REPORT ITU-R M.2077

Traffic forecasts and estimated spectrum requirements for the satellite component of IMT-2000 and systems beyond IMT-2000* for the period 2010 to 2020

(2006)

Scope

This Report presents traffic forecasts and estimated spectrum requirements for the satellite component of IMT-2000 and systems beyond IMT-2000 for the time period 2010 to 2020. It is a continuation of Report ITU-R M.2023 which contains spectrum requirements for IMT-2000 up to the year 2010. This Report provides the technical basis for related spectrum requirements identified in the Conference Preparatory Meeting (CPM) Report on WRC-07 Agenda item 1.4.

1 Introduction

Systems beyond IMT-2000 is a concept and telecommunication standard that is evolving within ITU. Systems beyond IMT-2000 are envisaged to provide ubiquitous, high-data rate, content rich services to highly mobile users anywhere in the world. The time-frame for the introduction of systems beyond IMT-2000 is currently targeted to be around 2010. Although beyond IMT-2000 services are expected to be dominated by terrestrial service providers, the satellite component of IMT-2000 and systems beyond IMT-2000 will play an integral part in systems beyond the IMT-2000 service provisions, especially in remote areas where terrestrial providers have minimal or no coverage.

The objective of this Report is to provide traffic forecasts including multimedia (MM) distribution services, and estimates of spectrum requirements for the satellite component of IMT-2000 and systems beyond IMT-2000 for the period 2010 to 2020. It builds upon subscriber forecasts, traffic models and application of the latest spectrum calculation methodology in compliance with Recommendation ITU-R M.1391 to determine the spectrum requirements.

2 Traffic forecast

This section describes the derivation of the traffic forecasts for the satellite component of IMT-2000 and systems beyond IMT-2000. Information is provided on the different services and applications used in each segment. Finally, the subscriber numbers and traffic usage profiles for each segment are combined to derive the overall traffic forecast.

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* The nomenclature for systems beyond IMT-2000 is contained in draft Resolution [IMT-NAME], which will be considered for adoption at the Radiocommunication Assembly 2007 (RA-07). Future revisions to this Report should take any decisions of the RA-07 in this regard into account.

2.1 Subscriber numbers

The Report uses as a baseline the results of extensive user requirement studies showing the global number of MSS subscribers as given in Table 1. In view of rapid developments after completion of the subscriber user requirements study, the numbers for 2010 and 2011 have been slightly adjusted to reflect the situation between 2002 and 2005, where the number of MSS subscribers increased from 643 000 by end of 2002 to 1 402 000 by the end of 2005, resulting in an annual growth rate of 29%. The adjusted numbers for 2010 and 2011 are 2.17 and 2.43 million subscribers, respectively. Two bounding scenarios with 9% and 14% annual growth have been selected to represent a pessimistic and an optimistic development, respectively. The starting position for these scenarios is 1.4 million established MSS subscribers at the beginning of 2006. In deriving MSS subscriber forecasts for systems beyond IMT-2000, various uptake variables like growth rates and penetration of cellular systems, growth rates and penetration of nomadic technologies (i.e. IEEE 802.16 and 802.20), gross domestic product per capita including growth rates and population distributions were considered. For the Regions Asia, North America, South America, Europe, Africa and the Arab States, the uptake variables are applied separately, taking into account different user segments (private, professional, corporate and institutional) and different usage environments (urban and rural).

TABLE 1

Global MSS subscribers for systems beyond IMT-2000 from 2010 to 2020

Subscribers ('000)	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Asia	690.75	893.83	1 109.85	1 332.78	1 547.54	1 756.76	1 966.21	2 253.40	2 506.80	2 770.32	3 053.13
North America	335.81	405.54	475.56	536.59	585.76	626.48	663.01	718.10	755.01	790.20	825.47
South America	56.33	71.45	88.14	104.67	120.22	135.10	149.95	170.33	187.72	205.78	224.99
Europe	751.03	896.69	1 038.76	1 158.47	1 249.92	1 321.94	1 384.63	1 484.69	1 545.75	1 602.53	1 659.05
Africa and the Arab States	23.48	25.80	30.69	35.64	40.48	45.16	49.68	54.91	59.89	65.44	70.81
Total land	1 857.40	2 293.31	2 742.90	3 168.15	3 543.92	3 885.44	4 213.48	4 681.43	5 055.17	5 434.27	5 833.45
Maritime	15.45	16.47	19.44	22.20	24.72	27.21	29.67	32.10	34.57	37.31	39.74
Aeronautical	2.98	3.13	3.74	4.33	4.88	5.38	5.87	6.36	6.88	7.45	7.95

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Subscribers for low traffic scenario	1.976	2.154	2.348	2.559	2.790	3.041	3.314	3.613	3.938	4.292	4.678
Subscribers for adjusted market review	2.170	2.425	2.766	3.195	3.574	3.918	4.249	4.720	5.097	5.479	5.881
Subscribers for high traffic scenario	2.365	2.696	3.074	3.504	3.994	4.554	5.191	5.918	6.746	7.691	8.768

Figure 1 shows the results of the user requirement forecast, the slight adjustments for 2010 and 2011 as well as the two bounding scenarios with 9% and 14% growth rate, respectively.

FIGURE 1

Number of MSS subscribers

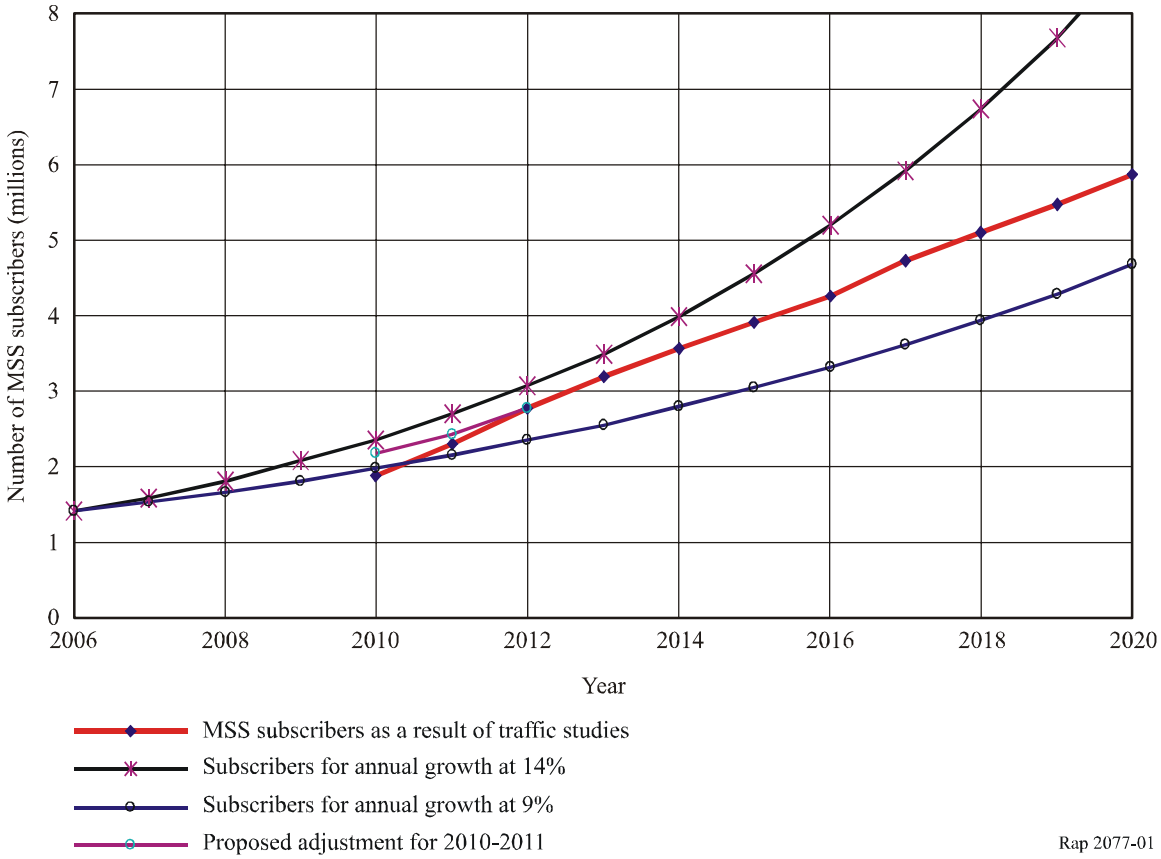


Table 2 shows the expected proportion of MSS subscribers by land, maritime and aeronautical users for the period 2010 to 2020. Although the characteristics of the three different subscriber types are somewhat different from each other, their impact on the overall spectrum requirement is insignificant. The sum of the three service types has therefore been taken for the spectrum calculations.

