RECOMMENDATION ITU-R M.1391-1

Methodology for the calculation of IMT-2000* satellite spectrum requirements

(1999-2006)

1 Scope

This Recommendation presents a methodology for the calculation of the spectrum requirements of the IMT-2000 satellite component. This methodology is based on the requirements and objectives defined in the relevant IMT-2000 Recommendations.

The methodology is structured to be independent of the details of the various systems which comprise the satellite component (e.g. orbits). The nature of the services likely to be supported by the system capabilities should be taken into account by the choice of appropriate values for the input parameters.

2 Introduction

International Mobile Telecommunications (IMT-2000) provide access, by means of one or more radio links, to a wide range of telecommunication services supported by the fixed telecommunication networks (e.g. PSTN/ISDN), and to other services which are specific to mobile users.

A range of mobile terminal types is encompassed, linking to terrestrial or satellite based networks, and the terminals may be designed for mobile or fixed use.

Key features of IMT-2000 are:

– high degree of commonality of design worldwide;
– compatibility of services within IMT-2000 and with the fixed networks;
– high quality;
– use of a small pocket-terminal with worldwide roaming capability;
– capability for multimedia applications and a wide range of services.

IMT-2000 are defined by a set of interdependent ITU Recommendations of which this one is a member.

The IMT-2000 satellite component accommodates a portion of the increasing general demands for mobile services. Considering that the satellite and terrestrial components of IMT-2000 are mutually complementary, and provide compatible services, adequate spectrum bandwidth is needed for both. A specific methodology is needed for the calculation of IMT-2000 satellite component requirements. Moreover, the IMT-2000 services are rich in information and user friendly (e.g. multimedia). Therefore, the need for providing users with access to various services, which are compatible with those which are provided by the IMT-2000 terrestrial component, needs to be recognized.

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* This methodology may also be used for systems beyond IMT-2000.

3 Related Recommendations

This Recommendation builds upon Recommendation ITU-R M.818 (Satellite operation within IMT-2000) and Recommendation ITU-R M.1167 (Framework for the satellite component of IMT 2000). It recognizes the requirements defined for the satellite component in Recommendation ITU-R M.1034 (Requirements for the radio interface(s) for IMT-2000), the needs of developing countries (see Recommendation ITU-R M.819) and the increasing interest in the provision of higher bit-rate services.

4 Background

The starting point for the development of a methodology is necessarily governed by the form of the telecommunication traffic statistics and their availability. It has been recognized in previous related Recommendations that the satellite component of IMT-2000 may have a variety of forms each of which will be the result of an optimization to meet a perceived market. In this Recommendation, two types of satellite IMT-2000 traffic have been considered, these are denoted multimedia and non-multimedia. The traffic demand is assumed to be given as Mbytes per month or minutes per month.

In general terms, advances in technology can be expected to result in the spectrum required to support a given amount of user traffic in a given service category to decrease over time. Technical advances associated with source coding and antenna design, for example, have allowed improved frequency reuse to be achieved in systems resulting in overall increases in spectrum efficiencies. For the mix of services to be supported by IMT-2000, the introduction of packet switching and delay tolerance techniques may also contribute to an improvement in spectrum efficiency.

These improvements in the use of spectrum are expected to be incorporated in IMT-2000 systems. They will help to offset requirements for additional spectrum created by projected increasing demands of user traffic, resulting from an increased customer base, which may be stimulated by the availability of new services. These factors have been taken into account in the development and application of the spectrum calculation methodology.

5 Recommended methodology

The ITU Radiocommunication Assembly,

recommends

5.1 that the following methodology be used for the calculation of the frequency spectrum requirements of the satellite component of IMT-2000.

5.2 Overview

Point-to-point IMT-2000 satellite traffic is divided into two main categories: multimedia and non-multimedia traffic. Multimedia traffic is traffic that is assumed to be carried by advanced systems supporting high data rates, narrow-spot beams and packet-switched services. Non-multimedia traffic is traffic assumed to be carried by systems supporting only low data rates, somewhat larger spot beams and circuit-switched services. Although there may be other types of systems, e.g. systems with very narrow-spot beams that only support narrow-band services, this division is considered to be useful in that it represents the range of different technologies that are expected to be in use in the time-frame of this study.

For the multimedia traffic, 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 point-to-point IMT-2000 satellite traffic would be provided by systems in the mobile-satellite service. Multicast/broadcast traffic may be provided by systems in either the BSS or MSS.

The non-multimedia traffic on the other hand is split into three service categories: low-speed data traffic, messaging and voice telephony. Each of these services is assumed to be carried on distinct carrier types. In addition to the point-to-point MSS traffic, a calculation methodology for multicast traffic is also presented.

5.3 Detailed description

The following sections give the equations to calculate the spectrum requirement for satellite IMT-2000 systems carrying multimedia (including broadcast/multicast traffic) and non-multimedia traffic respectively. If several systems are considered, the total spectrum requirement is calculated by adding the individual requirements of each system.

5.3.1 Multimedia traffic

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

$$S = N_{beams} \cdot B \cdot \left\lceil \frac{T_{BH} \cdot 8\,000}{3\,600 \cdot eff \cdot R} \right\rceil \quad (1)$$

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.

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 per month (for data traffic) or minutes per 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:

$$T_{BH} = \sum_i T_i \quad (2a)$$

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

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

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.

5.3.2 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 1 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.

Then, we obtain:

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

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 1 in this case because the traffic does not depend on the geographical location of the user

H: equal to 1 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.

Then, we obtain:

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

5.3.3 Non-multimedia traffic

As mentioned in § 5.2, 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 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: is the 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.:

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

5.3.4 Additional comments on the derivation of busy-hour traffic

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

The spectrum calculations should be carried out for several regions of the world, e.g. the three ITU Regions. To determine the peak spectrum requirement in a region, geographic peaking factors may have to be applied, depending on the resolution of the input traffic data.

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.