Frequency Sharing of IMT-2020 and Mobile Satellite Service in 45.5–47 GHz

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Abstract. In this paper, the possibility on frequency sharing of IMT-2020 and mobile satellite systems (MSS) in the 45.5–47 GHz band is investigated. This study is of great importance to related research community, industry and regulators which are currently investigating spectrum requirements and technology options for IMT-2020 and beyond. Focusing on the scenario of MSS GSO uplink as victim, we analyzed the interference from IMT-2020 to the MSS receiving GSO satellites (Sat) and compared that with the predefined threshold to assess whether the frequency sharing is possible. Different density of IMT-2020 stations and elevation areas are considered in sharing analysis. In addition, separation distance needed is simulated in terms of separation longitudes.

Keywords: International Mobile Telecommunication (IMT)
Mobile Satellite Service (MSS) · Frequency sharing · Interference assessment

1 Introduction

The development of IMT for 2020 and beyond is expected to enable new use cases and applications and addresses rapid traffic growth, for which contiguous and broader channel bandwidths than currently available for IMT systems would be desirable. This suggests the need to consider spectrum resources in higher frequency ranges [1]. The recent past WRC-15 has adopted the resolution of studies on frequency-related matters for IMT identification including possible additional allocations to the mobile services on a primary basis including 45.5–47 GHz bands for the future development of IMT for 2020 and beyond [2]. However, this band has been allocated on a co-primary basis to MSS [3], thus making it necessary and meaningful to study the sharing and compatibility of IMT-2020 and MSS.

Lots of work has done on sharing of IMT and other services, most of which are limited to IMT-2000 and IMT-Advanced systems. International Telecommunication Union (ITU) has published the relating reports on sharing of IMT-2000 and other services in [4], and that of IMT-Advanced and other services in [5, 6]. However, sharing of IMT-2020 and other services is in its infancy. Study of coexistence between

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5G small cells and Fixed Service (FS) at 39 GHz is done in [7], where required frequency rejection is given for tolerable interference on FS resulting from IMT-2020. [8] focuses on the spectrum sharing between IMT-2020 and Fixed Satellite Service (FSS) at 28 GHz, where the achievable performance of 5G under the FSS interference is simulated. [9] analyzed the coexistence of MSS and MS in 2.1/1.9 GHz band, and interference from MS on MSS is done assuming the MS CDMA scheme.

However, existing research mainly focused on the interference to earth stations (ES) and few concerned that to receiving Sat. Besides, aggregate interference from IMT on MSS is analyzed without consideration of IMT stations numbers. To the authors' best knowledge, few studies has assessed on frequency sharing of IMT-2020 and MSS at 45.5–47 GHz band. We focus on the interference from IMT systems to MSS receiving GSO Sat in 45.5–47 GHz with co-channel interference specified.

Existing work can be guide on our study, but still many challenges are undergo. Propagation model, power control schemes and antenna radiation patterns can all do effect on the frequency sharing of IMT-2020 and MSS. In particular, we consider the parameters provided by ITU, 3GPP and other newly publications. We first verify the interference scenarios and classify the interference cases in detail. Then we analyze the interference of IMT-2020 on MSS satellites in terms of different operating elevations and various densities of IMT nodes. In addition, the separation between IMT systems and MSS is simulated in terms of separation longitude with different operating latitudes. The contributions of this paper are twofold as follows:

- We evaluate and analyze the interference from IMT-2020 to MSS receiving GSO Sat in the band of 45.5–47 GHz with co-channel interference specified.
- We test different IMT station densities on simulation. Effective area percentage and equivalent UEs density are defined to describe aggregate interference from IMT to MSS.

The paper is organized as follows: Sect. 2 is the system model and interference assessment. Section 3 describes the simulation methods and the results analysis. Section 4 concludes the paper.

2 System Model and Interference Assessment

2.1 Sharing Scenario

We consider the coexistence scenario of MSS and IMT networks as illustrated in Fig. 1 where the MSS spot beam GSO satellite (Sat) and IMT-2020 is specified. In addition, no cooperation of these two networks is assumed.

2.2 Interference Assessment

The interference scenario from IMT to MSS uplink can be illustrated as Fig. 1. Detailed interfering model can be classified into 2 cases and separately denoted by C1–C2 in Fig. 1.