TABLE 2

MSS user distribution from 2010 to 2020

Subscriber proportions (%)	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Land	99	99.2	99.2	99.2	99.2	99.2	99.2	99.2	99.2	99.2	99.2
Maritime	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Aeronautical	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	100	100	100	100	100	100	100	100	100	100	100

Table 3 shows the forecast growth in satellite multimedia distribution subscribers in the period 2010 to 2020. The values are based on an analysis of European subscribers to satellite multimedia distribution services. The study is based on an assumed population of 252 million inhabitants by 2020 in the countries France, Germany, Italy, Spain and the UK.

TABLE 3

Satellite multimedia distribution subscriber numbers 2010 to 2020

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Penetration of satellite distribution as a percentage of overall European mobile subscribers (%)	4.60	6.20	8.00	10.00	11.90	13.90	25.20	16.40	17.20	17.70	18.00
Satellite distribution subscribers (millions)	11.59	15.62	20.16	25.20	29.99	35.03	38.30	41.33	43.34	44.60	45.36

2.2 User categorization

In deriving the MSS subscriber numbers shown in Table 1, four different user groups were considered:

Corporate users: Large organizations that require mobile services for their business critical applications, such as asset tracking.

Institutional users: Individuals and organizations operating in the governmental sector in areas such as emergency response, aviation services and maritime safety services.

Professional users: This includes individuals within businesses that require mobile telecommunications to perform their own jobs more effectively, entrepreneurs and private individuals in the top income percentile.

Private users: Private individuals that make use of mass market mobile services, as well as specialist mobile services.

Table 4 shows the different user categories associated with the different user groups by environment.

TABLE 4

User categories by environment

	Urban	Suburban	Rural
Corporate users	Media Retail Food and drink Services Transport	Construct Machinery Food and drink Aviation/space Motor/Packaging	Chemical Agricultural Leisure and travel Food and drink
Institutional users	Universities Libraries	Universities Libraries Research Hospitals	Schools Libraries Hospitals
Professional users	Entrepreneurs Bankers Consultants	Physicians IT professionals	Physicians IT professionals Leisure and travel
Private users	Children, youth and teen Singles Foreign communities	Young families Communities	Empty-nesters Communities

2.3 Radio services and applications used by each category

The service categorization used in this Report is the same as that in Report ITU-R M.2023 on spectrum requirements for IMT-2000. Basically, services are divided into multimedia and non-multimedia. Multimedia services are based on packet switched services, while non-multimedia services are mostly circuit-switched voice and data services. The multimedia and non-multimedia services are further subdivided as follows:

2.3.1 Non-multimedia

Voice: a voice coding rate of 8/16 kbit/s is assumed in Report ITU-R M.2023 but most MSS systems now use rates less than this and some use rates as low as 2.4 kbit/s.

Low-speed data: circuit mode data services, Report ITU-R M.2023 identifies rates of 9.6/16 kbit/s but it is assumed here to include any of the current circuit mode data services up to 64 kbit/s.

Messaging: low data rate messaging at 2.4/4.8 kbit/s. This was not included as a separate category in Report ITU-R M.2023 but has been addressed separately here because of the large number of satellite mobile subscribers for these services.

2.3.2 Multimedia

Voice: a voice coding rate of 8/16 kbit/s is assumed in Report ITU-R M.2023 but new services are likely to employ voice coding rates much less than this, possibly as low as 2.4 kbit/s.

Low-speed data: messaging and email (without attachments) services at 9.6/16 kbit/s.

Asymmetric services: one-way services including file transfer, database access, intranet/Internet, email (with attachments) image transfer, etc. at 144 kbit/s.

Multimedia interactive: videoconferencing and videotelephony at data speeds of around 144 kbit/s.

Multimedia distribution service: a multiplexed forward link with a carrier data rate of around 2.3 Mbit/s. The return link will be low rate and might use a terrestrial connection where available. This category was not included in Report ITU-R M.2023.

Table 5 shows the services and example applications:

TABLE 5

Radio services and applications

Radio services	Services	Example applications
Land	Non-multimedia Voice, messaging, low-speed data Multimedia Voice, low-speed data, asymmetric, distribution	Asset management, payphone, secure phone services, email, fax, satellite news gathering, Internet access, videoconferencing, TV
Maritime	Non-multimedia Voice, messaging, low-speed data Multimedia Voice, low-speed data, asymmetric, distribution	Crew/passenger calling, asset management, email, fax, safety services, videoconferencing, Internet access, TV, satellite news gathering
Aeronautical	Non-multimedia Voice, messaging, low-speed data Multimedia Voice, low-speed data, asymmetric, distribution	Passenger calling, email, Internet access, satellite news gathering, videoconferencing, radio, air traffic services, multimedia distribution

2.4 Usage profiles

The usage profiles in Table 6 are based on Report ITU-R M.2023 and are broken down by service type.

TABLE 6

Usage levels per month taken from Report ITU-R M.2023

Type	Units	2005	2010	Comments
Non-multimedia				
Voice	Min at 16 kbit/s	73	71	
Low-speed data	kbytes	8 365	8 175	Approximately 70 min/month at 16 kbit/s
Multimedia				
Voice	Min at 8 kbit/s	20	26	
Low-speed data	kbytes	2 584	3 380	Approximately 25 min/month at 16 kbit/s
Asymmetric	kbytes	26 154	34 247	Approximately 35 min/month at 104/144 kbit/s
Interactive	Min at 144 kbit/s	2	2	Low due to only a small portion (10% to 20%) of forecasted users will use the service

For multimedia distribution (e.g. satellite mobile TV), the number of subscribers and monthly usage profile per subscriber is not directly relevant to the traffic forecast. This is because of the inherent nature of these services; the same volume of traffic will be distributed regardless of whether it is received by one or many receivers/subscribers. The volume of multimedia distribution traffic is determined from commercial estimates of the channel throughput and number of channels required to provide the multimedia distribution service. It is assumed that the demand for services such as satellite mobile TV and rich media will increase, capturing some of the terrestrial mobile traffic because satellite services are inherently more suited to providing programs on a large scale, intended for large audiences, compared to terrestrial services.

TABLE 7

Multimedia satellite distribution traffic forecast (Mbytes/month)

MM distribution traffic forecast/year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Channel throughput (kbit/s)	256	256	256	512	512	512	1 024	1 024	1 024	1 536	1 536
Number of required channels based on user requirements study	30	30	30	30	35	35	35	35	40	40	40
Millions Mbytes/month	2.5	2.5	2.5	5	5.8	5.8	11.6	11.6	13.2	19.9	19.9
Number of channels assumed for low traffic scenario	17	17	17	17	17	26	26	26	26	26	26
Millions Mbytes/month for low traffic scenario	1.4	1.4	1.4	2.8	2.8	4.3	8.6	8.6	8.6	12.9	12.9
Number of channels assumed for high traffic scenario	26	26	26	26	26	35	35	35	35	35	35
Millions Mbytes/month for high traffic scenario	2.2	2.2	2.2	4.3	4.3	5.8	11.6	11.6	11.6	17.4	17.4

Table 7 shows the multimedia distribution traffic forecast under consideration. User requirement studies resulted in forecasts between 30 and 40 channels as shown in the second row, which needed some adjustments to reflect traffic sharing with alternative service providers via terrestrial cellular as well as satellite networks. For a low traffic scenario, 17 channels, and for a high traffic scenario, 35 channels have been assumed, respectively. Related traffic volumes are contained in rows 6 and 8 of Table 7.

2.5 User traffic per service application

This section derives the user traffic per service application for each of the identified service types. The variation between service applications was assumed to be in the services used rather than the usage profile of individual services. Table 8 shows the usage per month for individual services together with annual adjustment factors for the individual service applications.

TABLE 8

Usage levels for various service applications

Low traffic scenario	Multimedia applications					Non-multimedia applications		
	Voice	Interactive	Asymmetric forward	Asymmetric return	Low speed	Low speed	Messaging	Voice
Usage levels per month per user (min or Mbytes)	26.00	2.16	17.13	8.56	3.38	8.18	0.004	71.00
Annual adjustment factor for usage levels	1.053	1.000	1.000	1.000	1.058	0.996	1.000	0.994

High traffic scenario	Multimedia applications					Non-multimedia applications		
	Voice	Interactive	Asymmetric forward	Asymmetric return	Low speed	Low speed	Messaging	Voice
Usage levels per month per user (min or Mbytes)	26.00	2.16	25.69	18.24	3.38	8.18	0.004	71.00
Annual adjustment factor for usage levels	1.053	1.000	1.050	1.050	1.058	0.996	1.000	0.994

Table 9 shows the traffic share between the MM and non-MM as part of the satellite component of IMT-2000 and beyond IMT-2000. It is assumed that the requirement for multimedia services will continue to grow and that for non-multimedia services will continue to decrease. The figures for multimedia voice traffic have been derived by using Report ITU-R M.2023 figures for 2010 and increasing the usage level by approximately 5% per year. The figures for multimedia interactive services are assumed to remain constant for a low traffic scenario and show an increase of 5% per year for a high traffic scenario.

