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Characterisation Free Space Path Loss: Sub-6ghz and Millimetre Wave Frequency

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ABSTRACT: There is a free-space route loss in free-space propagation, which is the propagation path with no obstacles between the transmitter and the receiver. This is characterized as the radio wave signal's loss during free space transit. In order to build communication systems that can function as efficiently as possible despite potential problems, it is imperative to determine the path loss. Path loss has also been utilized in wireless survey instruments and radio communications to determine the antennas' signal strength. Given the growing significance of wireless devices, including software and survey instruments, it is now beneficial to comprehend the idea of radio path loss in its entirety. In order to gain a comprehensive understanding of the free space propagation path loss and the factors influencing it, the main objective of this paper is to simulate the phenomenon. MATLAB software is utilized in this process to generate graphs that provide a clear and easy-to-understand representation of the path loss. Four frequencies were chosen two from the sub-6 frequency range and another two from the milliwave frequency range, Results showed a trend of an increasing free space path loss with increase in distance and frequencies with a greater loss at milliwave, but loss can be mitigated with antenna gain and following other recommendations.

KEYWORDS: Frequency, Free Space propagation, Free Space Propagation path loss, Radio Wave propagation.

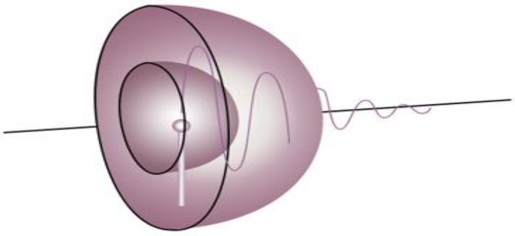
1. INTRODUCTION

When building a wireless network, network designers usually ask themselves two questions. one of the lines of communication between two distant stations. Second, what is the maximum allowed distance that the wireless channel can have in order to function? Designers must examine two essential components to determine the most straightforward approach to answering these concerns. These variables consist of the system's dynamic range and the loss in electromagnetic wave propagation. [1]. The dynamic range is estimated using receiver sensitivity and transmission power [2]. On the other hand, the term "EMW propagation loss" refers to the property that shows the amount of energy lost along the segment of the electromagnetic wave propagation route that travels from transmitter to receiver [3].

The connection budget is heavily influenced by free space path loss in addition to cable loss and antenna gain. Free space route loss is the term for the phenomena where the amplitude of the RF signal diminishes as it passes through free space. The signal strength will diminish even if there are no obstructions in the path of the sending and receiving antennas. An RF transmission's electromagnetic waves propagate while it passes across empty space, decreasing the signal's strength in the process. The idea of energy conservation states that the energy content of an area reduces with its size.

The free space propagation notion is the easiest scenario for radio signal propagation to understand. They are believed to radiate outward from the spot where the antenna is pointing them. Their method of propagation is similar to the ripples that form in a pond when a stone is dropped into it, traveling outward. The ripples gradually disappear from view as their level drops as they move farther out. In contrast to the two-dimensional pond example, radio signal transmission uses three-dimensionally dispersing waves. The loss in electromagnetic wave signal strength that would result from a line-of-sight path in open space (often air), absent any surrounding barriers to generate reflection or diffraction, is referred to in the telecommunication industry as "free-space path loss" (FSPL). It doesn’t include things such as gain of the antennas used at the transmitter and receiver and hardware defects that result in loss.

An illustration of the free space loss principle is shown below. Assume that the antenna, a tiny point, is the source of radio frequency energy sent in all directions. The wave appears to be spherical in shape and gets bigger as it moves farther away.



understanding-free-space-path-loss [4].

The energy emitted by the antenna that sends signals fills an ever-increasing sphere in free space. The further one gets from the antenna, the weaker the energy concentration is.

The 5 GHz frequency suffers from a larger free space path loss than the 2.4 GHz band. The loss increases in tandem with the frequency. If the intensity of the signal that was sent in both bands was equal, the 2.4 GHz devices would have a longer effective range than the 5 GHz devices. The free space path loss accounts for most of the variance. But there are also other factors, such antenna size and receiver sensitivity, that impact both 2.4 and 5 GHz radios.

