EVALUATION OF SIGNAL STRENGTH ATTENUATION ON CONCRETE WALLS USING WI-FI SIGNAL

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DECLARATION PAGE

I hereby declare that this work is the product of my research efforts undertaken under the supervision of (Dr. Hassan A Bashir) and has not been presented anywhere and will not be presented elsewhere for the award of degree or certificate. All sources have been duly acknowledged.

.... ……………………………………

Signature Date

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APPROVAL PAGE

This is to certify that this project report on the study of signal strength attenuation on concrete wall based on RFID a case study of Wi-Fi signal has been examined and approved by the undersigned persons on behalf of the Department of Electrical Engineering, Bayero University, Kano, as meeting one of the requirements for the award of M.Eng. (Electronics) Degree of Bayero University, Kano.

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DEDICATION

This work is dedicated to my late father Alh. Dahiru Muhammad Roni and my mother Hajiya Bilkisu with profound affection and gratitude for good foundation they laid for my academic life. May the Almighty Allah forgive all their sins and grant them paradise. Ameen.

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LIST OF ABBREVIATIONS

GPS	Global Positioning System
RFID	Radio Frequency Identification
LOS	Line Of Sight
NLOS	Non Line Of Sight
WI-FI	Wireless Fidelity
LAN	Local Area Network
WLAN	Wireless Local Area Network
GUI	Graphical User Interface
UWB	Ultra Wide Band
PT	Transmit Power
PR	Received Power
WPAN	Wireless Personal Area Network
RF	Radio Frequency
AP	Access Point
NIC	Network Interface Card
NFC	Near Field Communication
PDA	Personal Digital Assistant

ABSTRACT

Wireless communications for indoor environments is recognized to be very challenging, mainly due to the presence of obstruction that causes severe signal deterioration GPS is satisfied for outdoor communication but attract poor signal reception indoor. This research aims to study the Wi-Fi signal strength attenuation on concrete walls using Wi-Fi-enabled RFID devices. Empirically, an access point was used to transmit Wi-Fi signal to the laptop computer running insider software for the indication of signal level and measured results was obtained at every 10 m interval. For the theoretical results, Wiener II model was transformed into Matlab code and then simulation results were obtained. The graphs for both theoretical and Empirical result was then plotted and compared. The result showed that there is averagely 2dB difference between the measured and calculated path loss in free space and about 12dB in the presence of obstructed medium (concrete wall). The path loss model parameters were tuned based on the measured results and this yields an improved model with averagely 0.39dB difference between the measured and modified model in free space and 0.14dB in the presence of concrete wall. The modified Weiner II model that best predict the measured data was developed, so that the modified results can now be used to facilitate RF site survey without the necessary physical measurements, serves as a guide to a network designer in determining the best location of network devices. Determines based on the signal strength the position information of mobile user inside large buildings such as malls, hospitals, air ports, public places, factories and emergency services. Further research could be carried out to determine the path loss of Wi-Fi signal by considering the properties of different type of materials such as wood and glass also the effect of frequency on the signal can also be considered.

CHAPTER ONE

1.0 INTRODUCTION

The Global Positioning System (GPS) is highly reliable and accurate when used outdoors. However, in indoor environments, due to the additional signal loss imposed by walls of the buildings, the detection and decoding of GPS signals becomes a difficult task as such the wireless communication for indoor environments is recognized to be very challenging, mainly due to the presence of obstruction that causes severe signal deterioration due to multi-path and shadow fading (Pahlavan and Levesque, 2005). For this reason, the prediction of wall losses is a fundamental aspect in the planning of wireless communication in indoor area like position information of the mobile user inside large buildings, malls, hospitals, air ports, public places, factories and emergency services. This research aims to empirically and theoretically study the signal strength attenuation on concrete walls using Wi-Fi enabled RFID devices. The measured result will be compared with the theoretical Weiner II model result to test its ability to predict attenuation of the walls.

1.1 MOTIVATION AND SIGNIFICANCE OF THE STUDY

Wireless LAN communications typically are based on radio frequency signals that require a clear and unobstructed transmission path. Most of these obstructed materials are important to consider when planning a wireless network. The density of materials used in a building’s construction determines the number of walls the RF signals can pass through and still maintain adequate coverage. Concrete and brick walls are particularly difficult for signals to pass through. These structures will weaken or at times completely prevent wireless signal. The concrete wall that an RF signal has to pass through also affects the signal strength and must be taken into consideration when designing indoor wireless system. Technology such as GPS is restricted to outdoor communication when it comes to indoor environments GPS suffers from poor signal. Dedicated RFID device can communicate indoor but has a short transmission range. Wi-Fi enabled RFID is a system that uses an access point as a reader and Wi-Fi devices as tags. This is similar to RFID system as such it is used in this research to track signal quality in the presence of concrete walls.

1.2 AIM AND OBJECTIVES

The aim of this research work is to analyze Wi-Fi signal attenuation in concrete walls using Wi-Fi enabled RFID devices. The result of the analysis will be used to determine the location of mobile user inside building, malls, hospitals, air ports, public places, factories and emergency services. Also, this will provide vital information that could facilitates RF site survey to determine the optimum location of access points for provision of necessary service range.

1.3 OBJECTIVES

- To study the attenuation/path loss effect caused by concrete walls on Wi-Fi signal using a mathematical model;
- To develop mathematical model using concrete wall parameters to represent the attenuation effect of concrete walls;
- To conduct a practical measurement with access point and laptop computer running inSSIDer software.
- To create a graphical user interface (GUI) using matlab as a tool for interacting with the necessary data for path loss determination.

1.4 METHODOLOGY

Generally, it is nearly impossible to accurately determine the range of wireless signals through indoor facilities without performing some live testing. Thus in order to achieve the desired objectives of the study, the Wi-Fi-enabled RFID technology is taken to obtain a realistic analysis of the problems associated with the Wi-Fi signal when obstructed by concrete walls. The following procedure was followed :-

- The use of Weiner II model to study the signal strength for comparison to the practical measurements
- An access point was be used to transmit Wi-Fi signal to the laptop computer running insider software which is used to study the received signal strength at every10m distance interval.
- Mathematical model of the wall obstacle will be developed with concrete wall of relative permittivity of 4.6, thickness of 30cm and conductivity of 0.05 S/m
- Graphical user interface (GUI) for calculating the path loss and graph plotting was developed.

1.5 SCOPE AND LIMITATION OF THE RESEARCH

This research work is limited to studying the attenuation (path loss) at various distances of 2.4 GHz WI-Fi signal in the presence of concrete wall. The measured result obtained will be compared with result of the computed path loss model.

1.6 REPORT ORGANIZATION

The layout of this report is as follows: Chapter Two contains literature review of behavior of radio waves in the presence of walls, models for path loss determination and review of related work. Chapter Three presents the methodology, physical measurement and path loss calculation using Weiner II model .Chapter Four covers the result and analysis of simulated results from the model with the data obtained. Conclusions, contributions, contribution to knowledge and recommendations are presented in Chapter Five.

