SEPARATION DISTANCE REDUCTION BETWEEN 5G NR BASE STATION AND SATELLITE EARTH STATION AT C-BAND

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ABSTRACT

Increasing global data traffic made 5G (IMT-2020) a good solution, especially in the mid-band spectrum (the 3.5 GHz range), because it balances coverage and capacity. Thus, some countries have identified it as one of the candidate bands for 5G. C-band (from 3400 to 4200 MHz) is a mainstay of satellite communications and provides broadband connectivity in remote areas today. This paper discusses the feasibility of 5G (IMT-2020) and Fixed Satellite Service (FSS) system to coexist in the C-band range by analyzing the impact of the interference from 5G (IMT-2020) base stations towards the FSS earth station. This analysis is based on the most recent unwanted emissions limits used from 3GPP TS 38.104. The results show that in the adjacent channel scenario and by employing an elevation angle of 48° and a guard band from 41-100 MHz, 5G (IMT-2020) base station needs to be separated by at least 0.295 Km away from the FSS earth station. The protection distance increases by 26.35 Km when decreasing the guard band to 30 MHz. Thus, a new unwanted emission limit is proposed to reduce the protection distance in the 30 MHz guard band scenario.

KEYWORDS

FSS, interference, 5G, C-band, IMT-2020 and satellite communication.

1. INTRODUCTION

There has been a significant increase in mobile data traffic per smartphone worldwide from 2014 to 2027. In 2027, global monthly smartphone data traffic is projected to become 40.64 gigabytes per active smartphone worldwide [1]. As long as mobile data traffic increases, a new technology with suitable bands needs to take place to fulfill the required needs. 105 new 5G commercial networks have used the 3.5 GHz, making it the most popular mid-band 5G spectrum worldwide [2]. 5G (IMT-2020) technology will provide a variety of services and new experiences for the user, industries, and content provider, and also higher data rate, flexibility, and reliability compared to previous technologies like IMT-Advanced. This 5G technology allows a peak data rate of 20 Gbps for the downlink and 10 Gbps for the uplink while providing user data rates up to 100 Mbps for downlink and 50 Mbps for uplink [3]. The availability of at least 80-100 MHz of contiguous spectrum per 5G network operator is required to achieve the previous data rates.

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Among the frequency ranges allocated for the satellite systems, the C-band frequency range is the most critical frequency employed in providing the FSS services. Figure 1. shows the satellite services in C-band including broadcasting, mobile backhaul, ATM-networks, E-government, Oil and gas, maritime, etc. The extensive uses are due to its robustness to high rainfall and its technical capability to reach distant areas.

