Spectrum Availability for Next Generation Satellite Services: Coexistence with Terrestrial Mobile Services

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Abstract. Having available adequate and sufficient spectrum resources is a crucial factor to enable the fast growth of broadband mobile communications. Efficient use of scarce radio spectrum becomes more and more important. Especially in the lower frequency bands, with favorable conditions for mobile communications, spectrum will have to be shared between different services and applications. In this context effective sharing between mobile service and satellite services becomes increasingly important. It is no longer affordable to base the interference calculations on worst case assumptions. Therefore a novel and comprehensive approach of coexistence analysis is presented. The method discusses the extent to which propagation paths of various interference sources are correlated or not, and what the expected effect will be. Having a more realistic insight in the interference conditions could provide better viability of sharing arrangements, possibly with some realistic mitigation measures.

Keywords: satellite services, MSS, FSS, mobile communication, mobile service, MS, broadband, spectrum, sharing, propagation, ITU-R P.452, model, coexistence, correlation radio path losses, interference analysis.

1 Expected Demand for Mobile Services

It is commonly recognized that terrestrial mobile communications have shown tremendous growth over the last decades. Building on this success the technology evolved to subsequent generations of terrestrial mobile networks, called IMT (International Mobile Telecommunications) systems, providing broadband wireless data services that support novel applications, such as internet browsing, e-mail, messaging, social media and video sharing.

The enormous number of mobile users as well as the increase of mobile broadband applications boosts the need for wireless transmission capacity and as a consequence radio spectrum. The industry is responding to these needs by developing new technologies with a vastly enhanced performance (e.g. IMT-Advanced) and a more efficient and flexible use of the radio spectrum. The future use of the most advanced mobile technologies will provide significant gains in spectrum efficiency but will not be sufficient to cope with the growing demand for capacity. Studies from the International Telecommunications Union (ITU) [1] predict that the total spectrum

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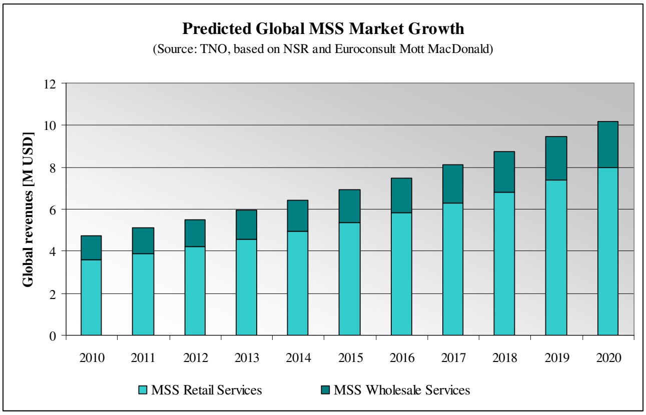
requirement for mobile cellular systems in the year 2020 will be significantly higher than the total frequency bands identified for the terrestrial component of IMT. Since adequate spectrum availability is considered to be a prerequisite for the success of the continuing development of IMT, there is a huge pressure to more make spectrum available for this purpose.

At the same time, the use of Mobile Satellite Services (MSS) is also expected to increase significantly over the next decade. This growth is driven by demand, for MSS offers (global) applications for handheld mobile terminals and is very well suited for the delivery of among others broadband data and internet services in rural areas. For this reason, MSS is seen as an important element of the European Digital Agenda, a key goal of which is to ensure broadband access for all European Citizens. But MSS also makes possible new applications and services, like for example asset tracking and fleet management in the maritime and transport sector, onboard communication services offered to airline passengers, monitoring of remote pipelines and oil installations and machine-to-machine applications in various sectors. Moreover, MSS offers a solution for emergency communications in regions where the fixed infrastructure has collapsed as a result of a natural disaster or a crisis. These so-called 'hot spots' can be reached by new satellites that are equipped with steerable spot beams. As a result of the above, the number of MSS handheld terminals in service is expected to be doubled or even tripled in 2020 and the revenues associated with MSS are predicted to grow at a rate of 7 to 8 percent per annum [2] [3], as figure 1 illustrates. Major satellite operators confirm these growth expectations, although some reservations are being made for the short term [4].


