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Preliminary Coexistence Studies between IMT-2020 systems and inter-satellite service in 26 GHz

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Abstract. This paper focuses on the sharing and compatibility studies of International Mobile Telecommunications 2020 (IMT-2020) and inter-satellite service (ISS) in 26 GHz frequency band, which was selected by International Telecommunications Union (ITU) as one of the most promising candidate frequency bands for 5G. Based on relevant ITU recommendations and reports, and current technical characteristics of both systems, a methodology is developed for the interference coexistence analysis between them. The spatial and temporal distribution analysis is proposed and the calculation of IMT-2020 aggregate interference takes the actual urban population into consideration. The results show that these two systems have considerable possibilities in coexistence in 26 GHz frequency band.

1 Introduction

Spectrum is one of the most basis factors of the development of IMT industry. As the demand for broadband wireless communication is growing at a high rate of speed, the deficits of spectrum requirement continue to increase. For the present, there is almost no more abundant frequency band can be used below 6 GHz, and then, finding several higher frequency bands for IMT-2020 is extremely necessary [1]. In this regard, International Telecommunications Union (ITU) has pointed out 11 candidate frequency bands (ranging 24.25-86 GHz) above 6 GHz during 2015 World Radiocommunication Conference (WRC-15) and asked for some feasibility verification on a worldwide scale [2]. ITU-R also set up Task Group 5/1 particularly and established Agenda Item (AI) 1.13 in WRC-19 to explore whether it is possible to share frequency bands between IMT and incumbent services.

24.25-27.5 GHz band (referred to as the 26 GHz band) is the lowest section in these candidate frequency bands of WRC-19 AI 1.13 and this band is already allocated to mobile service as a primary service in ITU Radio Regulations [3]. Thanks to its relatively low frequency and consecutively large bandwidth, 26 GHz band is attached great importance by the world and regional organizations, considering it to be utilized for the 5th generation mobile communication as soon as possible. However, there have been several incumbent services already. Before global commercial deployment, it is obligatory to ensure IMT system do not interfere with other incumbents.

Among the incumbents, inter-satellite service (ISS) operating in 25.25-27.5GHz gets much more concerns because of its complicacy and typicality [4]. It is necessary to conduct the sharing and compatibility studies to verify its coexistence possibility with IMT. This paper focuses on this issue. Based on ITU recommendations and reports, and current technical parameters of both systems, a methodology is developed for the interference coexistence analysis. The spatial and temporal distribution analysis is proposed and the calculation of IMT-2020 aggregate interference takes the actual urban population into consideration. The results show that these two systems have considerable possibilities in coexistence in 26 GHz frequency band. In the following, Section 2 briefly introduce the research background of ISS in 26 GHz band; Section 3 shows the technical characteristics of IMT and ISS in 26 GHz band; in Section 4, the methodology regarding IMT large-scale deployment is proposed; Section 5 gives the simulation results and summary is made in Section 6.

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2 Allocation Information

According to the Radio Regulations of ITU, ISS is allocated in the frequency band 25.25-27.5 GHz as primary service listed in Table 1 as below.

Table 1. Frequency allcation in the 25.25-27.5 GHz frequency range

International Table		
Region 1	**Region 2**	**Region 3**
25.25-25.5 FIXED INTER-SATELLITE MOBILE Standard frequency and time signal-satellite (Earth-to-space)		
25.5-27 EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED INTER-SATELLITE MOBILE SPACE RESEARCH (space-to-Earth) Standard frequency and time signal-satellite (Earth-to-space)		

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International Table		
Region 1	**Region 2**	**Region 3**
27-27.5 FIXED INTER-SATELLITE MOBILE	27-27.5 FIXED FIXED-SATELLITE (Earth-to-space) INTER-SATELLITE MOBILE	

ITU Radio Regulations advise that use of the 25.25-27.5 GHz band by the inter-satellite service is currently in accordance with space research and Earth exploration-satellite applications, and transmissions of data originating from industrial and medical activities in space.

