Co-channel Interference Between Satellite and 5G System in C Band

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Abstract. The 2019 World Radio Conference proposed to add 11 candidate frequency bands for the 5G system. Some of the C-bands are frequencies currently operated by the fixed-satellite service. When the 5G system and the fixed-satellite service share the same frequency band, the problem of co-frequency interference between systems is bound to occur. This paper studies the co-channel interference analysis from the 5G system to the FSS downlink in the 3400–3600 MHz frequency band. According to the specific interference scenario, antenna model and path loss model, Monte Carlo algorithm is used to evaluate the distribution of 5G interfering base stations, and the interference simulation analysis is carried out through link calculation, power control and system scheduling. The research results show that to meet the protection standards of the FSS system, the distance between the base station and the earth station needs to be at least 15 to 20 km. Moreover, the interference factors of the 5G system to the FSS mainly include angle between the main axis of the FSS earth station antenna and the direction of the base station interference signal, the number of 5G base stations, and the transmission power of 5G base stations.

Keywords: 5G · FSS earth station · Co-channel interference · Protection distance

1 Introduction

Communication technology is developing rapidly. Fifth generation mobile communication technology will support high-speed, low-latency and large- scale access services to enhance the overall performance of the system [1, 2]. World Radiocommunication Conference identifies millimeter wave bands as available frequency bands for 5G radio services [3]. For the sub 6 GHz frequency band, the World Radio Conference divided the 3400–3600 MHz frequency band as one of the candidate frequency bands for 5G systems [4]. However, this frequency band is also the frequency band where the fixed-satellite service operates. If the 5G system shares this frequency band with the satellite system, it will inevitably bring about interference problems between systems. Therefore, how to minimize the co-frequency interference between 5G systems and FSS is a prerequisite for large-scale deployment of 5G systems. Lots of research results show that when the FSS earth station (ES) is very close to the 5G system, the same channel deployment may become a big challenge. [5] analyzed in detail the three interference

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problems of C-band deployment of 5G systems and fixed-satellite services, and proposed measures to avoid interference based on the analysis results. For the problem of co-frequency interference, due to the limited site size of FSS earth stations, engineering measures and site-by-site coordination can be adopted to solve the problem of frequency coordination between operators and satellite operators. [6] studied the co-frequency interference between the 5G massive MIMO system and the FSS earth station on the 3.7–4.2 GHz, and analyzed the effect of the uplink and downlink transmissions of the 5G system on the satellite earth station. Lumped interference. Several interference mitigation techniques were identified and proposed, including protection distance, power control and frequency division.

In this paper, we mainly study the effect of interference from 5G system to the FSS earth stations in the downlink with 3400–3600 MHz band, where FES only works in the receiving mode. As the transmission power of 5G base station (BS) is far greater than that of 5G user equipment (UE), the interference from BSs to the FESs is larger than that of UEs to FESs. This paper focuses on the interference of 5G base stations to FSS earth stations. Through interference scenario simulation, system model assumptions, and interference simulation analysis, and finally determine the main interference factors of 5G BSs to FES.

2 Interference Scenarios and Analysis Methods

2.1 Interference Scenarios

The interference caused by 5G system to FSS earth stations mainly comes from 5G users and 5G base station [9]. However, because the transmission power of 5G base stations is much higher than that of 5G user equipment, the interference caused by base stations to FSS earth stations is much greater than that of 5G users. The following mainly studies the interference scenarios of 5G BSs to FSS ESs.

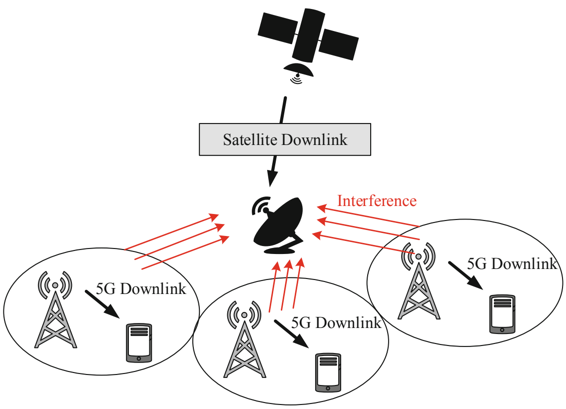

Fig. 1. Distribution topology of 5G BS and FSS ES

According to the current 5G network deployment, 5G base stations are numerous and densely distributed. When the strength of the base station interference signal received by the FSS ES is greater than its preset threshold, the low-noise module converter of the FSS ES is saturated with nonlinear distortion [5]. In this case, the FSS earth station will not work properly. This paper assumes that 5G base stations are evenly distributed around the FSS earth station in a ring. The distribution topology of 5G BS and FSS ES as shown in Fig. 1

2.2 Interference analysis

This paper uses the method in Recommendation ITU-R M.2101 to evaluate the interference of 5G BSs to FSS ESs. Since the user's position in the communication system is always changing, in order to approximate the operating state of the actual communication system, this paper uses the Monte Carlo algorithm to divide the entire system into multiple time segments for snapshot sampling. Then, the system simulation is completed according to the system's interference scenario, antenna model, path loss model, and propagation model.

