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Coexistence of 5Gwith Fixed Services

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ABSTRACT—Fifth generation (5G) network is a promising technology to support massive connectivity, improves quality of experience as well as supports sophisticated applications. Feasibility studies for deployment of 5G on higher frequency bands up to 86GHz have been recommended during world radio communication conference held in 2015 (WRC-15). Since such frequency band, especially 70GHz, have already been allocated to fixed service (FS) by spectrum regulatory bodies, 5G need to coexist with the incumbent system. This paper investigated feasibility of existence of a terrestrial 5G BS with FS terminal at 70GHz band considering interference from the FS terminal into the terrestrial 5G BS. The study considered a single FS terminal at different positions with respect to the 5G BS and evaluated signal to interference plus noise ratio at each sector of the 3-sector cell terrestrial 5G BS, considering immobile users at the edge of the 5G cell. The results suggested that terrestrial 5G BS can coexist with the FS terminal provided the deployment parameters of the former are carefully chosen.

KEYWORDS—5G, FS, coexistence, mmWave band.

INTRODUCTION

5G network is expected to provide minimum end-to-end latency; improvement in quality of experience; efficiency in utilization of resources; reduction in capital and operational expenditure (CAPEX and OPEX) through flattening the network architecture; and supporting versatile applications via software define networks [1]. These could only be achieved by deployment of 5G on a band with huge bandwidth. With the advancement in multiple-input-multiple -output (MIMO) technology, the factors that used to hinder deployment of mobile networks on high frequency can be mitigated [2]. As a result, spectrum operators recommended deployment of 5G network on high frequency bands.

The world radio communication conference of 2015 (WRC-15) have recommended frequency up to 86GHz for feasibility studies towards deployment of 5G network [3]. 70GHz band is a suitable for this purpose. However, International Telecommunication Union (ITU) Radio Regulation and Nigerian Communications Commission (NCC) have already allocated 71 to 74GHz band to fixed service (FS), fixed satellite services (FSS) and mobile services [4]. But, based on National Frequency Allocation Table (NFTA) [1], 71 to 74GHz band had already been allocate to FS. So, 5G need to coordinate with the incumbent FS. Figure 1 depicts the ITU allocation and the corresponding Nigeria allocation based on NFTA. Based on Figure 1, 5G network needs to coexist with FS.

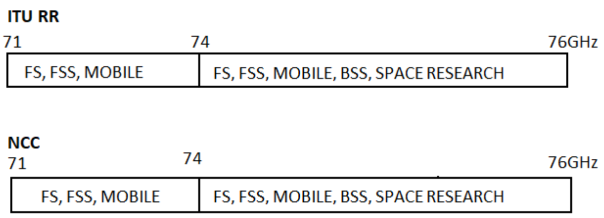

Figure 1: ITU and ECC allocation on 71-76GHz band

Recent studies on coexistence feasibility of different networks are include data base approach had been used in EU FP7 European research work cognitive radio (CoRaSat) to investigate feasibility of coexistence of FSS systems with incumbent fixed service (FS) systems on Ka-band [5]. The work found under-utilized spectrum allocated to FS systems within the Europe for additional deployment of FSS systems carriers. Moreover, the concept of cognitive radio (CR) has been used in coexistence studies of Ka-band satellite systems with terrestrial systems [6]. The cognitive user, FSS, is provided with intelligence based on its location, gain pattern and path loss awareness models. The information enables estimation of the interference it is generating to the incumbent FS system. Based on such information, the cognitive user is able to reduce the interference to an acceptable level that can be tolerated by the FS system. The research also found a limit to the number of uniformly distributed FSS terminals in an area that guaranteed an $\frac{I}{N}$ threshold of -10dB at the FS terminal.

Different from the existing relevant literatures, this paper investigates coexistence feasibility of terrestrial 5G BS with the incumbent FS system on 70GHz band, considering only co-channel interference form an FS terminal into a terrestrial 5G BS. The research uses a threshold signal to interference plus noise ratio (SINR) as a protection parameter for the 5G system. The threshold SINR of -8.266db had been found, prior to this study, at 5G innovation center of University of Surrey, United Kingdom via a link level simulation for different modulation and code rate schemes allowing a maximum block error rate (BLER) of 10% as

Table SEQ Table * ARABIC 1: SINR requirement for different code rates and modulation schemes performed at the 5G Innovation Centre of the University of Surrey.

and modulation schemes performed at the 5G Innovation Centre of the University of Surrey. Deployment distances of the terrestrial 5G BS were investigated such that the SINR on all sectors of a 3-sector cell 5G BS do not degrade below the required thresholds. At the end, it will be shown that 5G can coexist with the incumbent FS provided the deployment parameters of the former are carefully chosen.

