Coexistence of 5G and Fixed Links in the 71-76 GHz & 81-86 GHz Bands

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Abbreviations

3GPP	The 3rd Generation Partnership Project
5G	5th generation mobile networks or 5th generation wireless systems
AP	Access Point
EIRP	Equivalent Isotropically Radiated Power
F/B	Front-to-Back Ratio
FCC	Federal Communications Commission
FL	Fixed Link
I/N	Interference-to-Noise Power Ratio
ITU	International Telecommunication Union
LoS	Line of Sight
LTE	Long-Term Evolution
MIMO	Multiple Input Multiple Output
mmW	Millimeter Wave
NF	Noise Figure
NLoS	Non Line of Sight
NPRM	Notice of Proposed Rule Making
Rx	Receiver
Tx	Transmitter
UE	User Equipment
UMa	Urban Macro-Cell

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1. Introduction

This report discusses the coexistence of existing fixed microwave systems and mobile 5G systems in 70 GHz and 80 GHz bands. Presented results are preliminary and these coexistence studies will be further refined, as more accurate system modeling assumptions become available and more appropriate propagation models for coexistence studies at mmW bands are developed.

2. Analysis of Interference

2.1 Framework

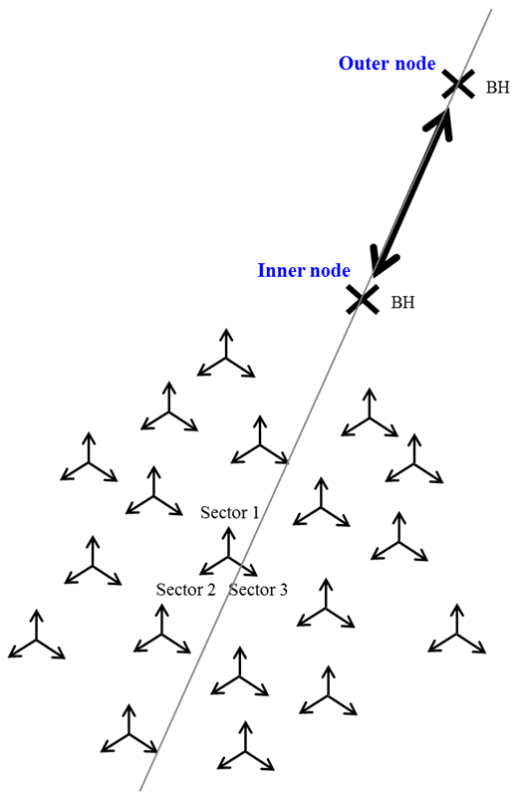

Figure 1. A topology of coexistence between 5G and Fixed link

2.1.1 System model

The 5G model primarily relies on a recent 3GPP Release 14 Technical Report [1] used to properly model and evaluate the performance of physical layer techniques using the above-6-GHz channel model(s). This report illustrates the channel model(s) for frequencies above 6 GHz up to 100 GHz.

Figure 1 describes a topology of coexistence between a 5G access system with 19 5G Access Points (APs) and a pair of point-to-point wireless system. The 5G AP is composed of three sectors with the coverage of 120 degrees azimuth. As a result, the 5G access system in this model has 57 sectors in total. Note that the cell sites are "dithered" within plus and minus 50 meters both in X and Y coordinates, from its designated position that forms a complete hexagon as an entire 19-AP system. One Fixed link Tx/Rx is placed surrounding the 5G access system with various distances and angles on the quadrant.

The Fixed link is a point-to-point wireless system; hence the antenna beam pattern that it uses is very narrow, i.e., the 3-dB angle is < 0.4 degree based on the ITU recommendation [2] as presented in Figure 3. The interference protection requirement is defined by the ITU and the FCC as follows. The ITU defines that as a primary-to-primary coexistence, -10 dB of I/N must be achieved, whereas the FCC defines that the interference must be at least 1 dB lower than the static threshold.

