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Investigation Of Suitable 5G Millimeter Wave Frequencies For Kut-City in Iraq

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Abstract: In order to design and plan for the next generation wireless communications system, for the channel, it is important to use a suitable model to predict appropriate and optimum frequencies. This paper is regarded as one of the few kinds of research in Iraq that deals with Millimeter-wave (Mm-waves) communication channels especially for Kut city which is located in eastern Iraq, on the left bank of the Tigris River, approximately 160 kilometers (99 miles) south of capital city Baghdad. In this article, different impacts of weather conditions on the strength of the transmitted signal in different environments and scenarios are presented. Moreover, the behavior of the millimeter-wave under the influence of many obstacles as it travels through the free space and atmosphere was studied. An NYUSIM simulator package is used to predict the performance of the channel. Two frequencies were used, 38 GHz and 60 GHz to test the channel performance and which frequency is best suited for Kut City environment. The weather database was real and actual obtained from the Iraqi weather reports authority. Moreover, the technical parameters of the mobile communications companies for 5G networks in Kut city were obtained and used via NYUSIM. The simulation result showed an agreement with the 38 GHz for its lower path loss and acceptable received power.

Keywords: atmospheric attenuation, mm-Wave propagation losses, weather condition effects, NYUSIM.

1. INTRODUCTION

Millimeter-waves are a wide range of spectrums, ranging from 30 to 300GHz, also have a bandwidth between 10 to1 mm, which means they will be larger than infrared waves and smaller than microwave and radio waves. It is also called the extremely high frequencies (EHF). It provides a wide range of benefits and applications for fifth-generation communications systems, and some will be mentioned as follow: first, the millimeter-wave could be utilized for transferring huge types of data, mobile communications, also are used for the strong speed internets, and it could be very advantageous, especially in (WPANs), more applications and other benefits that provided by the millimeter-Waves for the fifth generation nowadays and as shown in Fig. 1:

One of the big problems nowadays and with the development of technology every second is the atmospheric absorption, with the propagation mechanism effect.

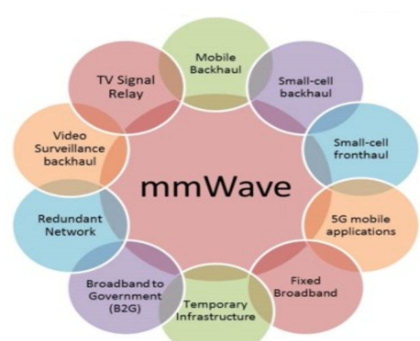

Figure 1. mm Wave Applications and Use-cases [1]

These challenges and difficulties are due to rain, fog, and water vapor. Each of the difficulties has a different effect on the frequency, at various rates, and also on the propagation path losses and the power received. Also it

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will cause several propagation mechanisms effect like scattering, reflection, and diffraction.

At millimeter-wave, it's important to calculate the characteristics of the propagated wave. The weather has a greater impact on millimeter-waves, due to their shorter wavelength, therefore it can be attenuated easily by the atmospheric impairment. One of the significant element in modeling the wireless channel is the (FSPL) referred to free space path loss, which is very important at millimeter-wave frequencies, as the permeation losses and these significant elements are studied and calculated in section 4 .

This paper makes a significant contribution because it is one of the few studies in Iraq that focuses on Millimeter-wave (Mm-wave) communication channels, notably in Kut. Previous studies [2] and [3] investigated the best frequencies for Baghdad city, but they relied on weather data from the internet and for specific cases, as opposed to the current study, which relied on real and current data from the Iraqi weather report authority, which is another contribution of our paper. Furthermore, real data of some technical parameters belonging to Kut city local communications mobile companies are obtained in order to programme the NYUSIM software package.

Different impacts of weather conditions on the strength of the transmitted signal in different environments and scenarios are presented. Moreover, the behavior of the millimeter-wave under the influence of many obstacles as it travels through the free space and atmosphere are studied. The calculations of the channel modeling that was simulated by the NYUSIM package with the use of real data from Iraqi weather reports were included in this article for both 38 GHz and 60 GHz frequency. According to UMi scenario (urban microcell) the results were simulated in Line-Of-Sight environment and the weather impacts are put into consideration during the simulation run like (rain, fog, temperature and gas) . For predicting the whole attenuation experienced by millimeter-Wave signal, the essential use of complicated channels models is needed, thus leading to the excellent performance of millimeter-wave.

The article was arranged as follows: section **2** presented an overview of the previous researches on the impacts of weather conditions and channel modeling, section **3** stated the atmospheric condition effects that consist of Rain, fog and gas attenuation in addition to absorption loss factors, section **4** addressed the mmWave channel modeling, R.M.S delay spread, path loss, attenuation and the received power, section **5** mentioned the channel model supported by the NYUSIM software, section **6** included the explanation of the simulation results, while in final section **7** the conclusion is set.

2. Literature survey of previous research

Some of the previously studied were reviewed in this section based on the year they were published. In [1,] a simple model for evaluating rain-induced attenuation is presented. It was discovered that the simple attenuation models used in their experiment performed admirably in the critical regions of low percentages of time.

Whereas in [4], the article discussed the interface between electromagnetic radiation and rain, as well as some test results in a frequency range ranging from (1-100 GHz). They used a Fortran computer programme for wavelengths ranging from 30 millimetre (10 GHz) to 3 millimetre (100 GHz) to calculate the attenuation and phase dispersion caused by evenly distributed rainfall. In 1999, on the other hand.

In [5], the authors discussed how weather and the atmosphere could affect the operation of millimeter-wave communications links in [5]. The Friis-free-space equation is a widely used equation for estimating signal attenuation due to electromagnetic wave spreading; for frequencies ranging from 500 megahertz to 10 gigahertz, the model provides an excellent calculation for propagation loss. They estimate transmission loss, molecular resonance of H2O, molecular resonance of O2, and precipitation in this article.

In [6], The effect of fog on mmWave propagation was investigated in [6]. The haze of fog Based on the gamma distribution, a Monte Carlo procedure was used to determine the model propagation, and millimeter-wave propagation methods at various frequencies were simulated. It has been determined that the greater the visibility, the shorter the distance of propagation. In addition, the lower the frequency, the shorter the attenuation and the better the transmission. Furthermore, the impact of fog on mm-wave propagation is quite weak below 35GHz.

