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Comparison and Analysis of the Path Loss Models used in E Band Communication System

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Abstract: ***Fifth - generation cellular systems are likely to operate in or near the millimeter-wave (mm Wave) frequency bands of 30–300 GHz, where vast spectrum currently exists with light use. At these mm Wave frequencies, the wavelength is so small that highly directional, steerable antennas may be used in novel ways. This research work presents empirically-based large scale propagation path loss models for fifth generation cellular network planning in the millimeter-wave spectrum based on real-world data at 28 GHz and 38 GHz. The model in this paper allows future realistic modeling of propagation conditions for millimeter wave transmission in urban microcellular environments. This model also suggests that in future millimeter wave communications, mobile devices shall deploy antennas with higher gains to compensate for the additional path loss due to the frequency leap from low microwave to the millimeter wave regime.***

Keywords: path loss models, SUI, ITU-R, mm wave, and 5G system

1. Introduction

Despite millimeter wave (mmWave) technology has been known for many decades, the mmWave systems have mainly been deployed for military applications. With the advances of process technologies and low-cost integration solutions, mmWave technology has started to gain a great deal of momentum from academia, industry, and standardization body. In a very broad term, mm Wave can be classified as electromagnetic spectrum that spans between 30 GHz to 300 GHz, which corresponds to wavelengths from 10 mm to 1 mm [1]. In this paper, however, we will focus specifically on 60 GHz radio (unless otherwise specified, the terms 60 GHz and mmWave can be used interchangeably), which has emerged as one of the most promising candidates for multi Gigabit wireless indoor communication systems [2]. 60 GHz technology offers various advantages over current or existing communications systems [3]. One of the deciding factors that makes 60 GHz technology gaining significant interest recently is due to the huge unlicensed bandwidth (up to 7 GHz) available worldwide. While this is comparable to the unlicensed bandwidth allocated for ultra wideband (UWB) purposes [4], 60 GHz bandwidth is continuous and less restricted in terms of power limits. This is due to the fact that UWB system is an overlay system and thus subject to very strict and different regulations [5]. The large bandwidth at 60 GHz band is one of the largest unlicensed bandwidths being allocated in history. This huge bandwidth represents high potentials in terms of capacity and flexibility that makes 60 GHz technology particularly attractive for gigabit wireless applications. Furthermore, 60 GHz regulation allows much higher transmit power compared to other existing wireless local area networks (WLANs) and wireless personal area networks (WPANs) systems.

The higher transmit power is necessary to overcome the higher path loss at 60 GHz. While the high path loss seems to be disadvantage at 60 GHz, it however confines the 60 GHz operation to within a room in an indoor environment. Hence, the effective interference levels for 60 GHz are less severe than those systems located in the congested 2–2.5 GHz and 5–5.8 GHz regions. In addition, higher frequency reuse can also be achieved per indoor environment thus allowing a very high throughput network. The compact size of the 60 GHz radio also permits multiple antennas solutions at the user terminal that are otherwise difficult, if not impossible, at lower frequencies. Comparing to 5 GHz system, the form factor of mmWave systems is approximately 140 times [6] smaller and can be conveniently integrated into consumer electronic products.

2. SUI Path-Loss Model

The SUI model covers three terrain categories common around the United States. Category A represents the maximum path-loss category which is a hilly terrain,

Table 1: SUI Model Parameters

Model Parameters	Terrain Type A	Terrain Type B	Terrain Type C
a	4.6	4	3.6
b	0.0075	0.0065	0.005
c	12.6	17.1	20

Category B represents an intermediate path-loss category, and Category C represents the minimum path-loss category with mostly flat terrains. The empirical formulas for this model were obtained based on experiments done in the Unites states [7].

The median path-loss for the SUI model can be generally written as

$$L = A + 10\gamma \log\left(d/d_0 \right) \qquad \text{.............. (1)}$$

for $d>d_o$, where d_o=100m. The term A in the above equation is given by $A = 20\log(4\pi d_o/\lambda)$, where λ is the wavelength in m. The path-loss exponent γ is given by

$$\gamma = a - bh_t + c/h_t \qquad (2)$$

In which the parameters a, b and c depend on the terrain category and are defined in the table below.