SYSTEM MODELLING

This study considered 71 GHz, frequency of point-to-point link in Nigeria. The scenario as depicted in Figure 2 consists of a terrestrial 5G BS with immobile users at the edge of their corresponding cells. Each user is assumed to be schedule by a single sector. The link between the sectors and their users are depicted with black lines. The incumbent interference from the FS terminal is depicted with red lines.

The signals on each of the sectors, on the assumption that there is power control such that users transmit equal power [8] is given by:

$$S_j = P_{UE} + G_{UE} - PL_{BU} + G_{BUj}(\theta_2, \varphi_2) \quad (1)$$

S_j, *is* the useful signal on sector j from user j, P_{UE} is the transmit power of UE j and $G_{UE}$is the gain of UE j antenna. Also, PL_{BU} is the Path loss between the sector j and user j and $G_{BUj(\theta_2,\varphi_2)}$ is the gain of sector j towards UE j.

The interference on each of the sectors based on [8] is given by:

$$I_j = P_{FS} + G_{\phi_f} - PL_{BF} + G_{BEj}(\theta_2, \varphi_2) \qquad (2)$$

P_{FS} is the a transmit power of the FS terminal with a gain of G_{ϕ_f} towards the terrestrial 5G BS. Also, $G_{BEj(\theta_2,\varphi_2)}$ is the gain of sector j of the terrestrial 5G BS towards the FS terminal and PL_{BF} is the path loss between the terrestrial 5G BS and the FS terminal.
So, the signal to interference ratio (SIR) on each of the sectors is given by:

The thermal noise of a sector with noise Figure of N_F, at an average temperature of T, based on [9] is given by:

$$N = N_F + 10KT \qquad (3)$$

where K is the Boltmann constant.

The SINR at each of the sector is then obtained by combining the presented equations as:

$$SINR_j = 10\left[\left(10^{(SNR_j/10)}\right)^{-1} + \left(10^{(SIR_j/10)}\right)^{-1}\right]^{-1} \qquad (4)$$

Where SIR and SNR are the signal to interference and signal to noise ratio in decibels respectively.

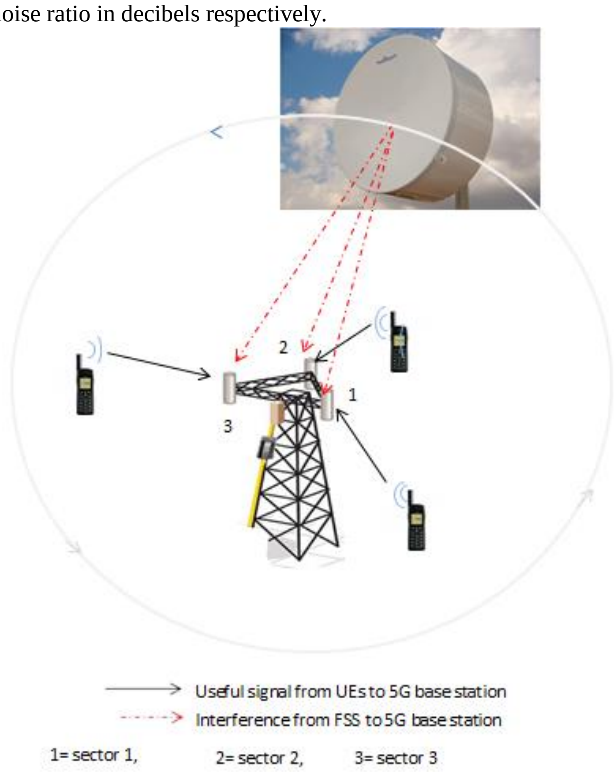

Figure 2: 3-sector cell base station with schedule user terminals around an FS terminal

The FS antenna gain for a point-to-point link, a function of off-axis angle (ϕ_s), depends on the heights of the FS and 5G terminals, relative azimuth angle between them. The off-axis according [6] is;

$$\phi_f = (\cos\cos(E_s)\cos\cos(\varepsilon)\cos\cos(\alpha) + \sin\sin(\varepsilon)\sin\sin(E_s))(5)$$

