Wasit Journal of Engineering Sciences

Journal homepage: https://ejuow.uowasit.edu.iq

mmWave Compound Link Budget Model of Dust and Humidity Effect

Hayder R. Idan[1] | B K J Al-Shammari[1] | Hasan F. Khazaal[1]

Affiliations
[1]Department of Electrical Engineering, University of Wasit, Wasit, Iraq

Correspondence

Hayder R. Idan,
Department of Electrical Engineering, University of Wasit, Wasit, Iraq
hadere301@uowasit.edu.iq

Received
5-May-2022
Revised
10-August-2022
Accepted
15-August-2022
Doi:
10.31185/ejuow.Vol11.Iss1.323

Abstract

MmWave Path Loss (PL) Link Budget (LB) modeling considerations are based on many different factors. For instance, the third generation partnership project (3GPP) model is mainly based on the distance from an Access Point (AP) and the frequency of transmission as well as the transmission link budget situation. Furthermore, there are certain interesting models about the effects of dust and humidity on the MmWave propagation. These models had introduced the consequences of the humid and dusty environments without consideration for the additional MmWave transmission LB parameters. First of all, this paper introduces an average dust and humidity model based on statistical Z-test in order to overcome the variation in the results between the three chosen models for dust and humidity effect in the MmWave range. Secondly, it proposes LB compound model, that comprises 3GPP PL LB with an average dust and humidity model. This introduced compound model has been applied on Rural Macro (RMa) PL LB with and without the presence of dust and humidity. The simulation of the presented model has been applied for distinct distances from the AP and MmWave transmission frequency range from 0.5 to 30 GHz. The compound model is simulated via Matlab for four scenarios (Out to Input (O2I)-low loss model, and Out to Input (O2I)-high loss model) (with and without dust and humidity). Through the results and at distance (100 m), frequency (30 GHz), and humidity (0,50,100) percentage, the path loss compound model will be (70.02, 70.57, 70.96, and 71.12) dB for the low loss model, and (94.02, 94.64, 94.91, and 95.1) for the high loss model.

Keywords: *MmWave, link budget, MmWave propagation, 5G standardization*

الخلاصة: تعتمد اعتبارات نمذجة ميزانية الارتباط MmWave (PL) (LB) على العديد من العوامل المختلفة. على سبيل المثال ، يعتمد نموذج مشروع شراكة الجيل الثالث (GPP3) بشكل أساسي على المسافة من نقطة الوصول (AP) وتواتر الإرسال بالإضافة إلى حالة ميزانية وصلة الإرسال. علاوة على ذلك ، هناك بعض النماذج المثيرة للاهتمام حول تأثيرات الغبار والرطوبة على انتشار موجات MmWave. قدمت هذه النماذج عواقب البيئات الرطبة والمتربة دون النظر إلى معلمات LB للإرسال MmWave الإضافية. بادئ ذي بدء ، يقدم هذا البحث نموذجًا متوسطًا للغبار والرطوبة يعتمد على اختبار Z الإحصائي من أجل التغلب على التباين في النتائج بين النماذج الثلاثة المختارة لتأثير الغبار والرطوبة في نطاق MmWave. ثانيًا ، يقترح نموذج LB المركب ، الذي يشتمل على ٣GPP PL LB مع نموذج متوسط للغبار والرطوبة. تم تطبيق هذا النموذج المركب المقدم على Rural Macro (RMa) PL LB مع وبدون وجود الغبار والرطوبة. تم تطبيق محاكاة النموذج المقدم لمسافات مميزة من نطاق تردد الإرسال AP و MmWave من ٠,٥ إلى ٣٠ جيجاهرتز. يتم محاكاة النموذج المركب عبر Matlab لأربعة سيناريوهات (نموذج خسارة منخفضة من الخارج إلى المدخل (O2I) ، ونموذج خسارة عالية للإدخال (O2I)) (مع وبدون الغبار والرطوبة). من خلال النتائج وعلى مسافة (١٠٠ م) ، والتردد (٣٠ جيجاهرتز) ، والنسبة المئوية للرطوبة (٠,٥٠١٠٠) ، سيكون النموذج المركب لخسارة المسار (٧٠,٠٢ ، ٧٠,٥٧ ، ٧٠,٩٦ ، ٧١,١٢) ديسيبل لنموذج الخسارة المنخفضة ، و (٩٤,٠٢ و ٩٤,٦٤ و ٩٤,٩١ و ٩٥,١) لنموذج الخسارة العالية.

1. INTRODUCTION AND RELATED WORK

Dust storms may cause MmWave communication system failures due to the attenuation, depolarization, and cross-polarization produced by storm particles. To accurately predict the effect of dust storms on MmWave communication systems, the computation of wave attenuation and cross-polarization is necessary. The above-mentioned effect parameters on MmWave propagation result mainly from scattering and absorption by storm particles. The majority of MmWave attenuation studies in sand and dust storms use the Rayleigh scattering approximation or Mie scattering theory [1]. Dust can decrease visibility to near zero, putting communication links out of commission for the duration of the storm. Sand and dust storms can be found in many places of the world, including the Middle East, the African Sahara, portions of Asia, arid Australia, and dry areas like Texas and Arizona in the United States Southwest. The transmitted signals are attenuated when MmWave passes through a medium containing precipitation, such as rain, snow, or dust particles, due to energy absorption and scattering by these particles [2]. Several of the prediction models for MmWave attenuation in a dust storm are based on theoretical notions like single-particle scattering theory. Some mathematical models, by comparison, are based on Rayleigh approximation and/or Mie scattering theory-based single-particle scattering theory, which does not account for multiple scattering effects or mutual interaction phenomena. Only approximations of dust particle parameters such as shape, dielectric constants, size, visibility level, and frequency are used [3]. These methods require knowledge of the scattering particles' electrical characteristics, such as their dielectric constant, geometrical shape, size, distribution, and visibility level during dust storms. Furthermore, the numerous interactions between these components make predicting the effect of a dust/sand storm on MmWave signal transmission extremely difficult. [4]. Dust storm impacts on MmWave propagation are typically approximated by solving the forward scattering amplitude function of a single particle. The Rayleigh approximation, accurate Mie scattering, and numerical models can all be used to solve this problem. The single-scattering approximation or multiple scattering modeling concepts is also used for randomly distributed particles in the air, relying on the concentration of dust particles in the dust storm unit volume [5]. The increased availability and use of data-hungry devices such as smartphones and laptops have resulted in a massive growth in worldwide mobile data traffic (GMDT). GMDT grew by 74 percent in 2015, reaching 3.7 Exabyte each month. This quantity is expected to reach 30.6 Exabyte by 2020 [6]. The Fourth Generation (4G) networks were not built to handle such rapid expansion. As a result, Fifth Generation (5 G) cellular standards will need to increase their capacity into the (Mm-Wave) band, which ranges from (3 - 300) GHz. Microwave bands (MW) are often limited because nearly all communication in cellular systems operates in the sub-3GHz band. As a result, migrating to the Mm-Wave frequencies is critical due to largely underutilized bandwidths, notably between 20 and 90GHz. These bands could be used in the (5G) system to increase a 1000-fold improvement in performance over current Advanced Long Term Evolution (A-LTE) networks [7]. Two recent trends have prompted a rethinking of Mm-Wave cellular feasibility. To begin, developments in Complementary metal-oxide– Semiconductor radio frequency CMOS RF and digital processing have made it possible to produce low-cost Mm Wave circuits suitable for commercial mobile devices [8]. This paper aims to evaluate the link budget (LB) of the Mm- waveband used for the 5G wireless network. To maintain the aim of the paper; some objectives are presented like,

1- Creating a compound model from the average model for the Rayleigh approximate model, Mie scattering model, and a Numerical model, which is combined with the 3GPP model. At this point, a composite (LB universal model) is developed to combine the effect of distance between transmitter-receiver (T-R), Building walls, Humidity, and Dust particles in Mm-Wave LB.

