Indoor Path Loss Model

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ABSTRACT

In this paper, a short-range indoor propagation at 2.4 GHz and 910 MHz was measured and modelled. The measurement operations were conducted to determine the path loss (PL) of Radio frequency (RF) at the communication lab of VIT University. In case of 910 MHz height of the transmitting antenna is increased and Okumura model is used for its path loss calculations. The lab has unique structure and segmented in different sections. The irregular structure of lab, further with various interior material used gives the unique characterization to the received power. The conclusion made in this paper primarily targets to distinguish practical path loss and theoretical path loss for 2.4 GHz and 910 MHz frequency in typical indoor room.

1. INTRODUCTION

Wireless communication is easily affected by the noise in the environment. Two common propagation models are considered here. (1) Outdoor Propagation Model (2) Indoor Propagation Model.

The path loss (PL) is the reduction in power density of a radio signal as it propagates in the space. The main factors contributing to path loss include propagation losses caused by the natural expansion of the radio wave front in free space, absorption losses caused when the energy of the radio signal is absorbed by the obstacles in the path and diffraction losses when part of the radio wave front is obstructed by an opaque obstacle. The PL adversely affect the QoS of a wireless link resulting in possible link failure and hence combating the path loss is a crucial task for any wireless system.

The loss of transmitted power is due to the presence of object such as writing tables, chairs, wooden blocks and so on. Therefore, the path loss model is significantly important to distinguish the RF wave propagation based on environmental effect. The model describes about the indoor propagation in UHF spectrum band in various measurement environment such as; office, residential area, multi-floored building and so on. This paper characterizes the amount of power loss due to indoor object on the RF signal. The Idea has been implemented using National Instruments Universal Software Radio Peripheral (NI USRP 2901).

The Main Idea is to transmit a RF signal from the hardware and to determine the power loss in the channel. Received power is measured using spectrum analyser. Then, we make use of the free space spreading loss formula from satellite communication book to determine the received power theoretically. It will be discussed briefly in further sections.

2. LITERATURE SURVEY

A similar experiment has been conducted in [1], where the research was based on Razak School corridor. The path loss was measured for indoor propagation at 2.6 GHz deployed for LTE network, the experiment is done in particular structured area, here analysis of path loss exponential component was done.

In [2], Implementation of cellular networks using SDR was done. The method analysed included dynamical allocation spectrum at a lower frequency for a link suffering from high path loss. For the analysis, a wireless link was set up using Universal Software Radio Peripherals (USRPs). (a)As the operating frequency is decreased to lower range, there will be increased requirement of bandwidth at lower frequency. Hence it should be ensured that the operating frequency is decreased only when there is availability of enough spectrum   depth at lower frequency. (b)Use of full-duplex in cellular network will increase the computational complexity of the communication system.

3. METHODOLOGY

LabView is a platform for graphical programming of digital communication systems. We use the help of LabView to interface with the NI USRP 2901 hardware. The details about the hardware has been studied from [3]. Spectrum Analyzer is used to measure the received power. An Ultra-Wide-Band antenna is used for the demonstration of the idea. One USRP acts as a transmitter and the spectrum analyser is used as the receiver. The Transmitter vi in LabView is used to transmit the RF signal wirelessly. Spectrum Analyzer gives the value of received power.

3.1 Mathematical modelling

Short Range indoor propagation model for 2 different setups are created and the analysis of Received power and Path Loss parameter is observed. The lab has unique structure and segmented in different sections. The unique structure of lab, further with various interior material used gives the unique characterization to the received power and hence to Path Loss parameter.

SETUP 1: Frequency – 2.4GHz; Transmitter antenna height = Receiver antenna height

$$\text{FSL [dB]} = 147.55222 + 20\log(f*10^9) \text{ [GHz]} + 20\log(d*10^3) \text{ [Km]} \tag{1}$$

SETUP 2: Frequency – 910MHz; Transmitter antenna height = 2 m; Receiver antenna height = 0.96 m.

$$\text{Median Path Loss (dB)} = FPL + A(f,d) - G(h_{te}) - G(h_{re}) - G(Area) \tag{2}$$

$$G(h_{te}) \quad = 20\log(h_{te}/200) \qquad 1000m > h_{te} > 30 \text{ m}$$

$$= 10\log(h_{te}/200) \qquad h_{te} < 30 \text{ m (Approximation taken)} \tag{3}$$

$$G(h_{re}) = 10\log(h_{re}/3) \qquad h_{re} < 3 \text{ m}$$

$$= 20\log(h_{re}/3) \qquad 10 \text{ m} > h_{re} > 3 \text{ m} \tag{4}$$

In both the setup distance between transmitter and receiver is varied and received power value is observed.

Above process is also done by varying the gain of the transmitter (10, 20, 30 in dB)

4. RESULTS AND DISCUSSIONS

In this paper we have calculated Path Loss from the observed transmitted power and Received power. The observed values of transmitted and received power are subjected to following set of fixed parameters;

(1) Transmitter Gain (2) Distance between the transmitter and receiver (3) Height of transmitter and receiver