Where ε is the elevation angle, in degrees, of the radio wave at the FSS terminal given by:

$$\varepsilon = \left(\frac{(z_b - z_a) * 10^{-3}}{d} - \frac{d}{2r}\right) * \frac{180^o}{\pi}(6)$$

$r = 8500Km$ is the effective earth radius. z_a, z_b and d are the height of the FS terminal, height of the 5G terrestrial BS and the distance between them respectively. The gain of an FS terminal of diameter, D, according to [6] is given by:

$$G_{\phi_f} = \{G_{max} - 25 * 10^{-3}\left(\frac{D}{\lambda}\phi_s\right)^2 \quad 0^0 < \phi_s \le$$
$$x_{t1} G_1, \quad x_{t1} < \phi_s \le x_{t2} 52 - 10\left(\frac{D}{\lambda}\right) -$$
$$25(|\phi_s|), \; x_{t2} < \phi_s \le 48^o 10 - 10\left(\frac{D}{\lambda}\right),$$
$$48^o < \phi_s \le 180^o(7)$$

A model recently released by 3GPP s used for the estimation of path loss between both the users and the FS terminal to the terrestrial BS. Figure depicts a configuration with user of height h_{UE} and 5G BS o height, h_{BS}, for path loss estimation.

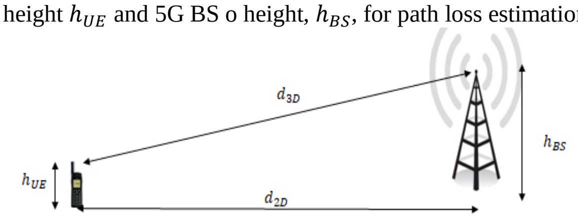

Figure 3: User terminal to 5G terrestrial BS configuration

According to [10], the relationship between d_{3D} and d_{2D} is:

$$d_{3D} = \sqrt{(d_{2D})^2 + (h_{BS} - h_{UE})^2} \qquad (8)$$

The non-line of sight pathlos between the UE and the 5G BS according to 3GPP recommendation [10] is given by:

$$PL_{BU} = max\ ((PL_{UMI-LOS},\ PL'_{UMI-NLOS})) \qquad (9)$$

Where,

$$PL_{UMI-LOS} = \{PL1, \quad 10 \le d_{2D} \le d'_{BP} \quad PL2, \quad d'_{BP} \le d_{2D} \le 5km \qquad (10)$$

With

$$PL1 = 32.4 + 20d_{3D} + 20f \qquad (11)$$

And

$$PL2 = 32.4 + 40d_{3D} + 20f - 9.5[(d'_{BP})^2 + (h_{BS} - h_{UE})^2] \qquad (12)$$

Also,

$$PL'(_{UMI-NLOS}) = 35.5d_{3D} + 22.4 + 21.3f - 0.3(h_{UE} - 1.5) \qquad (13)$$

With,

$$d'_{BP} = 4 * h'_{BS} * h'_{UE} * \left(\frac{f * 10^9}{c}\right) \qquad (14)$$

Where,

$$h'_{UE} = h_{UE} - 1 \quad (15)$$

$$h'_{BS} = h_{BS} - 1 \quad (16)$$

C is the speed of light (in m/s) and f is frequency of operation (in GHz).

The path loss between the terrestrial 5G BS and an FS terminal is obtained by replacing h_{UE} with h_{FS} in equations (12), (13), (14) and (15) above.

The antenna pattern of the 5G terrestrial BS also follows a 3GPP model in [11]. Each sector consists of a uniformly rectangular array. But for this analysis, only a single antenna element was considered per sector. The gain of the 5G antenna element depends on two off-axes angles: vertical off-axis angle, θ_2, and horizontal off-axis angle, φ_2. The gain of a 5G antenna element is given by:

$$G_{BE}(\theta_2, \varphi_2) = G_{BE,max} + RP_{BE}(\theta_2, \varphi_2) \quad (17)$$

$$= 8 + RP_{BE}(\theta_2, \varphi_2) \quad (18)$$

where, $G_{BE,max}$, the maximum gain of the antenna element having a value of 8dB. $RP_{BE}(\theta_2, \varphi_2)$ is the antenna element radiation pattern as a fuction of the two off-axes angles, θ_2 *and* φ_2 and:

$$RP_{BE}(\theta_2, \varphi_2) = -\left\{-\left(RP_{BE,V}(\theta_2) + RP_{BE,H}(\varphi_2)\right), 30\right\} (19)$$

