Quantify The Signal Attenuation Due To Foliage Depth in Millimeter Band

Authors

Shruti Choudhary\textsuperscript{1} Rohini Garg\textsuperscript{2}

\textsuperscript{1}M.Tech Scholar, Digital Communication, Marudhar Engineering College, Rajasthan, India
\textsuperscript{2}Associate Professor, ECE department, Marudhar Engineering College, Rajasthan, India

Email-shruti_choudhary@ymail.com, rohinigarg01@gmail.com

ABSTRACT

As wireless communication moves from long to short ranges with considerably lower antenna heights, the need to understand and be able to predict the impact of vegetation on coverage and quality of wireless services has become very important. The propagation of Electromagnetic waves in millimeter band is severely affected by foliage. The basic mechanism of radio wave propagation is: Reflection, Scattering, Interference, Refraction, Diffraction and Absorption. This paper presents a preliminary report of an ongoing research work investigating the effects of trees on radio signals at microwave frequencies. In this paper an attempt has been made to quantify the attenuation of microwave signal in Ka band at 35 GHz due to varying foliage length. It concludes that the signal attenuation doesn't increase linearly with foliage depth. An outdoor measurement system will be setup and used for characterizing the channel behavior at 35 GHz. The experimental setup is established at Engineering College Bikaner, Bikaner (western part of Rajasthan which belongs to Thar Desert region). For the measurement of signal attenuation, a Gunn oscillator trans-receiver system of 35 GHz (100mW) is used.

Keywords: Millimeter wave, modulation, demodulation, signal attenuation, foliage depth, power amplification.

1. INTRODUCTION

Interest in the effects of vegetation on communication systems has increased in recent years because of the widespread deployment of wireless broadband systems and demands for mobile high data rates access. The effect of vegetation, even when not in the direct path between the transmitter and receiver antennas, can be significant. The appearance of the foliage medium in the path of the communication link has found to play a significant role on the quality of service (QoS) for wireless communications over many years. Attenuation
due to foliage has long been recognized as a major limitation to design reliable communication system and limits the use of higher frequency for Line Of Sight (LOS) microwave links and radio communication. The millimeter wave spectrum (30-300GHz) is of increasing interest to service providers and systems designers because such wide bandwidths are valuable in supporting applications such as high speed data transmission and video distribution. To fulfill the increasing demand of high rate data and wideband communication, Ka band (27-40GHz) is under consideration [1]. While signals at lower frequency bands can propagate for many miles and penetrate more easily through buildings, millimeter wave signals can travel only a few miles or less and do not penetrate solid material very well. However, these characteristics of millimeter wave propagation are not necessarily disadvantageous. Millimeter waves can permit more densely packed communications links, thus providing very efficient spectrum utilization, and they can increase security of communication transmissions. Thus the reduction of cell size and base station antenna heights in cellular networks has forced the telecommunication sector and spectrum licensing authorities to investigate the impact of vegetation on radio wave propagation. This knowledge will assist in optimizing spectrum utilization and enhancing the quality of services provided. The study of propagation through vegetation is challenging due to variations in vegetation density, measurement geometry, and vegetation composition. In addition, vegetation is prone to environmental effects, such as wind, that can introduce dynamic variations in the channel signature.

Trees planted at strategic places all over the world beautify the environment and at the same time maintain a greener environment. However, their presence may have an adverse effect on telecommunication services as they may cause blockages to radio path by obstructing the line of sight between transmitter and receiver. As a result, propagating radio waves are forced to follow different paths to the receiver and this situation leads to signal degradation. Removing all trees obstructing line of sight is an impractical solution, but fade mitigation techniques such as adaptive coding and path modulation, path diversity etc. can be adopted to mitigate the effect. This will severely constrain the design of modern wireless communication systems.