TABLE 9

Traffic share (%) between multimedia (MM) and non-multimedia (non-MM) satellite services

MM and non-MM satellite services market share (%)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Percentage using non-MM	40	38	36	34	33	31	29	28	27	25	24
Percentage using MM	60	62	64	66	67	69	71	72	73	75	76

The figures for multimedia asymmetric traffic have been taken from Report ITU-R M.2023 figures for 2010. The monthly usage figure of 34 Mbyte/month/subscriber is equivalent to approximately 1 Mbyte/day/subscriber, which is a reasonable estimate for internet/email/file transfer type applications. The figures for multimedia low-speed data traffic have been derived by using Report ITU-R M.2023 figures for 2010 and increasing the usage level by 5.8% per year.

The figures for multimedia distribution are as shown in Table 7. Although no multimedia distribution satellite services are offered at present, it is assumed that these services will begin to take-off in the 2010 time-frame.

The figures for low-speed data traffic have been derived by using Report ITU-R M.2023 figures for 2010 and reducing the usage level by 0.4% per year.

It is assumed that all non-multimedia messaging users generate 0.004 Mbytes of messages per month. This is based on a figure of a 1 kbit message generated by each user per day. It is not considered that the message size will change with time. Hence the usage level for this service is kept constant. The figures for non-multimedia voice traffic have been derived by using Report ITU-R M.2023 figures for 2010 and reducing the usage level by 0.6% per year. This is in keeping with the general trend of non-multimedia services compared to multimedia services.

2.6 Traffic volume forecast

Tables 10 and 11 show the total multimedia and non-multimedia traffic volumes per month for voice and data services, respectively. These figures are derived by multiplying the usage profiles shown in Table 8 by the subscriber numbers, adjusted by the traffic share, shown in Table 9 and the annual growth factors, shown in Table 8.

TABLE 10

Total multimedia and non-multimedia voice traffic per month

Voice traffic (million min/month) for low traffic scenario	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
MM voice traffic	30.8	36.6	43.3	51.3	59.7	70.6	83.4	97.1	113.0	133.2	154.9
Non-MM voice traffic	56.1	57.8	59.3	60.7	63.8	64.9	65.8	68.9	71.9	72.2	75.1

Voice traffic (million min/month) for high traffic scenario	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
MM voice traffic	36.9	45.8	56.7	70.2	85.5	105.8	130.6	159.0	193.5	238.7	290.4
Non-MM voice traffic	67.2	72.3	77.6	83.1	91.4	97.3	103.1	112.8	123.2	129.3	140.7

TABLE 11

Total multimedia and non-multimedia data traffic per month

Data traffic (million Mbytes/month) for low traffic scenario	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
MM interactive traffic	2.6	2.9	3.2	3.6	4.0	4.5	5.1	5.6	6.2	7.0	7.7
MM asymmetric forward traffic	20.3	22.9	25.7	28.9	32.0	35.9	40.3	44.5	49.2	55.1	60.9
MM asymmetric return traffic	10.2	11.4	12.9	14.5	16.0	18.0	20.1	22.3	24.6	27.6	30.4
MM low-speed data traffic	4.0	4.8	5.7	6.8	7.9	9.4	11.2	13.0	15.3	18.1	21.1
Non-MM low-speed data traffic	6.5	6.7	6.9	7.0	7.4	7.6	7.7	8.0	8.4	8.5	8.8
Non-MM messaging traffic	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004

Data traffic (million Mbytes/month) for high traffic scenario	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
MM interactive traffic	3.1	3.6	4.2	5.0	5.8	6.8	8.0	9.2	10.6	12.5	14.4
MM asymmetric forward traffic	36.5	45.1	55.7	68.8	83.6	103.0	126.9	154.0	186.9	229.9	278.8
MM asymmetric return traffic	25.9	32.0	39.6	48.8	59.3	73.1	90.1	109.3	132.7	163.2	198.0
MM low-speed data traffic	4.8	6.0	7.4	9.3	11.3	14.1	17.5	21.4	26.1	32.4	39.6
Non-MM low-speed data traffic	7.7	8.3	9.0	9.6	10.6	11.3	12.0	13.2	14.4	15.2	16.5
Non-MM messaging traffic	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.007	0.007	0.008	0.008

3 Assessment of spectrum requirements

3.1 Methodology

Recommendation ITU-R M.1391 defines the following equations to calculate the spectrum requirements for multimedia and non-multimedia IMT-2000 systems.

3.1.1 Multimedia traffic

$$S = N_{beams} \cdot B \cdot \left\lceil \frac{T_{BH} \cdot 8000}{3600 \cdot eff \cdot R} \right\rceil \quad (1)$$

The basic equation required to calculate the spectrum requirement, S (MHz) for multimedia services is:

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 (kbits/s).

The symbols $\lceil\ \rceil$ mean rounding to the next largest integer. This is required to ensure an integer number of carriers. Typically, traffic forecasts are made for a number of traffic categories based on different environments, such as aeronautical, land and maritime, and different services, for example

mobile, transportable and vehicular. The traffic in the busy hour, T_{BH}, is calculated by adding the traffic requirement for all these categories (see equation (2a)). Since the traffic forecast is given in either Mbytes/month (for data traffic) or min/month (for example, for voice traffic) a conversion of these forecast numbers to Mbytes in the busy hour is required. This is done through the following equations:

$$T_{BH} = \sum_i T_i \tag{2a}$$

$$T_i = \frac{T_{Mi} \cdot p_{BHi} \cdot p_{HSi} \cdot H_i}{MD_i \cdot N_{beams}} \tag{2b}$$

$$T_i = \frac{T_{Mi} \cdot 60 \cdot R_{VC} \cdot p_{BHi} \cdot p_{HSi} \cdot H_i}{8\,000 \cdot MD_i \cdot N_{beams}} \tag{2c}$$

where:

T_{Mi}: forecast global traffic per month for traffic category i; if this is given in Mbytes, equation (2b) is used; if it is given in minutes equation (2c) is used

R_{VC}: coding rate (kbit/s)

p_{BHi}: portion of the diurnal traffic that occurs in the busy hour for traffic category i

p_{HSi}: portion of the global traffic that occurs in a hot spot cluster for traffic category i

H_i: busy hour offset factor (between 0 and 1) for traffic category i (see § 5.2.3)

MD_i: month to day conversion ratio for traffic category i

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 may somewhat underestimate the spectrum requirement.

3.1.1.1 Application for broadcast/multicast traffic

The broadcast/multicast traffic is a particular case of multimedia traffic. Some assumptions need to be made:

In equation (1):

eff: equal to one in this case, because broadcast/multicast traffic is fully loaded traffic;

T_{BH}: T is the forecasted multicasting traffic (Mbytes) to provide service over a beam area, because the notion of busy hour is not relevant for broadcast/multicast traffic.

Consequently, the following derivation can be made:

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

In equation (2b):

T_M: forecast global traffic per month given in Mbytes

p_{BH}: portion of the diurnal traffic that occurs in the busy hour (typically, p_{BH} = 1/24)

p_{HS}: equal to one in this case because the traffic does not depend on the geographical location of the user

H: equal to one because the traffic will be equally distributed in time and the notion of busy hour is not relevant for broadcast traffic

MD: month-to-day conversion ratio (typically, MD = 30 for multicast traffic)

N_{beams}: number of beams in a frequency reuse cluster.

Finally, the following derivation can be made:

$$T = \frac{T_M \cdot p_{BH}}{MD \cdot N_{beams}} \tag{4}$$

3.1.2 Non-multimedia traffic

As described in section 3.1, three types of non-multimedia traffic are considered: low-speed data traffic, messaging and voice telephony, each of which is assumed to be carried on separate carrier types. The three traffic types are designated by the subscript *i* in the following equations.