Predicted Global MSS Market Growth

(Source: TNO, based on NSR and Euroconsult Mott MacDonald)

Fig. 1. Predicted global MSS market growth until 2020

Serving the increasing number of MSS users and fulfilling the demand for enhanced broadband services presents a challenge to satellite operators. Having guaranteed and undisturbed access to sufficient spectrum resources is an essential basis for the successful operation of a satellite network and provisioning of reliable services. Since mobile communications are expected to grow, the demand for spectrum is increasing. A consequence of the expected increase in the use of MSS is that the feeder links will also require more capacity which implies the need for sufficient spectrum for Fixed Satellite Services (FSS) as well.

2 Spectrum Requirements

In general MSS and Mobile Services (MS) are seen as complementary services, as is illustrated in figure 2. In the IMT concept a satellite component has been included from the beginning onwards to provide voice and data communication services in regions outside terrestrial coverage. From the satellite service point of view a Complementary Ground Component (CGC) is envisaged to provide mobile satellite or broadcasting satellite services in areas where satellite reception is difficult. CGC consists of base station type equipment that may be collocated with terrestrial cell sites or can be placed stand-alone. To enable compatibility and easy terminal hand-over, terrestrial and satellite radio interfaces are required to have a high degree of common functionality and to operate in the same or adjacent frequency bands.

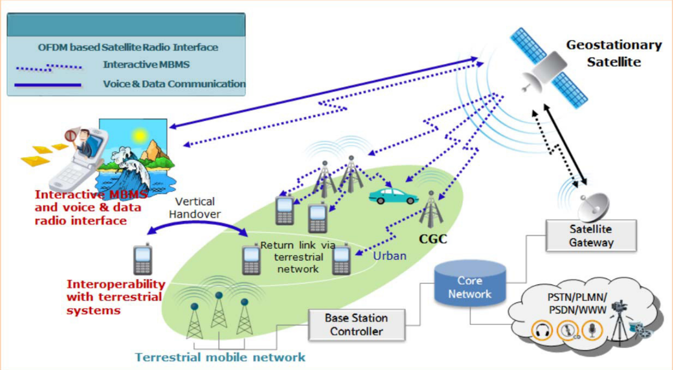


Fig. 2. MSS as a component in the overall IMT-Advanced concept [5]

To enable portable satellite terminals, similar to mobile phones used in the terrestrial mobile networks today, operation in the lower frequency bands (L, S and C-band) with their favorable propagation conditions is desired.

3 Frequency Allocations

During the consecutive ITU World Radio Conferences (WRCs) additional frequency bands were step by step allocated to MS, as shown in figure 3. The allocations for MS will affect the spectrum that is available for satellite services. This is the case in the band around 2 GHz where spectrum allocated to MSS is intertwined with the MS allocations. In the 3600 to 3800 MHz band there is an allocation for both FSS (i.e. feeder links for MSS systems) as well as MS, which means frequency sharing between both services becomes important. The trend is that the spectrum allocations for satellite services are under pressure and are not likely to increase.

Migration of systems that might as well use higher frequency bands (Ku or Ka band), such as VSAT, can make the lower bands more available for portable satellite terminals. This measure is not expected to be sufficient and the need for sharing between MS and MSS/FSS will become increasingly important.