According to [5], the inter-satellite service in 25.25-27.5 GHz works in uplink transmission, i.e., a satellite from geostationary satellite orbit (GSO) receives signal from a satellite or spacecraft from non-geostationary satellite orbit (non-GSO/NGSO). GSO is relatively static towards the Earth while its receiving antenna would keep tracking the location of non-GSO, which circles the Earth periodically. Because of the large height gap (GSO with 36,000 km above the ground and non-GSO with about 400-1000 km above the ground); the height of non-GSO is almost similar to that on the ground. And the interference occurs only when the GSO, which is tracking the non-GSO, is pointing also to the ground where there are considerable IMT network deployments (See Figure 1). To model the interfering scenario, it is critical to know how IMT system deploys and the GSO-NGSO tracking process.

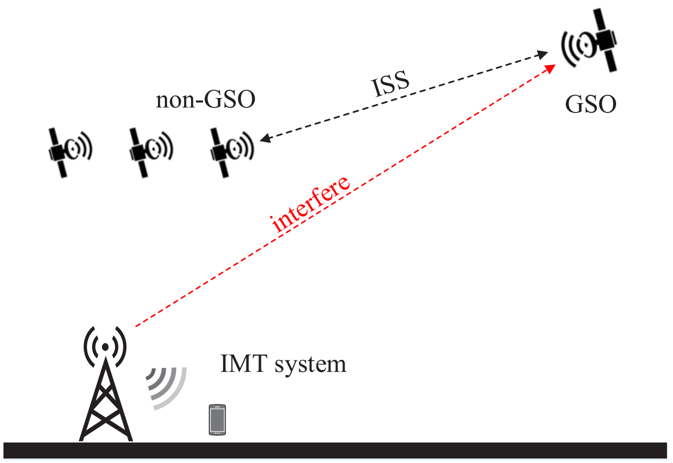

Figure 1. Typical scenario of interfered ISS

3 Technical Characteristics

This section provides the specific parameters used in the study. In particular, this paper mainly focuses on the interference from IMT to ISS in the same frequency band, which is the most important issue.

3.1 IMT system characteristics

Based upon many research cases [6], the interference from downlink is much more than that from uplink. Thus it is critical to study the interfering behavior of base station (BS) in IMT system. According to the study group of IMT in ITU [7][8], characteristics of BS for frequency sharing/interference analysis in the frequency range 24.25-33.4 GHz are listed in Table 2as below.

Table 2. Base station characteristics

Frequency	26 GHz
Duplex mode	TDD
Network topology density	30 BSs/km2
Network loading factor	20%
Antenna height	6 m (above ground level)
Sectorization	Single sector
Downtilt	10 degrees
Antenna pattern	Refer to Recommendation ITU-R M.2101
Element gain	5 dBi
Horizontal/vertical 3 dB beamwidth of single element	65° for both H/V
Horizontal/vertical front-to-back ratio	30 dB for both H/V
Antenna polarization	Linear ±45°
Antenna array configuration (Row × Column)	8x8 elements
Horizontal/vertical radiating element spacing	0.5 of wavelength for both H/V
Array Ohmic loss	3 dB
Conducted power (before Ohmic loss) per antenna element	10 dBm/200MHz
Base station maximum coverage angle in the horizontal plane	120 degrees

One obvious difference between 5G and 4G is that the massive MIMO is introduced in the sharing and compatibility studies. And in each time snapshot, the antenna main beam might point to different users, resulting in different interference level. When the electrical down-tilt steering and the electrical horizontal steering are both zero, a composite array pattern for 8x8 elements is shown in Figure 2. It is equivalent to that the served user equipment (UE) is located at a point in the normal direction of this antenna panel. The explicit formulas are referred in REC. M.2101 and the derivation procedures are shown in 3GPP TR 37.840 [9].

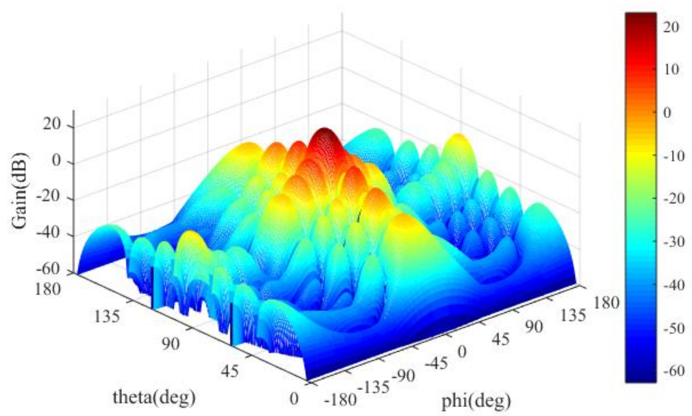

Figure 2.BS antenna gain pattern

20% network loading factor would normally represent a typical/average value for the loading of base stations across a

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large-scale network and therefore can be used for wide area analysis (province, national or larger satellite footprint, for example). It is necessary to introduce some modified parameters of the BS density to analyze large-scale deployment.