The investigation's primary goal was to characterize the route loss of a 3G wireless signal in urban and suburban environments. This topic is significant because the propagation environment has a similar impact on the signal's quality during transmission and reception. A comprehensive examination of the particular impacts of the propagation environment on the 3G signal in a given area as well as other wireless communication signals. The area in question was measured in the field using a test phone and a GPS receiver, and it was then classified as either an urban or suburban situation. The results of the study were applied to assess the performance of various currently in use signal propagation path loss prediction models in suburban and metropolitan environments. In urban environments, propagation models such as the Okumura-Hata model outperformed, however in suburban areas, Cost 231 and other models outperformed [5].

In further research on the propagation path loss models that are currently in use. The many known models of signal propagation path loss are compared with each other using field gathered data. The main reason for this is the large range of available signal propagation path loss models, each of which produces different results when applied in an unintentional propagation context and different results based on the specific type of propagation environment for which it is intended. The three environments from which the field data was gathered were the high population density urban environment, the medium-density suburban environment, and the low-density rural environment. The results of the study were obtained using a spectrum analyser. With the use of this tool, it was discovered that some propagation models could operate or produce notable outcomes in more than one propagation environment, whereas other signal propagation path loss models, such as the SUI path loss model and the COST-231, could produce notable outcomes and show good performances in each of the three propagation environments [6].

Understanding radio wave path loss in free space is the main goal of this work. It's critical to understand how this works because it plays a crucial role in communication system planning. We'll do simulations to get a good understanding of it.

2. FREE-SPACE PROPAGATION MODEL

The purpose of propagation modeling is to predict the average strength of the received signal at a certain distance from the transmitter. Propagation models predict that the average strength of the signal will steadily fall as the mobile device travels farther from the transmitter over a specific distance. The average received power is commonly estimated by taking the average of the signal values across a 5λ to 40λ measuring track.

With the free space propagation approach, the received signal strength may be anticipated when there is a free of obstruction, clear line of sight (LOS) between the transmitter and the receiver. The received power falls when the T-R separation distance increases to a particular power. Path Loss Signal attenuation is a positive number that is measured in dB. It is defined as the difference (in dB) between the effective transmitted power and the received power. The free space power received by a receiving antenna that is separated from a radiating transmitter antenna by a distance d is given by the Friis free space equation:

$$P_r(d) = \frac{P_t G_r G_t \lambda^2}{(4\pi)^2 d^2 L} \qquad (1)$$

Where d is the transmitter-receiver separation distance in meters, P_t is the transmitted power, P_r (d) is the received power, G_t and G_r are the transmitter and reception antenna gains, and L is the system loss factor unrelated to propagation (L > 1). For our needs, we shall take L = 1 denotes no hardware loss, and λ is the wavelength in meters. An antenna's affective aperture A_e and gain G are connected by:

$$G = \frac{4\pi A_e}{\lambda^2}$$

The physical size of the antenna affects the effective aperture of Ae, and the wavelength λ correlates to the carrier frequency by:

$$\lambda = \frac{c}{f} = \frac{2\pi}{\omega_C} \qquad (2)$$

The carrier frequency is represented by f in Hertz, the speed of light in meters/sec by ω_C in radians per second, and c in radians per second. An antenna that transmits power uniformly in every single direction with unit gain is called an isotropic radiator. It serves as wireless systems' reference antenna. The definition of the effective isotropic radiated power, or EIRP, is:

$$\text{EIRP} = P_t G_t \qquad (3)$$

Units of measurement for antenna gains are either dBi (dB gain relative to an isotropic antenna) or dBd (dB gain relative to a half-wave dipole antenna). Gaining unity entails: G is either 0dBi or 1.

The signal loss (in dB) between the real transmitted power as well as the received power for the free space path loss model where antenna gains are taken into account is;

$$PL(dB) = 10log\frac{P_t}{P_r} = -10log\frac{G_r G_t \lambda^2}{(4\pi)^2 d^2} \qquad (4)$$

As an alternative, the free space propagation loss may be acquired using the aforementioned logarithmic form, which expresses it in dB units. The antennas are presumed to possess unity gain in the absence of antenna gains, and path loss is calculated as follows:

$$PL(dB) = 10log\frac{P_t}{P_r} = -10log\frac{\lambda^2}{(4\pi)^2 d^2} \qquad (5)$$

Distance d must be in the transmitting antenna's far-field in order for the Friis equation to stay true. The area outside of a transmitting antenna's far-field is called the far-field region.