For non-multimedia (circuit-switched) traffic, the Erlang-B formula is used to convert the busy hour traffic in Erlang to the required number of circuits, i.e.:

$$S_i = N_{beams} \cdot ErlangB\left(T_{Erl,i}, GoS_i\right) \cdot B_i \tag{5}$$

where:

N_{beams}: number of beams in a frequency reuse cluster

$T_{Erl,i}$: busy hour traffic in one beam (Erlang) for traffic type *i*

GoS_i: grade of service (blocking probability) for traffic type *i*

B_i: carrier bandwidth (MHz) for traffic type *i*.

$$T_{Erl,i} = \frac{T_{M,i} \cdot H_i \cdot p_{HS,i} \cdot p_{BH,i} \cdot 8\,000}{N_{beams} \cdot MD_i \cdot R_i \cdot 60 \cdot 60} \tag{6a}$$

$$T_{Erl,i} = \frac{T_{M,i} \cdot H_i \cdot p_{HS,i} \cdot p_{BH,i}}{N_{beams} \cdot MD_i \cdot 60} \tag{6b}$$

where:

$T_{M,i}$: forecast global traffic per month for traffic type *i*; if this is given in Mbytes, equation (6a) is used, if it is given in minutes, equation (6b) is used

H_i: busy hour offset factor (between 0 and 1) for traffic type *i* (see § 5.2.3)

$p_{BH,i}$: portion of the diurnal traffic that occurs in the busy hour for traffic type *i*

$p_{HS,i}$: portion of the global traffic that occurs in a hot spot cluster for traffic type *i*

MD_i: month-to-day conversion ratio for traffic type *i*

N_{beams}: number of beams in a frequency reuse cluster

R_i: carrier data rate for traffic type *i*.

The total spectrum requirement for the non-multimedia traffic is then given by the summation of the requirement of the three different traffic types, i.e.:

$$S = \sum S_i \tag{7}$$

3.1.3 Additional comments on the derivation of busy hour traffic

The methodology assumes that the traffic requirements are given in Mbytes/ or min/month. Month-to-day and a day-to-busy hour factors are used to derive the traffic in the busy hour. These factors are derived based on traffic statistics or expected traffic behaviour, and Quality of Service considerations, such as delay tolerance of different services.

In the case of non-multimedia traffic, since there are three different traffic types, the busy hour of each traffic type may not occur at the same time. The spectrum requirements should be calculated in the overall busy hour. The busy hour offset factor, *H*, converts the busy hour traffic of each traffic type to the traffic in the overall busy hour.

3.2 Input parameters

Table 12 shows the global parameters and assumptions used in the spectrum requirements calculation. Based on actual developments over the past decade as well as developments in line with current R&D activities, the percentage of traffic in a "hot spot" is assumed to gradually decrease from 2010 to 2020 in order to account for continuing introduction of higher multibeam satellite systems.

TABLE 12

Global parameters and assumptions in the spectrum calculation

	Multimedia applications						**Non-multimedia applications**		
	Voice	**Interactive**	**Asymmetric forward**	**Asymmetric return**	**Low speed**	**Distribution**	**Low speed**	**Messaging**	**Voice**
Number of MSS systems sharing the traffic	2						3		
Portion of daily traffic during busy hour, p_{BHi}	0.1					0.042	0.1		
Month-to-day conversion ratio, M_{di}	25					30	25		
Busy hour offset factor, H_i	0.9					1	0.9		
Beams in a frequency reuse cluster, N_{beams}	7					3	7		
Coding rate, R_{vc} (kbit/s)	4								
Carrier data rate, *R* (kbit/s)							6	1	
Grade of service (1-blocking probability), *GS*							0.01		
Carrier bandwidth, *B* (MHz)	0.2					5	0.01	0.005	0.01
Efficiency factor (*eff*)	0.9					1			
Average effective data rate, *R* (kbit/s)	200					2 300	74		
Signalling overhead factor (%)	5.0					0.0		10.0	

TABLE 12 (*end*)

Low traffic scenario	**Multimedia applications**					**Non-multimedia applications**
Portion of global traffic in a hot spot cluster, P_{HSi} (%)	15.0 to 12.0				100	15.0 to 12.0
Asymmetric MM traffic loss in hot spots (%)		50				
Asymmetric MM return traffic relative to forward (%)			50			
High traffic scenario	**Multimedia applications**					**Non-multimedia applications**
Portion of global traffic in a hot spot cluster, P_{HSi} (%)	13.0 to 6.0				100	13.0 to 6.0
Asymmetric MM traffic loss in hot spots (%)		25				
Asymmetric MM return traffic relative to forward (%)			71			

The non-multimedia voice carrier bandwidth of 10 kHz and 5 kHz for non-multimedia is consistent with values in existing MSS systems. The 200 kHz carrier bandwidth and 200 kbit/s effective user rate assumed for multimedia systems is consistent with the mix of terminal types currently being developed for such systems. The carrier rate of 6 kbit/s and 1 kbit/s for non-multimedia low-speed data and messaging are consistent with values in systems that are in operation today. A voice coding rate of 4 kbit/s is assumed for multimedia systems, which is lower than the rate commonly used today.

Although no multimedia distribution satellite system is in operation today, it is anticipated that such a system will use the IMT-2000 (OFDM QPSK) standard with 5 MHz carrier bandwidth, enabling a transmission rate of 2.3 Mbit/s per carrier. The month-to-day conversion factor of 30 for multimedia distribution services and 25 for the remaining multimedia and non-multimedia services is taken from Recommendation ITU-R M.1391.

A frequency reuse cluster size of three is assumed for multimedia distribution systems and seven for other multimedia and non-multimedia systems. The factor of three is consistent with the larger beams expected to be used for multimedia distribution services. The factor of seven is consistent with a typical frequency reuse cluster size used by MSS systems. Several satellite operators will serve the market which will introduce spectrum inefficiencies. The calculations presented in this report assume that there will be two multimedia satellite systems and three non-multimedia satellite systems in operation from 2010. A hot spot traffic reduction between 25% and 50% has been assumed for asymmetric multimedia services to take into account that terrestrial networks may be able to provide the desired service more economically.

A lower return traffic has been assumed for asymmetric multimedia services which would be typical for some applications such as Internet access, file transfers (up and downloads), data bank access, emails (receive and transmit), etc. The packet-switched carrier efficiency was assumed to be 90% (i.e. the packet-switched carriers were on average 90% loaded), which represents a very efficient system. The percentage of diurnal (daily) traffic in the busy hour was assumed to be 10% for all systems excluding multimedia distribution and 4.2% (i.e. no busy hour) for multimedia distribution. A 1% grade of service is assumed for circuit-switched services. This figure is consistent with the value used by many operators today. A 10% spectrum overhead is assumed for the signalling and control channel traffic required to support the non-multimedia traffic. This is consistent with values in current MSS systems. It is anticipated that multimedia systems will be more efficient and will require a smaller signalling overhead. Therefore, a 5% signalling and consequently spectrum overhead is assumed for multimedia satellite systems. Distribution does not require any overhead.

3.3 Results

Figure 2 shows the overall spectrum requirements for the satellite component of IMT-2000 and systems beyond IMT-2000 from 2010 to 2020 for the low traffic scenario. Table 13 contains the detailed results for the various types of traffic. Figure 3 shows the overall spectrum requirements for the high traffic scenario with Table 14 containing the related detailed results for the various types of traffic.

As can be seen, the spectrum requirement from non-multimedia services remain approximately constant, whereas the increasing demand for multimedia services pushes up the spectrum requirement. The dominant contribution to the spectrum requirement is from multimedia asymmetric services (i.e. email, internet, intranet, file download type applications) and multimedia distribution (which are high bandwidth, content rich services). The contributions to the spectrum requirements from the remaining multimedia and non-multimedia services remain rather constant and relatively small.