2.1.2 Simulation setting

Table 1. Simulation parameters

Parameter	**Value**
Path loss	
Carrier frequency	73.5 GHz
Path loss model	UMa (Urban Macro) [4]
5G (AP)	
Number of antennas	16 × 16
EIRP	{72, 62, 57} dBm/GHz
Bandwidth	1 GHz
Temperature	290 K
Noise figure	7 dB
Antenna height	10 m
5G (UE)	
Number of antennas	4 × 4
EIRP	43 dBm/GHz
Bandwidth	1 GHz
Temperature	290 K
Noise figure	9 dB
Antenna height	1.5 m
Fixed link	
Tx power	19 dBm
Antenna gain	{50, 43} dBi
Bandwidth	1 GHz
Temperature	290 K
Noise figure	5 dB
Antenna height	{10, 25} m

As explained in Section 2.1.1, a Fixed link Tx-Rx pair is placed outside of the 5G system.
The front-to-back ratio (F/B) of a Fixed link node is typically 60 dB, according to the recommendation by the ITU [2].

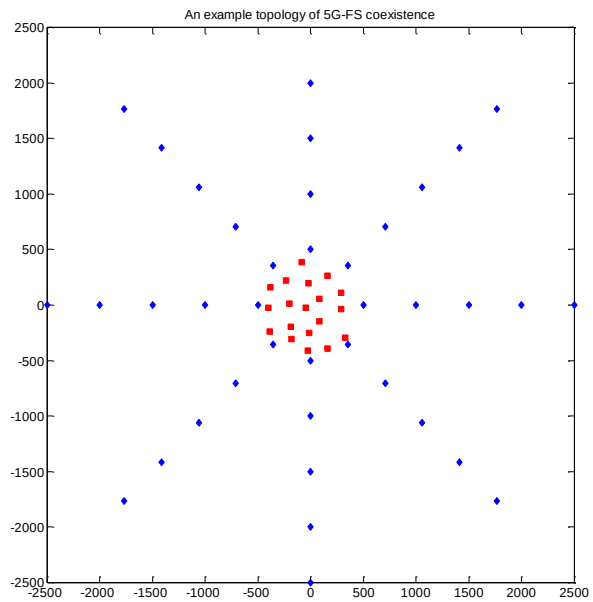

Figure 2. Locations of a Fixed link node in simulations

Also, to accurately evaluate the interference, we varied the location of the Fixed link Tx-Rx pair around the 5G system. Figure 2 illustrates all the locations of the 5G APs and the Fixed link nodes that were used in the simulations. Each red dot represents a 5G AP and a blue diamond indicates a location of a Fixed link node, and each diamond represents a "Tx" in a Fixed link-to-5G interference scenario and a "Rx" in a 5G-to-Fixed link interference scenario. In both the cases of 5G-to-Fixed link and Fixed link-to-5G interference, the interference levels that are measured with the Fixed link node at the given positions are *averaged*, so that we can generalize the result over all the possible geometrical scenarios.

The operational parameters of the 5G system and the Fixed link system are presented in Table 1. We assume that both the APs and UEs utilize directional antennas.

The metric, I/N, is defined as the ratio of interference power to noise power at an Rx device. The noise power is computed by

$$N = 10\log_{10}(k_B T \times 1000) + 10\log_{10}(BW) + NF \text{ [dBm]}$$

where $k_B = 1.38064852 \times 10^{-23}$. Also, T, BW, and NF indicate the temperature, the bandwidth and noise figure of an Rx, respectively. Considering the values of T, BW, and NF that are given in Table 2.1, the noise power values are -78.9752, -74.9752, and -76.9752 for a 5G AP, a Fixed link node, and a 5G UE, respectively. The interference criterion for a Fixed link Rx is defined by the ITU [2] as -10 dB, while that for a 5G Rx is set to -12 and -6 dB.

2.2 Methodology

This study uses the interference-to-noise ratio (I/N) as the metric that measures the level of interference at an Rx of either the Fixed link or 5G system.

An interference power that is received at a device is computed as

$$I = P_t + (G_t - L_t) + (G_r - L_r) - PL$$

where P_t denotes the transmit power of a Tx device, and $G_{t\ and\ r}$ and $L_{t\ and\ r}$ denote the antenna gain and loss at a Tx and Rx, respectively. Also, PL represents the path loss.

2.2.1 Path loss model

This study uses an Urban Macro-Cell (UMa) for path loss model, which is defined in one of the recent 3GPP standard documents for 5G in the mmW bands [1]. Note that a value of the carrier frequency, f_c, is in the unit of GHz and the distance, d_{3D}, is in meters. Note that the distance is subscribed by "3D" because it is defined reflecting both the azimuth and elevation planes. Also, the heights of a 5G AP and UE are denoted by h_{BS} and h_{UT}, respectively. Each of the path loss models is again defined separately with line-of-sight (LoS) and non-line-of-sight (NLoS) as follows.