Based on the true estimate range discovered, [7] discussed the effects of atmospheric variables on the power of the mmWave range signal that was propagated. The measurement results showed that the propagation signal was mitigated as a result of changes in weather conditions.

Where They discussed the accuracy of high-resolution radars in mist conditions in [8]. To demonstrate the quantitative effects of dense fog, they used a machine that generates fictitious haze. Empirical estimates show agreement with the expected purposeful outcome.

A study on the influence of atmospheric obstacles on mm-wave based on long-distance telephone services was presented in [9]. Using the MATLAB application, they investigated the effects of sedimentation, mist, and atmospheric absorption on diffuse millimeter-wave. Next They presented a space-frequency theory for modelling wireless communication channels operating at extremely high frequencies in [10], which investigated the effects of atmospheric conditions on millimeter-wave propagation.

The purpose of [11] was to provide a synopsis of the impact of atmospheric variations on mm-wave propagation, specifically the blending attenuation caused by rain rate, mist, water vapour, and oxygen. Finally, it was determined that the modification of a channel containing a large amount of information and concepts is critical for the better dissemination of fifth-generation wireless communication. The impact of rain on mmWave communications in tropical areas has been studied in [12]. A specific attenuation has been calculated at various millimeter-wave frequencies, and its variation has been assessed as a function of rainfall and frequency. Rain attenuation is very significant in both the 50 GHz and 60 GHz bands, even at very low rain rates, so these bands of frequencies can only be used for very short distance communication.

They discussed the characterization of 5G channels at millimetre wave using the NYUSIM-based Approach in Iraq, specifically for Baghdad city, in [2]. The articles demonstrated how changes in atmospheric conditions could affect the performance of mmWave transmission. Following that, in [3,] they investigated the best and most suitable 5G wave frequencies for Baghdad. For two months of the year (January and July), at frequencies 28 GHz and 73 GHz, an NYUSIM package was used to predict channel performance under weather conditions. It has been discovered that the 28 GHz frequency band is better suited for Iraqi environments.

The visibility of the 73 GHz and 28 GHz Frequency Bands MIMO Channels has been investigated in [13] for Outdoor. The MIMO channel is simulated over a frequency-selective Rayleigh fading channel using a practical scenario-relied on (SSCM) statistical spatial channel model. There were minor differences in path loss, coverage distance, and other factors between the 73 GHz and 28 GHz frequencies, so both are suitable for the new 5G system in general. A new planning and deployment tool for 5G radio networks has been released. The Close in Free (CI) channel model, which is included in the NYUSIM 5G radio design tool, is investigated in [14]. The study's goal was to develop new software to address the shortcomings identified in the NYUSIM tool. [15] contains a formalised paraphrase. An article discussed the use of MIMO Antennas and Statistical Channel Modeling of the Millimeter Wave at 73 GHz and 28 GHz Frequency Signals. The (AOA) and (AOD) angles, power loss, power delay profile, and route loss are all simulated in this study. These simulations use multiple antennas and account for the effects of weather conditions such as rain, humidity, and temperature.

3. Atmospheric condition effects

In the study of millimeter wave, there are some important concepts and terms that must be known to study the influence of the atmosphere within the wave during its spread in free space, and some of them are reviewed here:

A. *Atmospheric losses*

That means when the millimeter wave travels through the atmosphere it well be absorbed by different components of atmosphere such as O2 and H2O and others.

B. *Absorption loss factors*

- for example, the losses from gaseous and rain loss or other obstacles in millimeters environment.
- At particular frequencies those losses are higher, corresponding with what's called (mechanical resonant) frequency of the gas particles.
- for the aim of forecasting mm Wave propagation profiling's, both water vapor and oxygen resonances have been analyzed vastly.
- Three main weather condition effects (rain, fog, and gases) on the mm Wave propagation will be discussed. An estimation was done to see the impacts of these three-weather condition is presented and discussed in section Ⅵ (simulation results). The weather effects are listed as below:

C. *Propagation loss as a result of rain*

The atmospheric path loss explains only the side of signal attenuation that takes place when traveling in a vacuum, however in actuality, no signal can travel in a vacuum, but it will interface with air molecules, and thus it will lose energy as the signal travels in the diffusion path. Rain is considered one of the biggest concerns facing millimeter-wave diffusion. The attenuation due to the rain is more at frequencies higher than 100GHz. It has been concluded that the higher frequencies in millimeter-wave are not suited for outdoor communications, and the higher the rainfall, the more attenuation.

According to Crane's theory, the theoretic prognosis of rainfall particular attenuation relied on geophysical data of rainfall rate, the structure of rain, with the air temperature fluctuation is in (1) and (2) in [16]:

$$A_r = ar^b[\frac{e^{ubD}-1}{ub}](0 \le D \le d) \quad (1)$$

$$A_r = ar^b\left[\left\{\frac{e^{ubD}-1}{ub}\right\} - \left\{\frac{B^b.e^{cbD}}{cb}\right\} + \left\{\frac{B^b.e^{cbD}}{cb}\right\}\right] (d \le D) \quad (2)$$

Where $u = \frac{\ln(Be^{cd})}{d}$; $B = 2.3r^{-0.17}$; $B = 2.3r^{-0.17}$; $d = 3.8 - 0.6\ln(r)$ and path attenuation (Ar) due to rain are calculated in (dB), the path length is calculated in meters and the rain rate is evaluated in millimeters per hour. The rain attenuation coefficients a and b are polarization-dependent multiplier and frequency.

D. Propagation loss as a result of fog

Both fog and cloud are made up of water droplets, however its much smaller as opposed to that of rain-drops. In general fog-droplets are smaller than 0.01 cm in size . the effect of both fog and cloud very limited, however it may be essential in few uncommonly. According to studies, as the density of liquid water increases, so does the attenuation.

The Rayleigh approximation for frequency above 200 GHz is useful for clouds and fog consisting exclusively of tiny droplets, typically 0.01 cm and less, and the particular attenuation within a fog or cloud may be expressed as in (3) as in [17]:

$$\gamma_c(f,T) = K_l(f,T)M \qquad \text{(dB/Km)} \qquad (3)$$

Kl is the cloud liquid water of specific attenuation coefficient (dB/km)/(g/m3), M presents the liquid water density in the cloud or fog g/m3, where γ_c is the specific attenuation dB/Km within the cloud, T is the cloud liquid water temperature (K) and f is the frequency in GHz.