FIGURE 2

Total spectrum requirements for the low traffic scenario

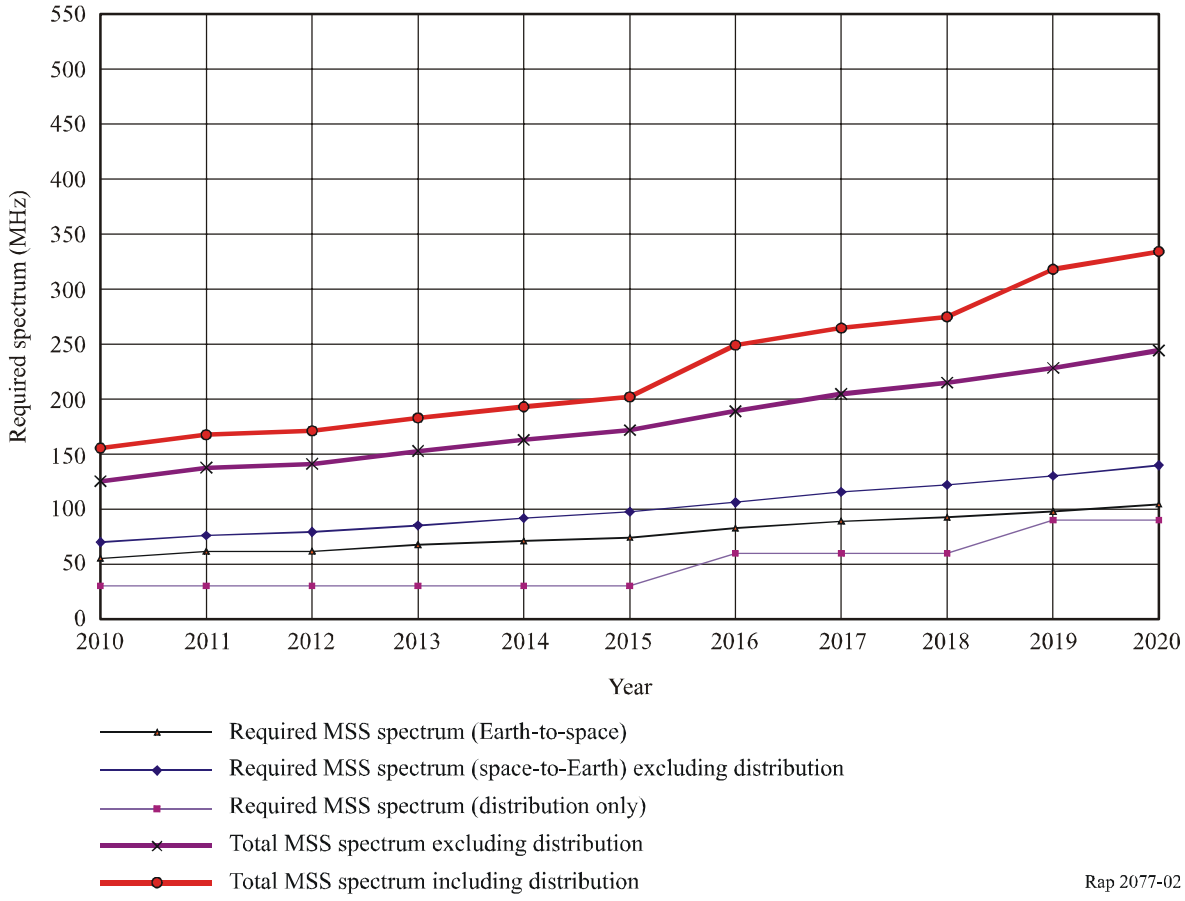


TABLE 13

Detailed spectrum requirements for the low traffic scenario

Total spectrum required (MHz)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MM voice traffic	2.9	2.9	2.9	2.9	2.9	2.9	5.9	5.9	5.9	5.9	5.9
MM interactive traffic	5.9	5.9	5.9	5.9	5.9	5.9	8.8	8.8	8.8	8.8	8.8
MM asymmetric forward traffic	29.4	32.3	35.3	38.2	44.1	47.0	50.0	55.9	58.8	64.7	70.6
MM asymmetric return traffic	14.7	17.6	17.6	20.6	23.5	23.5	26.5	29.4	29.4	32.3	35.3
MM low-speed data traffic	5.9	8.8	8.8	11.8	11.8	14.7	14.7	17.6	20.6	23.5	26.5
MM distribution traffic	30.0	30.0	30.0	30.0	30.0	30.0	60.0	60.0	60.0	90.0	90.0
Non-MM low-speed data traffic	17.6	17.8	18.0	18.0	18.5	18.5	18.2	18.7	19.2	18.7	19.2
Non-MM messaging traffic	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Non-MM voice traffic	8.1	8.1	8.1	8.1	8.3	8.3	8.3	8.3	8.5	8.3	8.5
Total MM spectrum (space-to-Earth, without distribution)	44.1	50.0	52.9	58.8	64.7	70.6	79.4	88.2	94.1	102.9	111.7
Total MM spectrum (Earth-to-space)	29.4	35.3	35.3	41.2	44.1	47.0	55.9	61.7	64.7	70.6	76.4
Total non-MM spectrum (space-to-Earth and Earth-to-space)	26.0	26.2	26.4	26.4	27.1	27.1	26.9	27.4	28.1	27.4	28.1
Total spectrum in forward direction (space-to-Earth, without distribution)	70.1	76.2	79.4	85.2	91.8	97.7	106.3	115.6	122.1	130.3	139.8
Total spectrum in return direction (Earth-to-space)	55.4	61.5	61.7	67.6	71.2	74.2	82.8	89.1	92.7	97.9	104.5
Grand total spectrum without distribution	125.5	137.7	141.1	152.9	163.1	171.9	189.1	204.7	214.9	228.2	244.3
Grand total spectrum with distribution	155.5	167.7	171.1	182.9	193.1	201.9	249.1	264.7	274.9	318.2	334.3

FIGURE 3

Total spectrum requirements for the high traffic scenario

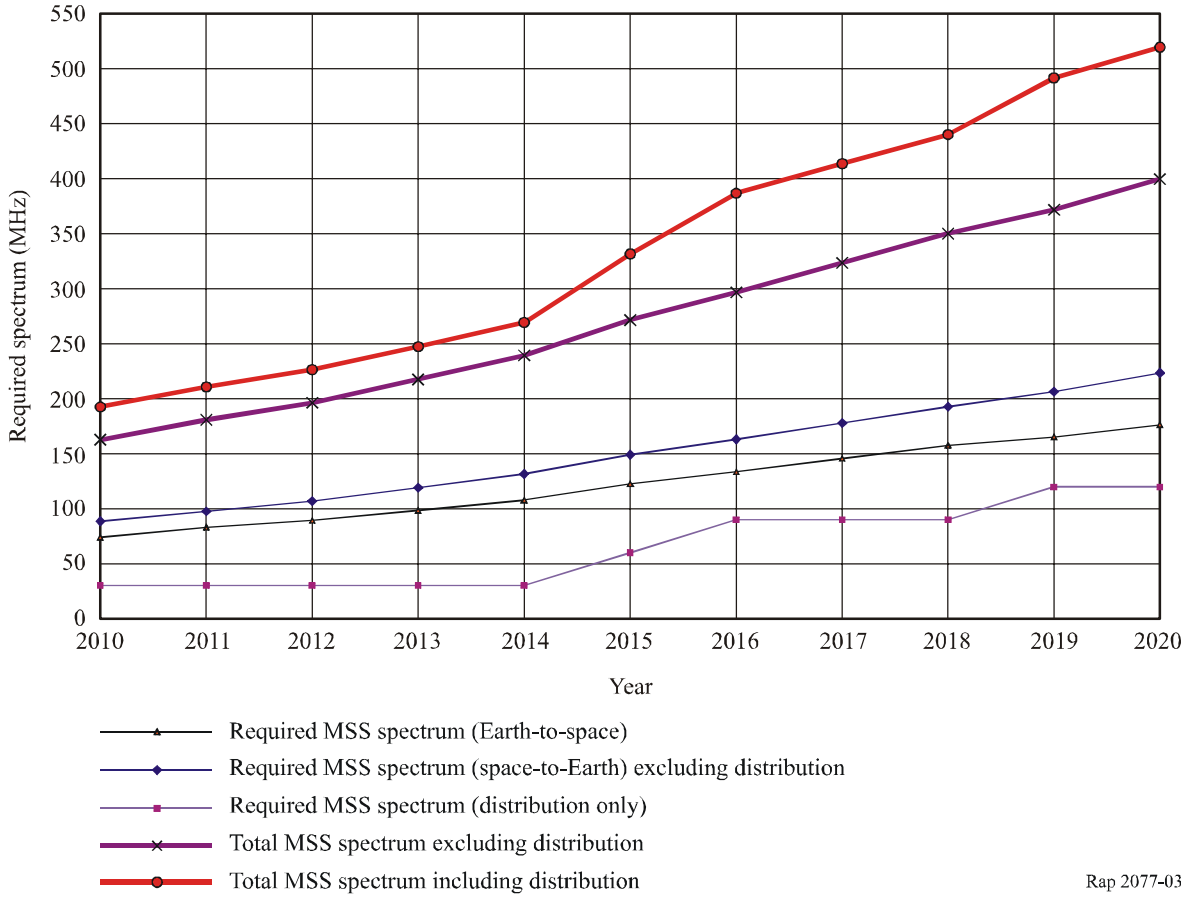


TABLE 14

Detailed spectrum requirements for the high traffic scenario

Total spectrum required (MHz)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MM voice traffic	2.9	2.9	2.9	2.9	2.9	2.9	5.9	5.9	5.9	5.9	5.9
MM interactive traffic	5.9	5.9	5.9	5.9	5.9	8.8	8.8	8.8	8.8	8.8	8.8
MM asymmetric forward traffic	47.0	52.9	61.7	70.6	82.3	94.1	105.8	117.6	129.4	144.1	158.8
MM asymmetric return traffic	32.3	38.2	44.1	50.0	58.8	67.6	76.4	85.3	94.1	102.9	111.7
MM low-speed data traffic	5.9	8.8	8.8	11.8	11.8	14.7	14.7	17.6	20.6	20.6	23.5
MM distribution traffic	30.0	30.0	30.0	30.0	30.0	60.0	90.0	90.0	90.0	120.0	120.0
Non-MM low-speed data traffic	18.2	18.5	18.7	18.9	19.4	19.4	18.9	19.2	19.2	18.5	18.0
Non-MM messaging traffic	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Non-MM voice traffic	8.3	8.3	8.5	8.5	8.8	8.8	8.5	8.5	8.5	8.3	8.1
Total MM spectrum (space-to-Earth, without distribution)	61.7	70.6	79.4	91.1	102.9	120.5	135.2	149.9	164.6	179.3	197.0
Total MM spectrum (Earth-to-space)	47.0	55.9	61.7	70.6	79.4	94.1	105.8	117.6	129.4	138.2	149.9