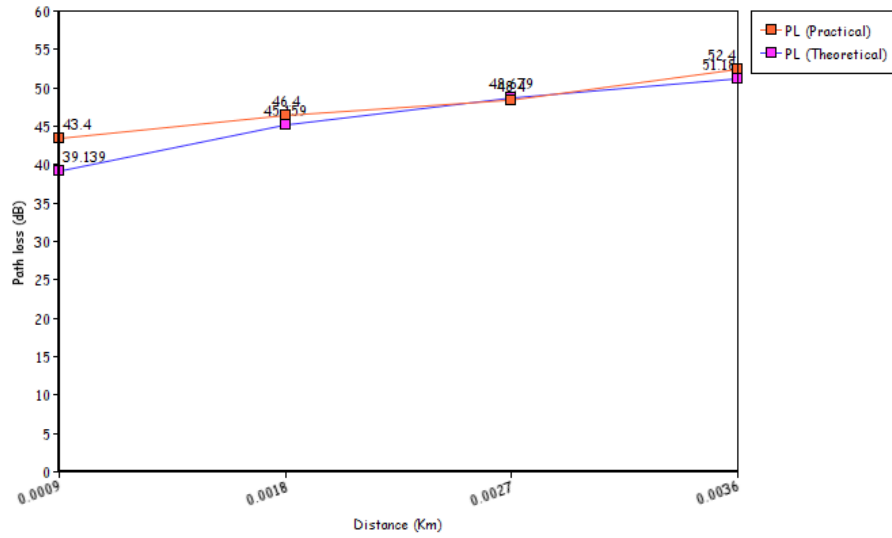## *4.1 Setup -1 (Free Space Propagation)*
Following are the observed practical and calculated theoretical value tabulation and comparison graphs for the free space propagation for 2.4GHz.

Table 1. Practical Observation (2.4GHz)

Transmitter Gain (dB)	Power transmitted (dB)	Distance between transmitter & receiver (Km)	Power received(dB)	Path Loss (dB) Practical
10	-55.6	0.0009	-99	43.4
		0.0018	-102	46.4
		0.0027	-104	48.4
		0.0036	-108	52.4
20	-45.6	0.0009	-90	44.4
		0.0018	-96	50.4
		00027	-99	53.4
		0.0036	-101	55.4
30	-35.5	0.0009	-74	38.5
		0.0018	-84	48.5
		0.0026	-85	49.5
		0.0036	-87	51.5

Table 2. Theoretical Observation (2.4GHz)

Distance between transmitter & receiver (Km)	Path Loss (dB) Theoretical
0.0009	39.139
0.0018	45.159
0.0027	48.679
0.0036	51.180

Figure 1. Distance vs Path loss (Gain = 10dB)

*4.2 Setup -2 (Okumura Propagation)*

Following are the observed practical and calculated theoretical value tabulation and comparison graphs for the Okumura propagation for 910MHzHz.

Table 3. Practical Observation (910MHz)

Transmitter Gain (dB)	Power transmitted (dB)	Distance between transmitter & receiver (Km)	Power received(dB)	Path Loss (dB) Practical
10	-55.6	0.0009	-103.4	47.8
		0.0018	-111.2	55.6
		0.0027	-115.7	60.1
		0.0036	-110	54.4
20	-45.6	0.0009	-98	52.4
		0.0018	-102	56.4
		0.0027	-107	61.4
		0.0036	-102	56.4
30	-35.5	0.0009	-84	48.5
		0.0018	-91	55.5
		0.0027	-100	64.5
		0.0036	-94	58.5

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Table 4. Theoretical Observation (910MHz)

Distance between transmitter & receiver (Km)	Path Loss (dB) Theoretical
0.0009	57.64
0.0018	63.66
0.0027	67.18
0.0036	69.68
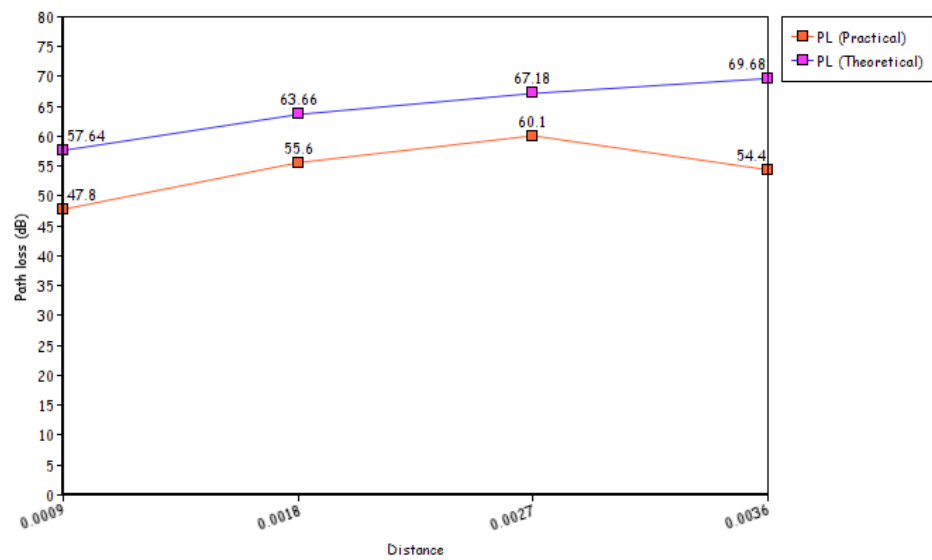
Figure 2. Distance vs Path loss (Gain = 10dB)

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4.3 Lab environment setup

Figure 3. Setup 1 – free space Model Setup

Figure 4. Setup 2 – Okumura Model Setup

5. CONCLUSIONS

 The measurement carried out at digital communication lab in VIT Vellore has proved that as we increase the distance between transmitter and receiver the path loss increases due to additional interferences in the environment (materials like tables, chairs, wall, floor etc.) inside the lab and this additional interference is responsible for the major loss in the power of the transmitted signal. This is one of the reasons for low speed of LTE systems inside the lab. As the power loss increases, the signal quality decreases causing the data rate to go down. We also observed that the Practical value of the Path loss is relatively close to the theoretical value calculated. Thus, we conclude that in an indoor environment the power loss is high due to the presence of many absorbing materials and objects.

6. REFERENCES

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