E. Propagation loss as a result of gas

Even in the absence of rain and fog, the atmosphere is dense with substances that impede signal propagation along the propagation route. The International Telecommunication Union suggested a model for atmospheric gases attenuation that characterizes it like a function of dry type atmospheric pressure, which is measured in (hectopascal) and is similar to oxygen pressure, and water vapour density, which is measured in g/m3. At a normal temperature of 15 degrees Celsius, the standard atmospheric pressure is (101325 Pa).

In instances when great precision is not required, for rapid and rough estimations of specific attenuation. The particular gaseous attenuation for frequencies over 350 GHz is calculated as in (4) in [21]:

$$\gamma = \gamma_0 + \gamma_w = 0.1820\, f\, N_D''(f) \qquad \text{dB/Km} \qquad (4)$$

Where $\gamma\,\omega$ and $\gamma\,o$ depict the given attenuations in dB/km owing to dry air (oxygen, non-resonant Debye attenuation, and pressure-induced nitrogen), f represents the frequency in GHz, where $N''(f)$ is the fictitious part of the frequency-dependent complex refractivity as in (5) [21]:

$$N''(f) = \Sigma_i S_i F_i + N_D''(f) \qquad (5)$$

$N_D''(f)$ is the continuos dry owing to Debye spectrum and the pressure-induced nitrogen absorption. For frequencies (f) above (118.750343) GHz oxygen line, the aggregation should begin at i = 38 rather than at i= 1. The sum extends over all lines (only oxygen lines higher than 60 GHz) complex must be inserted in the summation, The line's tensile strength is determined in (6) below and as in [18]:

$$S_i = a_1 \times 10^{-7}\, p\, \theta^3 \exp\left[\, a_2(1-\theta)\right] \ \text{for oxygen} \qquad (6)$$
$$= b_1 \times 10^{-1}\, e\, \theta^{3.5} \exp[b_2(1-\theta)] \ \text{for water vapour}$$

4. Millimetre wave channel model

In the spectrum band from 500 MHz and 10 GHz, the attenuation determined by using Fries free- space propagation equation, will have accurate propagation loss.

A. Path Loss & Attenuation Model

In NYUSIM, the close-in free space reference distance (CI) route loss model based on (1 m) fixed point is used, for an extra attenuation component because of different atmospheric attenuation coefficients, as shown in (7) at [19] :

$$PL^{CI}(f,d) = FSPL(f,1\,m)[dB] + 10n log_{10}(d) + AT[dB] + X_\sigma^{CI} \qquad \text{[dB]} \qquad (7)$$

Where d ≥ 1m

where (f) represent the carrier frequency in gigahertz, (d) is the 3D transmitter-receiver segregation distance, (AT) is the atmospheric attenuation term, is a zero-mean Gaussian random variable with a standard deviation in (dB). (n) is the Path Loss Exponent (PLE). The function FSPL (f, 1 m) represents the (Free Space Path Loss) in dB at a transmitter-receiver separation distance of 1 meter at the carrier frequency f and is given in (8) as follows:

$$FSPL(f,1\,m)[dB] = 20log_{10}\left(\frac{4\pi f\times 10^9}{c}\right) = 32.3\,dB + 20\,log_{10}(f)) \qquad (8)$$

where (c) is refered to speed of light, and (f) is the frequency in gigahertz. In (9) it characterizes the term (AT):

$$AT[dB] = \alpha[\tfrac{dB}{m}]d[m] \qquad (9)$$

B. Power Received

The received power for a millimeter Wave communication channel was derived in (10) by adding the power of each solitary multipath component in time. Friis-free-space equations describe the relationship between transmitted and received power.

$$Pr = Pt\; Gt\; Gr\; \frac{\lambda^2}{(4\pi d)^2} \qquad (10)$$

C. RMS Delay Spread

In any wireless setting, it is one of the most significant quantifiable values. The delay spread of a communications channel is a measure of its multipath richness in telecommunications. The change between the time of arrival of the earliest major multipath component and the time of arrival of the later multipath components may be described in general terms. The spatial properties of multipath as a function of angle can be described in a variety of ways. As future mm-Wave wireless systems rely on directed, adaptive antennas, angle spread is a propagation parameter that will become increasingly significant. Angle spread refers to the spatial dispersion of received signals arriving by multipath propagation, as evaluated against a mean arrival of an angle or departure.

The arrival of an angle (AOA) for a signal (for example, radio, optical, or acoustic) is the way from which the signal (for example, broadcast, visual, or audio) is received. The direction of propagation of a radio frequency wave impinge on an antenna array or the highest signal intensity during antenna rotation can both be used to make the measurement. [16] The AOA is determined by calculating the time deferred arrival (TDOA) between individual array items. An AoA system contains an antenna array on the receiver side, as illustrated as in Fig. 2, therefore the phase-shift of the incoming signal may be measured. The AOA and AOD is calculated as in (11) below:

$$H = \sqrt{\frac{M_{UE}M_{BS}}{P}} \sum_{P=1}^{P} \alpha_P \, a_{BS}(V_P) a_{UE}^{*}(w_p) \qquad (11)$$

Where $w \triangleq \sin(\emptyset)$ and $v \triangleq \sin(\theta)$, (UE & BS) is the user equipment antenna and the base station antenna respectively. a_{BS} & a_{UE}^{*} are the Array response vectors , ($V_P$and V_P) are the AOA/AOD angle, p refers to number of paths, H stands for channel. And finally α_P is the path gain.

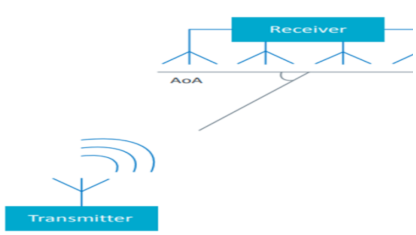

Figure 2. AOA method[16]

Angle Of Departure (AOD): The antenna array is used to guide the transmitted signal in a certain direction as shown in (3):

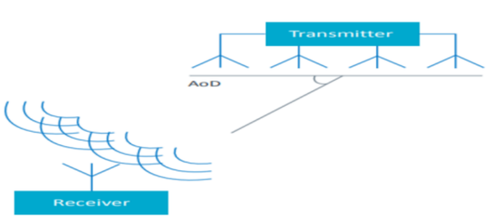

Figure 3. AOD method[16]