1.7 CONTRIBUTION TO KNOWLEDGE

The research greatly simplifies path loss calculation of signal passing through concrete wall, using the developed Matlab; graphical user interface designed for the improved model. It also serves as an additional system that guides network designer in determining best location for network devices without the necessary physical measurement.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter provides the basic and necessary theoretical concepts for understanding the propagation behavior of radio waves through concrete wall. Important aspects that will facilitate the study of the behavior of radio waves passing through concrete wall are discussed. Wireless communication (section 2.1) radio wave indoor propagation behavior (section 2.2), path loss (section 2.3), free space path loss (section 2.4), multipath effects (section 2.5), IEEE 802.11 Wireless fidelity (section 2.6), line-of-sight versus Non-Line-Of-Sight (section 2.7). Theoretical path loss model (section 2.8), RFID technology overview (section 2.9), Weiner II path loss model (section 2.10), Mean square error (section 2.11), Review of related literature (section 2.12) and Summary of related literature (2.13).The above listed sections will shed light on the behavior of radio waves with a Wi-Fi signal as case study when propagated through concrete wall.

2.1 WIRELESS COMMUNICATION

When radio waves transmit or travel from one device to another there are several issues one has to highlight. The radio energy attenuates as it propagates and when it passes through obstacles like glass, wood, concrete and metal surfaces. The mechanisms that occur when radio waves propagate through non line of sight are reflection, diffraction and scattering which are to be discussed in detail in the later sections.

2.2 RADIO WAVE PROPAGATION BEHAVIOUR INSIDE BUILDINGS

Generally, the radio wave propagation behaviour inside buildings comprises many mechanisms (Pathak,S.S.,R. 2013). One of them is the science behind the characteristics of the transmitter and receiver. Secondly, the propagation channel's effects which are related to path loss due to the propagation medium and any obstacles on the propagation path. The latter is mainly caused by reinforced metal rods within building skeletons, metal drain, water piping, and metal window shadowing line of sight between transmitter and receiver.

In indoor environments, the signal can only propagate through the air and through many other media. As a result, shadowing and multiple path propagation lead to multiple copies of the same signal traveling over several paths which have substantial impacts on the signal strength. The effects of the wave on a conducting obstacle induce currents in the obstacle, which is successively re-radiated by means of further electromagnetic waves in relevant directions.

However, in this environment, technical factors such as characteristics of devices have smaller impact on the signal than multiple path propagation. In this case, infinite number of waves from various directions can interfere with each other and various obstacles contribute to the extensive signal level variation within the buildings. The level of variation depends on the type of building, position of the transmitter and receiver.

From wave propagation point of view, there are two main types of buildings; buildings with large open spaces, such as airport and railway terminals, shopping malls, sport halls, and large assembly halls; and buildings with small open spaces; such as office and residential buildings etc. Wave propagation in buildings with large open spaces is spontaneously similar to propagation in free space. On the contrary, the propagation depends on the path loss and propagation medium such as concrete walls, which are considered in this work.

Indoor propagation can be strongly influenced by the surrounding environment. For example, adjacent buildings can be good reflectors, which may discourage the propagation between rooms. As mentioned earlier, indoor signal propagation is controlled by the same mechanism as that of outdoor. Reflection, diffraction, and refraction are among the factors that influence the propagation.

However, situation is much more unsettled indoors. For instance, signal levels sometimes varies depending on whether inside doors are closed or open for a building. The positions and distance between antennas also have serious influence on signal propagation; for example, antenna placed on the desk level in a room in terms of the received signal is very much different from those put on the ceiling, regardless of the antenna radiation pattern, the radiated wave will be uniform in the room.

To tackle the challenges encountered in indoor propagation, this work employs RFID with IEEE 802.11 (Wi-Fi) as a case study, to investigate and analyze indoor signal strength attenuation when obstructed by a concrete wall.

2.3. PATH LOSS

Usually, radio waves propagation inside buildings will travel in all possible directions in a straight line; as a result, radio waves interfere with objects, such as concrete wall. This is attributed to wave characteristics such as diffraction, reflection, refraction and absorption. All these factors contribute to signal distortions, fading, as well as propagation losses (path-loss).

Path loss depends among other things upon signal frequency, distance, antenna height and environmental (medium) characteristics. Frequency and distance are taken into account in most of the models for path loss calculation For example, Ray tracing models (Saadane, R., W., Mohammed 2012), empirical models and the most interesting models in recent years-dominant path model and the Par Flow approach. Antenna height and obstacles between transmitter and receiver are often considered; however, their effects are not clear and comprehensible (Sayegh, Z.,M. Latrach, F. Costen, G. El Zein, and G. Zaharia 2013). Radio waves or signal transmitted over a distance are always attenuated by obstacles; the amount of attenuation varies with the frequency of the signal, and the obstructing material type.

It was shown by (Smulders, P. F. M. 2003) that the lower the frequency the better the transmission of the signal is. This is because the signal wave is larger and can easily penetrate through air and through objects since there is much less path loss than at high frequency. Some observations shows that, if two radio systems have the same transmitting power and receiver sensitivity, (one system is at 5 GHz and the other at 2.4 GHz), then the 2.4 GHz radio would perform better because it has less path loss than a 5 GHz system.

The parameters relative permittivity, conductivity, and thickness can be used to estimate the effects of a concrete wall on a wireless system.Figure 2.1 show a transmission system consisting of a transmitter and a receiver given a transmitted power and received power, the system will encounter losses and gains as shown in the figure 2.1

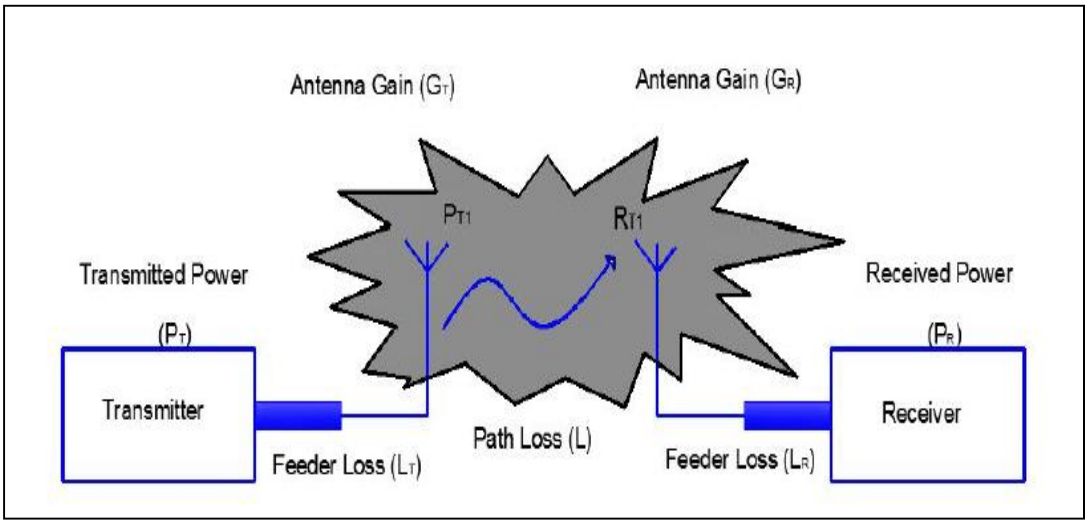


FIGURE 2.1 Components involved in Wireless system. Showing Transmitter and Receiver line-of-sight (Rakesh and Srivasta, 2013)