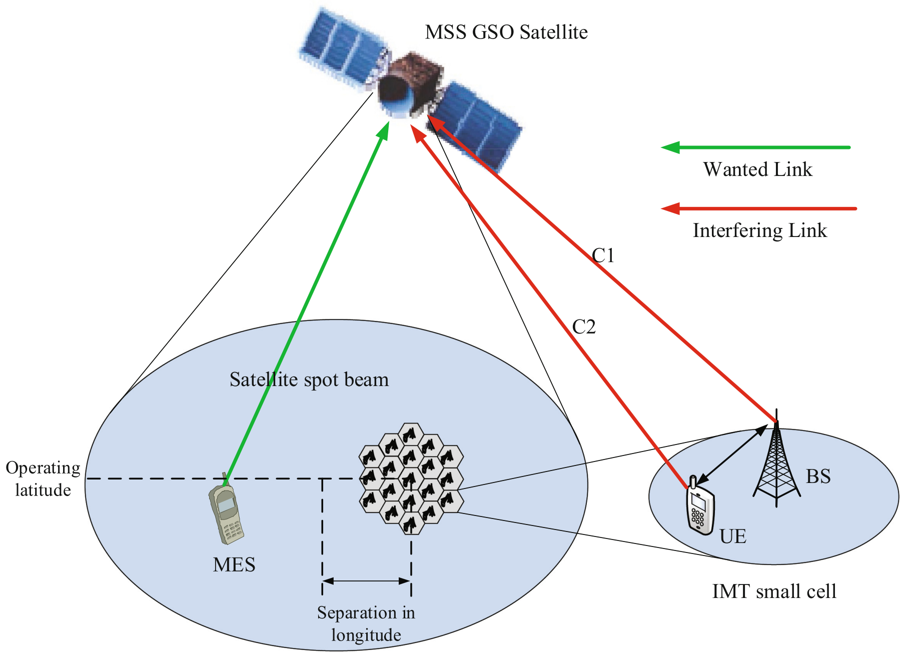

Fig. 1. Frequency sharing scenario of IMT and MSS

- **Case 1:** IMT downlink interfere MSS uplink, denoted by C1.
- **Case 2:** IMT uplink interfere MSS uplink, denoted by C2.

For C1–C2 each case, the interfering link contains two nodes, that is IMT transmitting nodes and MSS received nodes, denoted by *Tx* and *Rx* separately, where *Tx* limits to the IMT BS or UE while *Rx* limits to the MSS Sat. Transmit powers of i_{th} *Tx* is denoted by $P_i(Tx)$. Interference j_{th} *Rx* received from i_{th} *Tx* is $I_{j,i}$ and can be expressed as Eq. (1):

$$I_{j,i} = P_i(Tx) + G_i(Tx,\ \theta_d) + Gj(Rx,\ \theta_a) - PL_{j,i} \tag{1}$$

where the θ_d is the angle of departure for transmitting signals and the θ_a is the angle of arrive for the receiving signals, as illustrated in Fig. 2.

Omnidirectional radiation pattern is supposed as IMT-2020 BS antenna, with the vertical radiation pattern is referenced in [10]. For MSS Sat antenna pattern, we assumed a tapered circular apertures antenna with uniform distribution, described in Eq. (2) with $n = 0$ [11].

$$G(\phi) = G_{\max}\left|2^{n+1}(n+1)!\frac{J_{n+1}(\phi)}{(\phi)^{n+1}}\right|^2 \tag{2}$$

Antenna patterns for MSS Sat and IMT-2020 BS are shown in Fig. 3.