If only the interference of a single 5G BS to the satellite ES is considered, the interference power received by the ES:

$$I_{\mathrm{5G}} = \frac{P_{\mathrm{T,5G}} G_{\mathrm{5G}}(\theta_{\mathrm{BS,FES}}) G_{\mathrm{FES}}(\theta_{\mathrm{FES,BS}})}{PL_{\mathrm{5G,FES}}(d_{\mathrm{5G,FES}})} \tag{1}$$

Where $P_{T,5G}$ is the transmission power of the 5G BS; G_{5G} is the antenna gain of the 5G BS; G_{FES} is the receiving antenna gain of the FSS ES; $PL_{5G,FES}$ is the path loss between the 5G base station and the FSS ES; $\theta_{BS,FES}$ is the angle between the direction of the BS to the user and the direction of the BS to the FSS ES; $\theta_{FES,BS}$ is the angle between the direction of the satellite to the FSS ES and the direction of the BS to the FSS ES.

Therefore, the interference power of 5G BS received by FSS ES is:

$$I_{agg} = 10 \log \left(\sum\nolimits_{n=1}^{N} 10^{\frac{I_n}{10}} \right) \tag{2}$$

Where I_{agg} is the aggregate interference power of 5G BSs received by the FSS ES, and I_n is the $n-th$ interference power transmitted by the 5G BS.

3 System Model and Parameters

In the simulation, the 5G base station uses an 8 × 8 element array antenna model. The FSS ES uses the antenna model of Recommendation ITU-R S.465, in which the relation between the antenna gain of FSS ES and the space off-axis angle is:

$$\mathrm{G} = \begin{cases} 32 - 25\log(\varphi)\, dBi & \varphi_{\min} \le \varphi \le 48^\circ \\ -10\, dBi & 48^\circ \le \varphi \le 180^\circ \end{cases} \tag{3}$$

φ is the space the angle between the direction of the base station antenna and the main axis of the FSS ES antenna; φ_{min} is the minimum off-axis angle.

The propagation loss between 5G BS and FSS ES is mainly the link loss. This paper adopts the free space propagation model.

The main parameters determined by the 5G system and the FSS ES system according to the relevant recommendations of ITU-R are shown in Table 1:

Table 1. System parameters

Parameter	5G BS	UE	FSS earth station
Frequency band/MHz	3400–3600		3400–3600
Cell radius/m	300		–
Antenna model	ITU-R M.2101		ITU-R S. 465-6
Transmission power/dBm	50–60	23	–
Antenna height/m	20	1.5	22
Antenna downtilt	10°	–	
Antenna diameter/m	–	–	2.4
Antenna specification	64(8 × 8)	4(2 × 2)	–
Antenna array gain/dBi	5	5	20
Horizontal/vertical 3 dB width	65°	90°	–
Horizontal/vertical ratio	30	25	–
FSS noise factor/dB	5	9	–
Interference threshold/dB	–	–	I/N = −12.2 dB
Received noise level value	−118.6 dBm(10 lg KTB, T = 100 K, B = 1 MHz)		

4 System Simulation

In the actual operation of the communication system, the user's location plays a vital role, because the user's location determines the beamforming direction of the base station antenna it serves, which in turn affects the base station's interference to the FSS earth station direction. In the actual system, the user terminal changes all the time. In order to approximate the operating state of the actual system, the Monte Carlo method is used for static system-level simulation. Divide the entire system into multiple time segments, take snapshots and sample each time, and calculate the system status under the current snapshot. When the number of snapshots is sufficient, the system status in the real scene can be approximated.

According to the above system parameters, this paper mainly simulates co-channel interference of urban scenes. In the simulation, the transmission power of the 5G BS is 50–60 dBm, and the protection distance between the FSS ES and the 5G BS is initially set to 5 km. When the aggregate interference from the BS exceeds the specified interference threshold (I/N = −12.2 dB), the protection distance is gradually increased to 50 km. The relationship between the INR of 5G BSs to FSS ESs and the protection distance is shown in Fig. 2.