2-Study of the 3GPP free space attenuation model for the RMa scenario which includes the calculation of PLs through:

- Outdoor base path loss
- A loss of construction penetrating through the outside wall.
- Indoor loss function, and
- Density possibility.

3-A comparative study between the attenuation predicted by three models in the Dust environment such as:

- Rayleigh approximation,
- Mie scattering, and
- Numerical

with the presence and absence effect of the Humidity at frequencies (0.5 to 30) GHz.

4-Utilizing Statistical Z-test to confirm the convergence of the results of the attenuation models of all mentioned models. The rest of this manuscript is arranged as follows. The literature survey section 2. Section 3 reviews Dust particle losses. The 3rd Generation Partnership Project (3GPP) is studied in Section 4. The compound model is provided in Section 5. The results and discussion are presented in section 6. Finally, the conclusion is provided in Section 7.

2. LITERATURE SURVEY

In the article [9] the different impacts of weather conditions on the strength of the transmitted signal in different environments are presented. and the behavior of the millimeter-wave under the influence of many obstacles as it travels through the free space and atmosphere are studied. The article in [10] discussed the characterization of the fifth-generation channels at MmWave by using the NYUSIM package in Iraq and specifically in Baghdad city. The simulation results showed how would the variations of atmospheric conditions impacting the performance of MmWave propagation. In [11] the suitable and optimal fifth-generation wave frequencies for Baghdad-City were discussed. The study uses an NYUSIM package to predict how the channel will react under the weather condition, specifically for two months (July and January). They used two frequencies (28 and 73 GHz). The final result showed an agreement to 28 GHz in both two months.[12-new] explained how the weather conditions affect the strength of the transmitted signal in various environments and circumstances, as well as how the mmWave behaves as it passes through free space and the atmosphere.

[13] gave a comprehensive overview of channel models for 5G radio system design, including the overall framework of channel models as well the important differences between Mm Wave and microwave channel models. It also employed simulations to compare and contrast two representative channel models, the (3GPP model, and the New York University Simulation (NYUSIM model).

[14], reviewed MmWave propagation characteristics, including free-space path loss, atmospheric attenuation, rain, and foliage attenuation, material penetration, and other propagation factors. It then reviews MmWave channel models and the requirements and challenges for MmWave communication systems. [15] described a study on dust storm attenuate predictions depending on different theoretical methodologies and comparison with measurements, and the measurements show that dust storms are accompanied by relative humidity levels.

[16] studied the impact of propagating on microwave and millimeter waves in a dust storm. For a one–year period in Sudan, meteorological characteristics such as visibility and humidity, as well as their impact on 14and 22 GHz microwave propagation, were monitored for a year. It is apparent from the first empirical model that was proposed using data and can be used to predict dust storm attenuation. Through the presentation of previous research, some of which dealt with the characteristics of the fifth-generation networks using millimeter waves, the challenges and standards used in those networks, and the difference between millimeter-wave networks and microwave networks, several models were used, including the 3GPP model and the NYUSIM model. Some of them dealt with several models to predict the attenuation of millimeter signals due to sand and dust storms and the presence or absence of moisture. In this paper, a compound model is proposed that is based on the 3GPP model with an RMa scenario and an average model of dust particles. This model will be used for different frequencies and humidity levels.

3. DUST STORM ATTENUATION MODELLING

Sand and dust storms typically cause signal attenuation in (Mm W) transmissions. The impact of dust particles on communication system performance. As a result, exploring millimeter-wave propagation across dust storms is necessary for effective 5th generation linkages. The majority of prediction models for (Mm W) attenuation propagating through a sand storm depends on theoretical assumptions. It is based solely on estimates such as dust particle form, (G), (v_o), and (f). The chemical composition of dust samples, as well as frequency and humidity, influence their permittivity Various prediction models depend on various bases, such as (Rayleigh approximation, Mie theorem, and Numerical). approaches [4]

3.1 Rayleigh approximation model

This model, which is dependent on Rayleigh approximation and computed fading, can be provided for easily evaluated dust characteristics. Because dust strength decays in proportion to the visibility, the attenuation of this model can be calculated in (1) [5].

$$\alpha = 566.97 \times \left(\frac{1}{v_0}\right) \times \left(\frac{r_e}{\lambda}\right) \times (G) \quad [\mathrm{dB/km}] \tag{1}$$

Where

where $\boldsymbol{\alpha}$ is the attenuation parameter in (dB/km), $\boldsymbol{\lambda}$ is the wavelength in (m). $\boldsymbol{v_o}$ is the optical visibility (m), $\boldsymbol{r_e}$ (m) is the corresponding radius of the dust particle, and The factor (G) depends on the (ε) which can be calculated in (2) [3]

$$\boldsymbol{G} = \left[\frac{\boldsymbol{\varepsilon''}}{(\boldsymbol{\varepsilon'} + \mathbf{2})^{\mathbf{2}} + \boldsymbol{\varepsilon''}}\right] \tag{2}$$

The suspended particle's complicated permittivity about free space can be written in (2a) [3].

$$\varepsilon = \varepsilon' + j\varepsilon'' \tag{2a}$$

Where the dielectric constant's real and imaginary components are ε' and'ε'', respectively, the dielectric constant vs relative humidity relation, as in (2b) and (2c) [4].

$$\varepsilon'_H = \varepsilon' + 0.04 \times H - (7.78 \times 10^{-4}) \times H^2 + 5.56 \times 10^{-6} \times H^3 \tag{2b}$$

$$\varepsilon''_{\mathrm{H}} = \varepsilon'' + 0.02 \times \mathrm{H} - 3.71 \times 10^{-4} \times \mathrm{H}^2 + 2.76 \times 10^{-6} \times \mathrm{H}^3 \qquad (2c)$$

Where H is the humidity factor.