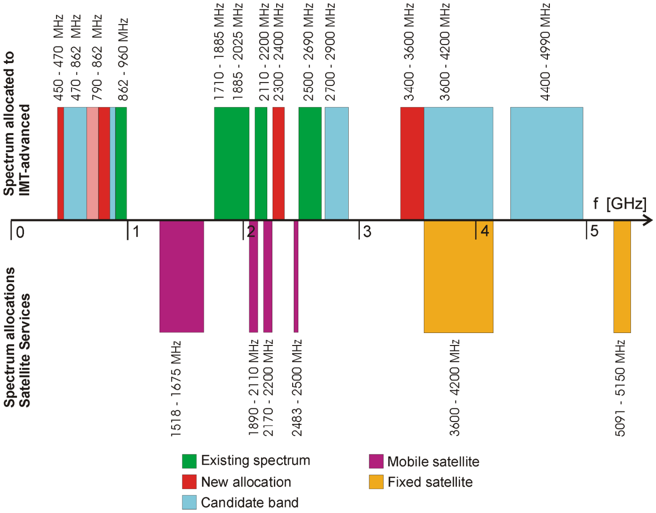


Fig. 3. Spectrum made available for IMT-Advanced and spectrum allocations for FSS and MSS (mostly on a shared basis)

4 Satellite Sharing with Terrestrial Mobile

In case of wireless communication networks with terrestrial and/or satellite components, operated and controlled by a single provider, spectrum sharing reduces to an optimization issue. However, in case different providers are involved the situation is more complex and conflicting requirements have to be dealt with, like interference criteria, mitigation techniques to improve spectrum sharing and the cost involved with implementing the mitigation measures. There is an urgent requirement to optimally exploit the possibilities for sharing and coexistence between radio services. Against this background, there is a need to perform the coexistence analysis as accurately as possible. This paper discusses a novel and comprehensive approach to further improve the coexistence analysis between FSS and MS services in the 3400 to 3600 MHz band, a case that is of particular current interest.

For MS not to interfere with existing FSS links, two criteria are taken into account [6]: the long-term and short-term interference criterion. The long-term interference criterion is used to ensure a good quality of the satellite link and specifies the interference level that must not be exceeded for more than 20% of the time. For satellite earth stations in the fixed satellite service this interference level amounts to 10% of the clear sky satellite system noise. For this criterion the interference contributions from all interference sources are assumed to vary simultaneously and are assumed to add on a power basis, meaning that interference contributions (and path losses) are considered to be correlated.

The short-term criterion is used to ensure the availability of the satellite link and specifies the maximum time percentage that a satellite link may be out-of-service due to a high level of interference (i.e. causing an increase of the satellite system noise which exceeds the satellite link margin). For this criterion the interference contributions from all interfering sources are assumed to vary independently and to add on a percentage-of-the-time basis, meaning that interference contributions (and path losses) are considered to be uncorrelated. For analogue satellite links this outage percentage is 0.03% and for digital links it is 0.005% [6].

To determine whether or not the interference criteria are exceeded, the propagation model described in ITU-R P452 [7] is used. We implemented this model and terrain data was used to calculate the interference level caused by a MS base station at a satellite earth station for various time percentages. Subsequently, for any (range of) azimuth and elevation angles of the satellite ground station, the percentage of time that an interference criterion is exceeded is calculated.

The example illustrated in figure 4 shows the areas around a satellite earth station within which a single MS base station will cause the long and short term criterion to be exceeded. Obviously, the area within which a single MS base station could cause interference exceeding the short term criterion is much larger then for the long term criterion. To obtain an area comparable to that of the long term, either a high outage percentage (of about 5%) has to be accepted or a high satellite link margin (of about 26 dB instead of 3 dB) has to be used by the FSS operator. Clearly, the short term criterion has more impact on spectrum sharing possibilities than the long term criterion. In the following analysis the focus will therefore be on the short term criterion.

