Gbyte/month. As for the maritime case, we assume 10% growth in the average requirements per user per year in the low traffic scenario, and 15% annual growth in the high traffic scenario. This leads to an average requirement for 2020 of 1.43 Gbyte/month in the low traffic scenario and 2.3 Gbyte/month in the high traffic scenario. If broadband connectivity to passenger aircraft becomes a significant driver of aeronautical requirements, the average data requirement is likely to be significantly higher than these figures.

3.2.4 Summary of user assumptions

The assumptions for the year 2020 are given in Table 6.

TABLE 6

Summary of requirements for 2020

Sector	**Number of broadband MSS users**	**Low traffic scenario; Average data requirements per user (forward + return) (Gbyte/month)**	**High traffic scenario; Average data requirements per user (forward + return) (Gbyte/month)**
Land	124 000	5.58	7.44
Maritime	45 210	3.9	6.4
Aeronautical	1 233	1.43	2.3

3.3 Calculation of the spectrum requirements

The spectrum requirements are determined using the methodology in Recommendation ITU-R M.1391-1. It is assumed that all broadband MSS traffic is carried in the form of "multimedia services" and hence the method in section 5.3.1 of this Recommendation was used. The busy hour traffic per beam is given by equation (3):

$$T_{BH} = \frac{T_M \cdot p_{BH} \cdot p_{HS} \cdot H}{MD \cdot N_{beams}} \qquad (3)$$

where:

- T_M: forecast global traffic per month (Mbytes);
- p_{BH}: portion of the diurnal traffic that occurs in the busy hour for traffic category *i;*
- p_H: portion of the global traffic that occurs in a hot spot cluster;
- H: busy hour offset factor (between 0 and 1), assumed to be 1 for this purpose;
- MD: month to day conversion ratio;
- N_{beams}: number of beams in a frequency-reuse cluster.

The total spectrum requirement is given by equation (4):

$$S = N_{beams} \cdot B \cdot \left\lceil \frac{T_{BH} \cdot 8\,000}{3\,600 \cdot eff \cdot R} \right\rceil \tag{4}$$

where:

- N_{beams}: number of beams in a frequency-reuse cluster;
- T_{BH}: busy-hour traffic in one beam (Mbytes);
- B: carrier bandwidth (MHz);
- eff: efficiency factor to take into account the average loading of each carrier;
- R: average effective data rate of a carrier (kbit/s).

And where $\lceil\ \rceil$ means rounding to the next largest integer. This is required to ensure an integer number of carriers.

The requirements are determined separately for land area and sea area. The requirements for the land area consist of all of the land sector requirements identified above plus half of the aviation sector uses. The spectrum requirements for the sea area consist of all of the maritime sector usage plus half of the aviation requirements (see Tables 7 and 8).

TABLE 7

MSS spectrum requirements for 2020 (low traffic scenario)

		Sea region	**Land region**	**Units**
Number of users in the world		45 800	120 000	
Traffic per user/month		3.91	5.56	Gbyte
Forecast global traffic per month		179 100	667 046	Gbyte
Forecast global traffic per month	T_M	183 420 000	683 055 000	Mbyte
Portion of the diurnal traffic that occurs in the busy hour	p_{BH}	0.1	0.1	Ratio
Beams for global coverage		400	200	
Average traffic per cluster		0.01	0.02	
Portion of the global traffic that occurs in a hot-spot cluster	p_{HS}	0.05	0.06	Ratio
Busy hour offset factor	H	1	1	
Month to day conversion ratio	MD	25	25	Effective days per month
Number of beams in a frequency reuse cluster	N_{beams}	4	4	
Busy hour traffic in one beam (Gbytes)	T_{BH} (calculated)	9 171	40 983	Gbyte
Efficiency factor to take into account the average loading of each carrier	eff	0.9	0.9	Ratio

TABLE 7 (*end*)

		Sea region	Land region	Units
Average effective data rate of a carrier (kbit/s)	R	1 000	1 000	kbit/s
Carrier bandwidth	B	1	1	MHz
Total spectrum requirement	*S* (calculated)	91	490	MHz
Uplink data/total		0.5	0.5	Ratio
Uplink spectrum requirement		45	202	MHz
Downlink spectrum requirement		45	202	MHz

TABLE 8

MSS spectrum requirements for 2020 (high traffic scenario)