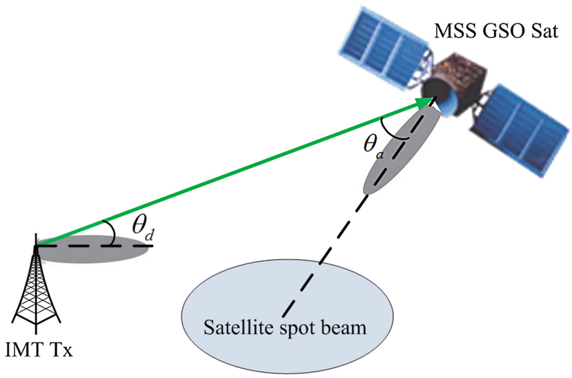

Fig. 2. Antenna radiation pattern for BS and Sat

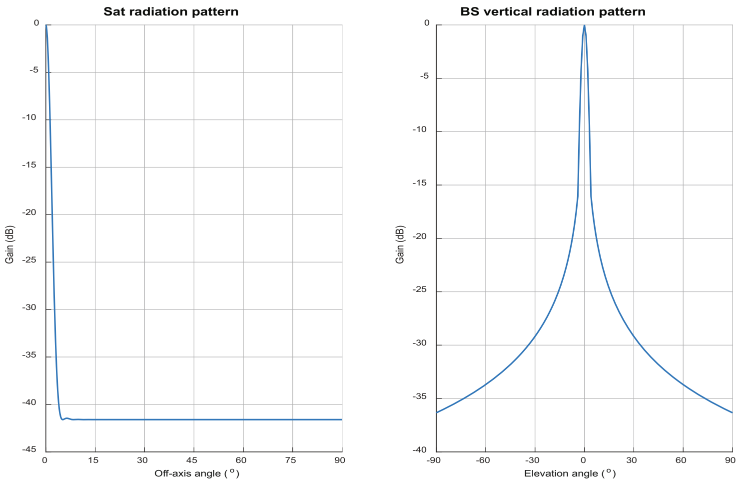

Fig. 3. Antenna radiation patterns for IMT BS and MSS Sat

Note that Tx power is assumed to be controlled with an LTE-like power control mechanism [12]. The uplink power control parameter PL_{x-ile} value is modified to 105.9 dB, with shadowing effect considered.

The path-loss $PL_{j,i}$ is calculated based on line-of-sight (LOS) in Recommendation ITU-R P.2001-2 [13] expressed as follows:

$$PL = 92.44 + 20\lg(fc/GHz) + 20\lg(d/km) + L_o \tag{3}$$

where L_o means other losses, characterized by operating frequency, MES elevation and local climate etc. L_o is mainly determined by rain attenuation with other inevitable factors like atmospheric attenuation and cross-polarization discrimination. Rain attenuation for p% percent of the time where p ranges from 0.001 to 1.0 is calculated about 13 dB for a typical city with specific p = 0.01, 58 mm/h rain drops is supposed [14].

Then the interference on j_{th} Rx considering number of N_{Tx} Tx should be summed as described in Eq. (4):

$$I_j = \sum_{i=1}^{N_{Tx}} I_{j,i} \tag{4}$$

The whole interference of IMT on MSS will be averaged as Eq. (5):

$$I = \frac{1}{N_{Rx}} \sum_{j=1}^{N_{Rx}} I_j \tag{5}$$

Interference from IMT systems on existing MSS systems should be compared with the pre-defined interference threshold. We select an equivalent satellite link noise temperature rise, $\Delta T/T = 6\%$, as the maximum interference threshold [15], where $\Delta T/T$ is defined as follow:

$$\frac{\Delta T}{T} = \frac{I}{N_0 B_{ref}} \tag{6}$$

where I is the receiving interference in the bandwidth of B_{ref}, N_0 is the thermal noise density corresponding to the equivalent noise temperature of the satellite link, B_{ref} is the MSS link reference bandwidth.

3 Performance Evaluation

3.1 Simulation Environment

Deterministic calculations, while being simple, do not always provide a complete picture of the interference scenarios that arise. For this reason, we use the recommended Monte Carlo method in simulation analysis [16]. Table 1 lists the system parameters in simulation.

3.2 Results and Analysis

3.2.1 Different IMT-2020 Stations Density

For area of satellite spot beam and IMT small cell are greatly different in size, and number of IMT BSs or UEs can do make difference on aggregate interference assessment. We define the effective area percentage (EAP) to describe the deployed IMT area in a spot beam.