With,

$$RP_{BE,V}(\theta_2) = -\left\{12\left(\frac{\theta_2 - 90}{65}\right)^2, 30\right\} \quad (20)$$

And

$$RP_{BE,H}(\varphi_2) = -\left\{12\left(\frac{\varphi_2}{65}\right)^2, 30\right\} (21)$$

The off-axes angles were calculated by assuming the origin of the global coordinate system was shifted to the position of the 5G terrestrial BS.
With the 5G terrestrial BS assumed to be pointing in a direction with angle α^o away from the positive x-axis and down tilted by an angle of β^o with slant angle of γ^o,the spherical coordinate of the FS terminal within the local coordinate system of the 5G terrestrial BS is$(\rho_2, \theta_2, \varphi_2)$. The transformation method of [11] was used to obtain the expessions for θ_2 and φ_2 as:

$$\theta_2 = \Big(cos\,cos(\beta)\,cos\,cos(\gamma)\,cos\,cos(\theta_1) + \big[sin\,sin(\beta)\,cos\,cos(\gamma)\,cos\,cos(\varphi_1 - \alpha) - sin\,sin(\gamma)\,sin\,sin(\varphi_1 - \alpha)\big]\,sin\,sin(\theta_1)\Big) \quad (22)$$

$$\varphi_2 = \arg\left(\begin{matrix} [\cos(\beta)\sin(\theta_1)\cos(\varphi_1 - \alpha) - \sin(\beta)\cos(\theta_1)] + \\ j\left[\begin{matrix} \cos(\beta)\sin(\gamma)\cos(\theta_1) \\ + \{\sin(\beta)\sin(\gamma)\cos(\varphi_1 - \alpha) + \cos(\gamma)\sin(\varphi_1 - \alpha)\}\sin(\theta_1) \end{matrix} \right] \end{matrix} \right) \quad (23)$$

Assuming the terrestrial 5G BS is pointing along the positive x-axis (=0) for sector 1, =120 for sector 2 and =20 for sector 3. In practical deployment, sectors are usually tilted by certain angle so as to reduce interference to neighboring cells. However, since we intend to evaluate maximum interference, all the sectors are assumed to be unstilted such that down tilt angle $\beta = 0°$, and slantangle $\gamma = 0°$.

Table 1: Parameters used in the study

Parametr	5G		FS
Carier frequency	73.5GHz		
Bandwidth	1GHz		
Pathloss model	UMi		
	BS	UE	FS
Maximum gain	8dBi per element	0 dBi	50dBi
Tranmit power		13dBm/MHz	19dBm/MHz
Antenna height	10m	1.5m	25m
temperature	300K		
Noise Figure	7dB		
Number of element	1		

In the scenario considered, 5G terrestrial BS was assumed to be at coordinate (0, 0) around a single FS terminal. Since high frequency signal transmission suffers from huge propagation losses, a cell size of 200m was assumed for the 5G terrestrial BS. The users are assumed to be immobile and placed at the edges of their respective cells. Other parameters used in the study are in Table 1. The FS terminal is then placed at different distances and relative azimuth angle to the 5G BS. The FS is deployed on r-θ coordinate with r=0:50:5000 and θ=0: π/50:2π. The Available SINR on each of the 5G sectors is evaluated, using MATLAB 2016a, as a function of distance and relative azimuth angles to the 5G BS.

.PERFORMANCE EVALUATION

The deployment of 5G micro BS parameters coexisting with FS terminal were investigated. Assuming the relative azimuth angle from the FS terminal to the 5G BS is 0^oalong the direction of the first sector ($\alpha = 0^o$). The 3D plot of the SINR availble on sectors 1,2 and 3 are as depicted in Figures 4,5 and 5 Respectively.

The minimum deployment distances for sector 1 are the points where the -8.266dB plane (grey in colour) cut the SINR 3D plot. Based this, when the relative azimuth angle are within a range of0^o *to* 3.6^0 *and* 0^o *to* -3.6^o, the sector has to be at a minimum of 1250m away from the FS terminal. Moreover, if the relative azimuth angle to the FS terminal is between 10^o *to* 35^o *and* -10^o *to* -35^o,the sector need to be atleast at a distance of 700m away from the FS terminal. In addition, within realtiv azimuth angle of 50^o *to* 280^o, only a minimu of 100m is required for the deployment of this sector such that the minimum SINR threshold of -8.266dB is always guaranteed.