TABLE 14 (*end*)

Total spectrum required (MHz)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total non-MM spectrum (space-to-Earth and Earth-to-space)	26.9	27.1	27.6	27.8	28.5	28.5	27.8	28.1	28.1	27.1	26.4
Total spectrum in forward direction (space-to-Earth, without distribution)	88.7	97.7	107.0	119.0	131.4	149.1	163.1	178.0	192.7	206.5	223.4
Total spectrum in return direction (Earth-to-space)	74.0	83.0	89.3	98.4	107.9	122.6	133.7	145.7	157.4	165.3	176.4
Grand total spectrum without distribution	162.6	180.7	196.3	217.4	239.3	271.7	296.8	323.7	350.1	371.8	399.8
Grand total spectrum with distribution	192.6	210.7	226.3	247.4	269.3	331.7	386.8	413.7	440.1	491.8	519.8

4 Sensitivity analysis

To investigate the sensitivity of the spectrum requirements, various parameters have been modified relative to a nominal moderate scenario that is somewhere in the middle between the low traffic and the high traffic scenarios.

Figure 4 shows the impact of the number of subscribers. It can be seen that the annual growth rate of MSS subscribers is a driving factor for the required spectrum.

FIGURE 4

Sensitivity analysis for number of MSS subscribers

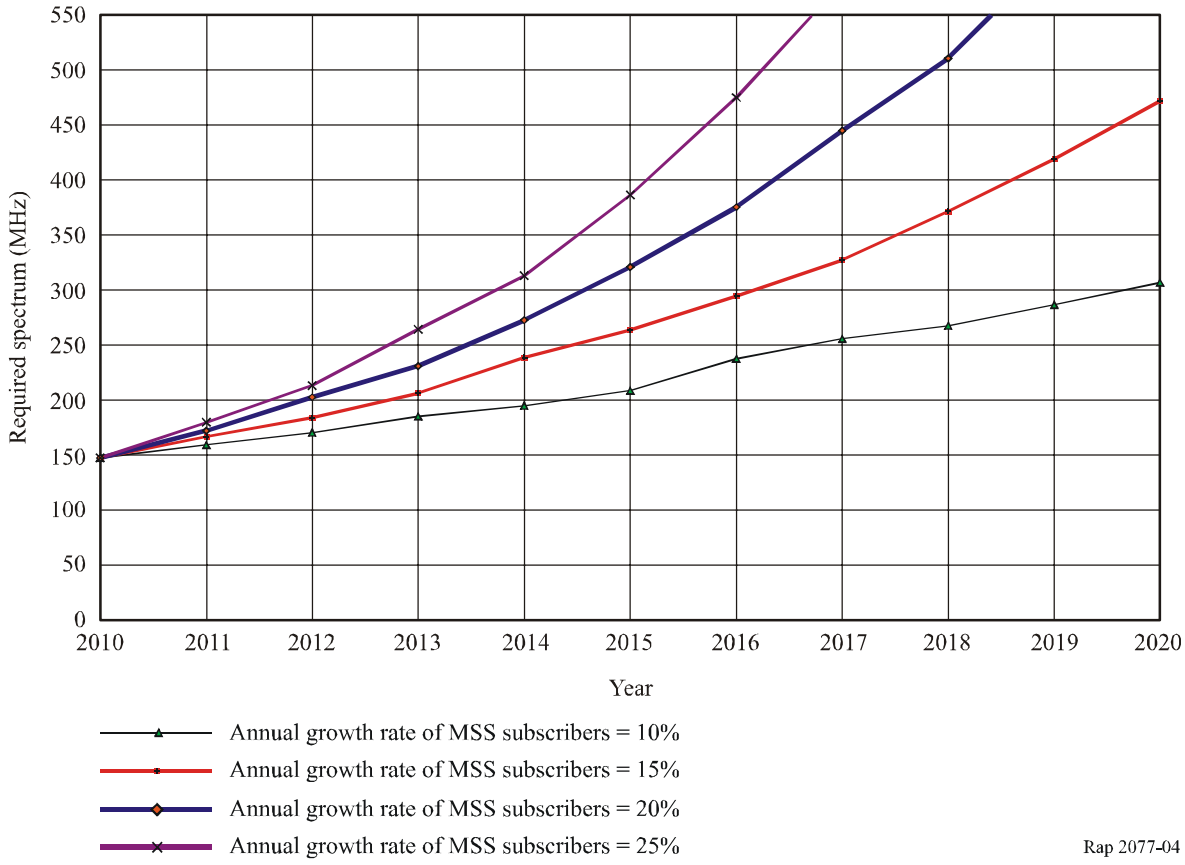


Figure 5 shows the impact of the percentage of global traffic in the worst-case cluster. Also this factor has a major impact on MSS spectrum requirements. To some extent, there is a compensating factor between increasing number of subscribers and percentage of traffic in hot spots as a strongly increasing MSS market will be a driving incentive to develop new higher spot-beam MSS satellites.

FIGURE 5

Sensitivity analysis for global traffic percentage in hot spot cluster

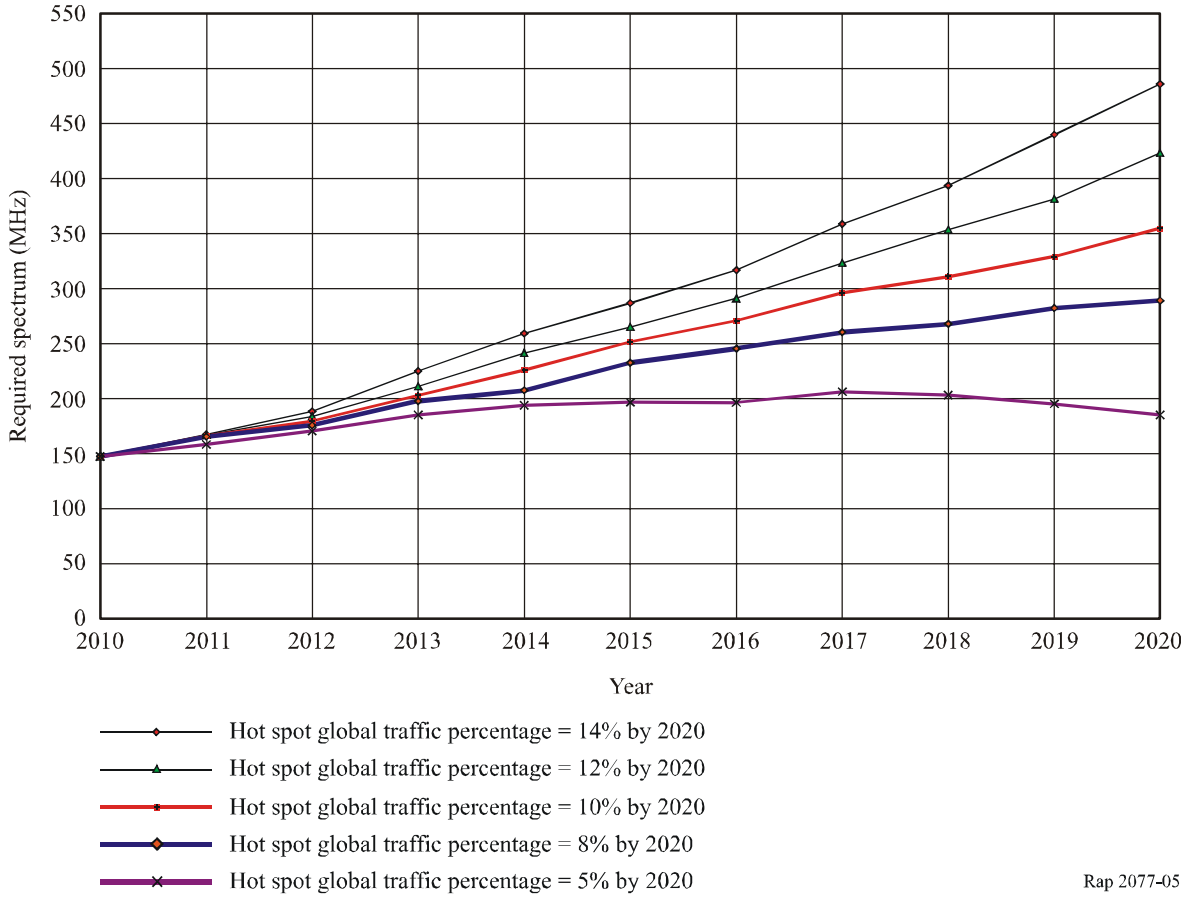


Figure 6 shows the impact of traffic loss in hot spots due to sharing with terrestrial services. This impact is not so strong but could be to the benefit of MSS service providers as traffic is more equally spread over the other beams so that the same system capacity can actually serve a higher number of MSS subscribers for a given bandwidth. The number of subscribers should not really be affected by this factor as it may just result in a lower use of the MSS terminal in hot spots.