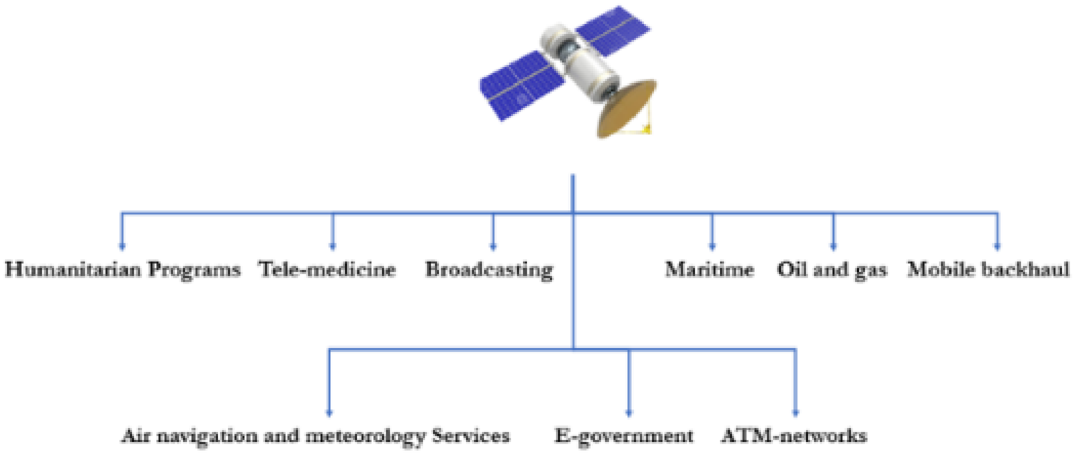

Figure 1. satellite services in C-band

Considering the urgency of the 3.5 GHz frequency band, which is within the C-band range, in providing communication services through satellite, then the coexistence between FSS and 5G (IMT-2020) needs to be considered carefully to avoid harmful effects from 5G (IMT-2020) to FSS and vice versa. Three possible types of interferences result from 5G New Radio and may affect the downlink earth station. The first type is due to in-band 5G emission as the incoming FSS signal's power flux density at the earth station location is very low while 5G base station which is closer to the earth station can produce a higher power level at the input to the FSS receiver than the desired satellite signal. The second type is unwanted emissions (out of band emission (OOBE) and spurious emission) generated by 5G operating in an adjacent band which may create interference to FSS. The third type is due to LNA/LNB overdrive. There are several studies related to the coexistence of FSS and IMT systems within the C-band range when the two systems are adjacent to each other. According to [4] coexistence between FSS and 5G system in TDD mode is feasible in the adjacent bands if separation distance is applied between the base station and FSS earth station. Meanwhile, sharing studies were conducted during the ITU WRC-07 cycle and concluded that across all studies, a common feature is that co-channel FSS and IMT operation requires a separation distance greater than the separation distance for the adjacent frequency operation [5]. Moreover, at WRC-15 studies concluded that adjacent channel in case of a macrocell requires apre-determined separation distance [6].

Hence, this paper aims to investigate the feasibility of coexistence between 5G (IMT-2020) and FSS in the adjacent band scenario through the interference analysis between those two systems at the C-band leading to determine a suitable separation distance. Furthermore, a new unwanted emission limit is proposed to reduce the separation distance resulting from the current unwanted emission limits, while improving the spectrum efficiency by reducing the guard band.

2. SYSTEM MODEL

This study on the coexistence and interference analysis between FSS and 5G (IMT-2020) is focused on the 3600-3700 MHz frequencies that lie between the 5G NR which operate on 3400-3600 MHz and FSS DL at 3700-4200 MHz where each transponder operates with 36 MHz bandwidth. The 5G operating bandwidth is assumed to be 100 MHz, with a 41-100 MHz guard band as stated in 3GPP TS 38.104 [7]. Figure 2 shows that the interference from the adjacent band is due to the very low power level of the incoming FSS signal. Thus, unwanted emissions generated by the IMT system operating in an adjacent band can create interference to FSS.

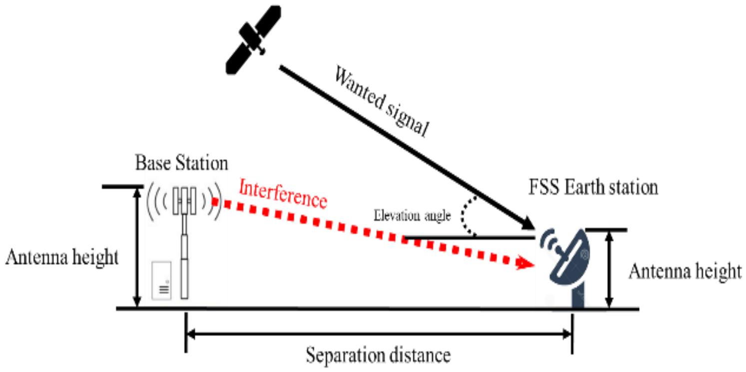

Figure 2. interference from adjacent band 5G emission

The analytical model used in this study to calculate the minimum path loss between 5G BS and FSS earth station is based on the FSS protection criteria specified in ITU-R S.1432 [8] and ITU-R M.2109 [5], and on 3GPP 5G BS out of band emission (OOBE) and spurious emission mask specified in 3GPP TS 38.104. The technical parameters of the FSS and 5G (IMT-2020) used in this paper are shown in Tables 1 and 2.

The propagation model used is based on the ITU model in ITU-R P.452-11 [9]. Path loss between the FSS earth station and 5G (IMT-2020) station is stated as follows

$$path\ loss(dB)=92.5+20*log(d)+20*log(f) \quad (1)$$

where d is the distance between the 5G base station and FSS earth station (in kilometers), and f is the carrier frequency in MHz.

Table 1. FSS Technical Parameters.

parameters	Value/Reference
Antenna diameter	1.8 - 3 m
Antenna radiation pattern	ITU-R Recommendation S.465 [10]
C-band transponder BW	36 MHz
Planned DL frequencies	3700-4200 MHz
Elevation angle	0-48 degree
Temperature	100°K [6]

Table 2. 5g (IMT-2020) Technical Parameters.