3.2 Mie scattering

It includes changes in dust particle size and form, which are represented by (AP) components in (3) [15].:

$$A_p = \frac{[c''_1 + c''_2 \times f^3 + c''_3 \times f^4]}{v^{1.07}} \qquad \mathrm{dB/km} \qquad (3)$$

$$\boldsymbol{c''_1 = 5.757 \times 10^{-5} \times C1} \qquad (3a)$$

$$\boldsymbol{c''_2 = 3.255 \times 10^{-12} \times C2} \qquad (3b) \text{ and}$$

$$\boldsymbol{c''_3 = 3.853 \times 10^{-7} \times C3} \qquad (3c)$$

where

$$\boldsymbol{C1 = \frac{6\varepsilon''}{(\varepsilon'+2)^2+\varepsilon''\text{^}2}} \qquad (3d)$$

$$\boldsymbol{C2 = \varepsilon'' \left\{\frac{6}{5}\frac{(7\varepsilon'^2+7\varepsilon^{n2}+4\varepsilon'-20)}{\left((\varepsilon'+2)^2+\varepsilon'^2\right)^2} + \frac{1}{15} + \frac{5}{3\left((2\varepsilon'+3)^2+4\varepsilon'^2\right)}\right\}} \qquad (3e)$$

and

$$\boldsymbol{C3 = \frac{4}{3} \times \left\{\frac{(\varepsilon'-1)^2(\varepsilon'+2)+[2\times(\varepsilon'-1)\times(\varepsilon'+2)-9]+\varepsilon''^4}{\left((\varepsilon'+2)^2+\varepsilon''\right)^2}\right\}} \qquad (3f)$$

where (f) is the working frequency and (c 1", c 2", and c 3") are parameters depending on the (ε) for dust particles. The parameter C is determined from dust particle complex permittivity (without effect humidity).

3.3 Numerical model

The Finite Difference Time Domain (FDTD) method was utilized to provide an equation that may be used to determine the attenuation of propagating Mm Wave from (0.5 GHz to 100 GHz) in dust, as shown in (4) [15]

$$\boldsymbol{\alpha = 8.686 \times 10^3 \sum_{k=1}^{K} \sigma_{ext}(k\Delta r) N(k\Delta r)\Delta r} \qquad (4)$$

$$\sigma_{ext} = \frac{8.05 \times 10^{-7}(f^{1.2}+1)}{V^{0.3} \times r} \times G \qquad [\mathrm{m}^2] \qquad (4a)$$

3.4Average Model

The implementation of the average model is investigated in this paper. The Rayleigh approximation, the Mie theorem, and numerical models are used to predict the attenuation of millimeter-wave (Mm-W) propagation through a dust storm. Figure 1 shows the stages of the creation of this model. using a Statistical Z-test to confirm the convergence of the results of the attenuation models of all mentioned models. Table 1 explains the parameters used in these models. In this paper, the dust storm particle radius of 11.25e-06 m was used for the calculation of wave attenuation. with a frequency range of (0.5-30) GHz and relative humidity of (0,50, 100). percentage. The samples' complex permittivity is 4.271-j0.109 and the optical visibility is 10m.

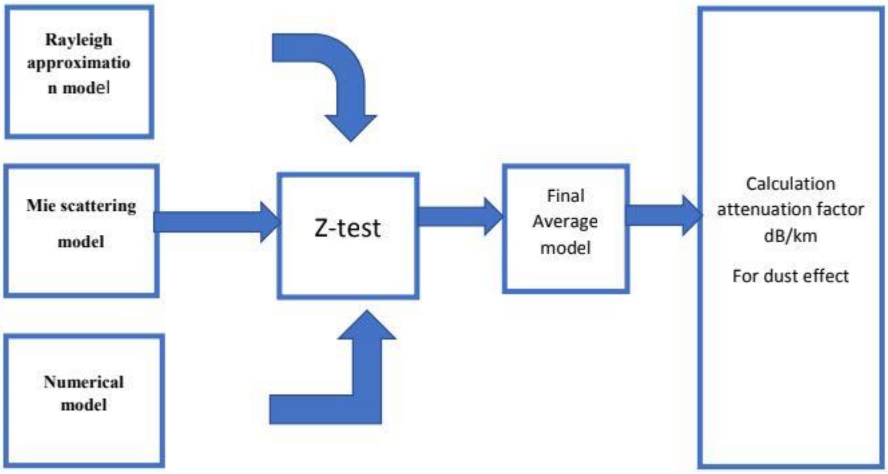

Figure 1 Average Dust effect presented as attenuation factor in (dB/km).

Table 1 Parameters of the dust storm

Parameters	The applicability ranges	Select value
f_c (carrier frequency GHz).	0.5 < fc < fH	0.5 < fc <30
v_0 is optical visibility	(1 -1000) m.	10m
Dust particle radius in meter[1]	5e-6 to 30e-6 meter.	11.25e-6
Relative humidity% H is	dry to 100	0 to 100
N (the max number concentration per cubic meter) [5].	Equal or less than 10^8	10^8
A chemical compound with complicated permittivity[3]	Є'- j Є" for SiO2	4.271-j0.109

4. THE 3rd GENERATION PARTENSHIP PROJECT PROJECT (3GPP RMa SCENARIO)

The (3GPP) is a project agreement between telecoms sector partners (Organizational Partners) to formalize worldwide mobile communications [17]. The 3GPP has distinct specifications like:

- the mobile industry in detail.
- Billing information.
- Speech coding at the source.
- Encryption.

In this paper, the path loss model for the 3GPP RMa scenario will be studied The RMa path loss model is generally used for tall transmitter heights above 35 meters and are important for predicting the statistical behavior of received signal strength and interference in rural settings [17]. Figures 2 and 3 show the location of the user and the BS in the (3GPP) model. Parameters of the RMa scenario are described in table 2. The PL of (3GPP - RMa scenario) for O2I loss of the penetration can be expressed as in (5)[18]

$$PL[dB] = PL_b + PL_{tw} + PL_{in} + N(0.\sigma_P^2) \qquad (5)$$

where PLb is the outer path base loss, PLtw is the building penetration loss over the wall, PLin is the depth in the building loss and ϭp is the penetration loss standard deviation. In the (3GPP) model. Materials like standard glass, Infrared Reflecting IRR glass, concrete, and wood are used. There are two models for losses (a high-loss model and a low-loss model), and the nature of these losses depends on the nature of the materials used in any scenario as shown in Table 3

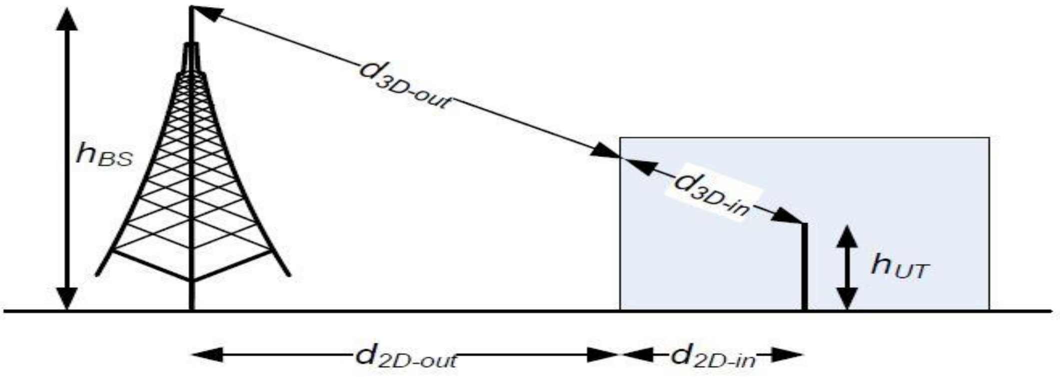

Figure 2 The communication between indoor and outdoor antennas [18.

