Sharing and compatibility studies of IMT systems with Earth Exploration-Satellite Service in 26 GHz frequency band

Zhaojun Qian*, Tan Wang, Zheng Fang, Tianqi He
State Radio Monitoring Centre, Beijing, 10037, China
School of Electrical & Electronic Engineering North China Electric Power University, Beijing, 102206, China
qianzhaojun@srrc.org.cn    He.tian.qi@163.com

Abstract. In this paper, the coexistence interference of 26 GHz-band International Mobile Telecommunications (IMT) and Earth Exploration-Satellite Service is analyzed based on actual satellite orbit and ITU-R system characteristic. Specifically, the aggregate interferences of IMT system base stations (BS) and users (UE) to Earth Exploration-Satellite Service earth station are studied, considering high frequency band radio propagation clutter loss. The results show that the IMT base station and user deployment can coexist with the Earth Exploration-Satellite Service in the band. The provided results are useful for design of future 26 GHz IMT-2020 (5G) wireless communications systems and Earth Exploration-Satellite Service.

1. Introduction
The millimeter waves have large available bandwidth and thus gigabit throughput can be easily achieved for future wireless communication systems. The 26 GHz frequency band has been identified as potentially suitable frequency band for IMT (International Mobile Telecommunications) systems [1], in dense urban areas to provide large bandwidth and high volume business [2]. It is assumed that the frequency band 28 GHz would be used as a separate level of coverage without macro cells, making the TDD (Time Division Duplex) more advantageous for such IMT systems. In China, the 26 GHz radio is approved by Chinese Ministry of Information Industry for local multipoint distribution system access network business, this band was carried out in China Mobile, China Telecom, China Unicom, China Netcom [3].

China Meteorological Agency has used 23.6-24 GHz, 36-37 GHz, 50.2-50.4 GHz and 86-90 GHz band as the main passive remote sensing band, moreover 35.5-36 GHz band as an active remote sensing band, and will use the 25.5-27 GHz band as the GSO earth exploration satellite service data transmission band.

This paper will analysis the sharing and compatibility studies of IMT systems’ micro station (BS) and User (UE) with the Earth exploration-satellite service earth station in the 26 GHz frequency band.

2. Allocation information in the 25.25-27.5 GHz frequency range
According to ITU-R Radio Regulation [4], the 26 GHz frequency band allocation are listed in Table 1 as below.
Table 1 Frequency allocations in the 25.25-27.5 GHz frequency range

| Region 1 | Region 2 | Region 3 |
|----------|----------|----------|
| 25.25-25.5 | FIXED | 5.536 |
| INTER-SATELLITE | 5.536 | MOBILE |
| Standard frequency and time signal-satellite (Earth-to-space) |
| 25.5-27 | EARTH EXPLORATION-SATELLITE (space-to Earth) |
| 5.536B | FIXED |
| INTER-SATELLITE | 5.536 |
| MOBILE |
| SPACE RESEARCH (space-to-Earth) | 5.536C |
| Standard frequency and time signal-satellite (Earth-to-space) |
| 5.536A |
| 27-27.5 | FIXED |
| INTER-SATELLITE | FIXED |
| 5.536 | INTER-SATELLITE |
| 5.536 5.537 |
| MOBILE | MOBILE |

5.536 Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications, and also transmissions of data originating from industrial and medical activities in space.

5.536A Administrations operating earth stations in the Earth exploration-satellite service or the space research service shall not claim protection from stations in the fixed and mobile services operated by other administrations. In addition, earth stations in the Earth exploration-satellite service or in the space research service should be operated taking into account the most recent version of Recommendation ITU-R SA.1862. (WRC-12)

5.537 Space services using non-geostationary satellites operating in the inter-satellite service in the band 27-27.5 GHz are exempt from the provisions of No. 22.2.

3. Technical characteristics

This section provides the specific parameters used in the study, as below.

3.1. Technical and operational characteristics of IMT systems operating in the 25.5-27 GHz frequency range

According to the liaison statement from WP 5D to TG 5/1 [5], characteristics of IMT systems for frequency sharing/interference analyses in the frequency range 24.25-33.4 GHz are listed in Table 2 as below.