From figure 2.1, the received power can be calculated using equation (2.1)

$$P_R = \frac{P_T G_T G_R}{L_T L L_R} \quad (2.1)$$

Where P_t is the transmitted power

P_R is the received power

G_R is the gain of the receiver

G_T is the gain of transmitter

L_T is the transmitter feeder loss

L_R is the receiver feeder loss

L is the path loss

Gain and losses are given as power ratio in watts. Effective Isotropic Radiated Power (EIRP) can be calculated as follows:

$$EIRP = P_{t=} \frac{P_T G_T}{L_T} \quad (2.2)$$

$$P_r = \frac{P_R L_R}{G_R} \quad (2.3)$$

The path loss of the signal can be expressed as the ratio of the EIRP to received power as shown in equation (2.4).

$$P_L(\boldsymbol{d}) = \frac{\boldsymbol{P_t}}{\boldsymbol{P_r}} \tag{2.4}$$

The path loss can be expressed in decibel as follows

$$\mathrm{P}_{\mathrm{L(d)}} = 10\log\frac{\mathrm{P_r}}{\mathrm{P_t}} \tag{2.5}$$

Some effective models like; log-distance path loss model, empirical models, path loss can generally be expressed in terms of exponents of the environment as shown in equation (2.6) and equation (2.7) respectively.

$$P_{L(d_o)=20\log(\frac{4\pi d}{\lambda})} \tag{2.6}$$

Where $PL(do)$ is the path loss at reference distance.

d is the distance between transmitter and receiver

λ is the wavelength

$$P_{L(d)=}P_L(d_o) + 10n_f lod\,\frac{d}{d_o} \tag{2.7}$$

Where

n_f is the path loss exponent

d_o is the reference distance

d is the distance between transmitter and receiver

$p_{l(d_o)}$ is the mean path loss measured in dB at reference distance do

λ is the wavelength

2.4. FREE SPACE PATH LOSS

Normally, when electromagnetic waves travel in free space, the wave’s path is described as a direct ray connecting the transmitter and the receiver. In order to calculate the free-space propagation loss, it is possible to use the Friis Transmission Equation (Rakesh, N. and S. K. Srivatsa, 2013)

$$FRPL = G_t G_r (\frac{4\pi d}{\lambda})^2 \qquad (2.8)$$

Where:

λ is the wavelength, $G_t$and G_r are gain values of the transmitting and receiving antennas respectively, and d is the physical distance between the transmitter and the receiver. Equation (2.8) can be expressed in decibels as follows

$$FRPL(dB) = 20log_{10}(\frac{4\pi d}{\lambda}) \qquad (2.9)$$

Generally, propagation loss in free space can be expressed as equation 2.9. G_t=G_r = 1: (Rakesh,N. and S.K Srivasta ,2013)

$$FSPL(dB) = 20log_{10}(d) - 20log_{10}(\lambda) + 20log_{10}(4\pi) \qquad (2.10)$$

2.5. MULTIPATH EFFECT

The three predominant processes of physics that influence propagation inside buildings are; reflection, diffraction and refraction. In addition, absorption of the signal depends on the signal wavelength and physical properties of the surfaces where the signal propagates. In an indoor environment, multipath effect can be greatly differ in comparison to an outdoor environment, as there are reflections from many cluttering objects and also reflections from walls, doors, and windows with closer inter-arrival of multipath components at the receiver. However, the signal propagation changes as the signal passes through different media of different electrical characteristics, when this occurs, the velocity of propagation as well as the direction changes considerably. The degree of variation in the signal strength depends on the degree of change in medium dielectric constants as the signal passes from medium to medium. The signals also experiences diffraction inside a room that occurs due to obstacles that have sharp edges; the amount of diffraction is subject to the signal properties and geometry of the edge. Indoor propagation waves face scatter in many directions adding to the constructive and destructive interference of a signal. However, as light waves are subject to reflection likewise radio waves are. In addition, reflection depends on the wavelength of the transmitted signal. Example, for 10 GHz signal frequency, the wavelength is lower when compared with 2.4 GHz and better transmission power. Equation 2.11 can be used to calculate the wavelength of the signal.

$$\lambda = \frac{c}{f} \tag{2.11}$$

Where c is the speed of light (3.0* 10^8m/s). Increasing signal frequency will result in the wavelength becoming small; as a result, the waves encounters many flat surfaces inside the buildings, which will result in reflection and refraction of the wave signal. This factor encourages the signal fading inside buildings. Figure 2.4 shows how the surrounding walls affect signal when passing from transmitter to receiver i.e it strikes surfaces inside the room there by giving many reflections.

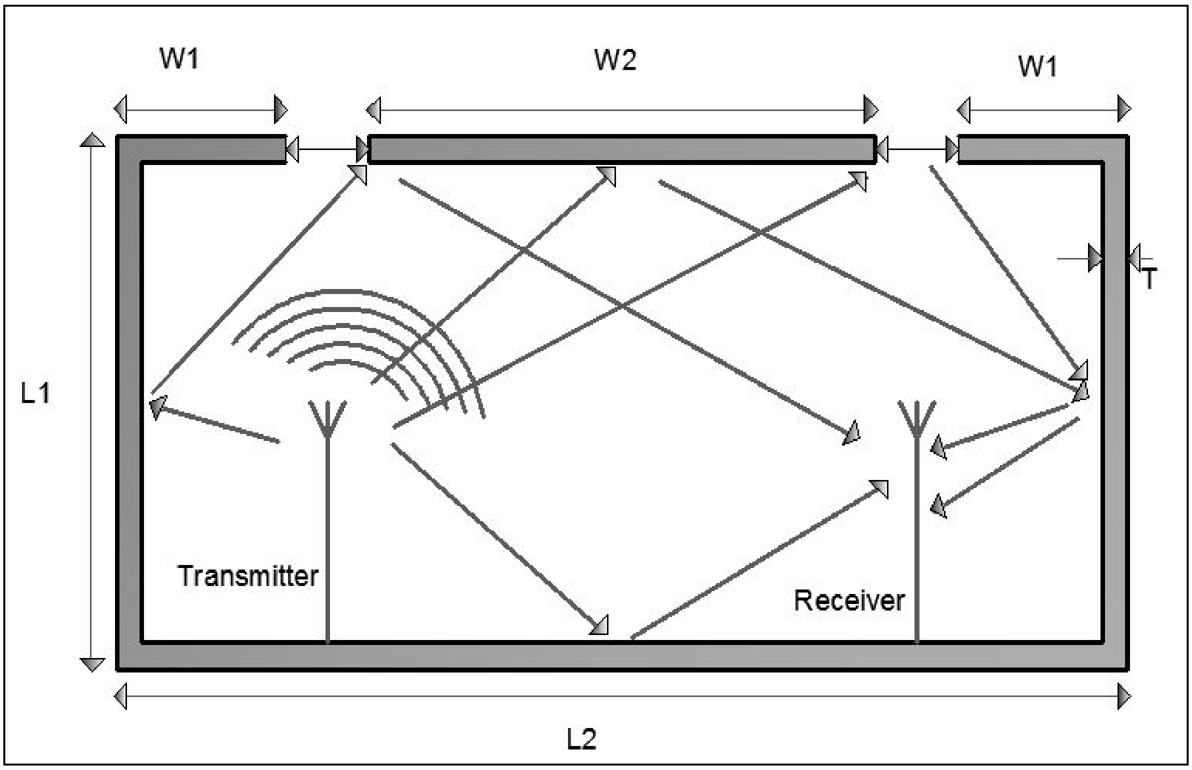


FIGURE 2.2 Transmitted Signal Arrives at the Receiver following Multiple paths (Rakesh. and Srivasta ,2013)

2.5.1. REFLECTION

Reflection occurs when a propagating radio wave strikes an object which has very large dimensions when compared to the Wavelength of the propagating wave (Jung W. K. Jongho et-al, 2010).