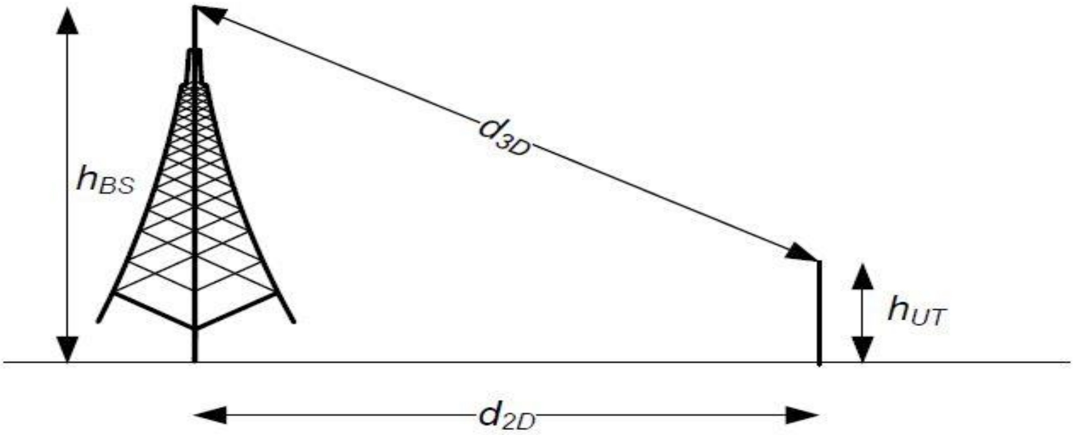

Figure 3 The communication in outdoor antennas [18].

Table 2 Evaluation parameters for RMa scenario

Parameters	RMa for The applicability ranges	Evaluation parameters(input)
f_c (carrier frequency GHz)	The frequency range 0.5 < fc < fH, where fH = 100 GHz .	0.5 < fc < 100
h_{BS} (the height of the base station in RMa)	10-150 m.	35m
h_{UT} (User Terminal) height	1-10 m.	1.5m
h = average height of the building.	5-50 m.	5 m
W = average width of street	5-50 m.	20 m
d2D = distance from h_{UT} to h_{BS}.	10m-10km.	10m-10 km
d_{2D-in} distance from h_{UT} to the outer wall toward RMa (h_{BS}).	(0-10) m.	10 m

Table 3 Material penetration losses **[18]**

Material	Penetration loss [dB]	Types of model
Standard multi-pane glass	$L_{glass}=2+0.2f$	IRR glass and concrete are used for high loss model
IRR glass	$L_{IIRglass}=23+0.3f$	
Concrete	$L_{concrete}=5+4f$	Standard glass and concrete are used for low loss model
Wood	$L_{wood}=4.85+0.12f$	

5. THE COMPOUND MODEL

In this paper, the implementation of the compound model depends on two major components. The first component (3GPP) of a model for the RMa is a scenario with varying distances and frequencies. The second component is that the average model is based on three different models ((Rayleigh approximation, Mie theorem, and numerical). The compound model can be calculated in (6)

$$\text{The compound model} = \text{Final average model} + \text{O2I path loss} \tag{6}$$

The compound model is simulated via Matlab for four scenarios (O2I - low loss model, and O2I - high loss model) (with and without dust and humidity).

6. RESULTS AND DISCUSSION

In this paper, the prediction of dust storm attenuation was studied using Rayleigh approximation, Mie equations, and numerical methods, as well as the presence and absence of humidity in the dust storm. After the studies of the channels mentioned above, the paper proposes an average model for the Rayleigh approximate model, the Mie scattering model, and a numerical model (using the Statistical Z-test), which when combined with the 3GPP model leads to a new model (the compound model). The 3GPP for RMa Line-of-sight LOS and non- Line-of-sight NLOS path loss models for frequencies ranging from 0.5 GHz to 30 GHz in two scenarios (the O2I high loss model and the O2I low loss model). The simulation results explain the behavior (Mm-Wave) signal propagating in the average model and the compound model as shown in the below figures.

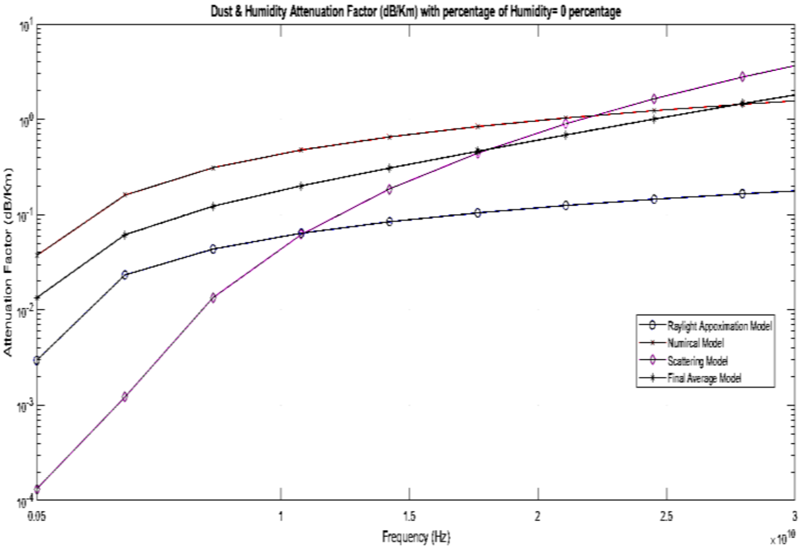

Figure 4 The attenuation for different models with range frequency (0.5-30) GHz at humidity (0) percentage.

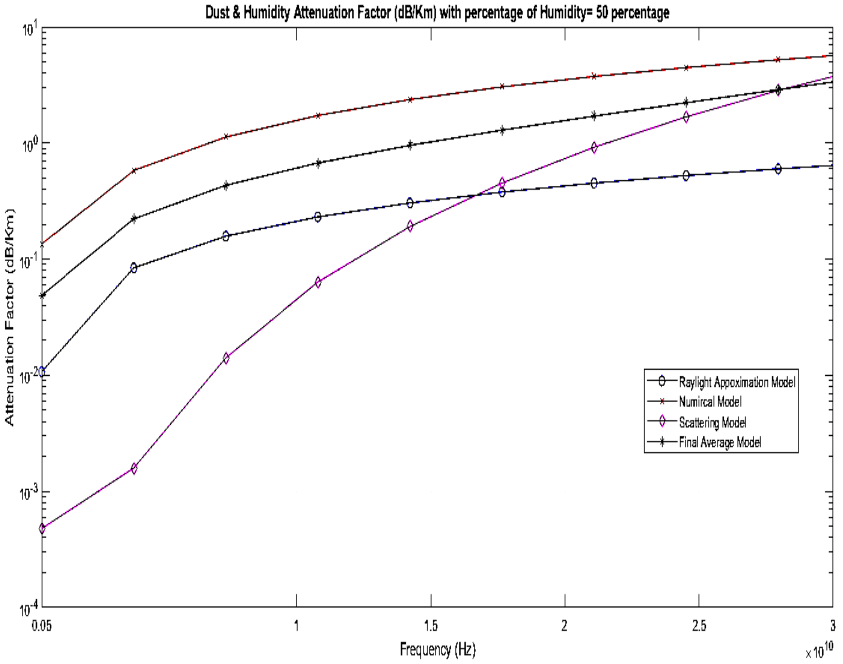

Figure 5 The attenuation for different models with range frequency (0.5-100) GHz and with humidity of 50 percentage