Parameters	Value/Reference
Bandwidth (MHz)	100
Max output power (dBm/100 MHz)	50
Antenna gain (dBi)	24
Spectrum Emission Mask (SEM)	3GPP TS 38.104 [7]
Frequency (MHz)	3400-3600

The FSS earth station protection criteria is based on interference to noise ratio (I/N) = -12.2 dB [6]. The maximum permissible interference power at the input of the receiver [11]

$$I_{max}=10\ log(kTrB)\ +(I/N)-w \quad (2)$$

k is Boltzman's constant 1.38*10-23(J/K), Tr is the noise temperature of the receiving system (earth station under clear sky conditions) in (K), B is the reference bandwidth of FSS transponder in (Hz), I/N is the ratio in (dB) of the permissible long-term interfering power from anyone interfering source to the thermal noise power in the FSS system and w is a thermal noise equivalent factor in (dB) for interfering emissions in the reference bandwidth (0 dB for digital systems), The interference power from IMT stations to FSS earth stations can be calculated using the following formula [6]:

$$I=EIRP_{5G}\text{- path loss (dB)} +G\ (\alpha) \quad (3)$$

Where $EIRP_{5G}$ is EIRP of the 5G base station, whereas G(α) is FSS earth station off-axis antenna gain toward the local horizon [10] given by:

$$G = 32\text{-}25log\ (\alpha)\ for\ \alpha \leq \alpha < 48^{o} \quad (4)$$
$$= \text{-}10\ dBi \qquad for\ 48^{o} \leq \alpha < 48^{o}$$

Where α is the angle between the interference signal direction and axis main beam from the FSS earth station in the frequency range 2-30 GHz and αmin = 1º. The required separation distance between the IMT station and FSS earth station can be found when I=I_{max} by combining equations (1), (3), and (4) and comparing the path loss in the equations (1) and (3).

3. Results and Analysis

Calculations were used to obtain the protection distance for the adjacent channel interference case. we assume that the EIRP is 75 dBm. Interference analysis is also carried out for different guard bands and elevation angles. Moreover, in this paper, we perform only the single interferer scenario. In addition, a new unwanted emissions mask is proposed to be used to add more efficiency for the spectrum regulators while planning margins or guard bands in new 5G frequency bands allocations to telecommunication operators.

3.1. Protection distance in case of adjacent channel interference in case of a single interferer

Table 3 shows the protection distance of the 5G (IMT-2020) base station and FSS earth station while considering different elevation angles and guard bands in the adjacent channel interference scenario in the case of a single interferer. The higher the angle between the interferer (5G BS) and the main axis beam from the FSS earth station (α), the smaller the protection distance needed between the interferer (5G BS) and the FSS earth station. Protection distance is constant for 48º

≤α≤180º. The minimum protection distance (295 m) occurs when the elevation angle is higher than or equal 48, while there is a guard band between 41-100 MHz, and it increases to 166 Km in case of zero guard band.

The EIRP limit is one of the essential parameters in IMT- 2020 technology deployment. In the U.S, the Federal Communications Commission has defined very high effective isotropic radiated power (EIRP) limits for the 28 and 39 GHz bands to reach 75 dBm/100 MHz [12].

Table 3. Protection Distances.

parameters	**Protection distance (Km)**			
Guard band (MHz)	0	5-10	10-40	41-100
ES elevation angle (5 º)	2792.1	1247.1	442.5	4.96
ES elevation angle (10º)	1177.4	525.9	186.6	2.09
ES elevation angle (20º)	496.5	221.78	78.69	0.8829
ES elevation angle (48º)	166.31	74.2	26.35	0.295

3.2. New mask proposal

Unwanted emissions consist of out-of-band emissions and spurious emissions [13]. Out of band emissions are unwanted emissions immediately outside the BS channel bandwidth resulting from the modulation process and non-linearity in the transmitter. Spurious emissions are emissions that are caused by unwanted transmitter effects such as harmonics emission, parasitic emission, intermodulation products, and frequency conversion products. Figure 3 shows the wide-area BS operating band unwanted emission limits. For the spurious emissions at a frequency offset higher than 40 MHz, it is assumed that 5G NR base stations shall conform to the limit of -52 dBm/MHz or -62 dBm / 100 kHz to facilitate coexistence with other legacy mobile systems operating in different frequency bands.