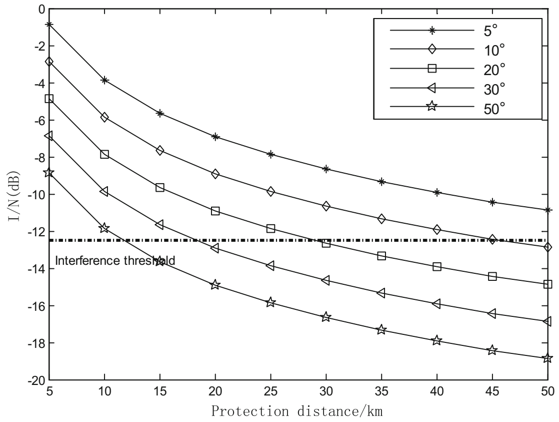

Fig. 2. Relationship between interference-to-noise ratio and protection distance received by FSS earth station

It can be seen from Fig. 2 that the larger the off-axis angle between the direction of the main beam of the FSS ES antenna and the interference signal of the BS, the smaller the protection distance required for coexistence between the satellite and the 5G system. If 95% interference threshold is considered. When the protection distance is 10 km, all the FSS earth stations except the ES with 50°off-axis angle cannot meet the conditions. Thus, increasing the angle between the main axis of the FSS ES antenna and the interference signal of the base station or increasing the protection distance can reduce the interference of the 5G BS to the FSS ES.

Figure 3 describes the relationship between the number of 5G base stations and the interference-to-noise ratio of FSS ES. The larger the angle, the greater number of base stations accommodated by FSS earth stations. But as the number of 5G base stations increases, the higher the interference-to-noise ratio, the greater the interference level of the FSS earth station. Thence, reasonable arrangement and control of the number of 5G base stations is one of the important means to reduce interference to FSS earth stations. Additionally, from the simulation results can be drawn, the higher the transmission power of the 5G BS, the stronger the interference level to the FSS ES, and the more difficult it is for the satellite to coexist with the 5G system. In order to minimize the impact of such situations on the FSS system, it is necessary to put forward higher requirements on the design of 5G base stations.

Figure 4 shows the relationship between the FSS earth station's received interference and noise ratio and the 5G base station and protection distance. When the 5G base station transmit power is 50 dBm, 53 dBm, 55 dBm, 57 dBm and 59 dBm, the required protection distance between the two systems is about 5 km, 7 km, 11 km, 16 km and 25 km respectively. The higher the transmit power of the 5G BS, the greater the protection distance required by the system, and the stronger the interference to the FSS ES, which is not conducive to the coexistence of satellites and 5G systems. In order to minimize the impact of such situations on the FSS system, it is necessary to put forward higher requirements for the design of 5G base stations.

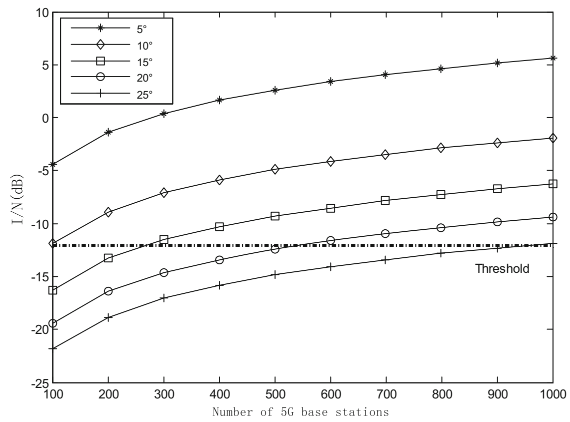

Fig. 3. The relationship between interference noise ratio and the number of BSs

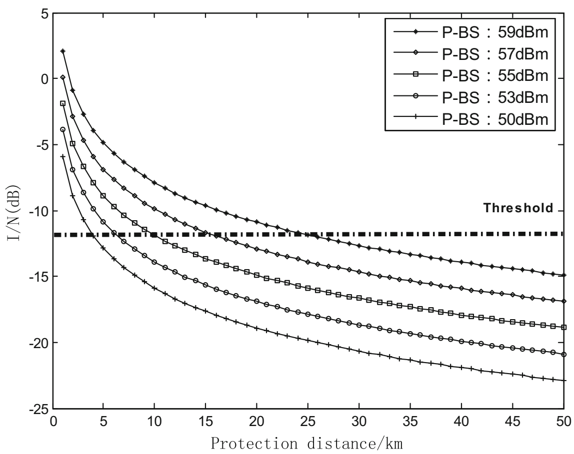

Fig. 4. The relationship between FSS interference to noise ratio and 5G base station transmit power

5 Conclusion

To solve the problem of interference coexistence between satellite and 5G system, this paper conducts interference analysis on the coexistence scenarios between 5G and FSS earth station. In the case of co-channel interference, we only consider the interference of 5G BS to FSS ES. Through the performance simulation of the interference-to-noise ratio of FSS receiver, it is concluded that to meet the interference threshold standard of FSS earth station, the protection distance between systems should be at least 15–20 km. Besides, the interference of 5G to the FSS system not only lies in the angle between the main axis of the FSS ES antenna and the interference signal of the 5G BS, but also depends on the number of 5G BSs and the transmission power.

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