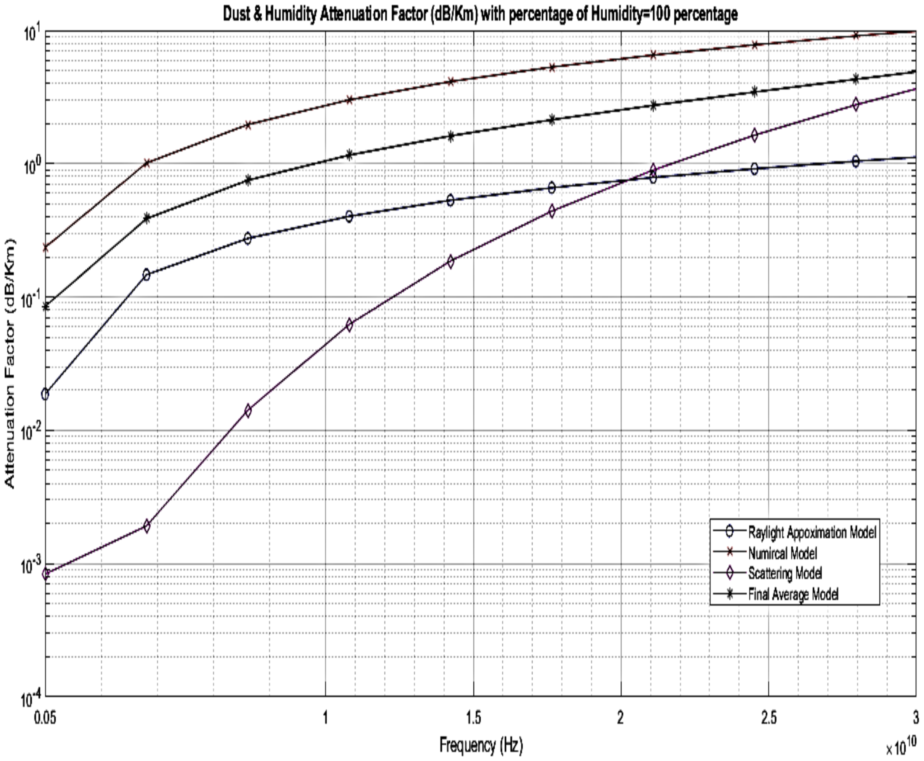

Figure 6 The attenuation for different models with range frequency (0.5-30) GHz and with humidity of 100 percent.

Figure 4, Figure 5, and Figure 6 represent average models for (**Rayleigh approximation, Mie equations, and numerical**) at a range of frequencies (0.5-30) GHz with humidity (0,50, 100) respectively, and this model increased with increased frequency and humidity.

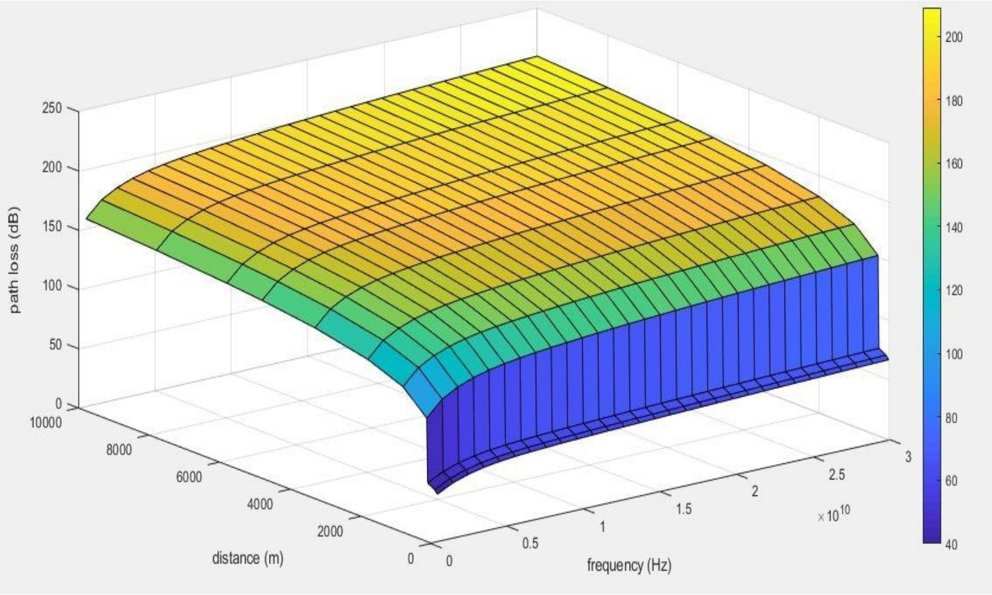

Figure 7 3D the compound model for the (O2I RMa-low loss model) without dust and humidity.

In figure 7, the path loss represents the compound model including ($3GPP$) for the (O2I RMa-low loss model) at different frequencies (0.5-30) GHz and distances (10-10.000) m between ($h_{\mathrm{BS}} - h_{\mathrm{UT}}$) without dust and humidity effect. It can be concluded that:

The path loss at distances below 300m is represented as Line-of-sight (LoS), and the path loss for other distances are represented as Non-line of sight (NLoS) because of the value of breakpoints.

- Path loss (O2I RMa-low loss model) increases with increased frequency and increased distance.

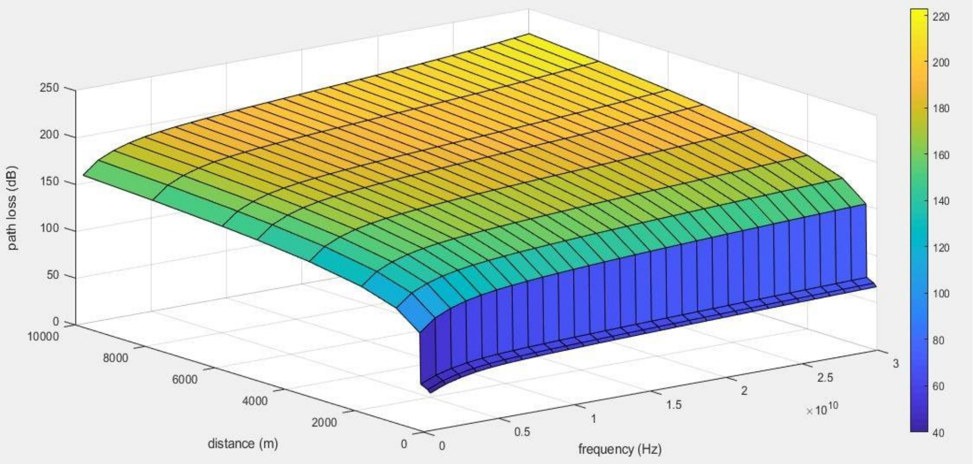

Figure 8 3D the compound model for the (O2I RMa-low loss model) with dust and without humidity.