3. DATA ANALYSIS

MATLAB was used to simulate the Free Space Propagation Path Loss. The most basic type of propagation system, known as free space propagation, makes advantage of space, the perfect medium for wave propagation. When using free space propagation, the system makes the assumption that there are no other obstacles in the way of the transmitter and receiver other than a straight line. Path loss, which is often given in dB units and represents the total average power loss over the signal's propagation distance, is the variable that is calculated. Four frequencies were employed in the simulation: two in the sub-6GHz frequency range and two in the above-6GHz milliwave frequency. These frequencies were selected as the program's input frequencies and were measured in gigahertz. The frequencies of choice are 60 GHz, 28 GHz, 5 GHz, and 2 GHz. The simulation was conducted using a range of frequencies in order to study the variations in Path Loss that each frequency experiences across empty space.

4. PROGRAM CODES

CODE 1

```
% Free Space Propagation Loss
clc;
close all;
clear all;
frequency_2GHz = 2e9; % Frequency in Hz (28 GHz)
frequency_5GHz = 5e9; % Frequency in Hz (60 GHz)
c = 3e8; % Speed of light in m/s
% Calculate wavelengths
w1 = c / frequency_2GHz;
w2 = c / frequency_5GHz;
```

```
d = linspace(1, 10000, 10000);

% Calculate Free Space Path Loss (FSPL) using Friis equation
fspl_2GHz = ((4*pi)^2)*(d.^2)/ (w1^2 )
fspl_5GHz = ((4*pi)^2) *(d.^2)/ (w2^2 )
plot(d, 10*log(fspl_2GHz), 'y', 'LineWidth', 2); hold on;
plot(d, 10*log(fspl_5GHz), 'g', 'LineWidth', 2); hold off;
grid on;
xlabel('Distance (meters)');
ylabel('Free Space Path Loss (dB)');
title('Free Space Path Loss vs Distance for 2 GHz and 5 GHz');
legend('2 GHz', '5 GHz');
```

CODE 2

```
% Constants
c = 3e8; % Speed of light in meters/second
d0 = 1;  % Reference distance in meters

% Frequency range from 1 GHz to 70 GHz
f = linspace(1e9, 70e9, 100); % 100 points between 1 GHz and 70 GHz

% Distance values
distances = [1000, 5000, 10000]; % in meters

% Calculate FSPL for each distance
fspl_d1 = 20*log10(4*pi*distances(1)*f/c);
fspl_d2 = 20*log10(4*pi*distances(2)*f/c);
fspl_d3 = 20*log10(4*pi*distances(3)*f/c);

% Plotting
figure;
plot(f/1e9, fspl_d1, 'b', 'LineWidth', 2);
hold on;
plot(f/1e9, fspl_d2, 'r', 'LineWidth', 2);
plot(f/1e9, fspl_d3, 'g', 'LineWidth', 2);

% Labeling and formatting
xlabel('Frequency (GHz)');
ylabel('Free Space Path Loss (dB)');
title('Free Space Path Loss vs Frequency');
legend(sprintf('d = %d m', distances(1)), sprintf('d = %d m', distances(2)), sprintf('d = %d m', distances(3)), 'Location', 'northwest');
grid on;
hold off;
```