While the spectrum efficiency is a need for all the telecommunication systems, and as shown in Figure 3, the maximum limit to facilitate co-existence is -52 dBm/MHz or -62 dBm / 100 kHz from a frequency offset higher than 40 MHz (41-100 MHz) will result in a separation distance of 0.295 Km by applying the equations in part A. However, when the guard band decreases to 10-40 MHz range, the maximum limit will be -13 dBm/MHz or -23 dBm / 100 kHz and in this case, the separation distance will increase to 26.35 Km as shown in Table 3. So, to maintain the same separation distance as in the 41-100 MHz case, the maximum limit -62 dBm / 100 kHz should be shifted from a frequency offset higher than 40 MHz to lower parts than 40 MHz. Furthermore, Figure 4. shows a proposed mask with a frequency offset higher than 30 MHz in order to apply a 30 MHz guard band. Substituting the new value (-62 dBm / 100 kHz) at 30 MHz guard band instead of (-23 dBm / 100 kHz) in equations (3) and (4) will result in separation distances equal to the case of 41-100 MHz guard band.

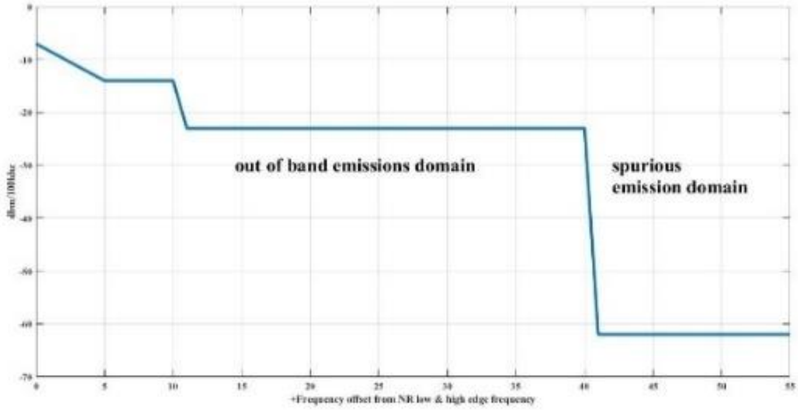

Figure 3. Unwanted emissions limits [7] (dBm/100 kHz)

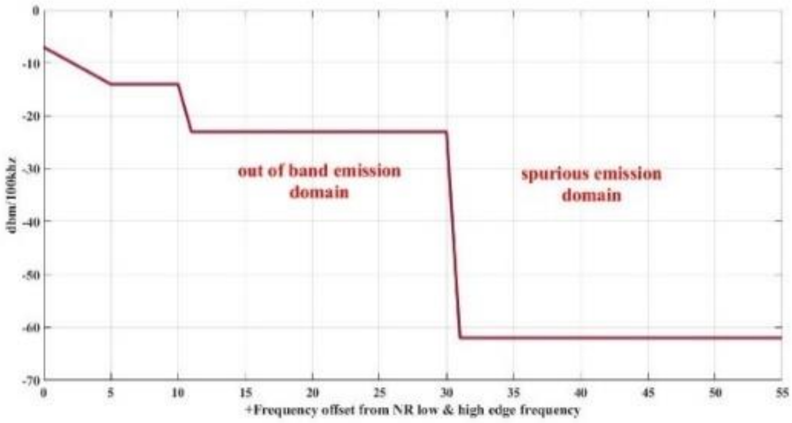

Figure 4. proposed new unwanted emissions limits for the spurious emissions at a frequency offset higher than 30 MHz (dBm/100 kHz)

4. CONCLUSIONS

This paper considered the interference analysis between the FSS and 5G (IMT-2020) system in the C-band, one of the 5G (IMT-2020) spectrum's most important candidates. The results of the adjacent-channel analysis show that the required separation distance is 0.295 km in the case of a guard band from 41 to 100 MHz at a 48º elevation angle.

When the guard band decreases the separation distance increases while increasing the elevation angle will also decrease the separation distance. A new mask is proposed which will lead to the reduction of the required separation distance in the case of the 30 MHz guard band from 26.35 Km to 0.295 Km. thus, efficient use of the scarce spectrum resources. We plan to use signal processing techniques to meet the new proposed mask in the future.

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