The LoS component of UMa path-loss model is defined as

$$PL_{uma,los} = 32.4 + 40log_{10}(d_{3D}) + 20log_{10}(f_c) - 10log_{10}((d'_{BP})^2+(h_{BS}-h_{UT})^2)$$

while the NLoS component is defined as

$$PL_{uma,nlos} = 13.54 + 39.08log_{10}(d_{3D}) + 20log_{10}(f_c) - 0.6(h_{UT}-1.5).$$

$d'_{BP} = 4\ h'_{BS}\ h'_{UT}\ f_c/c$, where f_c is the center frequency in Hz, $c = 3.0\times10^8$ m/s is the propagation velocity in free space, and h'_{BS} and h'_{UT} are the effective antenna heights at the BS and the UT, respectively. In UMa scenario the effective antenna heights h'_{BS} and h'_{UT} are computed as follows: $h'_{BS} = h_{BS} - h_E$, $h'_{UT} = h_{UT} - h_E$, where h_{BS} and h_{UT} are the actual antenna heights, and the effective environment height h_E is a function of the link between a BS and a UE. In the event that the link is determined to be LOS, h_E=1m with a probability equal to $1/(1+C(d_{2D}, h_{UT}))$ and chosen from a discrete uniform distribution uniform(12,15,…,(h_{UT}-1.5)) otherwise. A distance on a two-dimensional plane, d_{2D}, is a distance disregarding a difference between the heights of Tx and Rx.

For the path-loss models, we also take shadow fading into consideration. According to [1], a shadow fading follows a log-normal distribution, and is characterized by the standard deviation. The value of standard deviation for each path-loss model is given in Table 2.

Table 2. Shadow fading standard deviation [4]

Scenario	σ_{SF} (dB)
UMa LoS	4.0
UMa NLoS	6.0

Table 3. LoS probabilities [4]

Scenario	LoS probability
UMa	Outdoor users: $P_{LOS} = \min(18/d_{2D},1)(1-\exp(-d_{2D}/63)) + \exp(-d_{2D}/36)(1+C(d_{2D},h_{UT}))$ where

	$C(d_{2D}, h_{UT}) = \begin{cases} 0 & , h_{UT} < 13\text{m} \\ \left(\frac{h_{UT} - 13}{10}\right)^{1.5} g(d_{2D}) & , 13\text{m} \le h_{UT} \le 23\text{m} \end{cases}$ and $g(d_{2D}) = \begin{cases} 0 & , d_{2D} \le 18\text{m} \\ (1.25e-6)(d_{2D})^3 \exp(-d_{2D}/150) & , 18\text{m} < d_{2D} \end{cases}$ Indoor users: Use $d_{2D\text{-}out}$ in the formula above instead of d_{2D}

Table 3 shows LoS probability for the two path loss models. Although 3GPP defines path loss models for outdoor and indoor scenarios, this study assumes outdoor only since it is reasonable that a coexistence with a wireless Fixed link more likely occurs outdoor. Therefore, we consider the outdoor LoS probabilities only in this study.

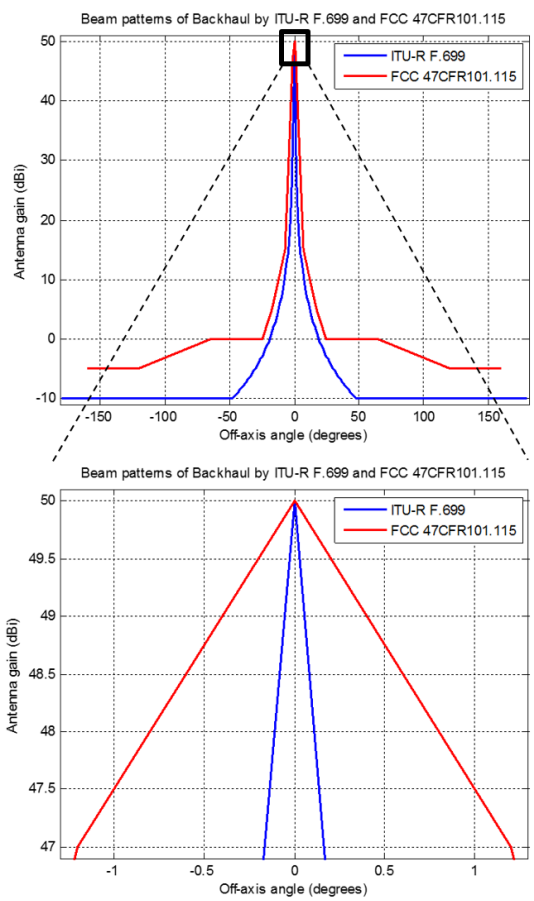

Figure 3. Antenna beam patterns for Fixed link by the ITU [2] and the FCC [3]