		Sea region	Land region	Units
Number of users in the world		45 800	120 000	
Traffic per user/month		6.37	7.41	Gbyte
Forecast global traffic per month		292 000	890 000	Gbyte
Forecast global traffic per month	*TM*	299 091 000	911 008 000	Mbyte
Portion of the diurnal traffic that occurs in the busy hour	p_{BH}	0.1	0.1	Ratio
Beams for global coverage		400	200	
Average traffic per cluster		0.01	0.02	
Portion of the global traffic that occurs in a hot-spot cluster	p_{HS}	0.05	0.06	Ratio
Busy hour offset factor	*H*	1	1	
Month to day conversion ratio	*MD*	25	25	Effective days per month
Number of beams in a frequency reuse cluster	N_{beams}	4	4	
Busy hour traffic in one beam (Gbytes)	T_{BH} (calculated)	14 955	54 660	Gbyte
Efficiency factor to take into account the average loading of each carrier	*eff*	0.9	0.9	Ratio
Average effective data rate of a carrier (kbit/s)	*R*	1 000	1 000	kbit/s
Carrier bandwidth	*B*	1	1	MHz
Total spectrum requirement	*S* (calculated)	148	540	MHz
Uplink data/total		0.5	0.5	Ratio
Uplink spectrum requirement		**74**	**270**	MHz
Downlink spectrum requirement		**74**	**270**	MHz

Hence, with these assumptions, the overall broadband MSS requirement for the year 2020 is estimated at 202 MHz each for both uplink and downlink in the low traffic scenario and at 270 MHz each for both uplink and downlink in the high traffic scenario. It may be noted that it may be possible to reduce the requirement by use of dual polarization systems. However, such systems have not been used previously for small antenna MSS systems and the feasibility of such use is currently under study in ITU-R.

4 Overall MSS spectrum requirements

While the requirements in Report ITU-R M.2077 can be considered as independent of those in the two studies above, it would not be appropriate to add the requirements in Report ITU-R M.2077 to those determined above.

The provision of any additional frequencies for the MSS in bands identified under WRC-12 Agenda item 1.25 would allow, over time, a migration of some classes of MES currently operating in the 1-3 GHz range to these new bands. This would create some additional capacity in the 1-3 GHz range to accommodate the predicted growth in handheld type devices which are more difficult to accommodate in higher frequency bands. Given the congestion for all services in the bands below 3 GHz, the most effective way to produce additional capacity for MSS in the 1-3 GHz range is most likely by allowing a transition of MSS applications which use directional antennas to higher frequency bands.

There are some existing allocations to the MSS in the 4-16 GHz range but these are all shared with the FSS. Separate technical studies have shown very limited possibilities for the broadband MSS applications of the type considered in this Report to operate in those bands due to technical incompatibility with the FSS. This is partly due to the need for systems operating in FSS bands to meet off-axis e.i.r.p. limits to ensure protection of other FSS networks, and leads to a requirement for relatively large antennas. Consequently, existing MSS applications in the bands shared with the FSS are limited to the characteristics of FSS systems which, for example, mean relatively large earth station antennas.

Consequently, there are currently no MSS bands in the 4-16 GHz range which can be considered as having the possibility to accommodate the requirements for broadband MSS assessed in this Report.

5 Summary

The spectrum requirements calculated for the MSS by the year 2020 give a range of requirements depending on whether the low traffic or high traffic scenario is assumed.

From the two studies described above it is concluded that the spectrum requirements for the MSS in the range 4-16 GHz to be considered in the context of WRC-12 Agenda item 1.25 are as shown in Table 9.

TABLE 9

Estimated spectrum requirements by 2020 in the 4-16 GHz range

	Low traffic scenario	**High traffic scenario**
Estimated spectrum requirements in the Earth-to-space direction (as contiguous as possible)	240 MHz	335 MHz
Estimated spectrum requirements in the space-to-Earth direction (as contiguous as possible)	240 MHz	335 MHz

Regarding the size of any new bands to be allocated to the MSS, two possibilities can be considered: (1) basing new MSS spectrum allocations on the low traffic scenario and (2) basing the new MSS spectrum allocations on the high traffic scenario. Option (1) runs the risk that if higher growth would occur, this would be constrained by a shortage of allocated spectrum. Option (2) runs the risk that allocated spectrum might not be used in the short-term, if a lower than anticipated growth rate occurs.

It may be noted that the Earth-to-space and space-to-Earth requirements are the same, reflecting the assumption of equal forward and return link data requirements.

Although it might seem surprising that the uplink and downlink requirements are the same considering that traffic for web browsing applications is typically asymmetric, the assumption fits the current trend towards user generated web content, which would tend to reduce the asymmetry. It should also be noted that a common application for land MSS usage is for news journalism involving the transmission of voice and images from remote locations. These applications are dominant in the uplink direction, so also have the effect of providing some balance to other applications which are dominant in the downlink direction. Variations from this assumption may decrease the MSS requirements in the Earth-to-space direction or increase the MSS requirements in the space-to-Earth direction.