D. Extra Attenuation Factors

There are different extra factors that will impact the frequencies higher than 10 GHz, which are attenuation caused by mist, fog, or rain and absorption caused by gases or water vapor. A better comprehension of the aforementioned factors is significant in order to design a perfect Mm-waves channel model for time-varying weather and atmospheric conditions. For Mm-communications waves, [17] the total transmission loss is as in Fig. 4 and Fig. 5 below:

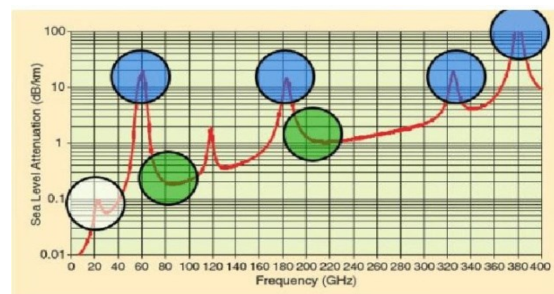

Figure 4. Atmospheric attenuation of electromagnetic radiation[17]

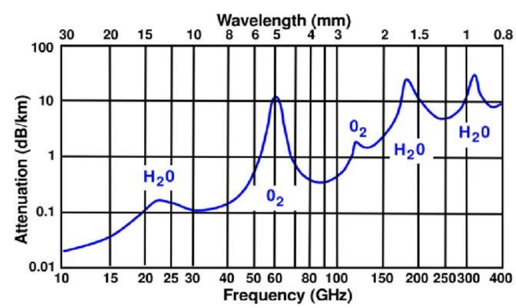

Figure 5. Effect of oxygen absorption across the mm-Wave[17]

The total attenuation is measured as in (12) below:

$$Attenuation(dB) = 92.45 + 20log_{10}(dkm) + a + b + c + d + e \qquad (12)$$

Where (a, b , c ,and e) represents an extra attenuation (dB) due to water vapor, mist or fog oxygen , and rainfall respectively. While d is absorption losses (dB) because of other gases. Path loss depicts a drop in the energy density of electromagnetic wave when it is transmitted and spreads through space. while, shadowing happens fundamentally in Non-Line of Sight (NLOS) scenarios that caused from obstacles and in turns, allow important attenuation of signal strength. For a multipath channel, the statistical power distribution of a received signal power will be represented by Power Delay Profile (PDP) as a function of propagation delays. PDP is a necessary parameter that describe Mm-Wave radio propagation [17].

5. CHANNEL MODEL SUPPORTED BY NYUSIM

The channel model that was developed by the New York University Wireless Group was based on Mm-wave and established for frequencies from 0.5 to 100 GHz. This model generates sample functions of the spatial and temporal channel impulse response (CIR) from both directional and omnidirectional channel models that are enhanced by models and measurements of NYUSIM WIRELESS [18]. The simulator have two modes, Drop Based and spatial consistency modes. Fig. 6 depicts a screenshot of the NYUSIM's GUI (graphical user interface). Channel impulse responses (CIRs) taps can be generated by NYUSIM that performs Monte Carlo simulations at specific separation distances between the transmitter and receiver. Users should provide the range of T-R separation distances as well as the number of samples.

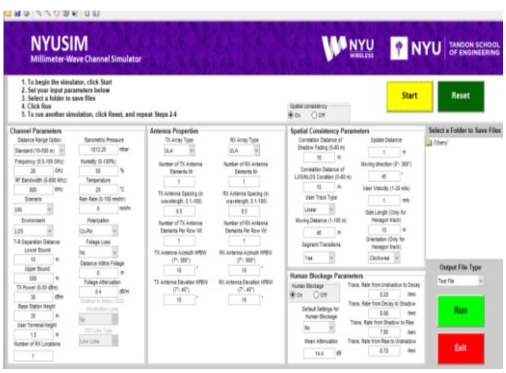

Figure 6. Graphical User Interface

For a PC server with two processors and 96.0 GB RAM, one hundred (100) CIRs could be generated by NYUSIM within 22 minutes in different formats as output files (such as seven for each .mat files, seven sets of .txt files, and five .png files). As seen in the GUI of Fig. 6, the NYUSIM channel simulator requires 28 parameters for both channel and antenna setting. The GUI's panel antenna characteristics provides **12** input parameters for transmitter and reception antenna arrays, while propagation channel is included in the panel channel characteristics that needs different input parameters [18]. In Table 3 an explanation for the legend of outputs simulation figures were presented.

6. Methodology of the work

This section presents an overview of the methodology of the work model. First of all, weather conditions of Kut city were collected from the weather reports for two seasons, winter and summer. The minimum and maximum temperatures in Kut city among

these two season were 8.5˚ and 50˚ respectively. The effect of weather condition, Rain, fog and gas is presented. Two frequencies were chosen for the simulator which is 38 and 60 GHz respectively. Table 1 and 2 shows the input parameters for winter and summer in Kut city, Iraq.

TABLE 1. Input parameters for winter

Parameter	Selected value	Parameter	Selected value
Amount of Power Transmitted (Pt)	30 (dBm)	***HPBW RX antenna elevation***	8.6°.
Polarization.	Co-Polarization.	***Pressure at the surface of the earth***	995 (mbar)
Scenario.	UMi.	***Temperature***	8.5° C
The quantity of RX locations .	1	***Humidity***	80%
Type of array TX.	ULA	***rate of precipitation***	20(mm/ hr)
HPBW TX antenna azimuth	10.9°.	***Environment***	LOS
HPBW.RX antenna azimuth	10.9°.	***Bandwidth***	800 (MHz)
HPBW.TX antenna elevation	8.6°.	***Frequency***	38-60 (GHz)

TABLE 2. Input parameters for summer

Parameter	Selected value	Parameter	Selected value
Amount of Power Transmitted (Pt)	30.2 (dBm)	***HPBW RX antenna elevation***	8.6°
Polarization	Co-Polarization	***Pressure at the surface of the earth***	1029 (mbar)
Scenario	UMi	***Temperature***	50°C
The quantity of RX locations .	1	***Humidity***	17 %
Type of array TX.	ULA	***rate of precipitation***	0 (mm/hr)
HPBW TX antenna azimuth	10.9°	***Environment***	LOS
HPBW RX antenna azimuth	10.9°	***Bandwidth***	800 (MHz)
HPBW TX antenna elevation	8.6°	***Frequency***	38-60 (GHz)

TABLE. 3 legend of the figures

Parameter	Definition
N	PLE
Σ	standard deviation of shadow fading
Omni	Omnidirectional
Dir	Directional
Dir_best	the path with the most power received
Pr	Received power
PL	Path loss
PLE	Path loss exponent

7. Simulation Results

After setup necessary parameters in the GUI of the NYUSIM, then the following results for 38 and 60 GHz were obtained after running the channel simulator for two season namely winter and summer.