ITU has invented two parameters (Ra and Rb as shown in Table 3) to build a relationship between amounts of BS and land area where the IMT system would be. For instance, the land area of China is about 9.6 million km2 and it would be supposed that there are 1,008,000 (9,600,000km2*7%*5%*30BSs/km2) IMT-2020 base stations nationwide. Although this parameter represents an average value, not distinguished regarding the IMT demands from different countries, they are discussed and agreed by experts from the world in ITU.

Table 3. Large-scale deployment characteristics

Ra	7% for Urban
Rb	5%
Land area of China	9,600,000 km2

3.2 ISS system features

According to the ISS study group in ITU-R [10] and ITU-R REC. SA.1414 as Reference [5], the characteristics of ISS in the frequency range 25.25-27.5 GHz is shown in Table 4. This paper takes China's parameter as the case study, where the GSO is data-relay satellite (DRS) and non-GSO is referred to as spacecraft.

Table 4. Characteristics of existing DRS system

Transmitting spacecraft	
Network	China
Orbital locations	300-500 m (400 m for simulation)
Frequency range	25.25-27.50 GHz
Transmission rate	≤ 600 Mbit/s
Modulation	PSK
Polarization	Circular
Antenna size	≤ 0.8 m
Tx antenna gain	≤ 44.5 dBi
Tx antenna pattern	Rec. ITU-R S.672
Necessary bandwidth	≤ 600 MHz
Maximum e.i.r.p spectral density	-5.5 dBw/Hz
Receiving DRS	
Network	China
Orbital locations	Rec. ITU-R SA.1275 or Rec. ITU-R SA.1276
Antenna size	4.2 m
Rx antenna gain	57.5 dBi
Rx antenna pattern	Rec. ITU-R S.672
System noise temperature	1000 K
Interference criterion	I/N = -10 dB [11]

According to the satellite antenna radiation pattern from ITU-R REC. S.672 [12], Figure.3 represents the simulation result of receiving DRS/GSO antenna gain.

The propagation models for sharing and compatibility studies take the free space loss, atmospheric loss and clutter loss into account, based on the study group in ITU-R [13] and ITU-R REC. P.619 [14]. According to the elevation of each base station, the clutter loss is averaged under probabilities of different location.

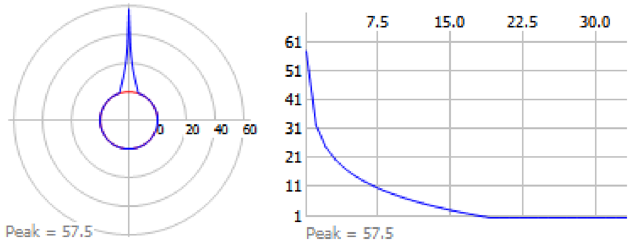

Figure 3. Receiving DRS antenna gain pattern

4 Analysis Process

To model the IMT aggregate interference towards the GSO receiver, it is difficult to simulating the BSs one by one, especially for a national scale. The approach embodied in this paper is developed referring ITU-R REC. F.1509 [15], where it is preferred to use a center base station (CBS) to replace a great area of IMT BSs. Each CBS's transmitting power is the sum of BS's power of all that coverage. In this paper, 36 cities are chosen as CBSs in mainland of China based on their special position (See Figure 4). Among them, 27 cities are provincial capitals, four are municipalities and five are specifically-designed cities in the state plan, as listed in Table 5.