Table 2 The Parameters of IMT-2020 (5G)

| Parameter                  | Value | Parameter                  | Value                                      |
|----------------------------|-------|----------------------------|--------------------------------------------|
| Bandwidth (MHz)            | 200   | Antenna pattern            | Recommendation ITU-R M.2101 [6]           |
| BS Tx power (dBW)          | -5    | Element gain (dBi)         | 5                                          |
| UE Tx power (dBW)          | -11   | Horizontal/vertical 3 dB   | 65                                         |
|                            |       | beamwidth of single        |                                             |
|                            |       | element (degree)           |                                             |
| Network topology           | 30 BSs/km² | Horizontal/vertical        | 30                                         |
and characteristics

| Frequency reuse | 1 | Antenna polarization | Linear ±45º |
|-----------------|---|----------------------|-------------|
| BS antenna height (m) | 6 | Base station antenna array configuration (Row × Column) | 8x8 elements |
| UE antenna height (m) | 1.5 | UE antenna array configuration (Row × Column) | 4x4 elements |
| Sectorization | Single sector | Horizontal/Vertical radiating element spacing | 0.5 of wavelength |
| Downtilt (degree) | 10 | Array Ohmic loss (dB) | 3 |
| Antenna deployment | Below roof top | Conducted power (before Ohmic loss) per antenna element (dBm/200 MHz) | 10 |
| Network loading factor (%) | 50 | Base station maximum coverage angle in the horizontal plane (degrees) | 120 |
| BS TDD activity factor (%) | 100 | |

3.2. Technical and operational characteristics of Earth exploration-satellite service operating in the 25.5-27 GHz frequency range

1) Satellite orbit parameters and earth station locations

Table 3 lists locations of earth stations that use the frequency bands given in the following sections [7].

Table 3  Non-GSO and GSO earth station locations

| Non-GSO and GSO earth stations | Longitude (deg) | Latitude (deg) |
|--------------------------------|----------------|----------------|
| Beijing [GSO] | 116.3 E | 40.1 N |
| Jiamusi [Non-GSO] | 130.3 E | 46.7 N |

2) Space-to-Earth data transmission from non-GSO satellites

This section provides the RF parameters needed to conduct interference assessments and sharing studies for space-to-Earth data transmission from typical non-GSO satellites [7]. These downlinks originate from instruments on the spacecraft. The characteristics for Non-GSO systems can be found below in Table 4.

Table 4  System parameters for recorded data playback services in the band 25.5-27 GHz

| Parameter | Science data dissemination |
|-----------|---------------------------|
| Carrier centre frequency (MHz) | 26 703.4 |
| Necessary Bandwidth (MHz) | 300 |
| Polarisation | RHCP |
| Earth station antenna diameter (m) | 6.5 |
3) **Raw data downlink and data dissemination for GSO systems**

This section provides the RF parameters needed to conduct interference assessments and sharing studies for raw data downlink and data dissemination for GSO systems [7]. Table 5 includes a typical characteristics for GSO systems.

| Parameter                                           | Value          |
|-----------------------------------------------------|----------------|
| Antenna height (m)                                 | 10             |
| Earth station antenna gain toward satellite (dBi)   | 64.5           |
| Earth station antenna radiation diagram             | Rec. ITU-R S.465-6 |
| Minimum elevation angle (degree)                    | 5              |

Table 5 System parameters for Recorded data playback services in the band 25.5-27 GHz

3.3. **Propagation models for sharing and compatibility studies**

The analyses are based on the propagation models described in Recommendation ITU-R P.452-16 [8]. According to the LS form ITU-R SG3, “The clutter correction in section 4.5 of Recommendation ITU-R P.452 should not be used for the TG 5/1 interference analyses, as it assumes specific knowledge of the location of the transmitter, receiver and nearby obstacles. Instead, the method of the draft new Recommendation ITU-R P.[Clutter] [9] should be used to calculate additional loss due to clutter.”