1. Winter season results using frequency 38, and 60GHz

The 3-D Angle of Arrival and Departure are shown in (7) and (8) respectively for a single link between base station and user mobile for UMi (Urban Microcell) scenario (which is an outdoor environments), Line of Sight (LOS), and T-R separation of 500 meters for winter season using 38 and 60 GHz.

The AOA and AOD spectrums Fig. 7 and Fig. 8 shows the four multipath taps grouped into four AOA and AOD respectively. These figures can be used to study channel impulse response (CIR) that was affected by antenna beam widths. NYUSIM generates 3-D plotting to represent the Mm-waves that propagates through a 3D space, which is more practical.

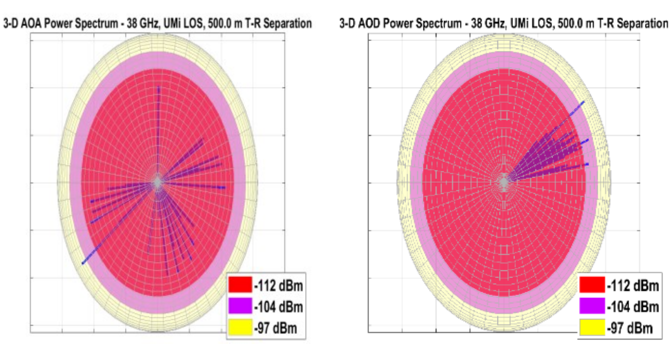

Figure 7. The 3-D of AOD and AOA at 38GHz for winter season

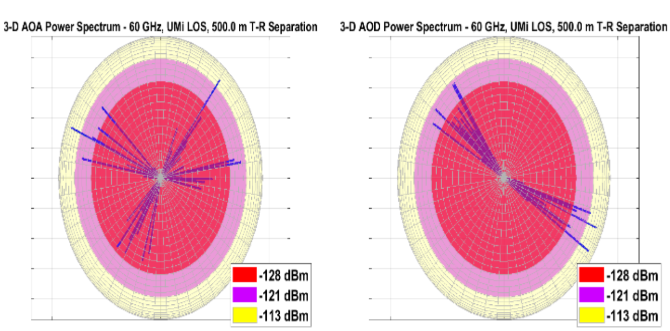

Figure 8. The 3-D of AOD and AOA at

Fig. 9 and Fig. 10 depict the omnidirectional anddirectional of Power Delay Profile (PDP) for the same month. The power delay profile (PDP) plots the intensity of a signal received over a multipath channel as a function of time delay, and the channel response appears as a series of pulses that may be used to extract channel characteristics like delay spread. As shown in Fig. 9, there exist three peaks which represents three multipath taps for omnidirectional measurements while directional measurements has four peaks which represents four multipath taps . Here, all parameter used to generate this PDP curve were included in Tables (1) and (2)

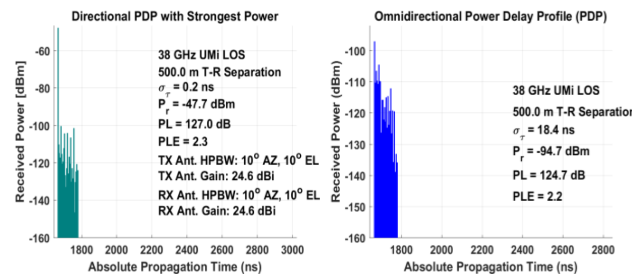

Figure 9. Power Delay Profile (PDP) directed and omnidirectional at 38 GHz for the winter season

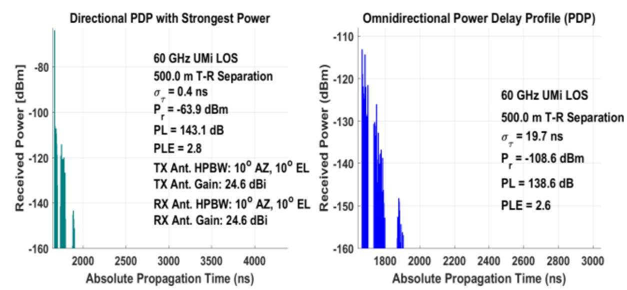

Figure 10. Power Delay Profile (PDP) directed and omnidirectional at 60 GHz for the winter season

Fig. 11 and Fig. 12 shows path loss and receive power charts using 38 and 60 GHz at winter season. For the Path Loss profile shown in Fig. 10, both 38 and 60 GHz curves has same behavior when increasing the distance and they are both decrease for received power profile but 60 GHz will decrease relatively more than 38 GHz curve.

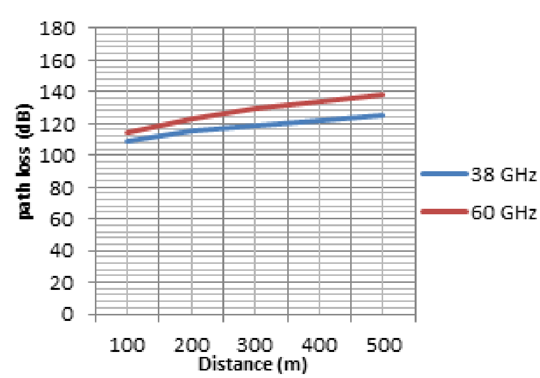

Figure 11. Path loss chart using 38 and 60 GHz for winter season

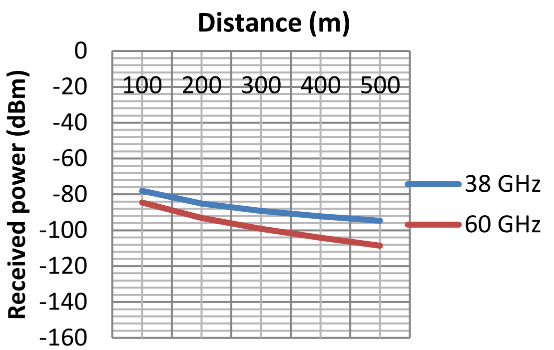

Figure 12. Receive power charts using 38 and 60 GHz for winter season

2. *summer season results using frequency 38 , and 60 GHz*

As shown in Table 2, for summer season different parameters have been used with the same scenario (UMi) and at Line-Of-Sight (LOS) environment, separation distance of 500 m at both (38 GHz and 60 GHz) as in winter season.