In figure 8, the path loss represents the compound model including ($3GPP$) for the (O2I RMa-low loss model) at different frequencies (0.5-30) GHz and distances (10-10.000) m between ($h_{\mathrm{BS}} - h_{\mathrm{UT}}$) with dust and without humidity effect. It can be concluded that:

- Path loss (O2I RMa-low loss model) increases as frequency and distance increase.
- Because of the value of breakpoints, the path loss at distances less than 300m is represented (LoS), while the path loss at other ranges is represented (NLoS).
- The compound model in figure 8 is greater than the compound model in figure 7 for the same distance and frequency because the compound model in figure 8 is due to the dust effect and the compound model in figure 7 is not.

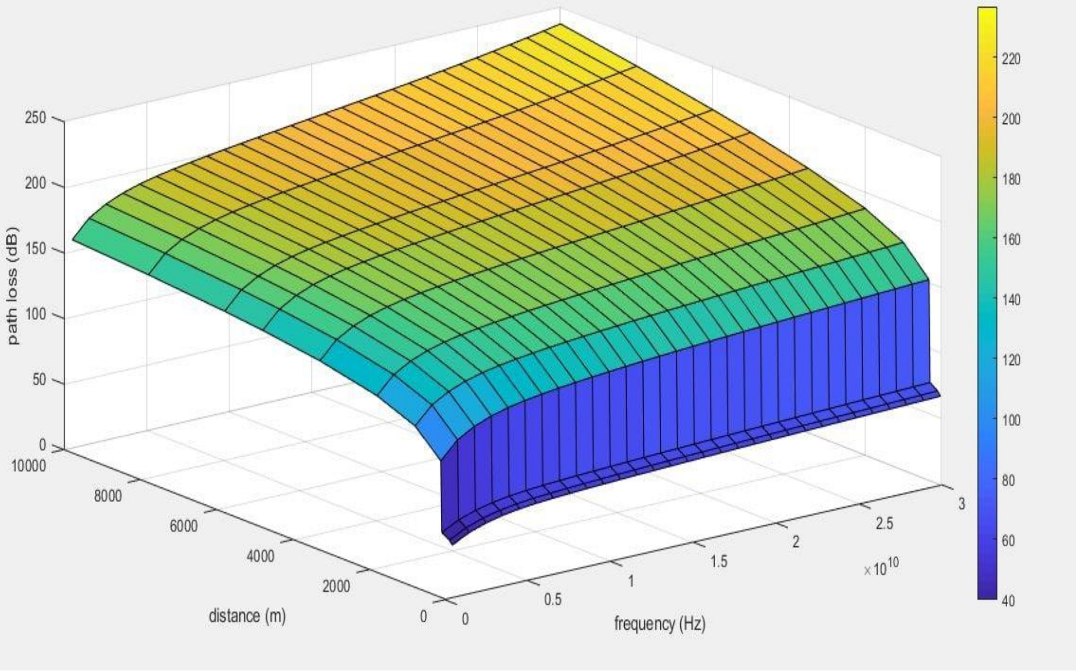

Figure 9 3D the compound model for the (O2I RMa-low loss model) with dust and with humidity of 50%**.**

In figure 9, the path loss represents the compound model including ($3GPP$) for the (O2I RMa-low loss model) at different frequencies (0.5-30) GHz and distances (10-10.000) m between ($h_{\mathrm{BS}} - h_{\mathrm{UT}}$) with dust and wit humidity (50%) effect. It can be concluded that

- Path loss (O2I RMa-low loss model) increases with increased frequency and increased distance.
- The path loss at distances below 300m is represented (LoS), and the path loss for other distances is represented (NLoS) because of the value of breakpoints.
- The compound model in figure 9 is greater than the compound model in figure 8 for the same distance and frequency because the dust with humidity (50%) in figure 9 is greater than the dust with humidity (0%) in figure 8.

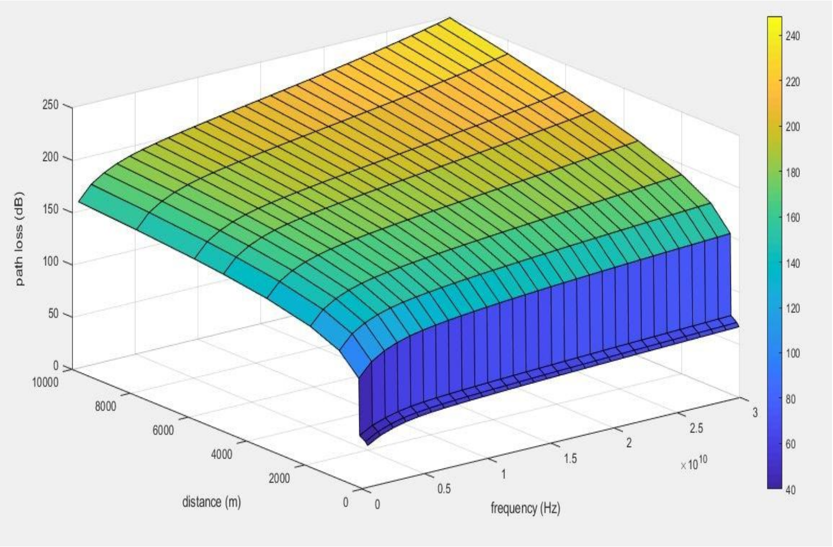

Figure 10 3D the compound model for the (O2I RMa-low loss model) with dust and with H=100percent.

In figure 10, the path loss represents the compound model including ($3GPP$) for the (O2I RMa-low loss model) at different frequencies (0.5-30) GHz and distances (10-10.000) m between ($h_{\mathrm{BS}} - h_{\mathrm{UT}}$) with dust and wit humidity (100%) effect. It can be concluded that

- Path loss (O2I RMa-low loss model) increases with increased frequency and increased distance.
- The path loss at distances below 300m is represented (LoS), and the path loss for other distances are represented (NLoS) because of the value of breakpoints.
- The compound model in figure 10 is greater than the compound model in figure 9 for the same distance and frequency because the dust with humidity (100%) in figure 10 is greater than the dust with humidity (50%) in figure 9.