It should be noted that the traffic forecasts, from which these spectrum requirements were derived, can only be afforded by cost-effective MSS systems if those spectrum requirements are addressed through new MSS allocations that are in large block of contiguous spectrum, rather than a large number of small bands. It is therefore highly desirable that new MSS allocations are, to the extent possible, contiguous.

Annex 2 describes the calculation of the spectrum requirements for a proposed Medium Earth Orbit (MEO) MSS system, determining the spectrum requirement based on the system design.

Annex 1

TABLE 10

Derivation of average data requirements for land broadband MSS user (based on Table 32b in Report ITU-R M.2078)

SC	SE	User density (users/ km^2)	Session arrival rate per user (sessions/ h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Data/ session (kbit)	Sessions/ day	Data/ day (Mbyte)	User density weighting	Average MB/day
3	2	10 855.2	6.30E-01	379.8	214.8	81 581	15.1	150.6	0.1699	25.5764
3	5	1 337.3	1.04E+00	275.2	172.2	47 389	25.0	144.4	0.0209	3.0215
3	6	91.2	2.99E-01	282.4	161.1	45 495	7.2	39.9	0.0014	0.0569
4	2	2 708	9.95E-01	88	810.7	71 342	23.9	208.0	0.0424	8.8122
4	5	23.6	1.13E+00	105	819.8	86 079	27.1	285.0	0.0004	0.1052
4	6	13.3	1.18E+00	95.3	814.2	77 593	28.3	268.2	0.0002	0.0558
5	2	15 288.6	1.33E+00	16	227.2	3 635	31.9	14.2	0.2392	3.3886
5	5	1 858.7	2.34E+00	11.8	255.1	3 010	56.2	20.6	0.0291	0.6002
5	6	183.8	1.68E+00	15.3	203.6	3 115	40.3	15.3	0.0029	0.0441
8	2	3 254.6	9.32E-01	868.8	486.2	422 411	22.4	1 153.4	0.0509	58.7382
8	5	55.3	1.03E+00	868.8	493.1	428 405	24.7	1 292.7	0.0009	1.1186
8	6	5.8	7.39E-01	868.8	493.1	428 405	17.7	927.5	0.0001	0.0842
9	2	412	1.23E+00	144	79	11 376	29.5	41.0	0.0064	0.2643
9	5	103	1.23E+00	144	79	11 376	29.5	41.0	0.0016	0.0661
9	6	10	4.11E-01	144	20	2 880	9.9	3.5	0.0002	0.0005
10	2	309	1.23E+00	16	4	64	29.5	0.2	0.0048	0.0011
10	5	52	1.23E+00	16	4	64	29.5	0.2	0.0008	0.0002
10	6	10	4.11E-01	16	4	64	9.9	0.1	0.0002	0.0000
13	2	4 506.7	5.03E-01	1 360.8	148.6	202 215	12.1	298.0	0.0705	21.0142
13	5	104.6	1.76E+00	1 358.1	175.2	237 939	42.2	1 226.9	0.0016	2.0081
13	6	24.1	1.14E+00	1 249.6	177.9	222 304	27.4	742.5	0.0004	0.2800
14	2	5 574.9	2.54E-01	121.6	30.3	3 684	6.1	2.7	0.0872	0.2392
14	5	677.9	2.97E-01	177.8	981	174 422	7.1	151.8	0.0106	1.6099
14	6	58.7	3.23E-01	177.6	852.6	151 422	7.8	143.3	0.0009	0.1316
15	2	10 690	3.15E+00	7.9	33.2	262	75.6	2.4	0.1673	0.4049
15	5	1 945.2	3.14E+00	30.1	29.3	882	75.4	8.1	0.0304	0.2469
15	6	148.6	2.47E+00	36.5	30.7	1 121	59.3	8.1	0.0023	0.0189
18	2	1 339	4.11E+00	595	153	91 035	98.6	1 096.2	0.0210	22.9669
18	5	72	4.11E+00	653	148	96 644	98.6	1 163.7	0.0011	1.3111
18	6	10	4.11E-01	1 030	72	74 160	9.9	89.3	0.0002	0.0140

TABLE 10 (*end*)