2.5.2. DIFFRACTION

Diffraction occurs when the visual contact between transmitting and receiving antennas is blocked by a sharp-edged surface. The secondary waves resulting from the obstructing surface are present throughout the space and even behind the obstacle, resulting to a bending of waves around the obstacle, even when a line-of-sight path does not exist between transmitter and receiver (Ratnayake, N. L., K. Ziri-Castro, S. Hajime, and J. Dhammika, 2011).

2.5.3. REFRACTION

Refraction is defined as a change in direction of a radio wave resulting from changes in the velocity of propagation of the medium through which it passes. This may result in a situation in which only a fraction or no part of the line of sight wave reaches the receiving antenna.

2.6 Wi-Fi

Wi-Fi stands for Wireless Fidelity. It refers to a system which is called IEE 802.11 standards (WirelessLAN), and was developed by IEEE in 1997. People prefer using Wi-Fi because it uses a single base station in the shape of a box with wired connection to the internet, such as a Digital Subscriber Line (DSL), cable, or T1 line. It can broadcast to multiple users over distance of 100 meters indoor and 400 meters outdoor.

2.7 LINE-OF-SIGHT VERSUS NON-LINE-OF-SIGHT

A signal radiated from an antenna travels along one of the three routes: Ground wave, Sky wave, or Line-of-sight (LOS) in outdoor environments (Saadane, R., W., Mohammed 2012). Based on the operating frequency range, one of the three is stronger; low frequencies below 3 MHz travel commonly as ground waves, diffraction of these waves around obstacles is strong due to their long wavelength. Most long distance low-frequency radio communication between (30 MHz- 300 MHz) is a result of ground wave propagation. Example of these include amplitude modulation (AM) broadcast band and military communication. At frequencies higher than 30 MHz, LOS is the dominant propagation mode (Sayegh, Z.,M. Latrach, F. et-al 2013). Moreover, the most well known positioning system is the Global Positioning System (GPS) (Kaplan, 2005), which is satellite-based and very successful for tracking users in outdoor environments.

However, the inability of satellite signals to penetrate buildings puts GPS in a disadvantage in indoor environments. The indoor radio propagation channel is characterized as site specific, exhibiting severe multi-path effects and low probability of line-of-sight (LOS) signal propagation between the transmitter and the receiver (Pahlavan and Levesque, 2005), making accurate indoor positioning very challenging. For indoor location sensing a number of wireless technologies have been proposed, such as infrared (Want et al., 1992), ultrasound (Priyantha et al., 2000), Wi-Fi (Bahl and Padmanbhan, 2000; Youssef and Agrawala, 2005; King et al., 2006; Papapostolou and Chaouchi, 2009; Ubisense), Ultra WideBand (UWB) (Ingram et al., 2005), and more recently RFID (Hightower et al., 2000; Ni et al., 2003; Wang et al., 2007; Stelzer et al., 2004; Bekkali et al., 2007; Lee and Lee, 2006; Han et al., 2007; Yamano et al., 2004; Xu and Gang, 2006; Papapostolou and Chaouchi, 2009) As a result, a signal can be transmitted either to a satellite or to a receiving antenna which is in the line of sight of the transmitting antenna.

Contrary, Non-Line-Of-Sight (NLOS) is a situation where a signal from a wireless transmitter passes several obstructions before arriving at a wireless receiver. The signal may be reflected, refracted, absorbed or diffracted. These create multiple signals that arrive at the receiver from different paths, with different strength at different times. Therefore, wireless systems developed for NLOS environment have to take these phenomena into consideration to overcome this problem and this makes the systems more complex than those for LOS. RFID communications with Wi-fi offers operators the solution to address many problems regarding multimedia indoor communication with remarkable performance in NLOS environment, because the obstacles to be transmitted through cannot easily affect the transmissions at a frequency 2.4 GHz. Examples of such applications are; object localization, location based service, RFID based indoor tracking etc.

In a communication system, a received signal differs from the transmitted signal due to various transmission losses. The most significant transmission losses for LOS transmission are: attenuation, noise, fading, and absorption.

2.7.1 ATTENUATION

Attenuation is a general term that refers to any reduction in the strength of a signal. Attenuation occurs with any type of signal, whether digital or analog. Sometimes called *loss,* attenuation is a natural consequence of signal transmission over long distances. The extent of attenuation is usually expressed in units called decibels (dBs).If P_t is the signal power at the transmitting end (source) of a communications circuit andP_r is the signal power at the receiving end (destination), and then$P_t > P_r$ the power attenuationA_p in decibels is given by the formula:

$$A_P = 10\log(\frac{P_r}{P_t}) \qquad (2.12)$$

2.8 THEORETICAL PATH LOSS MODEL

Theoretical models were derived based on the physical laws of wave propagation. The theoretical path loss prediction models are describe in the following sections.

2.8.1 LOG- DISTANCE MODEL

This is given as $PL(d) = PL(do) + 10n\log(d)$ (2.13)

Where $PL(d)$ is path loss $PL(do)$ = power loss (dB) at 1m distance (30 dB), n is path loss coefficient, d is distance meter between transmitter and receiver. From the equation 2.13, the value n is computed as follows:$n = \frac{PL(d)-30}{10log10(d)}$ This is commonly used one slope log-distance model The traditional attenuation factor is given by PL_{AF}=$PL_{free\,space}(d)$ $+AF$ Where AF is attenuation factor due to walls, partitions, glass doors etc.