FIGURE 6

Sensitivity analysis for traffic loss in hot spot clusters

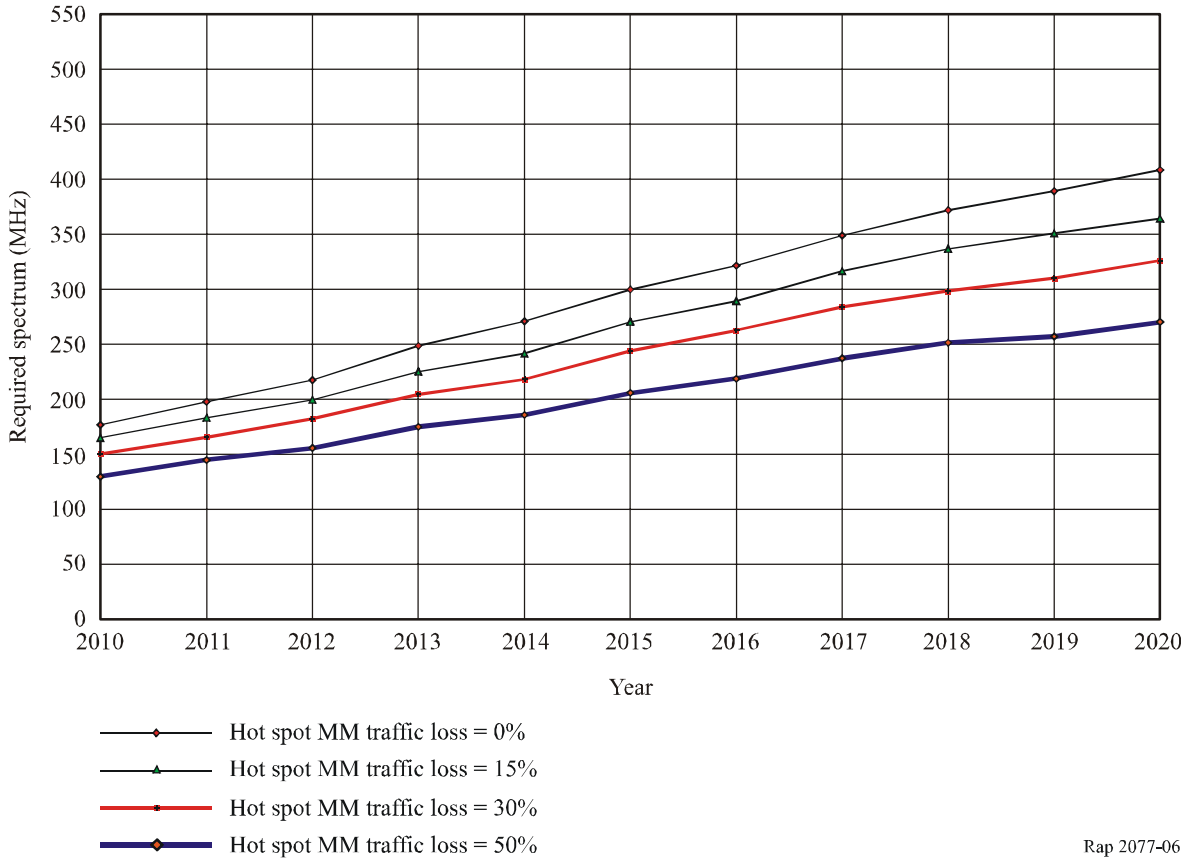


Figure 7 shows that the impact of the return to forward ratio of asymmetric MM services has a rather minor influence.

FIGURE 7

Sensitivity analysis for percentage of asymmetric MM traffic

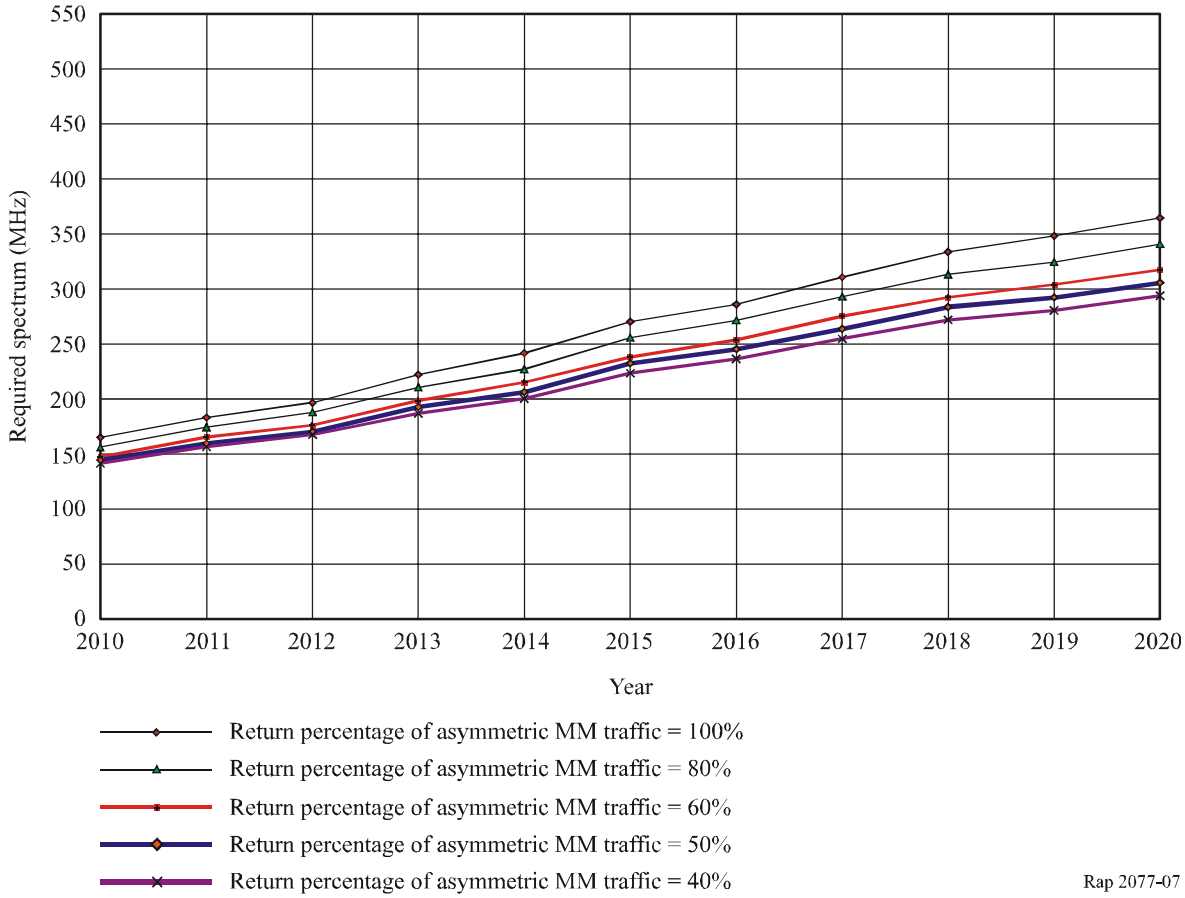
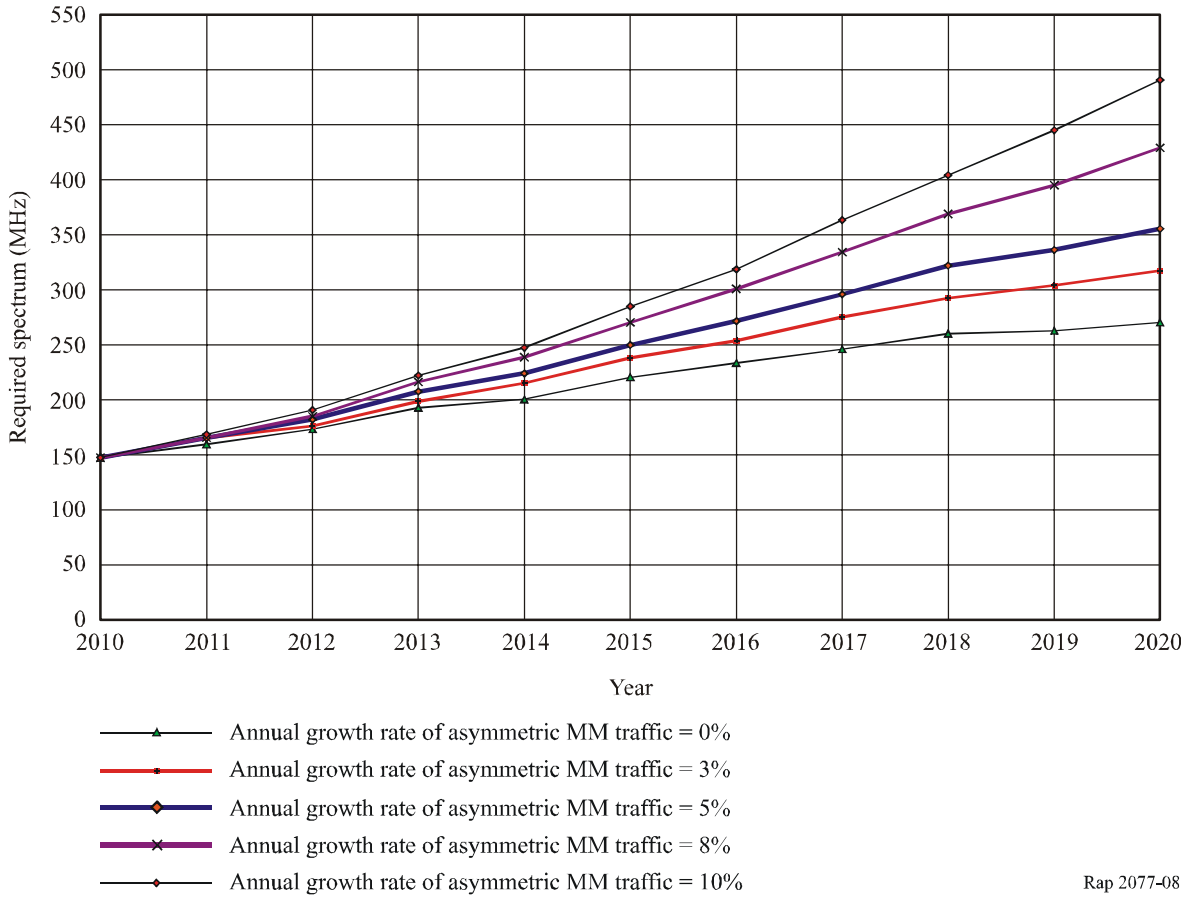