Figure 3 compares antenna patterns for the Fixed link system that are defined by the ITU and the FCC. The lower figure magnifies the range of [-1.2, 1.2] degrees of the off-axis angle.

Figure 4 presents an example of antenna beam pattern of a 5G AP.

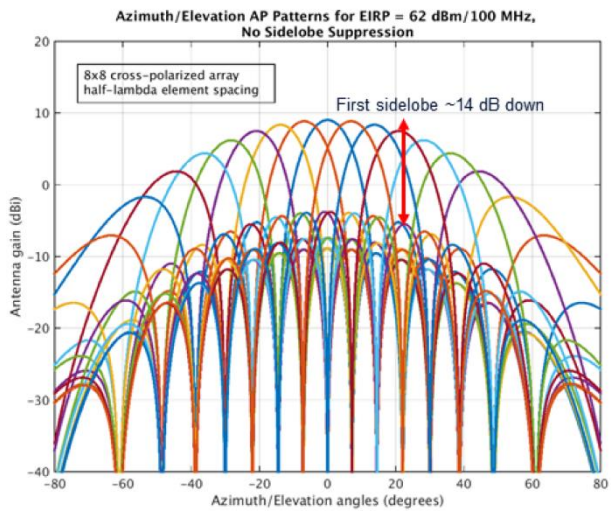

Figure 4. Example of antenna beam pattern of a 5G AP

2.3 Results and discussion

Figures 5 and 6 show the simulation results for the two scenarios:

1. Fixed link to 5G APs
2. 5G APs to Fixed link

Interference that a 5G system causes into a Fixed link system is potentially higher than the one in the other direction. The I/N ratio in case of interference from the fixed link into the 5G AP is lower than the 5G I/N threshold in most cases. However, the I/N ratio in case of interference from the 5G APs into the fixed link is higher than the fixed link I/N threshold in most cases.

The main reason why a 5G-to-Fixed link interference is higher is that the interference is *aggregated* over the 57 cells/sectors. On the other hand, in a Fixed link-to-5G interference scenario, the interference from one Fixed link Tx arrives at 57 Rx cells/sectors in the 5G system, which results in an *average* over the 57 sectors.