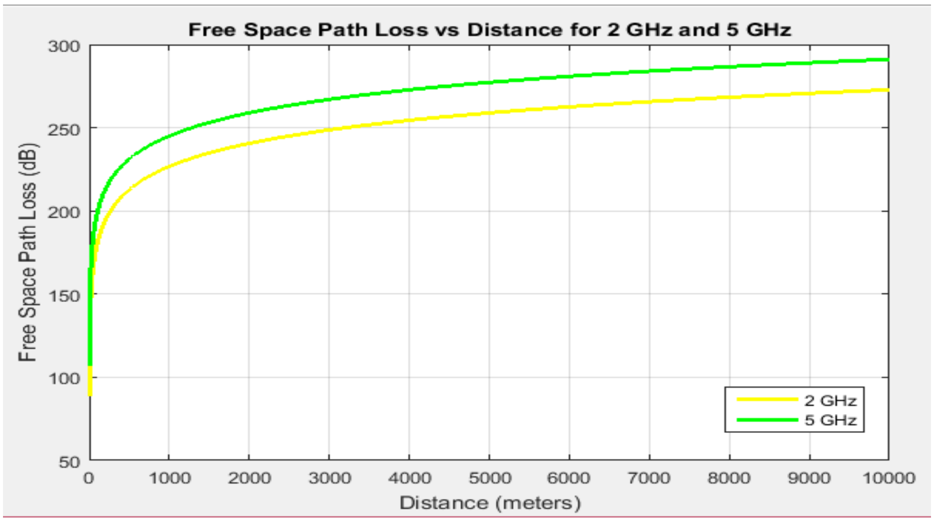


Figure 2: Free space path loss in km and in DB. (2Ghz and 5Ghz sub-6Ghz frequency)

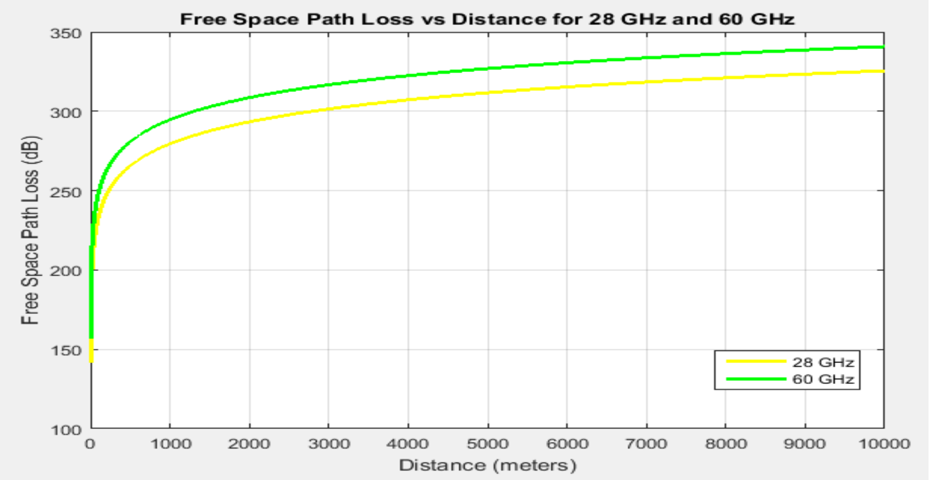


Figure 3: Free space path loss in km and in DB (28Ghz and 60Ghz millimetre wave frequency)

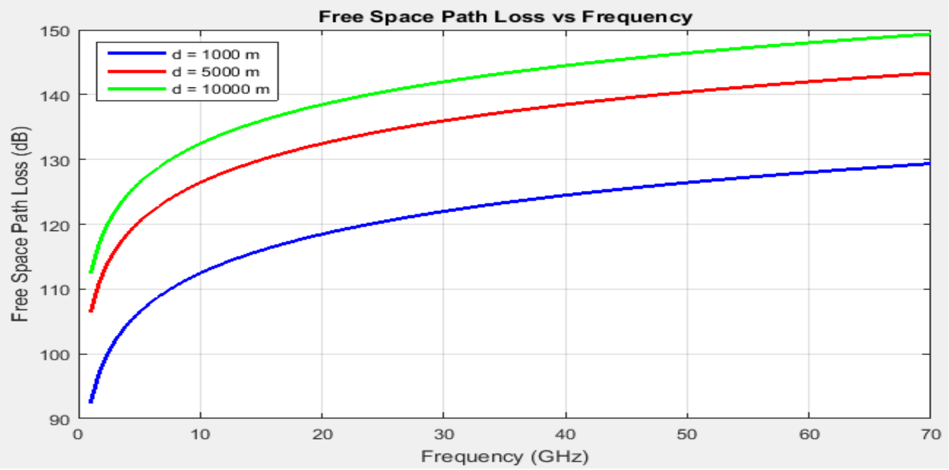


Figure 4: Free space path loss against frequency for different distance d.