Figure 8 shows the impact of the annual growth rate for asymmetric MM services which could actually become a driving factor if MSS multimedia services become more affordable with new advanced high power/high multibeam systems.

FIGURE 8

Sensitivity analysis for annual growth rate of asymmetric MM services



5 Radio regulatory background

Table 15 lists the allocations to the MSS in the ITU Radio Regulations (RR) which amount to 2 × 121.5 MHz. However, in some regions, the bands 2 500-2 535 MHz and 2 655-2 690 MHz, or parts thereof, are not available, leaving only around 2 × 86.5 MHz. Worldwide availability of MSS spectrum is an almost essential condition for IMT-2000 and systems beyond IMT-2000 satellite applications.

TABLE 15

Current MSS spectrum allocations in the 1-5 GHz band

Uplink band (MHz)	Downlink band (MHz)	Bandwidth (MHz)
1 626.5-1 645.5, 1 646.5-1 660.5	1 525-1 544, 1 545-1 559	2 × 33
1 610-1 626.5	2 483.5-2 500	2 × 16.5
1 668-1 675	1 518-1 525	2 × 7
1 980-2 010	2 170-2 200	2 × 30
2 670-2 690	2 500-2 520	2 × 20
2 655-2 670	2 520-2 535	2 × 15
Total allocated spectrum		**2 × 121.5**

6 Summary and conclusions

The traffic forecasts and anticipated spectrum requirements for the satellite component of IMT-2000 and beyond IMT-2000 are presented for the period 2010 to 2020. Based on a conservative forecast of subscribers for the satellite component of IMT-2000 and systems beyond IMT-2000 for the period 2010 to 2020, and applying Recommendation ITU-R M.1391 spectrum calculation methodology for IMT-2000 systems, the overall spectrum requirements for a pessimistic and an optimistic scenario are shown in Table 16. The main reason for the imbalance between Earth-to-space and space-to-Earth directions are distribution applications and asymmetric multimedia services showing higher spectrum requirements on space-to-Earth links.

The anticipated low traffic scenario is based on 9% MSS subscriber growth per year starting with the known number of MSS subscribers of 1.4 million at the beginning of 2006. Incentives for new investments resulting in continuing introduction of high multibeam systems with more than 200 beams will therefore be low, thus not leading to a significant reduction of percentage of traffic in hot spots. Further assumptions are asymmetric MM traffic loss in hot spots around 50%, no growth of asymmetric MM services and 50% of asymmetric return MM traffic relative to the forward direction. Distribution with 17 data channels to optimize use of the assumed 30 MHz available bandwidth by 2010, and 26 channels beyond 2015.

The anticipated high traffic scenario is based on a 14% MSS subscriber growth per year. Strong incentives for investments in new MSS technologies will result in introduction of high multibeam systems with larger reflectors and around 600 beams which will be introduced gradually until 2020. Further assumptions are asymmetric MM traffic loss in hot spots around 25%, annual growth rate of 5% for asymmetric MM services and 71% for asymmetric return MM traffic. Distribution with 26 data channels up to 2015 and 35 data channels thereafter.

Distribution applications should consider maximizing the number of channels made available to the subscriber as a function of totally available bandwidth, channel bandwidth, channel quality, number of spot beams and satellite systems.

Unlike non-multimedia applications, the traffic from multimedia satellite service applications will continue to grow rapidly.

The dominant contribution to the spectrum requirements is from the multimedia distribution and asymmetric services.

Support of a specific grade of mobility at a given bandwidth is only possible up to a certain operating frequency due to fast fading phenomena, and therefore, for high mobility, suitable operating frequencies would be up to 6 GHz.

TABLE 16

Required spectrum for the low and high traffic scenarios

Spectrum required (MHz)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Low traffic scenario											
Spectrum in Earth-to space direction	55	61	62	68	71	74	83	89	93	98	105
Spectrum space-to-Earth excluding distribution	70	76	79	85	92	98	106	116	122	130	140
Total spectrum without distribution	125	137	141	153	163	172	189	205	215	228	245
Spectrum for MM distribution services	30	30	30	30	30	30	60	60	60	90	90
Grand total spectrum including distribution	155	167	171	183	193	202	249	265	275	318	335
High traffic scenario											
Spectrum in Earth-to-space direction	74	83	89	98	108	123	134	146	157	165	176
Spectrum space-to-Earth excluding distribution	89	98	107	119	131	149	163	178	193	206	223
Total spectrum without distribution	163	181	196	217	239	272	297	324	350	371	399
Spectrum for MM distribution services	30	30	30	30	30	60	90	90	90	120	120
Grand total spectrum including distribution	193	211	226	247	269	332	387	414	440	491	519

To investigate the sensitivity of the spectrum requirements, various parameters have been modified relative to the nominal scenario. This analysis revealed that the annual growth rate of MSS subscribers and the percentage of global traffic in the worst-case cluster are driving factors for the required spectrum. To some extent, there is a compensating factor between the increasing number of subscribers and percentage of traffic in hot spots as a strongly increasing MSS market will be a driving incentive to develop new higher spot-beam MSS satellites. Of significant influence is also the annual growth rate for asymmetric MM services. Less significant are variations to traffic loss in hot spots due to sharing with terrestrial services. The return to forward ratio of asymmetric MM services has a rather minor influence.

Table 17 shows the required spectrum taking into account existing allocations. Considering that out of 2×121.5 MHz of currently allocated MSS spectrum in the range 1-5 GHz, only around 2×86 MHz are globally available, additional global MSS allocations are needed commencing with around 14 MHz by the year 2010 and increasing up to 114 MHz by the year 2020 for a low traffic scenario, including 30 MHz and 90 MHz for distribution applications by 2010 and 2020, respectively. A high traffic scenario would require around 33 MHz by 2010, increasing to 257 MHz by 2020. These estimates include 30 MHz and 120 MHz for multimedia distribution by 2010 and 2020, respectively.

TABLE 17

Required new global MSS spectrum allocations in the 1-6 GHz range

Required spectrum (MHz)	Low traffic scenario		High traffic scenario	
	2010	**2020**	**2010**	**2020**
Spectrum in Earth-to-space direction	55	105	74	176
Spectrum in space-to-Earth direction excluding distribution	70	140	89	223
Spectrum for multimedia distribution in space-to-Earth direction	30	90	30	120
Total required spectrum	155	335	193	519
Required new allocations in Earth-to-space direction		19		90
Required new allocations in space-to-Earth direction excluding distribution		54	3	137
Required new allocations in space-to-Earth direction including distribution	14	144	33	257