These parameters are obtained at 2GHz frequency and receive antenna height of 2m. In order to use the model for other frequency and receive antenna heights [8], the following correction terms can be used.

$$L = L + \Delta L_f + \Delta L_h$$

Where

$$\Delta L_f = 6\log(f/2000)$$

and the receive antenna height correction term is given by[9]

$$\Delta L_h = \begin{cases} -10.8\log(h_r/2), & \text{Categories } A, B \\ -20\log(h_r/2), & \text{Category C} \end{cases}$$

Where h_r is the receive antenna height.

3. ITU-R Model

For different types of environment ITU (International Telecommunication Union) has given a model for various scenarios that we have used in our research work , these are listed as below [11].

- **For Small To Medium Size City**

$\alpha=((1.1*\log_{10}(f_c)-0.7)*h_{re})\ 1.56*\log_{10}(f_c)-0.8)$

$C_m=0$

$PL=46.3+(33.9*\log_{10}(f_c))-(13.82*\log_{10}(h_{te}))-\alpha+((44.9-6.55*\log_{10}(h_{te}))*\log_{10}(d))+C_m$

- **For Large City**

$\alpha = (3.2*(\log10(11.75*hre))\hat{}2) -4.97$

$C_m=3$

$PL= 46.3+(33.9*\log_{10}(f_c))-(13.82*\log_{10}(h_{te}))-\alpha+((44.9-6.55*\log_{10}(h_{te}))*\log_{10}(d))+C_m$

4. Results

In this particular work we have prepared a matlab graphical user interface which would allow us to evaluate the 5g communication system in more detail as well as under various scenarios such as Terrain type

1) Size of antenna
2) Distance between nodes

The prepared GUI allows us to dynamically change the pattern and parameters for 5G communication systems and thus will allow us to evaluate the two models in more detail.

GUI model prepared in matlab:

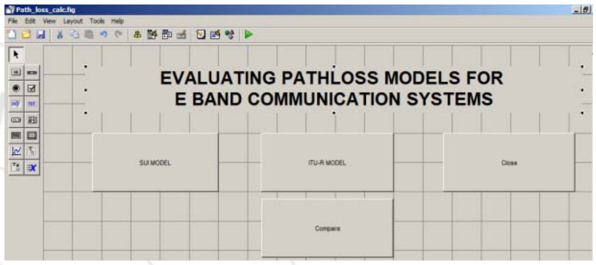

Figure 1: GUI Prepared in Matlab

The above graphical user interface gets the data from the user and then plots the path loss for that particular models. The results can be summarized in tabular form as below:

Table 2: Comparison of SUI and ITU-R

Frequency	MS Antenna Height	BS Antenna height	Distance	Topography	Path loss in SUI	Path loss in ITU-R
2 GHz	1m	30m	10km	Small to medium	92.2dB	71.3 dB
2 GHz	1m	30m	10km	Large city	93.04dB	75.12 dB
2 GHz	1m	30m	10km	Sub urban area	84.24dB	71.3 dB
2 GHz	1m	30m	10km	Open rural area	56.4dB	N A