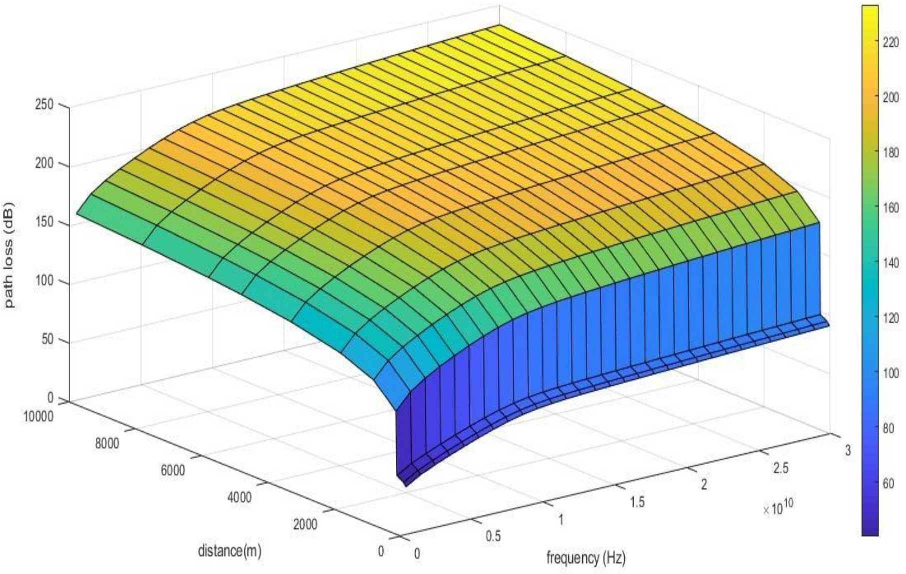

Figure 11 3D the compound model for the (O2I RMa-high loss model) without dust and humidity.

In figure 11, the path loss represents the compound model including ($3GPP$) for the (O2I RMa-high loss model) scenario at different frequencies (0.5-30) GHz and distances (10-10.000) m between ($h_{\mathrm{BS}} - h_{\mathrm{UT}}$) without dust and humidity effect. It can be concluded that:

- The path loss at distances below 300m is represented (LoS), and the path loss for other distances is represented (NLoS) because of the value of breakpoints.
- Path loss (O2I RMa-high loss model) increases with increased frequency and increased distance.

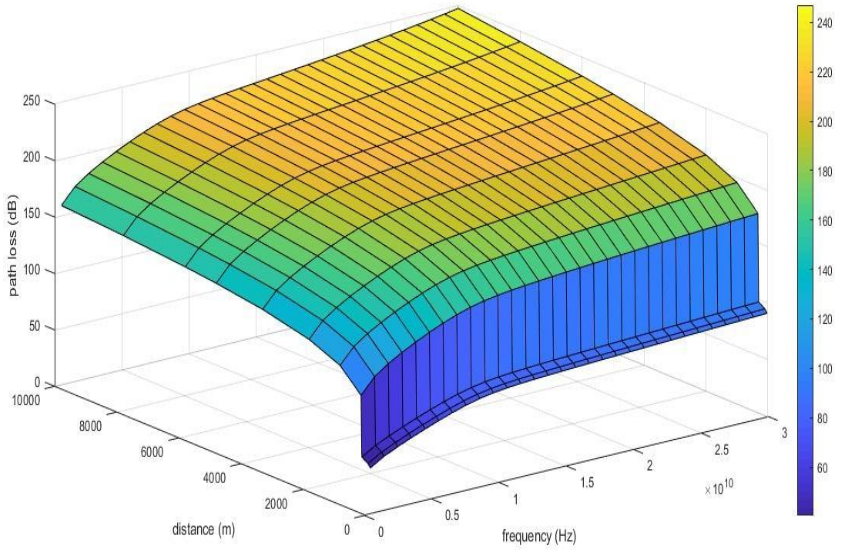

Figure 12 3D the compound model for the (O2I RMa-high loss model) with dust and without humidity.

In figure 12, the path loss represents the compound model including ($3GPP$) for the (O2I RMa- high loss model) scenario at different frequencies (0.5-30) GHz and distances (10-10.000) m between ($h_{\mathrm{BS}} - h_{\mathrm{UT}}$) with dust and without humidity effect. It can be concluded that:

- Path loss (O2I RMa-high loss model) increases with increased frequency and increased distance.
- The path loss at distances below 300m is represented (LoS), and the path loss for other distances is represented (NLoS) because of the value of breakpoints.
- The compound model in figure 12 is greater than the compound model in figure 11 for the same distance and frequency because the compound model in figure 12 is due to the dust effect and the compound model in figure 11 is not.

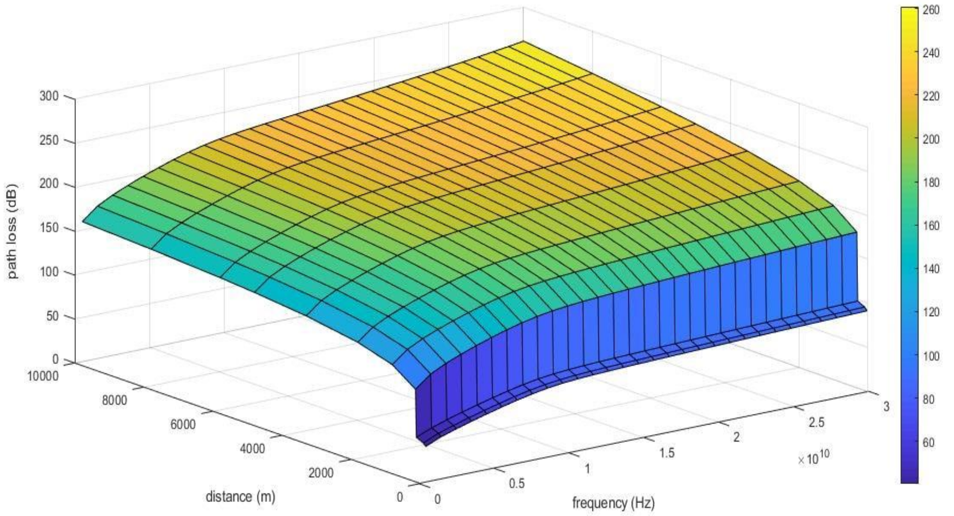

Figure 13 3D the compound model for the (O2I RMa-high loss model) with dust and with humidity of 50%**.**

In figure 13, the path loss represents the compound model including ($3GPP$) for the (O2I RMa-high loss model) scenario at different frequencies (0.5-30) GHz and distances (10-10.000) m between ($h_{\mathrm{BS}} - h_{\mathrm{UT}}$) with dust and wit humidity (50%) effect. It can be concluded that

- Path loss (O2I RMa-high loss model) increases with increased frequency and increased distance.
- The path loss at distances below 300m is represented (LoS), and the path loss for other distances is represented (NLoS) because of the value of breakpoints.
- The compound model in figure 13 is greater than the compound model in figure 12 for the same distance and frequency because the dust with humidity (50%), as shown in figure 13 is greater than the dust with humidity (0%), as shown in figure 12.