The variations in path loss among the four distinct selected frequencies by using the simulated results were seen. Plots displaying trend-following findings were displayed. There was an increase in path loss on frequencies 2GHz/5GHz as well as 28GHz/60GHz, from figure 2 and figure 3 for sub-6GHz at 500 meter away from the transmitter there was a path loss of about 280dB while for the mmwave for the same distance free space path loss is over 320dB This demonstrates how, when a signal travels the distance between the transmitter and receiver, it tends to suffer from significant path loss at higher frequencies. However, compared to the higher frequencies, lower frequencies incur less path loss as their signal propagates over a longer distance between the transmitter and the receiver, meaning that it maintains most of its original intensity. Another important point of note is that at the same frequency either sub-6GHz or above 6GHz is the change in distance, as the distance increases the free space path loss increases.

5. CONCLUSION

Through this work, a model for radio wave propagation in free space has been successfully simulated. We have determined the differences in free-space propagation path loss between various sub-6GHz and milliwave frequencies, as well as how to mitigate antenna transmission issues by raising the antenna's gain. Furthermore, as an increase in gain might strengthen the signal and enhance receiver reception, it would also aid in lowering free space loss. Similar to this, more bandwidth increases the quality of the antenna by allowing it to pick up a wider range of radio waves. Directional antennas are made up of several parallel components that aid in the propagation of electromagnetic field energy in that direction. We could also alter the size and shape of the antenna, add more element arrays, reflector arrays, and parabolic reflectors, as well as create spatial diversity. Directionality also plays a key role in enhancing the radio signal that is delivered. This signal is enhanced by alignment, which in turn lessens interference from undesirable. This paper contributes to our understanding of the utility and significance of the free space propagation path loss model by simulating the propagation system using MATLAB. Understanding the idea of the free space path loss was made easier with the help of the output graph. The users can enter any carrier frequency, which is taken from the program code. We will be able to identify the similarities and differences between the generated outputs at the two separate sub-6GHz and mm-wave input frequencies. In conclusion, a higher frequency results in a bigger loss in the free space propagation path as it passes along the line that connects the transmitter and receiver.

6. RECOMMENDATIONS

Interest in wireless communication devices and many uses for radio waves in general has increased. It is crucial to consider the path loss in order to build additional systems. Despite the fact that free space propagation is not as practical as other radio wave propagations, ideas and concepts from this field can nevertheless be applied to it, particularly with regard to path loss. A system for radio wave propagation can also be developed using path loss as its foundation. In light of this, it is also advised to introduce fresh path loss model systems, especially for urban settings where are many obstacles in the way, it is recommended to develop new techniques or tools to reduce the impact of radio path loss on communication networks. Further study is advised on devices that can increase signal strength by using the radio path loss as a guide. Additionally, this work can be used as a foundation or source of additional information for anyone planning to conduct research on free space propagation.

REFERENCES

1. Aaron D.M., A.R.B., Emmanuel D.R., Matthew, Z.M., Isabel N.(2020). Radio Wave Propagation: Simulation of Free Space Propagation Path Loss. International Journal of Emerging Trends in Engineering Research, 8(2) 1-7
2. Sulyman, A.I., Alwarafy, A., MacCartney, G.R., Rappaport, T. S., and Alsanie, A. (2016). Directional Radio Propagation Path Loss Models for Millimeter-Wave Wireless Networks in the 28-, 60-, and 73-GHz Bands.” IEEE Transactions on Wireless Communications. 15(10) 6939-6947. https://doi.org/10.1109/TWC.2016.2594067
3. Daniel, A. Tilahun G. and Teshager, A. (2016). Effect of Ionosphere on Radio Wave Propagation.” International Journal of Research. 3(9) 65-74. https://study-ccnp.com/understanding-free-space-path-loss/
4. Ekeocha, A., Onyebuchi, N. and Uzoechi, L. (2016). Path loss characterization of 3G wireless signal for urban and suburban environments in Port Harcourt City Nigeria. International Research Journal of Engineering and Technology. 3(3)
5. Sharma, P. and Singh, R.K. (2010). Comparative Analysis of Propagation Path loss Models with Field Measured Data.” International Journal of Engineering Science and Technology. 2(6)

6. Bakare, B.I., Orike S. and Ibanibo T.S. (2022). Design and Simulation of Television White Space Technology for Rural Broadband Connectivity in Nigeria, Quest Journals, Journal of Electronics and Communication Engineering Research 8(11) 15-23.

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