2.8.2 ITU PATH LOSS MODEL

The one-Slope model is a modified power law model (Goldsmith,A.,2005)

$$\Pr(dBm) = Pt(dBm) + K(dB) - 10nlog10(\frac{d}{do}) \qquad (2.14)$$

as in the free space model, K equals -39 dB (reference path loss for 1 m). The path loss exponent n is calculated via a minimum mean square error (MMSE) fit to empirical data. Finally, the ITU indoor path loss model is described by the following formula (Seybold,J 2005):

$PL = 20log10(f) + 10nlog10\ (d) + Lf(n) - 28dB$ For f=2400 MHz and $Lf(n) = 0$ (same floor)

$PL = 39.6 + 10nlog10(d)$

2.8.3 AFC MODEL

A more complicated attenuation factor model is extension of AFC model (Seidel S.Y.,Rappapat, T.S., 1992)

$$PL(d) = 47.8 + 10 * nlog10(d) \qquad (2.15)$$

and two slope model for corridor is

$PL(d) = 53.2 + 25.8log10(d)$ <9meter 56.4 +29.1$log10(d) > 9meters$ (2.16)

2.9 RFID TECHNOLOGY OVERVIEW

An RFID system can be broken down into two key dimensions. The technical infrastructure includes the actual data capture technology comprised of tags, readers, and transmission medium. (Charlie F., and Natalie K et-al., 2006). The logical infrastructure refers to the overall identification (ID) scheme used in representing objects. The ID scheme includes the actual coding or naming system for objects, the database or registry that contains the information relating to the codes or IDs, and lastly an ID resolution mechanism for matching the ID data with object information.

2.9.1 THE LOGICAL INFRASTRUCTURE OF AN RFID SYSTEM

In a typical RFID application, tag data acts as a reference to more detailed information about the tagged object. Unique identifiers (or codes) resolve to information stored in databases, similar to how a license plate works (Charlie F., and Natalie K et-al., 2006). Just as there are many license plate numbering schemes, there are many different coding systems used in RFID applications. Many of these are proprietary; others are based on more open standards. Some RFID applications use codes specially created for a new service while others might use existing numbering systems, like an ISBN or UPC for example, which are simply encoded and stored on RFID tags instead of barcodes.

For every set of codes there exists a database or registry that contains the records that match the IDs. In a toll collection system for example, the vehicle’s transponder transmits a unique ID that refers to the user’s account information.

2.9.2 CONVERGING TECHNOLOGIES

RFID systems are essentially short-range, low frequency, low-bit rate wireless networks. (Charlie F., and Natalie K et-al., 2006). Since their origins in the late 1940s, they have been developed specifically to exchange small amounts of data over relatively short distances using tags and readers based on proprietary air interface protocols, and more recently ISO and EPC standards. Up until now, these dedicated RFID networks have evolved independently of the new generation of short-range wireless data networks like Bluetooth, Zigbee and Wi-Fi and NFC (near field communication). (Charlie F., and Natalie K et-al., 2006).

But these old and new trajectories have begun to converge, and the “RF” component of RFID has expanded to include these more recent wireless technologies. In other words, RFID applications are starting to “piggy back” onto today’s established WPANs and WLANs using active tags that communicate with these networks’ air interface protocols. (Charlie F., and Natalie K et-al., 2006). In this sense, active RFID tags are a subset of more common communication devices like cell-phones, PDAs, and Wi-Fi enabled laptops, only with fewer input/output features (like keypads, screens, etc.) and transmitting less data. Similarly, traditional RFID networks are a subset of today’s broad menu of wireless networks. While dedicated RFID systems will continue to develop, we will see more RFID applications that exploit the growing base of Bluetooth modules in consumer devices, while cell phones will increasingly integrate NFC technology for “touch-based” RFID applications. ZigBee-enabled RFID will use wireless sensor networks to track mobile assets and Wi-Fi-enabled RFID will allow organizations to leverage existing WLAN investments or choose to invest in a wireless infrastructure that will have multiple purposes, rather than building separate networks. Of these possibilities, Wi-Fi and NFC-based RFID have seen the most activity so far. (Charlie F., and Natalie K et-al., 2006).

2.9.3 RFID VERSUS WI-FI

Radio frequency (abbreviated RF, rf, or r.f.) is a term that refers to alternating current (AC) having characteristics such that, if the current is input to an antenna, an electromagnetic (EM) field is generated suitable for wireless broadcasting and/or communications. This electromagnetic field is referred to as RF wave or radio wave. (searchnetwork.techtarget.com).The abbreviation RFID stands for radio frequency identification, i.e. information carried by radio waves. RFID systems are mainly used to identify objects or to track their location without providing any indication about the physical condition of the object. RFID is using the radio frequency (RF) technology for establishing communication among it’s nodes including the reader and tags.

An RFID system can be broken down into two key dimensions. The technical infrastructure includes the actual data capture technology comprised of tags, readers, and transmission medium. The logical infrastructure refers to the overall identification (ID) scheme used in representing objects. The ID scheme includes the actual coding or naming system for objects, the database or registry that contains the information relating to the codes or IDs, and lastly an ID resolution mechanism for matching the ID data with object information. On the other hand, a wireless local area network (WLAN) is a flexible data communications system that can use either infrared or radio frequency (RF) technology to transmit and receive information over the air (Charlie F., and Natalie K et-al., 2006).

A typical wireless LAN comprised of an Access Point (AP) and Network Interface Card (NIC) installed on the wireless device in that area. The access point is essentially the wireless equivalent of a LAN hub in wired networks. An access point is typically connected with the wired backbone through a standard Ethernet cable, and communicates with wireless devices by means of an antenna. The coverage area of the access point determines the boundary of the LAN (Local Area Network) and it is forming a cell. The size of the cell depends upon the strength of the propagated infrared or radio signal and some other environmental features.

2.9.4 Wi-Fi-ENABLED RFID

Wi-Fi-enabled RFID is commonly used for location-based services that track objects in a specific physical context, like children in a theme park, cars in a parking lot, equipment in a manufacturing plant, etc. It is considered a more accurate system than a traditional RFID network for determining the location of tagged objects. A regular RFID system can give what is called the “choke point” location, or zone-based location, meaning the location of the tag is known only in relation to the reader detecting its presence. A Wi-Fi network on the other hand can determine the precise (x, y) coordinates of a tag using triangulation methods, similar to how GPS works (Charlie F., and Natalie K et-al., 2006).

In these RFID systems, tags are Wi-Fi devices, and Wi-Fi access points function as readers. The MAC address on the tag serves as the unique identifier, and location software determines the specific coordinates. Additional application software can transform coordinates in terms that are meaningful to a user by matching them to specific locations, e.g., Room 222, or quadrants on a map of the area. A Wi-Fi application then, can identify both what the device is, e.g., a wheelchair, a truck, etc., and where it is, e.g., in corridor 12, in parking spot 45C. Some tags may contain additional data derived from integrated sensors (Charlie F., and Natalie K et-al., 2006).Kidspotter is an interesting example of an application that has successfully used active Wi-Fi-enabled tags to track children in theme parks. Kidspotter’s child tracking system was installed at Denmark’s Legoland in 2003 (Charlie F., and Natalie K et-al., 2006). A Wi-Fi-based system was chosen after having considered more traditional RFID technology, which would have required hundreds of readers in order to pinpoint kthe location of a child with the same precision as the Wi-Fi network, which comprises only readers. Furthermore, Legoland was able to leverage its existing Wi-Fi infrastructure, which it uses for point-of-sale equipment, Wi-Fi hotspots, and other functions in its theme park. In addition to generating revenues from the Kidspotter service, the application has also been used to determine traffic patterns within the park, including where people travel and how fast or slow, i.e., it can determine if a patron slows down in front of a particular billboard.