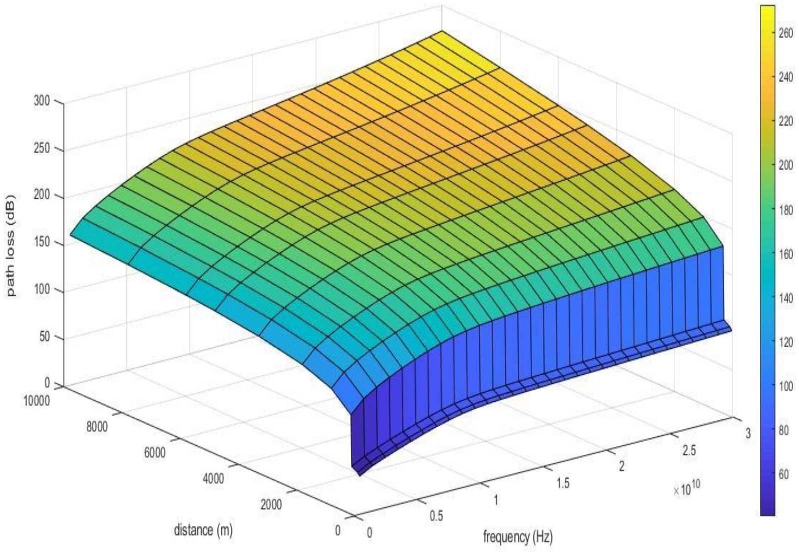

Figure 14 3D the compound model for the (O2I RMa-high loss model) with dust and with H=100percent.

In figure 14, the path loss represents the compound model including ($3GPP$) for the (O2I RMa-high loss model) scenario at different frequencies (0.5-30) GHz and distances (10-10.000) m between ($h_{\mathrm{BS}} - h_{\mathrm{UT}}$) with dust and wit humidity (100%) effect. It can be concluded that

- Path loss (O2I RMa-high loss model) increases with increased frequency and increased distance.
- The path loss at distances below 300m is represented (LoS), and the path loss for other distances is represented (NLoS) because of the value of breakpoints.
- The compound model in figure 14 is greater than the compound model in figure 13 for the same distance and frequency because the dust with humidity (100%), as shown in figure 14 is greater than the dust with humidity (50%), as shown in figure 13.

7. CONCLUSION

This paper proposes a compound model from the average model for (the Rayleigh approximate model, the Mie scattering model, and a Numerical model) (using the Statistical Z-test), which is combined with the 3GPP model of the 3GPP for RMa LOS and NLOS path loss models for frequencies ranging from 0.5 GHz to 30 GHz in two scenarios (O2I high loss model, and O2I low loss model) with a range distance of 10–10,000 m. The type of building (standard glass, wood, IRR glass, concrete, etc.) affects the channel characteristic of O2I penetration loss. In four cases (without dust and humidity, with dust and humidity equal to zero, with dust and humidity 50%, and with dust and humidity 100%) at a distance (100m) and frequency (30 GHz). it can be noticed that the path loss compound model for the O2I low loss model (70.02, 70.57, 70.96, and 71.12) dB for each case, respectively. The path loss compound model for the O2I high loss model (94.02, 94.64, 94.91, and 95.1) dB for each case, respectively. Therefore, this proposed model is necessary for determining the LB in wireless (5G) communications that use MmWave in various environments.

REFERENCES

1. Chen, Hsing-Yi, and Chao-Cheng Ku. "Calculation of wave attenuation in sand and dust storms by the FDTD and turning bands methods at 10–100 GHz." IEEE Transactions on Antennas and Propagation 60.6 (2012): 2951-2960.
2. Elsheikh, Elfatih AA, et al. "Dust storm attenuation modeling based on measurements in Sudan." IEEE Transactions on Antennas and Propagation 65.8 (2017): 4200-4208.
3. Eltahir, E. I., et al. "Effects of humidity on sand and dust storm attenuation predictions based on 14 GHz measurement."
4. Sharif, Sami Mohamed. "Dust storms properties related to microwave signal propagation." (2011).
5. Ahmed, Abobakr S., Adel A. Ali, and Mohammed A. Alhaider. "Airborne dust size analysis for tropospheric propagation of millimetric waves into dust storms." IEEE Transactions on Geoscience and Remote Sensing 5 (1987): 593-599.
6. Cisco, Cisco Visual Networking Index. "Global Mobile data traffic forecast update 2015-2020, White paper, 2016." Online: https://www. cisco. com/c/dam/m/en in/innovation/enterprise/assets/mobilewhite-paper-c11-520862.

7. Roh, Wonil, et al. "Millimeter-wave beamforming as an enabling technology for 5G cellular communications: Theoretical feasibility and prototype results." IEEE communications magazine 52.2 (2014): 106-113.
8. Rappaport, Theodore S., James N. Murdock, and Felix Gutierrez. "State of the art in 60-GHz integrated circuits and systems for wireless communications." Proceedings of the IEEE 99.8 (2011): 1390-1436.
9. Saadoon, Hawraa J., Thamer M. Jamel, and Hasan F. Khazal. "Investigation of Suitable 5G Millimeter-Wave Frequencies for Kut-City in Iraq." International Journal of Computing and Digital Systems 11.1 (2022): 1-12.
10. Al-Shuwaili, Ali, and Thamer M. Jamel. "5G Channel Characterization at Millimeter-Wave for Baghdad City: An NYUSIM-based Approach." 2021 18th International Multi-Conference on Systems, Signals & Devices (SSD). IEEE, 2021.
11. Jamel, Thamer M., Thulfaqar A. Sahib, and Rafel K. Mohammed. "Optimum and Appropriate 5G Millimetre-Wave Frequencies for Baghdad City."
12. Hawraa J Saadoon , Thamer M Jamel and Hasan F Khazal “The Effects of Different Weather Conditions On 5G Millimeter Waves Propagations at 38 GHz and 73 GHz For Kut-City in Iraq”, Wasit Journal of Engineering Sciences 2022.
13. Sun, Shu, et al. "Propagation models and performance evaluation for 5G millimeter-wave bands." IEEE Transactions on Vehicular Technology 67.9 (2018): 8422-8439.
14. I. A. Hemadeh, K. Satyanarayana, M. El-Hajjar, and L. Hanzo, “Millimeter-Wave Communications: Physical Channel Models, Design Considerations, Antenna Constructions, and Link-Budget,” IEEE Commun. Surv. Tutorials, vol. 20, no. 2, pp. 870–913, 2018, doi: 10.1109/COMST.2017.2783541.
15. Eltahir, E. I., et al. "Humidity Effect on Dust Storm Attenuation Prediction for 21 GHz Microwave Links in Sudan." 2020 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE). IEEE.
16. Khan, Haibat, and Keith M. Martin. "A survey of subscription privacy on the 5G radio interface-The past, present and future." Journal of Information Security and Applications 53 (2020): 102537.
17. MacCartney, George R., and Theodore S. Rappaport. "Rural macrocell path loss models for millimeter-wave wireless communications." IEEE Journal on selected areas in communications 35.7 (2017): 1663-1677.
18. 3GPP, “Study on channel model for frequencies from 0.5 to 100 GHz,” 3rd Generation Partnership Project (3GPP), Technical Specification Group Radio Access Network, Valbonne, France, Tech. Rep. 3GPP TR 38.901 V16.1.0 (2019-12), Release 16, Dec. 2019 143.