SC	SE	User density (users/ km^2)	Session arrival rate per user (sessions/ h/users)	Mean service bit rate (kbit/s)	Average session duration (s)	Data/ session (kbit)	Sessions/ day	Data/ day (Mbyte)	User density weighting	Average MB/day
19	2	1 030	1.23E+00	144	21	3 024	29.5	10.9	0.0161	0.1756
19	5	52	4.11E-01	144	21	3 024	9.9	3.6	0.0008	0.0030
19	6	10	4.11E-01	144	21	3 024	9.9	3.6	0.0002	0.0006
20	2	1 030	1.23E+00	16	41	656	29.5	2.4	0.0161	0.0381
20	5	52	1.23E+00	16	41	656	29.5	2.4	0.0008	0.0019
20	6	10	4.11E-01	16	25	400	9.9	0.5	0.0002	0.0001
								9 562.1	1.0	**152.4**

Table 10 is based on Table 32b in Report ITU-R M.2078. Report ITU-R M.2078 estimates the spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced for three years: 2010, 2015 and 2020. The user data requirements for the year 2020 in Report ITU-R M.2078 are used as a basis to estimate the average land MSS requirements for the same year. Report ITU-R M.2078 is itself derived from the work contained in Report ITU-R M.2072. Report ITU-R M.2072 assesses the communication requirements for each combination of service category and service environment. For example the data requirements for service category 3 and service environment 2 are based on assumptions for the following applications: “Videotelephony 1”, “Hi-quality video phone”, “Videoconference”, “Mobile TV/broadcast IP TV”, “Telemedicine”, “Secured transactions (biometrics)” and “IP Web radio”. Further detail and other examples are given in Table 54 of Report ITU-R M.2072.

To estimate the spectrum requirements for an average land MSS user, modifications are made to the assessment in Report ITU-R M.2078. Firstly, the requirements in the following service environments are not considered to be representative of a typical MSS user and have therefore been removed: SE 1 (Dense urban teledensity, home service usage pattern), SE 4 (sub-urban teledensity, home service usage pattern) and SE 3 (Dense urban teledensity, public area service usage pattern). Secondly, all cases for which the mean service bit rate exceed 2 Mbit/s are removed on the basis that such high data rate requirements are unlikely to be carried by MSS. Thirdly, the rows in Table 32c for which the data requirements are expected to be zero are not included. With these changes, the remaining combinations of service category and service environment are those in Table 10.

The numbers in the columns headed “Data/session”, “sessions/day” and “Data/day” are derived from the figures in the preceding columns. To determine the average data for an MSS user, the data in each combination of service category and service is weighted by the user density for that row. For example the density of users in SC 2/SE 3 is higher than in SC 3/SE 5 and hence to determine the average usage, the data requirements must be weighted higher for SC 2/SE 3 in accordance with the different user densities. The numbers in the column headed “user density weighting” are determined as the ratio of the user density for each row over the total user density for all scenarios (which is 62 877 users/km^2).

Annex 2

Example calculation of spectrum requirements for an MSS network

Unlike the two studies in the body of this Report, which derived bandwidth requirements following the methodology contained in Recommendation ITU-R M.1391-1, the calculation in this section was conducted having in mind the provision of next-generation MSS services to a specific market, namely that which is likely to require relatively HDRs, typically ranging from 10 to 50 Mbit/s per user, by means of a non-geostationary MEO satellite system operating with multiple spot beams in both directions of transmission in order to serve large geographic areas.

The user terminals targeted are larger than handheld terminals, equipped with electronically or mechanically steerable and highly directive antennas, which could be used by entities such as emergency crews, police or commercial enterprises requiring high capacity and cost-effective communications to and from remote mobile units.

The baseline modulation scheme used was QPSK with turbo product coding (TPC) rate 3/4, with a required overall threshold C/N of 5.9 dB. 50 Mbit/s transmissions would then require about 43 MHz of bandwidth. The satellite multiple spot beams will employ a 1/7 frequency reuse scheme, and consequently the total bandwidth requirements for the forward links would be about 300 MHz, assuming that all contiguous beams require the full 50 Mbits/s transmission rate. In practice, it is likely that some form of adaptive coding/modulation scheme would be employed that would allow further optimization of the throughput/availability/bandwidth variables on a real-time basis.

For the return links, there may be applications also requiring up to 50 Mbit/s of data rate per terminal. The return links may therefore require as much bandwidth as the forward links, i.e., up to 300 MHz.

Based on the link budget results, individual satellites having total bus power capabilities of 10 kW would provide quasi-global coverage and total system capacities ranging from 116.5 Gbit/s to 428 Gbit/s for the case of a 24 satellite constellation.