Children wear tagged wristbands or badges that have been registered to the caretaker’s mobile phone number for a fee. If the child goes missing, the caretaker sends an SMS message to the Kidspotter application server, which will return the child’s location in terms of Legoland’s map coordinates (based on 5x5-meter quadrants). The MAC addresses for Legoland’s tags are registered with the application server so that Kidspotter tag signals are recognized as such by the Wi-Fi access points. The same technology is also being tested in Yokohama, Japan for tracking school children. The I-Safety system uses the city’s Wi-Fi infrastructure for tracking children within a specific area called the “Watch Spot.” Parents can track their child’s location on their PC or cell phone, but additionally, cars are tagged so that they will be notified of any children playing in the area as they drive through it. Also, children can press an emergency button on their tags to alert a network of tagged security guards and volunteers chosen by the parents, so that the closest one to an emergency call can respond.

2.10 WEINER-II PATH LOSS MODEL

In simple terms the path loss is the difference between the transmitted power and the received power of a wireless communication system. This may range from tens of dB to more than a 100 dB e.g. if the transmitted power of a wireless communication system is 30 dBm and the received power is -90 dBm then the path loss is calculated as 30-(-90)=120 dB. Path loss is sometimes categorized as a large scale effect (in contrast to fading which is a small scale effect).

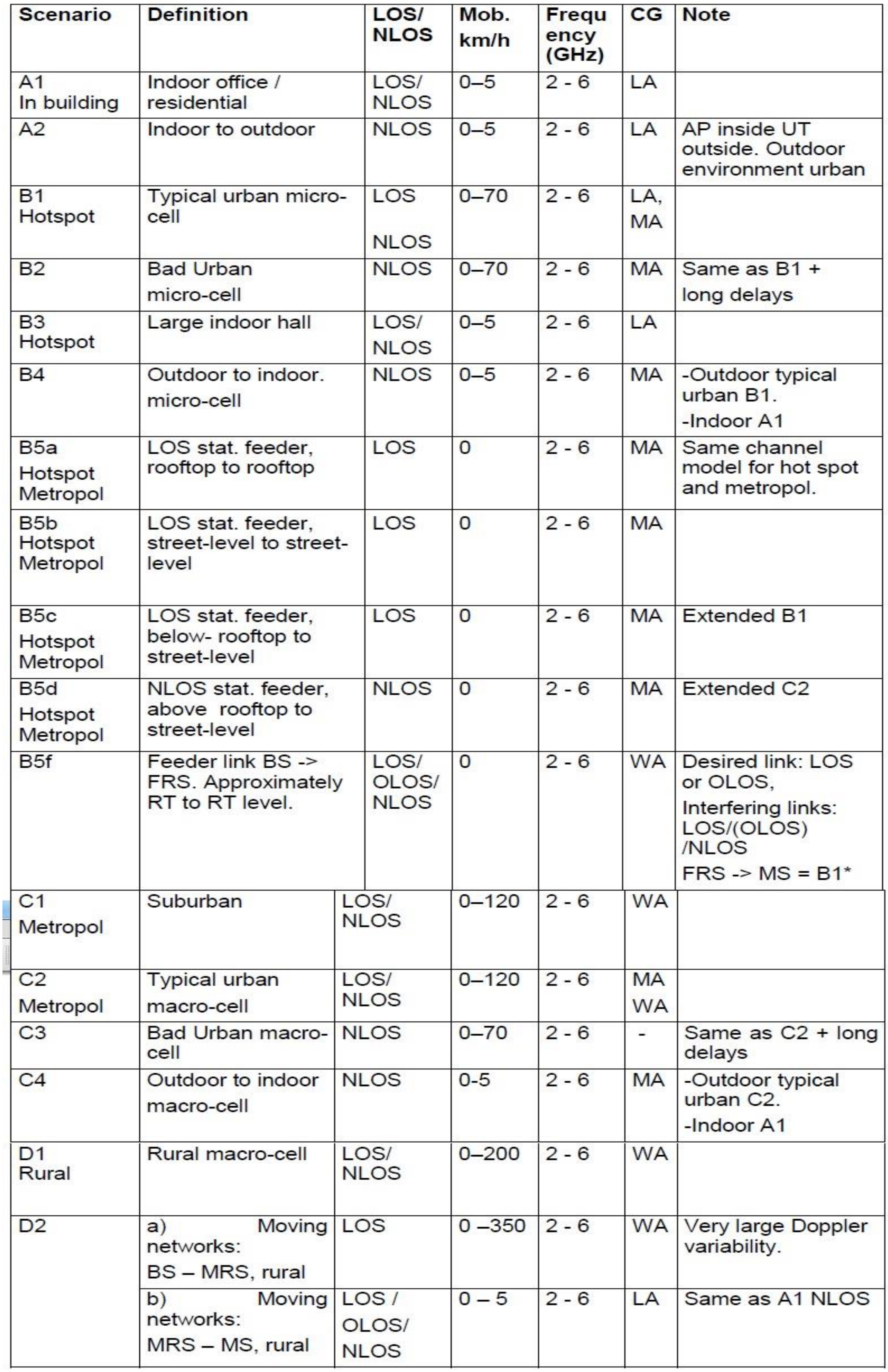
According to the WINNER-II model the path loss can be calculated as:

$$PL = 20\log_{10}(d[m]+6.4 + 20\log_{10}(\frac{fc[GHz]}{5.0}) + \mathrm{X} \qquad (2.17)$$