Table 1. System parameters

Parameter	Value
IMT-2020 system	
Carrier frequency	46 GHz
Inter-site distance	200 m
BS transmit PSD	36 dBm/MHz
BS antenna pattern	Equation (1d) Ref [10]
BS feeder loss	1 dB
UE transmit PSD	7.5 dBm/MHz
UE feeder loss	1 dB
MSS system	
Sat transmit power	50 W
Sat antenna main lobe gain	41.6 dBi
Sat antenna radiation pattern	Equation (2)
Link noise temperature	501 K

$$EAP = \frac{Area\ of\ IMT}{Area\ of\ spot\ beam} \tag{7}$$

Figure 4 shows the interference of IMT BSs to MSS receiving GSO Sat on different EAP and MES elevations. The results show that $\Delta T/T$ always exceeds the threshold of $\Delta T/T = 6\%$, making it scarcely possible to deploy IMT-2020 downlink co-frequency with MSS uplink in the same geographical region.

We define the Equivalent UEs Density (EUD) as the ratio of total UEs and area of spot beam, described as Eq. (8).

$$EUD = \frac{Number\ of\ UEs}{Area\ of\ spot\ beam} \tag{8}$$

Figure 5 shows the interference from IMT UEs to MSS receiving GSO Sat on different EUD. The results show that $\Delta T/T$ exceeds the threshold of $\Delta T/T = 6\%$ when EUD exceeds about $600/\text{km}^2$. Typical IMT-Advanced active UE density is $18/\text{km}^2$ for dense urban macro, $115/\text{km}^2$ for dense urban micro [5]. Considering the IMT-2020 new arising Machine-to-Machine (M2M) services, M2M device subscribers will occupy an increasingly large proportion in UEs. For example, subscriptions in China in 2030 are predicted to be 22.7 billion, about 450 times of 50 million in 2013 [17]. Likelihood or not of sharing between IMT-2020 interfering UEs and MSS receiving GSO Sat will be possible only once whether used for M2M services in this band, the accurate EUD of IMT-2020 and that of specific RF technical characteristics in a satellite spot beam will be made available.