The difference in foliage penetration for 10 GHz and 35GHz is not dramatic, while for 90GHz it is considerably higher. This leads to the result that the 35GHz band is well suited for fire detection behind foliage [9]. Attenuation due to foliage and vegetation has long been recognized as a major limitation to reliable communication system operating at frequency above 10 GHz [2]. It restricts the path length of radio communication systems and limits the use of higher frequencies for line-of-sight microwave links. So if the devices having the working frequency near about 35 GHz is taken then communication will be effective.
2. EXPERIMENTAL SETUP

Fig 1. Block Diagram of 35 GHz Link System

The experimental system comprises a continuous-wave (CW) 35 GHz transmitter using a 100 mW Gunn source with a transmitting antenna of 18\(^0\) beam width and 22 dB gains. The transmitter transmits a maximum power of 20 dBm. The receiving side carries a receiving horn antenna identical to the transmitter, followed by a cavity mixer with a 15 dBm local oscillator operating at 34 GHz. The 1 GHz IF output of the mixer is fed to a preamplifier followed by a driver amplifier. The amplified output is displayed on a signal analyzer (spectrum analyzer). Receiver is capable of providing a useable base band output with received millimeter wave signal levels as low as -80 dBm. The all arrangement for the link is situated in Bikaner city at Engineering College Bikaner, which is western part of Rajasthan state, India.

Fig 2. Experimental site at Govt. Engineering College Bikaner

During this experiment, the signal attenuation measured with respect to the number of Neem trees of almost same size. The ten trees were considered one by one in the path between transmitter and receiver. The observations show that 35.1 dB attenuation was found when ten trees of equal depth (5 feet) and height (7 feet) each were in the path. The attenuation versus number of Neem trees measurement result shows that initially high attenuation and then becoming more gradual after five trees. It means that the signal is
attenuated as it travels through these trees, but also as the signal passes through several trees it becomes randomly polarized explaining the gradual transition in attenuation.

3. RESULT AND OBSERVATIONS

Canopy Size (Neem) = Height 7 feet
And canopy size = 5 feet.

Gunn Voltage = 3.87 Volt
And Current = 0.53 Ampere
IF frequency = 1.08 GHz,
Reference Level = -12 dBm
Height of Transmitting and Receiving Antenna = 7 ft.

Table: 1 Attenuation with different number of trees

<table>
<thead>
<tr>
<th>No of Trees</th>
<th>Distance in feet</th>
<th>Received Power LOS (dBm)</th>
<th>Received Power LOS with foliage (dBm)</th>
<th>Attenuation (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37</td>
<td>-36.7</td>
<td>-42.3</td>
<td>5.6</td>
</tr>
<tr>
<td>2</td>
<td>53</td>
<td>-38.1</td>
<td>-50.4</td>
<td>12.3</td>
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<td>3</td>
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<td>10</td>
<td>181</td>
<td>-63.8</td>
<td>-98.9</td>
<td>35.1</td>
</tr>
</tbody>
</table>

Fig 3. Signal attenuation with number of trees
In this experiment, the signal attenuation measured with respect to the number of neem trees of almost same size of diameter of 5 feet and height of 7 feet. Ten trees were taken one by one into account in the LOS path between transmitter and receiver. The observations show that 35.1dB attenuation was found when ten trees of equal depth and height were in the LOS path. The attenuation versus number of trees measurement result shows initially high attenuation and then becoming more gradual after a few trees. It means that the signal is attenuated as it travels through these trees, but also as the signal passes through several trees it becomes randomly polarized explaining the gradual transition in attenuation. These results show a change in attenuation rate from a high value at small foliage depth to a reduced rate at larger foliage depths particularly at 62.4 GHz. This is explained by the interaction between the coherent and scatter components. At small foliage depth, the received power is primarily determined by the coherent component and this decreases at a rate proportional to the extinction cross section of the trees.

**CONCLUSIONS**

The observations taken during present work concludes that the signal attenuation at 35 GHz is not increasing proportional to the number of trees or the foliage depth. The effect of foliage length in the path of a point to point link influence the received signal as by providing an additional attenuation to that of free space but due to scattering and depolarization of signal by longer foliage length results in lateral contribution to the received signal. The experimental result shows that for foliage length of 5feet, the signal attenuation is 0.3413 dB/m and for foliage length of 50 feet, the signal attenuation is 0.2139 dB/m.

**FUTURE WORK**

In the future work, comparison with other types of trees, many scattering prediction models can be done. Variation of attenuation due to scattering with different trees with high environmental temperature and arid climate can also be studied. Variation of attenuation due to temperature, due point and other climate parameters can also be studied. The effects from external factors such as wind and rain on the forested channel needs further study and verification. These are important research work required for building a reliable communication system operation in extreme weather conditions such as heavy rainfall and strong wind. We design an algorithm for power saving on the transmitter which provide save the power when environment will be changed.
REFERENCES