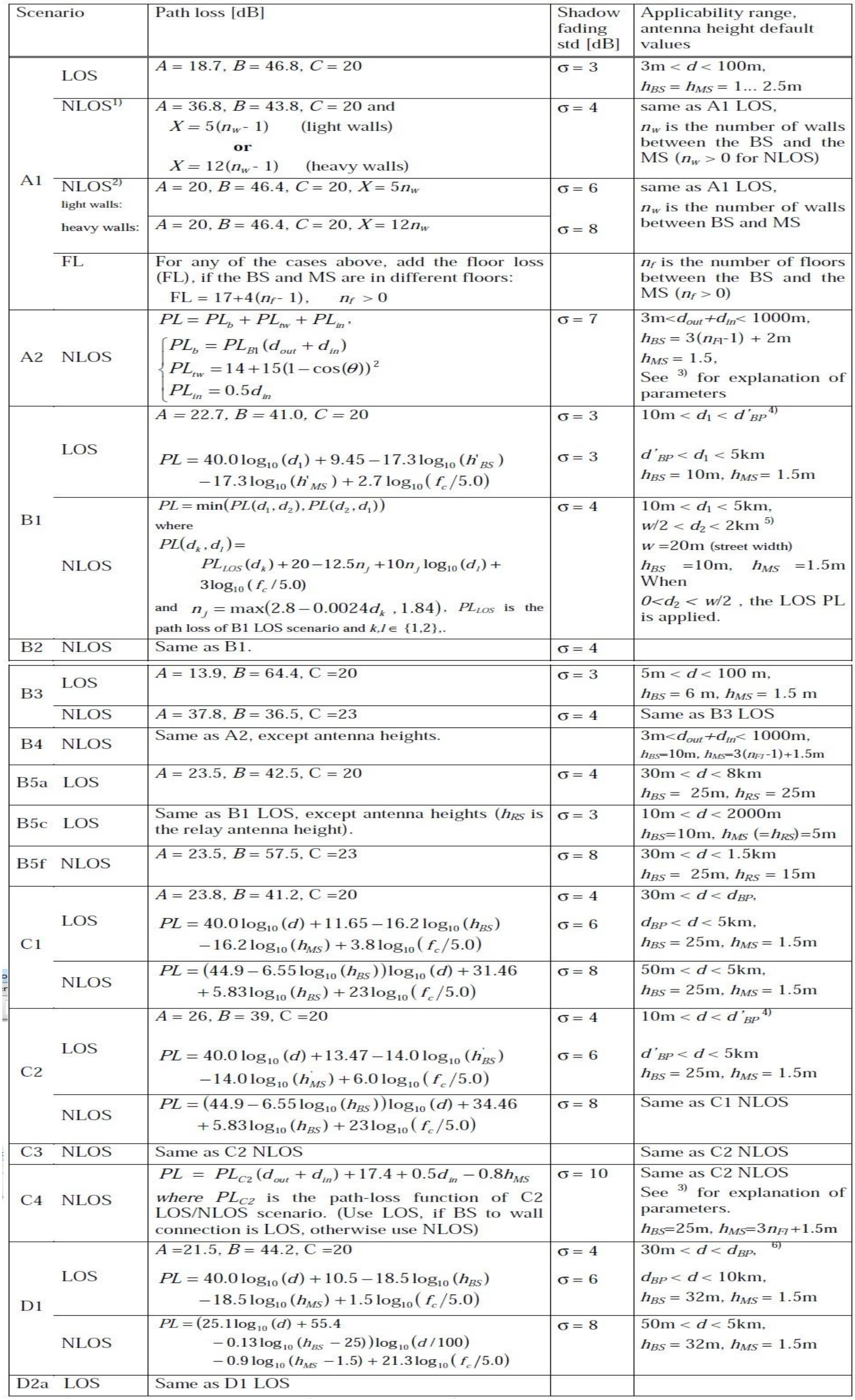
$$PL = 20\log_{10}(d)+46.4 + 20\log_{10}(\frac{fc}{5.0}) \qquad (2.18)$$

Here d is the separation between the transmitter and receiver in meters f_c is the frequency in GHz, A is the path loss exponent, B is the intercept i.e path loss in dB reference to 1m distance and C is the frequency dependent parameter. X is the environment specific parameter such as path loss due to a wall.PL_{free} is the path loss in a free space line of sight environment (here A=20, B=46.4 and C=20). Table 2.1 describes the different environments defined in the WEINNER-II model. Once an environment is selected the path loss parameters A, B and C can be selected from the table further down. A separate equation for the path loss is given where the parameters A, B and C are not sufficient to describe the scenario.

Table 2.1 Description of Different Environment Scenario Define By Weiner II Model



Scenario	Definition	LOS/ NLOS	Mob. km/h	Frequency (GHz)	CG	Note
A1 In building	Indoor office / residential	LOS/ NLOS	0–5	2 - 6	LA	
A2	Indoor to outdoor	NLOS	0–5	2 - 6	LA	AP inside UT outside. Outdoor environment urban
B1 Hotspot	Typical urban micro-cell	LOS NLOS	0–70	2 - 6	LA, MA	
B2	Bad Urban micro-cell	NLOS	0–70	2 - 6	MA	Same as B1 + long delays
B3 Hotspot	Large indoor hall	LOS/ NLOS	0–5	2 - 6	LA	
B4	Outdoor to indoor. micro-cell	NLOS	0–5	2 - 6	MA	-Outdoor typical urban B1. -Indoor A1
B5a Hotspot Metropol	LOS stat. feeder, rooftop to rooftop	LOS	0	2 - 6	MA	Same channel model for hot spot and metropol.
B5b Hotspot Metropol	LOS stat. feeder, street-level to street-level	LOS	0	2 - 6	MA	
B5c Hotspot Metropol	LOS stat. feeder, below- rooftop to street-level	LOS	0	2 - 6	MA	Extended B1
B5d Hotspot Metropol	NLOS stat. feeder, above rooftop to street-level	NLOS	0	2 - 6	MA	Extended C2
B5f	Feeder link BS -> FRS. Approximately RT to RT level.	LOS/ OLOS/ NLOS	0	2 - 6	WA	Desired link: LOS or OLOS, Interfering links: LOS/(OLOS) /NLOS FRS -> MS = B1*
C1 Metropol	Suburban	LOS/ NLOS	0–120	2 - 6	WA	
C2 Metropol	Typical urban macro-cell	LOS/ NLOS	0–120	2 - 6	MA WA	
C3	Bad Urban macro-cell	NLOS	0–70	2 - 6	-	Same as C2 + long delays
C4	Outdoor to indoor macro-cell	NLOS	0-5	2 - 6	MA	-Outdoor typical urban C2. -Indoor A1
D1 Rural	Rural macro-cell	LOS/ NLOS	0–200	2 - 6	WA	
D2	a) Moving networks: BS – MRS, rural	LOS	0 –350	2 - 6	WA	Very large Doppler variability.
	b) Moving networks: MRS – MS, rural	LOS / OLOS/ NLOS	0 – 5	2 - 6	LA	Same as A1 NLOS