In the 26.7034 GHz and 26.76 GHz frequency, interference values are calculated using 37.1196 dB and 37.1283 dB Clutter loss median values, respectively. It should be explained that, because the distance of protection in 1km, the value of clutter loss varies with distance, and the actual situation is more complex, so the simulation is only carried out in the protection distance 1km.

3.4. **Protection criterion of EESS**

Recommendation ITU-R SA.1026 [10] contains the interference criteria for space-to-Earth data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit.

| Item                                                                 | Value                      |
|----------------------------------------------------------------------|----------------------------|
| Protection criterion long-term(no more than 20% of the time)         | -140 dBW per 10 MHz        |
Protection criterion short-term (no more than 0.0125% of the time) -116 dBW per 10 MHz

Recommendation ITU-R SA.1160 [11] contains the interference criteria for data dissemination and direct data readout systems in the Earth exploration-satellite and meteorological-satellite services using satellites in the geostationary orbit.

Table 7 Interference criteria for stations in the EESS and MetSat service using spacecraft in the geostationary orbit

| Interfering signal power (dBW) in the reference bandwidth to be exceeded for no more than 20% of the time | Interfering signal power (dBW) in the reference bandwidth to be exceeded for no more than p% of the time |
|---|---|
| –131.7 dBW per 10 MHz | –116.3 dBW per 10 MHz p 0.25 |

4. Technical analysis

4.1. Interference topology from IMT base station / UE to EESS

Recommendation ITU-R M.2101 [6] and last study period[12] provides the methodology how to model the IMT network and use Monte-Carlo simulation to evaluate the aggregated interference to other systems. According to the micro station density (30BS/km²), the earth station around the protective distance, with inter-site distance (200 m), continuous deploy IMT-2020 (5G) micro station (Figure 1), and each IMT-2020 (5G) micro station as the center within 40 meters deploy one IMT-2020 (5G) UE. Each IMT-2020 (5G) UE in an arbitrary position and randomly communication with IMT-2020 (5G) micro station, meanwhile IMT-2020 (5G) micro station point to the IMT-2020 (5G) UE using main beam. Total rings release is three.

It should be noted that IMT-2020 network will only be deployed in hotspot area and not seamless coverage. Some areas will not deploy IMT systems and the real deploy. IMT base station numbers will be less than theoretical calculation value.

Fig 1. Aggregated IMT base stations scenario

This topology is very suitable for EESS earth station located in urban or suburban area which is co-located with IMT systems.

4.2. Calculations

The simulation calculation using Visualyse software, the specific calculation process is as follows:

a) Calculation of EESS earth station off-axis angle
In order to calculate the antenna gain of EESS earth station in the direction of the IMT base station, the off-axis angle of IMT base station from EESS earth station antenna boresight must be determined Firstly. Figure 2 illustrates the geometry, where the EESS earth station is at point O and the IMT base station is at point A.

\[ I = 10 \log \left( \sum_{n=1}^{X} 10^{\left( \frac{E_{\text{EIRP}} - L - G_{\text{ESS}}}{10} \right)} \right) \] (dB) (1)

where:
- \( n \): index of the micro station and UE;
- \( E_{\text{EIRP}} \): micro station or UE e.i.r.p.;
- \( L \): propagation loss between the micro station and UE of index n and the EESS earth station (based on Recommendation ITU-R P.452 and Clutter loss);
- \( G_{\text{ESS}} \): Relative antenna gain (dBi) of the EESS station in the direction of the UE of index n.