Figure 4. The locations of 36 center base stations

Table 5. Center base station information

City	Population (million)	Weight	Packing BSs numbers
Beijing	19.61	6.52%	65722
Shanghai	23.02	7.65%	77138
Guangzhou	12.70	4.22%	42561
Shenzhen	10.36	3.44%	34710
Chongqing	28.85	9.59%	96664
Nanjing	8.00	2.66%	26824
Xi'an	8.47	2.82%	28376
Wuhan	9.79	3.25%	32791
Zhengzhou	8.63	2.87%	28908
Tsingtao	8.72	2.90%	29205
Tianjin	12.94	4.30%	43356

City	Population (million)	Weight	Packing BSs numbers
Shenyang	8.11	2.69%	27164
Chengdu	14.05	4.67%	47074
Hangzhou	8.70	2.89%	29155
Xiamen	3.86	1.28%	12935
Ningbo	5.33	1.77%	17861
Dalian	6.69	2.22%	22418
Shijiazhuang	10.70	3.56%	35861
Harbin	10.64	3.54%	35642
Fuzhou	7.06	2.35%	23658
Jinan	7.06	2.35%	23658
Kunming	6.68	2.22%	22375
Lanzhou	4.02	1.33%	13456
Taiyuan	4.32	1.44%	14472
Changchun	7.73	2.57%	25900
Hefei	7.79	2.59%	26105
Nanchang	5.30	1.76%	17760
Changsha	7.31	2.43%	24501
Haikou	2.25	0.75%	7526
Guiyang	4.62	1.54%	15488
Xining	1.25	0.42%	4190
Hohhot	3.00	1.00%	10056
Nanning	6.99	2.32%	23411
Yinchuan	2.16	0.72%	7252
Lhasa	0.58	0.19%	1931
Urumqi	3.55	1.18%	11896
Total	300.80	100.00%	1008000

The packing BSs numbers and their weight are determined by population while the total number of BSs in mainland China is about 1,008,000 that have been mentioned in Section III. For example, the population of Beijing occupies 6.52% of the total population and its packing BSs number is 65,722 with the same percent of 1,008,000. The packing number would be turned into decibel and added to the transmitting power of a BS,hence creating one CBS's transmitting power.

Combined with the CBS deployment, simulation analysis can be divided into two different but complementary methods:

- Spatial distribution, where the aggregate interference to a DRS at a specified orbital location is computed as the high-gain receiving antenna of the DRS/GSO is scanning its whole visible area.
- Temporal distribution, where it is supposed to compute the temporal characteristics of the interference from IMT to DRS/GSO, when GSO is tracking non-GSO.

5 Simulation Result

The aggregate impact of BS is analyzed in the following steps. In both cases, the simulation takes into account:

1) Step 1: Choose a DRS/GSO at E59/113/169 degrees as the victim satellite in interfered ISS system.

2) Step 2: Distribute uniformly the horizontal direction of each CBS's array antenna panel.

3) Step 3: For each CBS, uniformly generate much enough users within 40 meters. And calculate the relative antenna beamforming gain towards the victim DRS/GSO satellite when its mean beam is pointing to one random selected user.

4) Step 4: Calculate the link budget from each CBS's transmitter to the victim DRS satellite receiver.

5) Step 5: Calculate the aggregate interference and use the ratio of interference and noise (I/N) in decibel as the interference result.

5.1 Spatial distribution analysis

It is assumed a low-orbiting satellite is moving over the land area of China while its DRS keeps tracing it and scanning the area of IMT system in a grid-based manner. The step size of the grid is 50 km throughout the scanned area, and every spot in this grid will be snapshotted for 500 times. Figure 5 to Figure 7 are the average interference-noise ratio results for the three victim DRS.