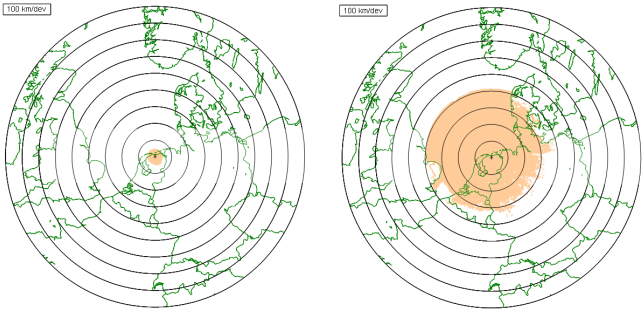


Fig. 4. Example of areas within which the long term (left) respectively short term (right) criterion will be exceeded by a single MS base station

In general the assumptions made as basis for the criteria and the way in which the total interference caused by multiple MS base stations at a satellite earth station is calculated, are well suited for the case that only a limited number of dispersed MS base stations have to be considered.

However, in case a large scale deployment in cities is considered, with many MS base stations in a clutter environment, two complications arise. Firstly, the calculation becomes rather complex and a large amount of environmental data is required to determine the clutter loss for each base station. Secondly, the assumption made for the short term criterion that the interference contributions of all MS base stations arriving at the satellite earth station are uncorrelated becomes unlikely. Considering for instance a large scale MS network deployment in a city, at a large distance from a satellite earth station, the propagation paths between each MS base station and the satellite earth station are very close together (nearly identical from a propagation perspective). This suggests that the interference contributions of the MS base stations at the satellite earth station are more likely to be highly correlated even for short periods of time. This means that the periods of high interference at the satellite earth station due to each base station will occur more simultaneously instead of randomly spread in time. As a consequence, the actual outage percentage caused by a MS network deployment in a city can be considerably less than predicted when considering the contributions of all interferers uncorrelated as is currently common practice.

An alternative approach is suggested here, which is dedicated to modelling the interference effects of a large scale MS network deployments in cities on FSS systems. This approach has been used to estimate the outage percentage at satellite earth stations in the Netherlands for various scenarios (i.e. MS network deployments in various cities).

To reduce the computational complexity, a large scale MS network deployment in a city is modeled as a single (equivalent) base station by assuming propagation losses between each individual MS base station and the interfered-with satellite earth station are highly correlated. For this, a real large scale deployment of a broadband mobile network (based on Wimax technology) in Amsterdam served as a reference. For this network deployment the total power per channel, radiated towards the horizon, was measured. These measurements are subsequently used to determine the E-EIRP (Equivalent - Effective Isotropic Radiated Power) of a single base station in an uncluttered environment resulting in the same total power per channel towards the horizon (see figure 5). Knowing all the specifics of the BWA deployment in Amsterdam, the deployments in other cities are modeled in the same manner by scaling the E-EIRP according to the corresponding coverage area.

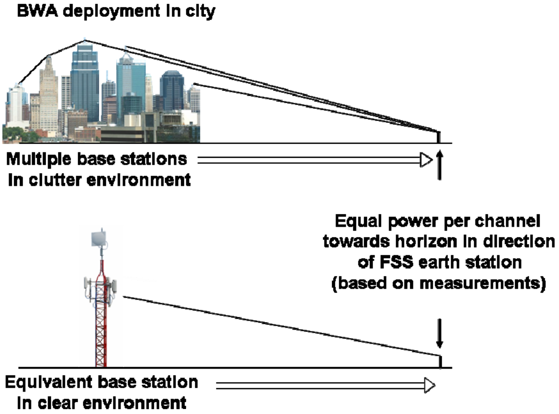


Fig. 5. Modelling of MS deployment in a city

The total outage percentage due to deployments in several cities still depends on the extent to which the propagation loss on paths between the base stations in the various cities and the satellite earth stations are correlated. Again these paths can be close together or partly coincide (suggesting some or high correlation) or be widely separated (suggesting low or no correlation). At the moment that this study was performed, no model to predict the correlation in the path losses between different paths was available. This forced us to compute both the best-case (full correlation) and worst-case (no correlation) situation which, even for a limited number of cities with MS network deployments, leads to calculated outage percentages with a large difference.