Based on SINR available on sector 2, when the FS terminal is at relativce azimuth angle of 0 t0 70, a minimum deployment distance of about 100m ie needed. The lagest deployment distnace of about 20m needed by the 5G BS occures when the relative azimuth angle is between 100 to 126.

For sector 3, 200m is also required by the 5G Bs irrespective of the relative azimuth angle to the FS terminal.

As a result, sector is the most critical and determines the overall deployment distance of the terrestrial BS. Hence, 5G terrestrial BS requires a minimum distance of about 1.25km away for an FS backhaul terminal.

Since sector 1 determines the deployment distance of the 5G terrestrial BS, a 2D plot of minimum deployment distance of the 5G BS for different transmit powers of the FSS terminal at elevation angle commonly used in Nigeriaria so that a minimum SINR of -8.2dB is always guranteed on sector 1 is depicted in Figure 7. The minimum 5G terrestrial BS deployment distances required based on FSS transmit powers (Po) and elevation angles are as reported in Table 1.

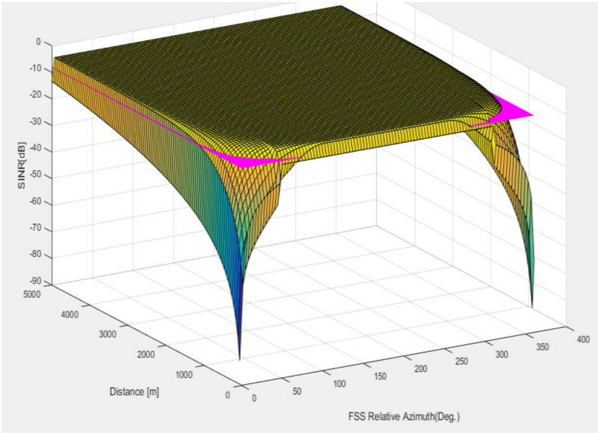

Figure 4: SINR on sector 1

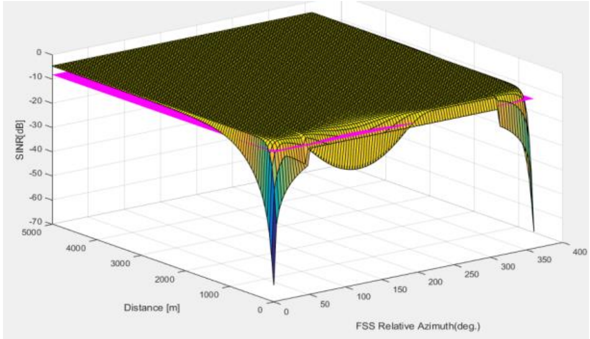

Figure 5: SINR on sector 2

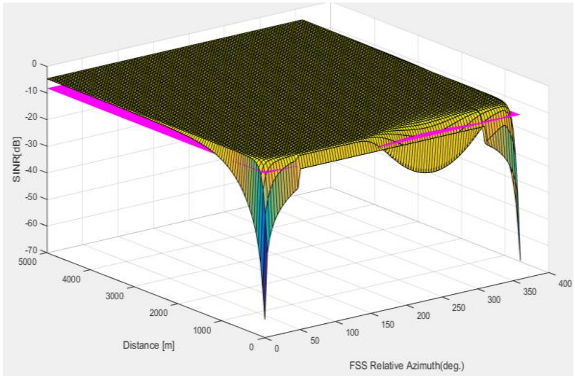

Figure 6: SINR on sector 3

CONCLUSION AND FUTURE WORK

Coexistence of a terrestrial 5G BS with an Fs terminal for a backhaul link at 73.5GHz. the study is highly impotant towards world radiocommunication conference to be held in 2019 (WRC-19), where final decision will be made regarding allocation to 5G system allocation. The research considered only interference from he Fs terminak into the 5G terretrial BS. The research also used singnal to intefernce plus noise ration as the protection parameter of the 5G system. A threshold of -8.266dB, obtained via link level simulation (performed prior to this research) performed at the 5g innovation centre of the universty of surrey. Using recently released 5G antenna gain and pathloss models, a FS terminal at different positions to the terrestrial 5G BS and evalauted the SINR at each sector of the 3sector 5G BS. It has been found that a minimum distance of about 1.25km away from the FS terminal is reqired by the terrestrial 5G BS.

However, the study is not exhaustive as the users were considered immobile, contrary to real live scenation where users mostly move. As a result further study considering this is needed.

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