The 3-D of Angle of Arrival (AOA) and Angle of Departure (AOD) are shown in Fig. 13 and 14. Where Fig. 15 and Fig. 16 depict the omnidirectional and directional of Power Delay Profile (PDP) at 38 GHz and 60 GHz.

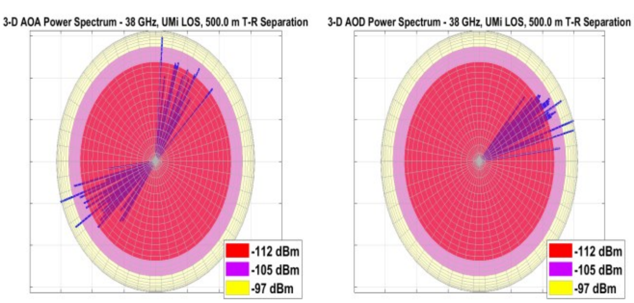

Figure 13. The 3-D of AOD and AOA at 38GHz for summer season

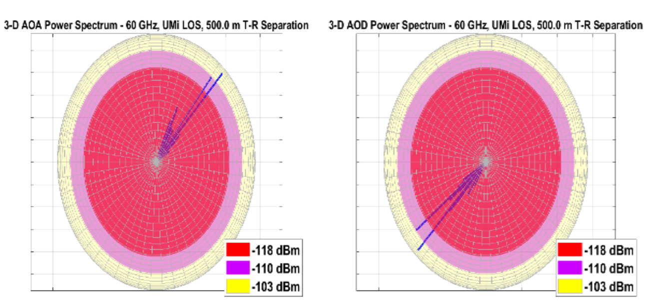

Figure 14. The 3-D of AOD and AOA at 60 GHz for summer season

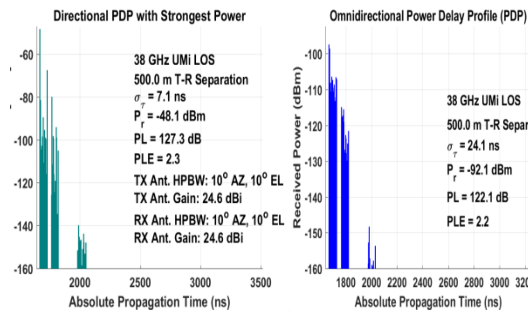

Figure 15. the directional and Omnidirectional of Power Delay Profile (PDP) at 38 GHz for summer season

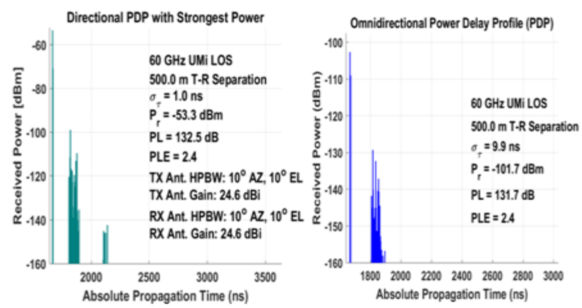

Figure 16. the directional and Omnidirectional of Power Delay Profile (PDP) at 60GHz for winter season.

The Fig. 17 & Fig. 18 below shows the path loss different between the 38 GHz and 60 GHz , at UMi scenario under LOS environment with the effect of the atmospheric impairments (humidity, temperature and pressure) , and it is showing that the path loss for the 60 GHz is higher than the path loss for the 38 GHz. For the received power at 60 GHz is lower than the received power at 38 GHz.

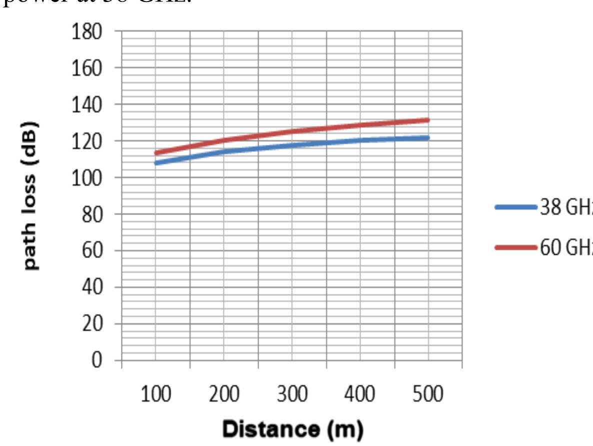

Figure 17. Path loss at 60 GHz & 38 GHz

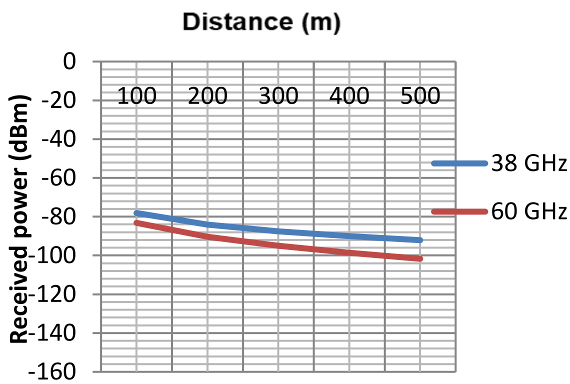

Figure 18. Received power at 60 GHz & 38 GHz

In the next figures, MATLAB have been used for our calculations, with the use of weather condition and with the help of mobile communications companies for 5G networks in Kut city, the attenuation caused by Rain, Fog and Gas is presented for various frequencies and different rain rate and fog visibility. Fig. 19 present the attenuation caused by rain:

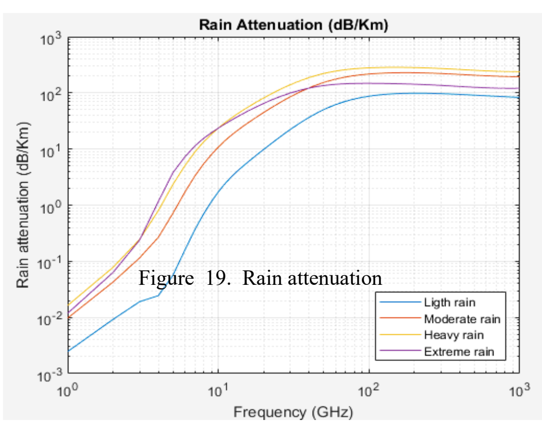

Figure 19. Rain attenuation

The attenuation signal that spread through rainfall areas is calculated in this model. At rainfall region when the electromagnetic signals spreads through it, it will be attenuated. Rain attenuation considered as a control fading mechanism, and it could fluctuate relying on the year and the location. According to the ITU rainfall Model Recommendation ITU-R P.838-3 the attenuation of rain is calculated.