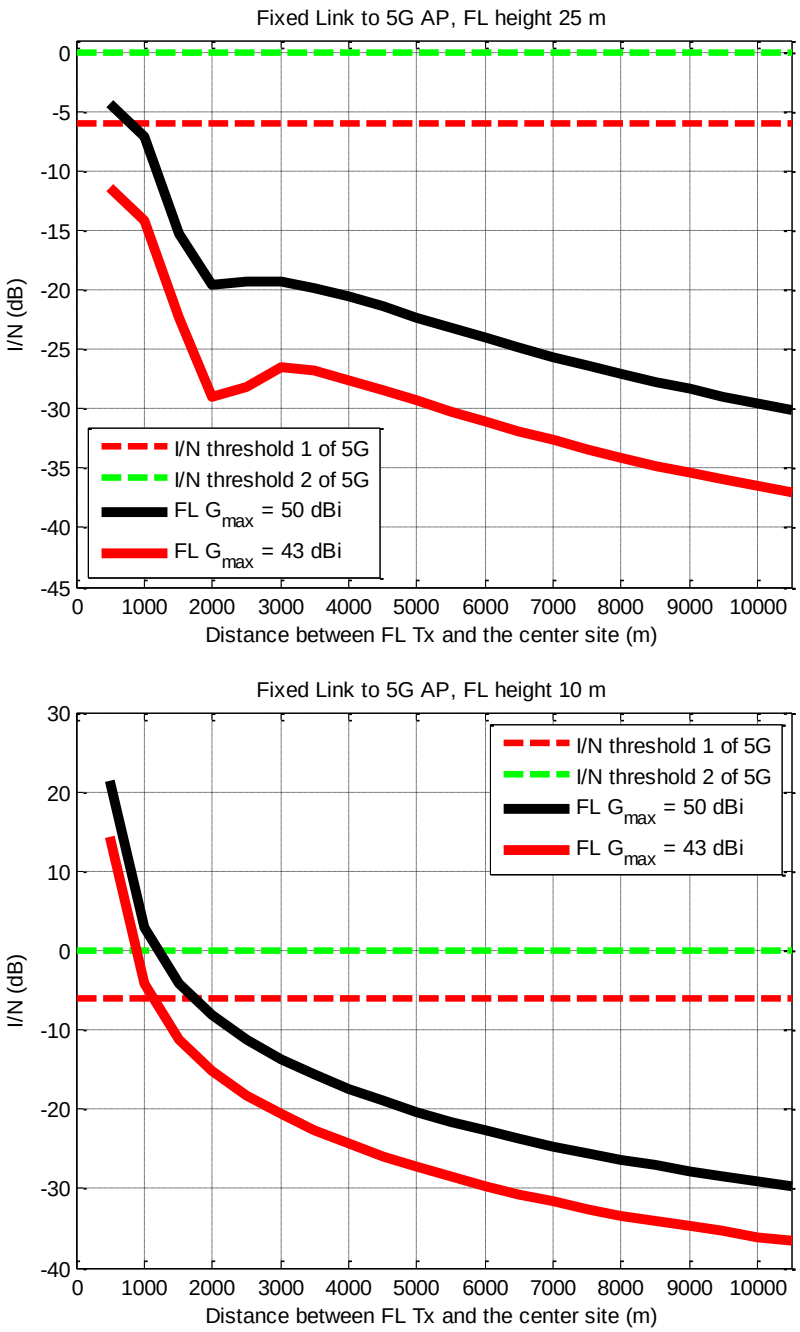

Figure 5. Interference from Fixed link into 5G AP

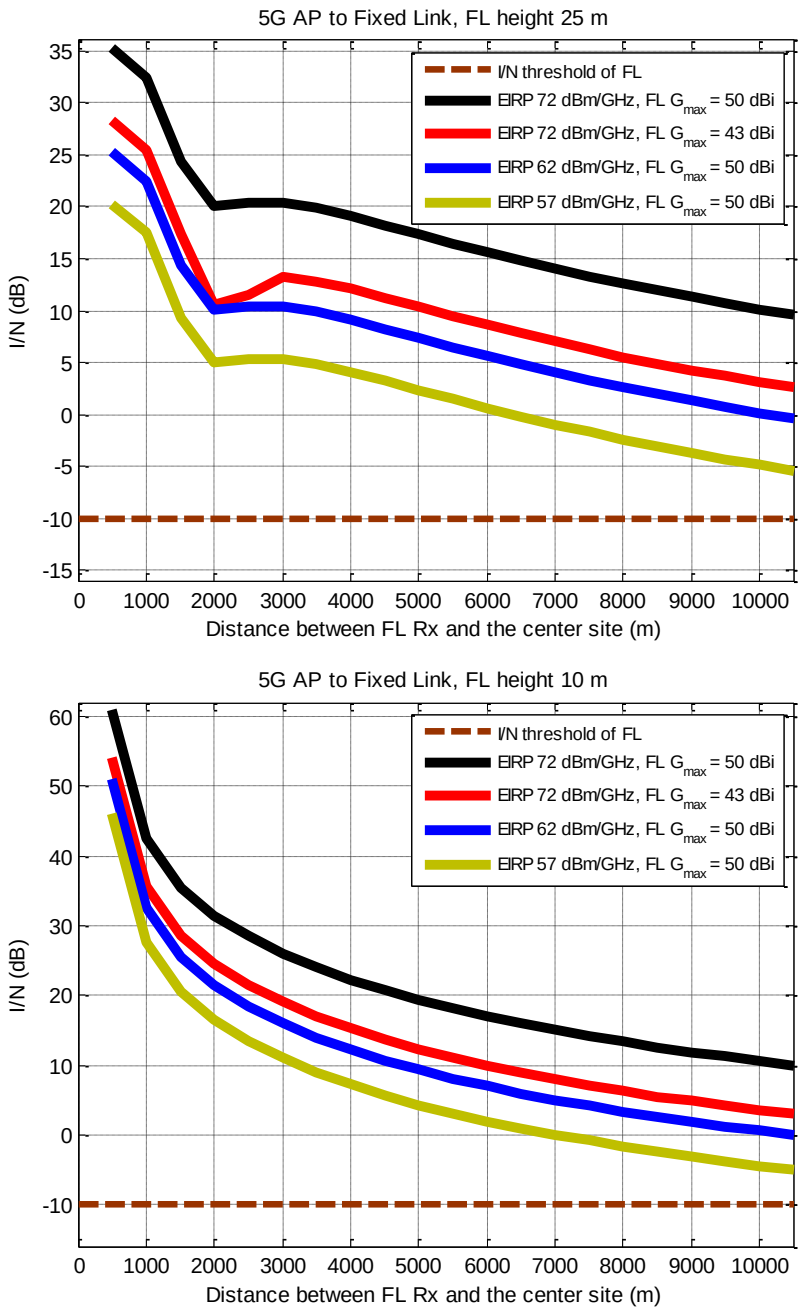

Figure 6. Interference from 5G APs into Fixed link (without beam shut down)

3. Mitigation of 5G-to-Fixed link Interference

We then studied the impact of shutting down the 5G AP beam(s) responsible for interference at the fixed node as mentioned above and found that the technique is indeed effective in suppressing the interference as shown in Figure 7.

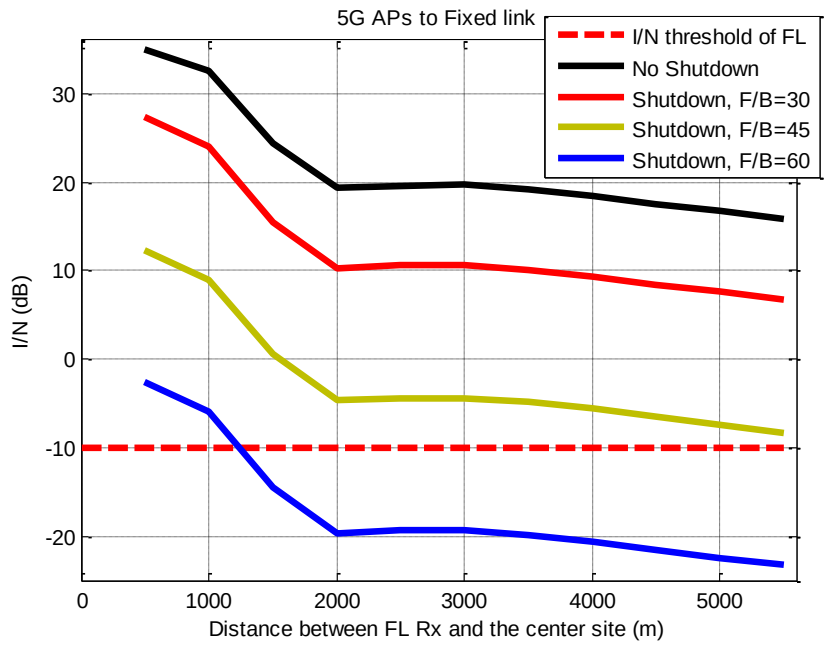

Figure 7. Interference from 5G AP into Fixed link (with beam shut down)

Figure 7 also demonstrates the impact of the 5G AP antenna front to back (F/B in the figure) ratio. As the ratio becomes higher, the AP-to-Fixed link interference becomes lower. This confirms the fact that with shutdown, the interference dominantly comes from the "Backside" beam of the APs.

4. Conclusion

Coexistence of a 5G access system and a wireless Fixed link system in the 70 GHz Band (71-76 GHz) has been discussed in this Appendix. Our simulation results showed that the 5G APs into Fixed link interference is the most significant and the technique of shutting down beams was effective in suppression of 5G-to-Fixed link interference while keeping the performance of the 5G system acceptable.

5. References

[1] 3GPP, *3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Channel model for frequency spectrum above 6 GHz (Release 14)*, TR 38.900, V1.0.0, June 2016.

[2] ITU, *Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz*, Recommendation ITU-R F.699-7.

[3] Federal Communications Commission, *Code of Federal Regulations, Title 47, Part 10*.

[4] G. MacCartney and T. Rappaport, "73 GHz Millimeter Wave Propagation Measurements for Outdoor Urban Mobile and Backhaul Communications in New York City," in *IEEE ICC 2014*.