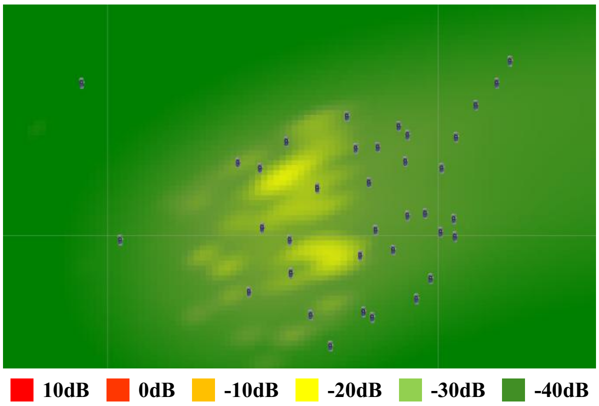

Figure 5. The spatial simulation result of the victim DRS at E59 degrees

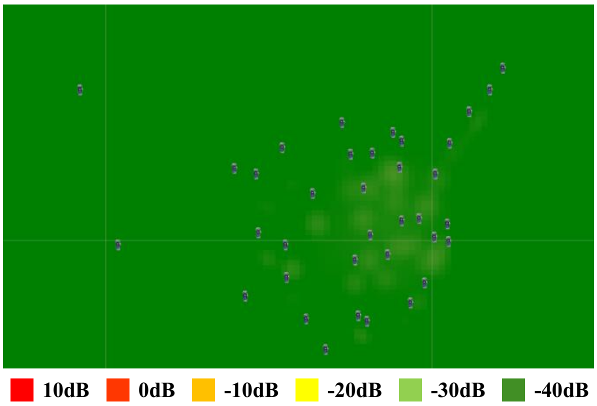

Figure 6. The spatial simulation result of the victim DRS at E113 degrees

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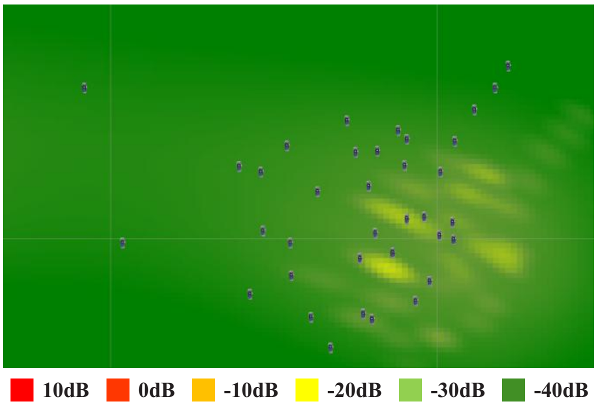

Figure 7. The spatial simulation result of the victim DRS at E169 degrees

The protection criterion of ISS is listed in Table 4, the spatial distribution results from these three interference scenarios are all under *I/N* = -10 dB. A few areas have peak value at about -20dB and the average of interference margin seems to be more than 10dB for these scenarios.

5.2 Temporal distribution analysis

In this case, a dynamic simulation is used. A DRS satellite with the receiving system is assumed to be located at a prescribed geostationary orbital location and to be tracking a moving low-orbiting satellite inclined by 57 degrees with respect to the equatorial plane (randomly selected). The simulation is time step based, with step size 1 second. At each step, the aggregate interference to the DRS receiving system from the 36 CBSs is calculated. The total simulation time is 365 days.

1) DRS & low-orbiting satellite: The DRS at E59/113/169 degrees is tracking a representative low-orbiting satellite respectively. The results inclueded the relationship of I/N and simulated time as well as its CDF scheme are shown in Figure 8 to Figure 10.

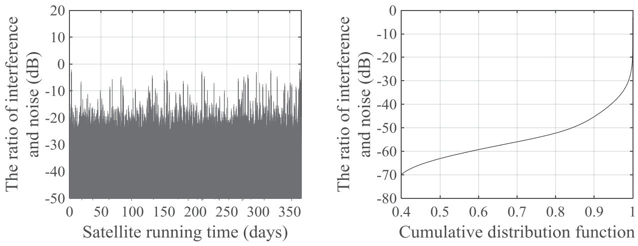

Figure 8. The temporal results of the DRS at E59 degree & a low-orbiting representative from ITU-R SA.1414.

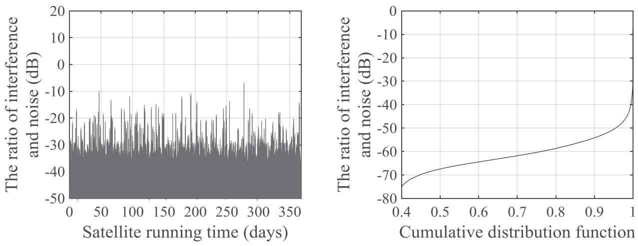

Figure 9. The temporal results of the DRS at E113 degree & a low-orbiting representative from ITU-R SA.1414.

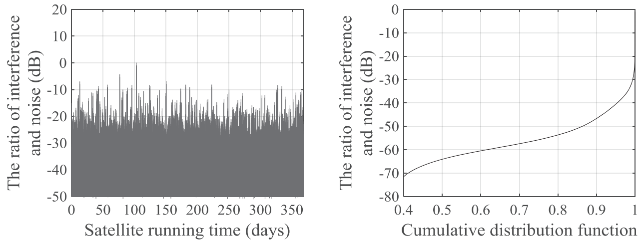

Figure 10. The temporal results of the DRS at E169 degree & a low-orbiting representative from ITU-R SA.1414.