As shown in Fig. 19 the attenuation increase with the increase of frequency, also four type of Rain rate were used (Light rain, Moderate rain, Heavy rain and Extreme rain). It can be noticed that the attenuation rise with increased Rainfall. In (10) it depict the attenuation model of signals that spread through the rainfall regions caused by rain in MATLAB that were used in this calculation [23]:

$$y_r = Kr^{\alpha} \tag{10}$$

where **r** is the rain rate and it was taken as (4,16,50,150) in millimeter per hour respectively. Where $\boldsymbol{\alpha}$ and K exponent rely on the state of polarization and was taken as (Co-polarization), the angle of elevation for the signal path (0˚), and the frequencyup used were from 10 up to 1000 GHz .

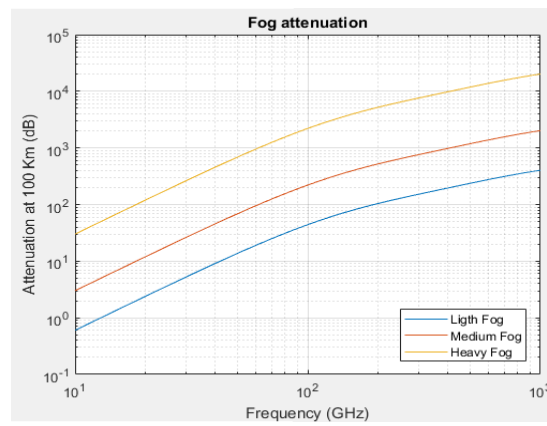

Figure 20. Fog attenuation

The attenuation of signal that spread across clouds and fog are estimated in this model. Clouds and fog are from similar atmospheric circumstance. The attenuation is calculated based on the ITU Recommendation ITU-R P.840-6.

Figure 20, shows the attenuation caused by fog in different kinds like (Light Fog, Medium Fog and Heavy Fog) for frequencies up to 1000 GHz, where real data measurement were used from the weather reports authority for Kut City, it is obvious that with the increase of fog density the attenuation as well increase specially for high frequencies. The model attenuation is implemented for both fields as polarized and the non-polarized. Equation (11) shows the propagation loss (attenuation) caused by fog at each frequency in MATLAB weath using range of frequencies varies from 10 to 1000 Gigahertz, a water density of 0.01, 0.05 and 0.5 g/m^3 respectively for the three type of fog visibility [24]:

$$y_c = K_l(f)M \tag{11}$$

$K_l(f)$ quantity is the coefficient of a specific attenuation, and M is the water density liquid in gm/m^3.

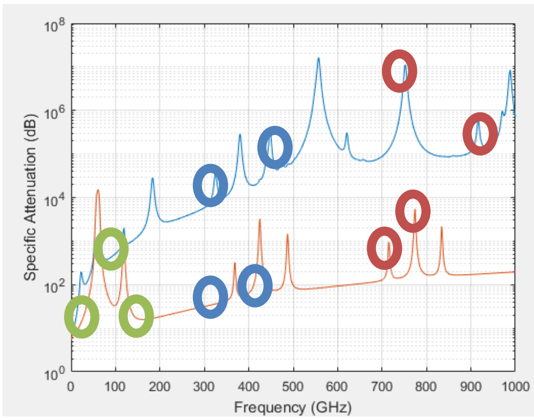

Figure 21. Gas attenuation

In Fig. 21 the green circles represent the range of frequencies that has lower attenuation like 28 GHz and 38 GHz, while the blue circle shows the acceptable range of frequencies that has attenuation level similar to attenuation in current communication channels. Red circles shows the high rates of attenuation in specific frequencies, so it is viable for indoor communication.

Equation (4, 5 and 6) as was discussed in section 3 were also used in evaluation the attenuation for gas in MATLAB, where the frequency range were used from 10 to 1000 GHz, for atmospheric pressure of 1029 kPa, water vapor density of 7.4 g/m^3 and a temperature of 16C$^{\circ}$.

Table 4. below shows different values that represent the AOA, AOD, R.M.S Delay spread, Received power and path loss for 38 GHz frequency at a separation distance of 500 m and an antenna configuration of 32X8. The power delay profile (PDP) gives the intensity of a signal received through a multipath channel as a function of time delay. The time delay is the difference in travel time between multipath arrivals. In telecommunication, the delay spread is a measure of the multipath richness of a communication channel.

TABLE. 4 AOA, AOD, R.M.S Delay Spread and Received Power For 32X8 Antenna, 38GHz, 500M

Beam	Time Delay (ns)	Received Power (dBm)	Phase (rad)	Azimuth AoD (degree)	Elevation AoD (degree)	Azimuth AoA (degree)	Elevation AoA (degree)	Path Loss (dB)	R.M .S Delay Spread (ns)
1	1667	-101.2	3.9	32	-21.6	211.7	22	131.2	1.4
2	1670	-112.2	3.1	21	-26.2	55.8	20	142.1	7.1
3	1673	-115.6	1.9	25	-24.6	202.6	3	145.5	7.6
4	1677	-107.4	0.9	10	-17.5	47	40	137.4	0.3
5	1680	-114.9	6	28	-22.4	44.1	4	144.4	8.3
6	1684	-121.3	6	30	-23.2	65.5	-1	150.8	6.3
7	1689	-107.9	5.5	34	-21.4	36.1	14	137.9	1.8
8	1693	-115.6	4.7	11	-21.9	40.3	-10	145.6	2.2
9	1697	-121.9	2.4	9	-22.4	28.1	17	151.8	2.7
10	1702	-114	3.9	15	-24.5	207.4	-3	144	3.7

8. Conclusion

This paper is considered as the first study for the city of Kut, The centre of wasit province, as well it is one of the very few studies in Iraq that considered the impact of different weather condition on the mm Wave. Furthermore, as another contribution of our paper, the current study used real data from the Iraqi weather report authority. In addition, real data of some technical parameters belonging to Kut city local communications mobile companies is obtained in order to programme the NYUSIM software package.