As an example, we consider the case of a large scale MS network deployment in 15 cities (of which one is in Germany) and its effect on FSS systems located in Burum.

Fig. 6. Example of a large scale MS network deployment in 15 cities

Since in Burum multiple satellite ground terminals are present, the outage due to MS interference has been calculated for all visible satellite locations. For the satellite ground terminals, the following parameters are used: 11 meter dish, 75°K system noise temperature. In addition, the (satellite) link margin is taken to be 3 dB.

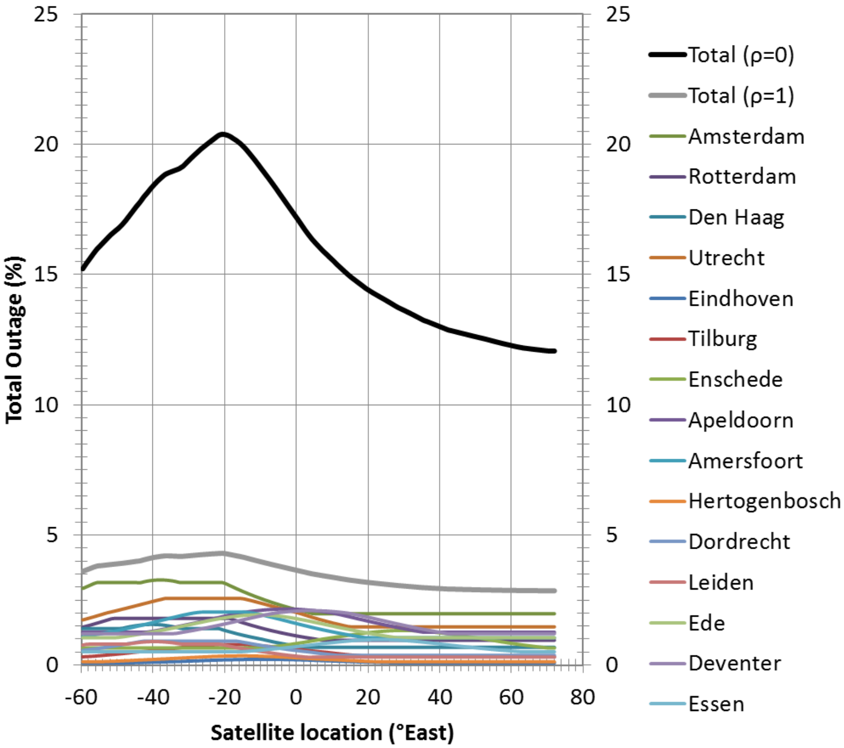


Fig. 7. Outage caused by each city and total outage assuming full correlation (ρ=1) and no correlation (ρ=0)

As shown in the figure above, the large scale MS network deployment results in outages of 2.9 ~ 4.3 % (correlated) and 12.1 ~ 20.4 % (uncorrelated) respectively, depending on which satellite (location) the satellite ground terminal is aimed. This shows that both assumptions (fully correlated or uncorrelated) lead to quite different results.

To obtain more accurate predictions, a recognized model to predict the correlation of the path losses between different paths is highly desired. Although not yet available, research is on-going in order to gain further insight in the correlation between path losses and thus to be able to develop an adequate model [8], [9].

5 Conclusion

Spectrum sharing requires a model by which interference can be accurately predicted. The current model is suitable if only a small number of dispersed interferers have to be considered. For more complex scenarios, as cellular like deployments in cities where many base stations are located within a relative small area in a clutter environment, it is less suited and will result in an overestimation of the outage percentage. To obtain more accurate predictions, a recognized model to predict the correlation of the path losses between different paths is required. This requirement is stressed by the burdens involved with implementing the mitigation techniques necessary to meet the objectives, which should be kept to a minimum.

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