2) DRS & low-orbiting satellite constellation: The DRS at E59/113/169 degrees is tracking a practical constellation, which constituted by 10 satellite units (See Figure11). The tracking strategy is to establish transmitting link with the nearest satellite unit in the in visible area range, as a scheduling method.

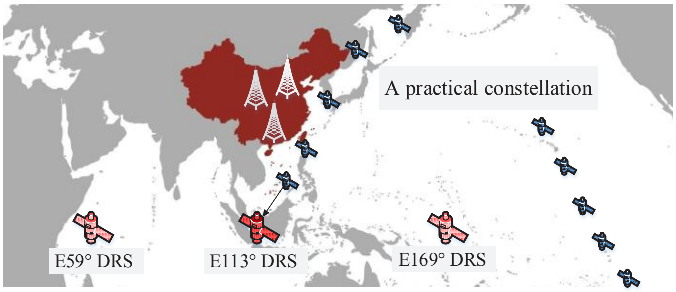

Figure 11. The sketch map of the DRS at E113 degrees tracking a ten-unit constellation

Figure 12 to Figure 14 present the simulation results of DRS at different orbit respectively.

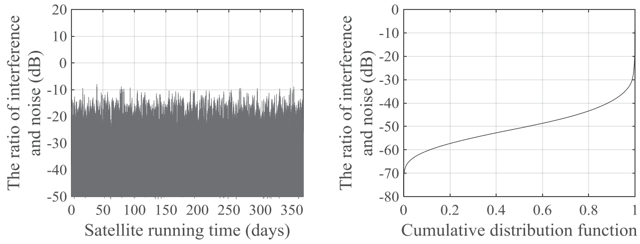

Figure 12. The temporal results of the DRS at E59 degree & practical constellation

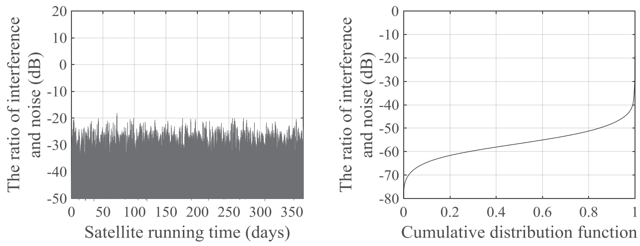

Figure 13. The temporal results of the DRS at E113 degree & practical constellation

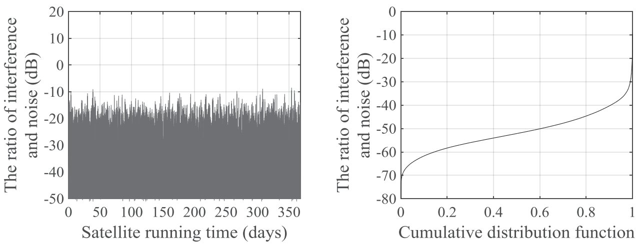

Figure 14. The temporal results of the DRS at E169 degree & practical constellation

To measure whether it exceeds the protection level or interference criterion of ISS, the percent of interfered time is computed in Table 6. Except for the criterion of interference value, there is also a ceiling margin (0.1%) of the percent of time with I/N > -10dB. As shown below, all results of the interference from IMT to the receiving DRS are far less than this percent margin.

Table 6. Interference result

Scenario	The percent of time with I/N>-10dB in satellite running time
GSO 59° , Custom non-GSO	0.00679%
GSO 113° , Custom non-GSO	0.00019%
GSO 169° , Custom non-GSO	0.00245%
GSO 59° , constellation	0.00057%
GSO 113° , constellation	0
GSO 169° , constellation	0.00038%

6 Conclusion

This paper introduces a methodology which aggregates large-area IMT base stations into a certain amount of center base stations properly, and takes China as an example to model IMT system interfering the DRS of inter-satellite service. For spatial distribution, the aggregate interference from downlink IMT system does not exceed the interference criterion of DRS receiver in ISS system. For temporal distribution, it is also under control in long-term operation. Based on these preliminary results, it is considered IMT will not cause harmful interference to ISS. Further studies may concentrate on the uplink aggregate interference from UEs, more complicated propagation model and larger area range with more CBSs.

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