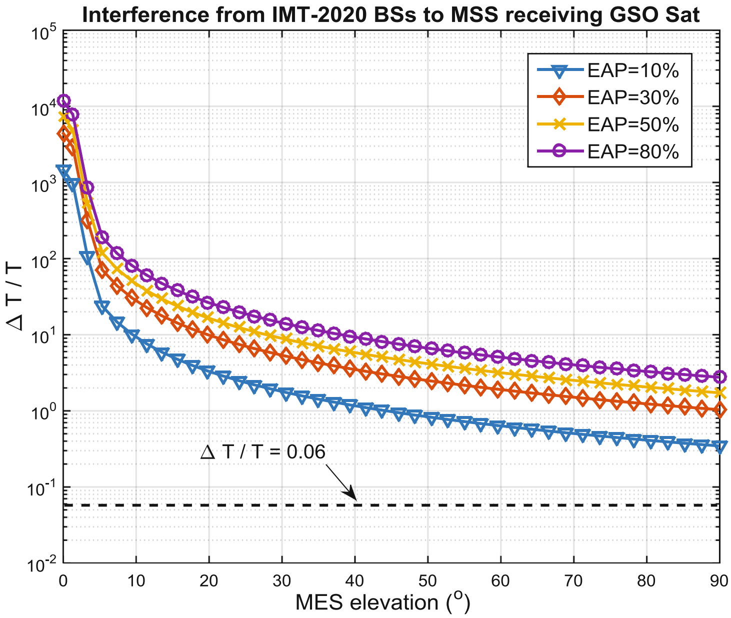

Fig. 4. Interference from IMT-2020 BSs to MSS receiving Satellite

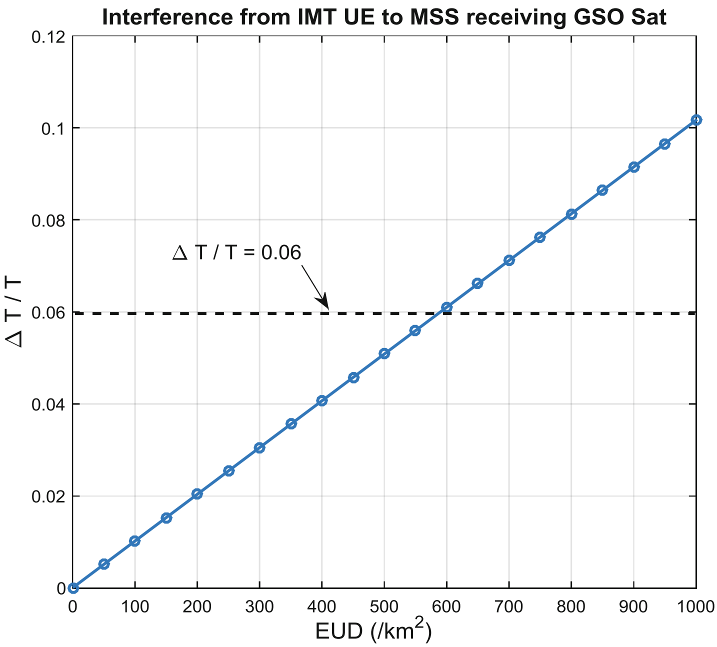

Fig. 5. Interference from IMT-2020 UEs to MSS receiving Satellite

3.2.2 Separation Needed in Longitude

To keep the interference of IMT BSs to victim MSS GSO Sat under the threshold, additional loss should be provided by alternative geographic separation, here particular refer to separation in longitude (SiL) as illustrated in Fig. 1. Same latitude of satellite spot beam and IMT deployment, IMT BSs density of $EAP = 30\%$ are supposed.

Figure 6 shows the interference of IMT BSs to MSS receiving GSO Sat in terms of different of MES elevations and SiLs. It shows that the needed SiL differentiate with the operating MES elevation. The SiL increases as MES elevation is smaller for IMT BSs has bigger antenna gain towards MSS receiving GSO Sat. From Fig. 6, the SiL should be more than about 7° when MES elevation is 90° to guarantee the MSS GSO Sat.

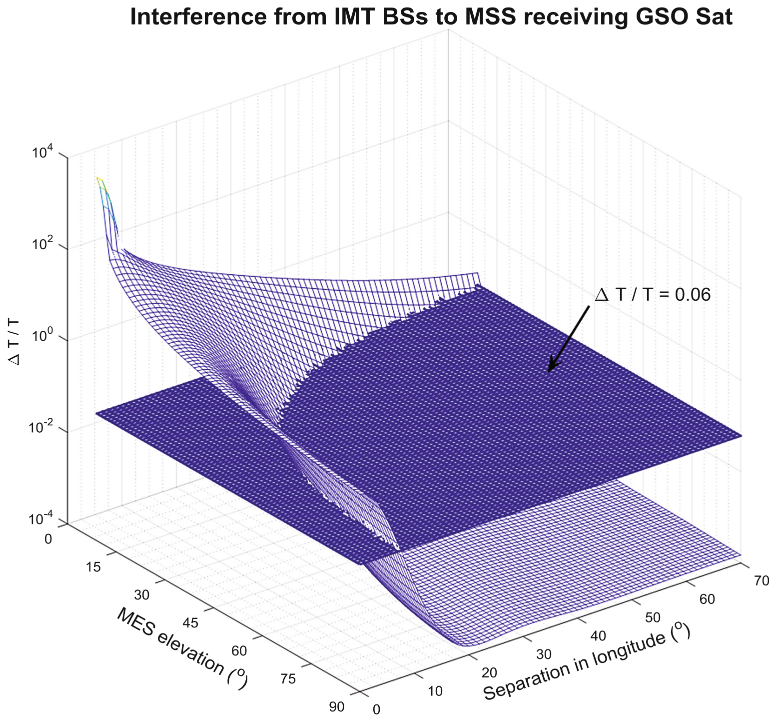

Fig. 6. Interference from IMT-2020 BSs to MSS receiving Satellite under different longitude separations and MES elevations

4 Conclusion

In this paper, we investigated the frequency sharing of IMT-2020 and MSS in the band between 45.5–47 GHz. The interference from IMT on receiving MSS GSO Sat is simulated and compared with the predefined threshold. Particularly, we analyzed the interference in terms of different IMT deployment densities and MES elevations. In addition, the separation needed to protect the MSS GSO Sat from IMT BSs excessive interference is given in terms of longitude separation. Simulation can be reference guide for spectrum relating issues for IMT-2020 and beyond.

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