4.3. Results of studies

The simulation assumes that the IMT-2020 (5G) micro station and terminal are the same frequency as EESS, GSO and NGSO, and the results are as follows:

a) GSO case

If the IMT-2020 (5G) micro station activity factor is 50%, assuming that the Beijing earth station protection distance is 1km, the IMT-2020 (5G) micro station and the terminal are used as interference sources to calculate the total interference value. The number of interference samples (1 minutes intervals) was 3135 (the simulation time was longer than 2 days), and the total interference values were from -164.26 (dBW/10 MHz) to -175.7 (dBW/10 MHz). For long term interference standard -131.7 (dBW/10 MHz), the interference margin is from 32.56 dB to 44 dB, and there is a sufficient margin from the protection criterion. Fig. 3 is the CDF curve of the simulation results. It can be seen that the total interference values are smaller than the interference criterion for the 20%, 0.25% percentage time.
b) Non-GSO case

If the IMT-2020 (5G) micro station activity factor is 50%, assuming that the Jiamusi earth station protection distance is 1km, the IMT-2020 (5G) micro station and the terminal are used as interference sources to calculate the total interference value. The calculated number of samples (30 days long and 1 minute intervals) is 43201. Among them, when the link between earth station and LEO satellite is set up, the number samples of interference calculation is 2313. The total number of samples exceeded the set value interference provisions short-term protection criterion values is 0, the aggregate interference value exceeds the number of samples for long-term protection standards value is 19, accounting for the proportion of samples to establish the link is 0.82%, far lower than the 20% percentage of interference time requirements, meet the protection criterion. Fig. 4 is a CDF curve of simulation results. It can be seen that the total interference values are smaller than the interference criterion for the 20%, 0.0125% percentage time.

The above results do not take into account the actual geographical information.

5. Summary and analysis of the results of studies

For Beijing earth station distance protection is 1km, IMT-2020 (5G) micro station activity factor is 50% and clutter loss median value is 37.1dB, compared to the long-term interference criterion, interference margin from 32.56 dB to 44 dB. There is a sufficient margin from the protection criterion.

For Jiamusi earth station protection distance is 1km, IMT-2020 (5G) micro station activity factor is 50% and clutter loss median value is 37.1283 dB, the aggregate interference value exceeds the number
of samples for long-term protection standards value is 19, accounting for the proportion of samples to establish the link for 0.82%, far less than criterion.

The results show that the IMT base station and user deployment can coexist with the Earth Exploration-Satellite Service earth station in the band. The provided results are useful for design of future 26 GHz IMT-2020 (5G) wireless communications systems and Earth Exploration-Satellite Service.

Acknowledgment
This work was supported by the National Science and Technology Major Project under Grants No. 2015ZX03002008.

References
[1] Bleicher A. The 5G phones future. IEEE Spectrum, 2013, 50(7): 15-16.
[2] Tan Wang, Gen Li, Jiaxin Ding, Qingyu Miao, Jingchun Li, and Ying Wang, "5G Spectrum: Is China Ready?", IEEE Communications Magazine, pp. 58-65, 2015.
[3] S. Y. Geng, Xing Li, Wei Hong, and X. W. Zhao, “Mm-wave 26 GHz channel characterization for future wireless communications,” in 2016 International Conference on Control and Automation, 2016, pp. 475-480.
[4] Report ITU-R Radio Regulations, 2016.
[5] Liaison statement from WP 5D to TG 5/1, “Spectrum needs and characteristics for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz,” 2017.
[6] Recommendation ITU-R M.2101-0, “Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies,” 2017.
[7] DRAFT NEW REPORT ITU-R SA.[EESS/MET CHAR], “Characteristics to be used for assessing interference to systems operating in the Earth exploration-satellite and meteorological-satellite services, and for conducting sharing studies,” 2017.
[8] Recommendation ITU-R P.452-16, “Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz,” 2015.
[9] DRAFT NEW RECOMMENDATION ITU-R P.[CLUTTER] “Prediction of Clutter Loss,” 2017.
[10] Recommendation ITU-R SA.1026-4, “Aggregate interference criteria for space-to-Earth data transmission systems operating in the Earth exploration-satellite and meteorological satellite services using satellites in low-Earth orbit,” 2009.
[11] Recommendation ITU-R SA.1160-2, “Interference criteria for data dissemination and direct data readout systems in the earth exploration-satellite and meteorological satellite services using satellites in the geostationary orbit,” 1999.
[12] Report ITU-R SA.2329-0, “Sharing assessment between meteorological-satellite systems and IMT stations in the 1 695 1 710 MHz frequency band,” 2014.