NYUSIM is useful tool to design next generation 5G communication wireless systems, that make use of frequency bands of 38-60 GHz. Moreover, this tool (i.e., NYUSIM) can know and determine the appropriate frequencies according to the climate and the geographical location of the city.

The NYUSIM was used to evaluate the effect of atmospheric conditions related to Kut, Wasit, Iraq city for aforementioned frequency bands. Through simulation measurements, the large separation distance and frequency bands, will increase path loss, especially for the frequency 60 GHz. In contrast, increasing separation distance will decrease the received power using 60 GHz compared with 38 GHz.

Moreover, the attenuation for each frequency is increased when the rain rates increase as well. For temperature condition, the path loss has maximum value at 60 GHz compared with 38 GHz frequency band. The 38 GHz is better for the received signal, although the influence of factors is more significant because in summer, the temperature is more affected, and in the event of rain, the effect is great. With regard to 60 GHz, the influence of factors is less on it, and therefore the attenuation is less, but nevertheless, the received signal is less by using 38 GHz.

A thorough research on the researches that studied the effect of the atmosphere and how best to treat it have been presented. also an overview of difficulties and challenges faced by the millimeter waves has been taken, this is important, and it needs to be solved, because it's a major pillar of the new fifth generation.

References

[1] Stutzman WL, Dishman WK. A simple model for the estimation of rain-induced attenuation along earth-space paths at millimeter wavelengths. Radio Science. 1982 Nov;17(06):1465-76.

[2] A. Al-Shuwaili , and Th. M. Jamel, 5G Channel Characterization at Millimeter-Wave for Baghdad City: An NYUSIM-based Approach,the 18th International Multi-Conference on Systems, Signals & Devices (SSD'21), Tunisia, 2021.

[3] Thamer M, Thulfaqar A, and Rafel K, Optimum and Appropriate 5G Millimeter Wave Frequencies for Baghdad City. The 3rd Conference of Post Graduate Researches & Graduation Projects ,CPGR′2021, 19 – 20 May 2021.

[4] Medeiros Filho FC, Cole RS, Sarma AD. Millimetre-wave rain induced attenuation: theory and experiment. InIEE Proceedings H (Microwaves, Antennas and Propagation) 1986 Aug 1 (Vol. 133, No. 4, pp. 308-314). IET Digital Library.

[5] Frey TL. The Effects of the Atmosphere and Weather on the Performance of a mm-Wave Communication Link. Applied Microwave and Wireless. 1999 Feb;11:76-81.

[6] Wei Y, Wu Z, Wu T. Research on the effects of offing fog on millimeter wave propagation. InOcean Remote Sensing and Monitoring from Space 2014 Dec 10 (Vol. 9261, p. 92611B). International Society for Optics and Photonics.

[7] Han C, Duan S. Impact of atmospheric parameters on the propagated signal power of millimeter-wave bands based on real measurement data. IEEE Access. 2019 Aug 5;7:113626-41.

[8] Golovachev Y, Etinger A, Pinhasi GA, Pinhasi Y. Millimeter Wave High Resolution Radar Accuracy in Fog Conditions—Theory and Experimental Verification. Sensors. 2018 Jul;18(7):2148.

[9] Nagaraj P. Impact of atmospheric impairments on mmwave based outdoor communication. arXiv preprint arXiv:1806.05176. 2018 Jun 13.

[10] Golovachev Y, Etinger A, Pinhasi GA, Pinhasi Y. The Effect of Weather Conditions on Millimeter Wave Propagation.

[11] Nandi D, Maitra A. The effects of rain on millimeter wave communication for tropical region. In2019 URSI Asia-Pacific Radio Science Conference (AP-RASC) 2019 Mar 9 (pp. 1-3). IEEE.

[12] Nandi D, Maitra A. The effects of rain on millimeter wave communication for tropical region. In2019 URSI Asia-Pacific Radio Science Conference (AP-RASC) 2019 Mar 9 (pp. 1-3). IEEE.

[13] Al-Omary A. Investigating the Visibility of 28 and 73 GHz Frequency Bands for Outdoor MIMO Channel. International Journal of Computing and Digital Systems. 2020 May 1;9(03).

[14] Squali L, Aloh JC, Riouch F. New Tool for 5G Radio Network Planning and Deployment. InThe Proceedings of the Third International Conference on Smart City Applications 2019 Oct 2 (pp. 634-646). Springer, Cham.

[15] Ram N, Gao H, Qin H, Oo MT, Htun YT. Statistical Channel Modelling of Millimetre Waves at 28 GHz and 73 GHz Frequency Signals Using MIMO Antennas. InJournal of Physics: Conference Series 2021 (Vol. 1732, No. 1, p. 012184). IOP Publishing.

[16] Qingling Z, Li J. Rain attenuation in millimeter wave ranges. In2006 7th International Symposium on Antennas, Propagation & EM Theory 2006 Oct 26 (pp. 1-4). IEEE.

[17] Sector IR. Recommendation ITU-R P. 840–6 attenuation due to clouds and fog. International Telecommunications Union. 2013.

[18] Series P. Attenuation by atmospheric gases and related effects. Recommendation ITU-R. 2019 Aug:676-12.

[19] Sun S, MacCartney GR, Rappaport TS. A novel millimeter-wave channel simulator and applications for 5G wireless communications. In2017 IEEE International Conference on Communications (ICC) 2017 May 21 (pp. 1-7). IEEE.

[20] https://infocenter.nordicsemi.com/index.jsp?topic=%2Fnwp_036%2FWP%2Fnwp_036%2Faoa_aod.html

[21] Rappaport TS, MacCartney GR, Samimi MK, Sun S. Wideband millimeter-wave propagation measurements and channel models for future wireless communication system design. IEEE transactions on Communications. 2015 May 18;63(9):3029-56.

[22] Sun S, MacCartney GR, Rappaport TS. A novel millimeter-wave channel simulator and applications for 5G wireless communications. In2017 IEEE International Conference on Communications (ICC) 2017 May 21 (pp. 1-7). IEEE.

[23] Radiocommunication Sector of International Telecommunication Union. Recommendation ITU-R P.838-3: Specific attenuation model for rain for use in prediction methods. 2005.

[24] Radiocommunication Sector of International Telecommunication Union. Recommendation ITU-R P.840-6: Attenuation due to clouds and fog. 2013.

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