Figure below shows the graph for pathloss in SUI model:-

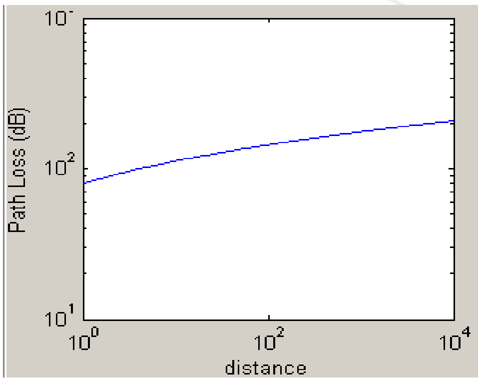

Figure 2: Graph between pathloss (y axis) and distance (x axis) for SUI model

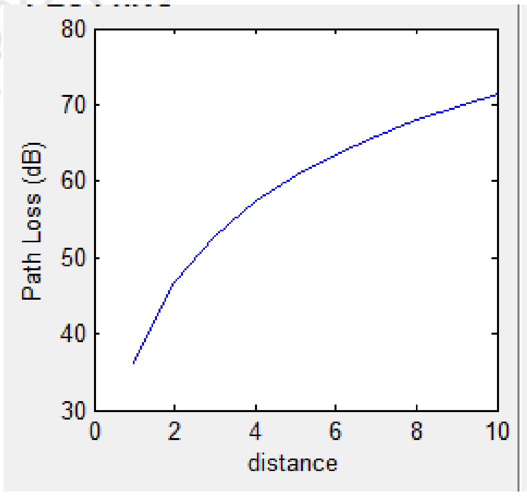

Figure 3: Graph between pathloss(y axis) and distance (x axis) for for ITU-R model

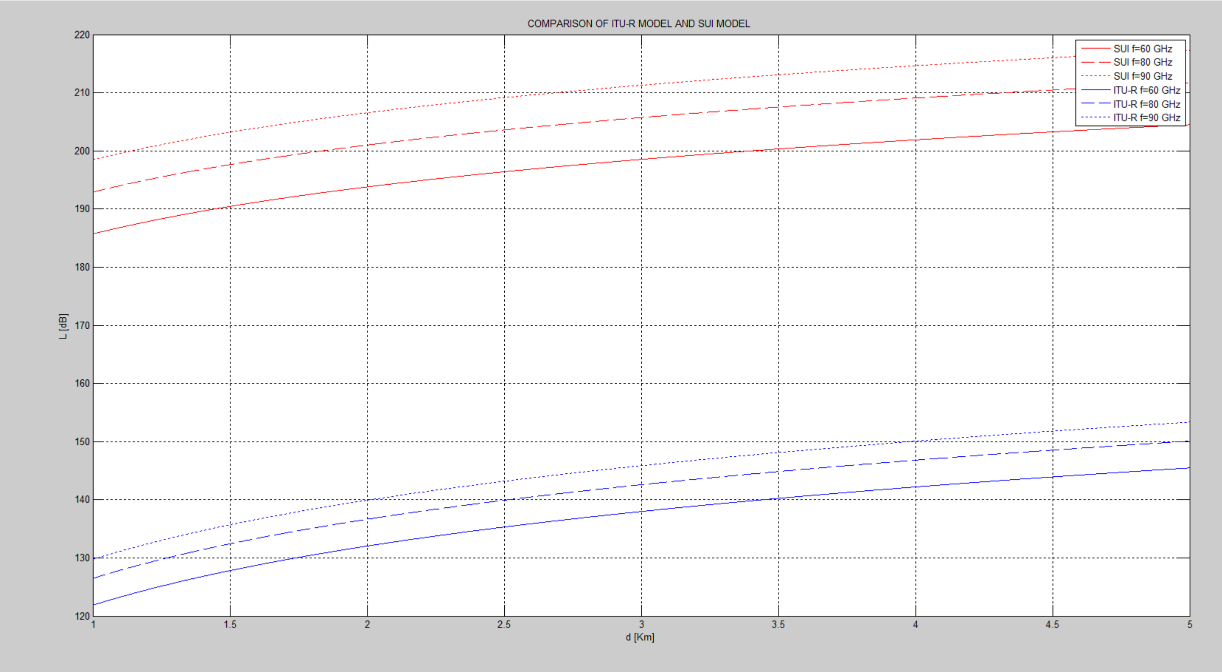

Figure 4: Graph showing comparison between SUI and ITU-R model for different frequencies

Thus based on above results it can be seen that ITU-R model offers lower path loss at the above parameters.

5. Conclusion

The E-band, has opened up new potentials and challenges for providing affordable and reliable Gigabit per second wireless point-to point links.

The popularity of multimedia applications [14] and broadband internet has created an ever increasing demand for achieving higher throughputs in cellular and wireless networks .Due to the higher carrier frequencies; the antennas are more directional, making E-band systems mainly suitable for line-of-sight (LOS) applications.

Rain and obstacles more severely attenuate radio signals in the E-band. Consequently, with the same transmit power and link availability requirements, E-band wireless links can operate over shorter distances when compared to microwave systems.

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