Scenario		Path loss [dB]	Shadow fading std [dB]	Applicability range, antenna height default values
A1	LOS	$A = 18.7$, $B = 46.8$, $C = 20$	$\sigma = 3$	$3\text{m} < d < 100\text{m}$, $h_{BS} = h_{MS} = 1 \ldots 2.5\text{m}$
	NLOS$^{1)}$	$A = 36.8$, $B = 43.8$, $C = 20$ and $X = 5(n_w - 1)$ (light walls) **or** $X = 12(n_w - 1)$ (heavy walls)	$\sigma = 4$	same as A1 LOS, n_w is the number of walls between the BS and the MS ($n_w > 0$ for NLOS)
	NLOS$^{2)}$ light walls:	$A = 20$, $B = 46.4$, $C = 20$, $X = 5n_w$	$\sigma = 6$	same as A1 LOS, n_w is the number of walls between BS and MS
	heavy walls:	$A = 20$, $B = 46.4$, $C = 20$, $X = 12n_w$	$\sigma = 8$	
	FL	For any of the cases above, add the floor loss (FL), if the BS and MS are in different floors: $\text{FL} = 17+4(n_f - 1)$, $n_f > 0$		n_f is the number of floors between the BS and the MS ($n_f > 0$)
A2	NLOS	$PL = PL_b + PL_{tw} + PL_{in}$, $\begin{cases} PL_b = PL_{B1}(d_{out} + d_{in}) \\ PL_{tw} = 14 + 15(1 - \cos(\theta))^2 \\ PL_{in} = 0.5 d_{in} \end{cases}$	$\sigma = 7$	$3\text{m} < d_{out} + d_{in} < 1000\text{m}$, $h_{BS} = 3(n_{Fl} - 1) + 2\text{m}$ $h_{MS} = 1.5$, See $^{3)}$ for explanation of parameters
B1	LOS	$A = 22.7$, $B = 41.0$, $C = 20$ $PL = 40.0\log_{10}(d_1) + 9.45 - 17.3\log_{10}(h'_{BS}) - 17.3\log_{10}(h'_{MS}) + 2.7\log_{10}(f_c/5.0)$	$\sigma = 3$ $\sigma = 3$	$10\text{m} < d_1 < d'_{BP}$ $^{4)}$ $d'_{BP} < d_1 < 5\text{km}$ $h_{BS} = 10\text{m}$, $h_{MS} = 1.5\text{m}$
	NLOS	$PL = \min(PL(d_1, d_2), PL(d_2, d_1))$ where $PL(d_k, d_l) = PL_{LOS}(d_k) + 20 - 12.5n_j + 10n_j\log_{10}(d_l) + 3\log_{10}(f_c/5.0)$ and $n_j = \max(2.8 - 0.0024d_k, 1.84)$. PL_{LOS} is the path loss of B1 LOS scenario and $k,l \in \{1,2\}$,.	$\sigma = 4$	$10\text{m} < d_1 < 5\text{km}$, $w/2 < d_2 < 2\text{km}$ $^{5)}$ $w = 20\text{m}$ (street width) $h_{BS} = 10\text{m}$, $h_{MS} = 1.5\text{m}$ When $0 < d_2 < w/2$, the LOS PL is applied.
B2	NLOS	Same as B1.	$\sigma = 4$	
B3	LOS	$A = 13.9$, $B = 64.4$, $C = 20$	$\sigma = 3$	$5\text{m} < d < 100\text{ m}$, $h_{BS} = 6\text{ m}$, $h_{MS} = 1.5\text{ m}$
	NLOS	$A = 37.8$, $B = 36.5$, $C = 23$	$\sigma = 4$	Same as B3 LOS
B4	NLOS	Same as A2, except antenna heights.		$3\text{m} < d_{out} + d_{in} < 1000\text{m}$, $h_{BS} = 10\text{m}$, $h_{MS} = 3(n_{Fl} - 1) + 1.5\text{m}$
B5a	LOS	$A = 23.5$, $B = 42.5$, $C = 20$	$\sigma = 4$	$30\text{m} < d < 8\text{km}$ $h_{BS} = 25\text{m}$, $h_{RS} = 25\text{m}$
B5c	LOS	Same as B1 LOS, except antenna heights (h_{RS} is the relay antenna height).	$\sigma = 3$	$10\text{m} < d < 2000\text{m}$ $h_{BS} = 10\text{m}$, h_{MS} $(= h_{RS}) = 5\text{m}$
B5f	NLOS	$A = 23.5$, $B = 57.5$, $C = 23$	$\sigma = 8$	$30\text{m} < d < 1.5\text{km}$ $h_{BS} = 25\text{m}$, $h_{RS} = 15\text{m}$
C1	LOS	$A = 23.8$, $B = 41.2$, $C = 20$ $PL = 40.0\log_{10}(d) + 11.65 - 16.2\log_{10}(h_{BS}) - 16.2\log_{10}(h_{MS}) + 3.8\log_{10}(f_c/5.0)$	$\sigma = 4$ $\sigma = 6$	$30\text{m} < d < d_{BP}$, $d_{BP} < d < 5\text{km}$, $h_{BS} = 25\text{m}$, $h_{MS} = 1.5\text{m}$
	NLOS	$PL = (44.9 - 6.55\log_{10}(h_{BS}))\log_{10}(d) + 31.46 + 5.83\log_{10}(h_{BS}) + 23\log_{10}(f_c/5.0)$	$\sigma = 8$	$50\text{m} < d < 5\text{km}$, $h_{BS} = 25\text{m}$, $h_{MS} = 1.5\text{m}$
C2	LOS	$A = 26$, $B = 39$, $C = 20$ $PL = 40.0\log_{10}(d) + 13.47 - 14.0\log_{10}(h'_{BS}) - 14.0\log_{10}(h'_{MS}) + 6.0\log_{10}(f_c/5.0)$	$\sigma = 4$ $\sigma = 6$	$10\text{m} < d < d'_{BP}$ $^{4)}$ $d'_{BP} < d < 5\text{km}$ $h_{BS} = 25\text{m}$, $h_{MS} = 1.5\text{m}$
	NLOS	$PL = (44.9 - 6.55\log_{10}(h_{BS}))\log_{10}(d) + 34.46 + 5.83\log_{10}(h_{BS}) + 23\log_{10}(f_c/5.0)$	$\sigma = 8$	Same as C1 NLOS
C3	NLOS	Same as C2 NLOS		Same as C2 NLOS
C4	NLOS	$PL = PL_{C2}(d_{out} + d_{in}) + 17.4 + 0.5d_{in} - 0.8h_{MS}$ *where* PL_{C2} is the path-loss function of C2 LOS/NLOS scenario. (Use LOS, if BS to wall connection is LOS, otherwise use NLOS)	$\sigma = 10$	Same as C2 NLOS See $^{3)}$ for explanation of parameters. $h_{BS} = 25\text{m}$, $h_{MS} = 3n_{Fl} + 1.5\text{m}$
D1	LOS	$A = 21.5$, $B = 44.2$, $C = 20$ $PL = 40.0\log_{10}(d) + 10.5 - 18.5\log_{10}(h_{BS}) - 18.5\log_{10}(h_{MS}) + 1.5\log_{10}(f_c/5.0)$	$\sigma = 4$ $\sigma = 6$	$30\text{m} < d < d_{BP}$, $^{6)}$ $d_{BP} < d < 10\text{km}$, $h_{BS} = 32\text{m}$, $h_{MS} = 1.5\text{m}$
	NLOS	$PL = (25.1\log_{10}(d) + 55.4 - 0.13\log_{10}(h_{BS} - 25))\log_{10}(d/100) - 0.9\log_{10}(h_{MS} - 1.5) + 21.3\log_{10}(f_c/5.0)$	$\sigma = 8$	$50\text{m} < d < 5\text{km}$, $h_{BS} = 32\text{m}$, $h_{MS} = 1.5\text{m}$
D2a	LOS	Same as D1 LOS		

2.11 MEAN SQUARE ERROR (MSE)

The MSE is the ratio of dispersion of measured path loss values and describes how good the propagation model matches the experimental data. It is commonly used to verify the accuracy of path loss models. Mean square error formula is given by

$$\text{MSE}= \sqrt{\frac{1}{N}\sum_{1}^{N}(Pm-\text{Pr})^2} \tag{2.19}$$

2.12 REVIEW OF RELATED LETERATURE

In 2014 Kedar,N. publish a paper “study of RF propagation losses in homogeneous brick and concrete walls using analytical frequency dependent models” which estimate the attenuation of different types of brick and concrete walls using the electromagnetic method of general solution of wave equation using boundary condition, based on his findings the attenuation of solid concrete wall at 5GHz was 10dB. Similarly, Daniel P. et-al (2003) conducted a research on “Measurement and modeling of propagation losses in brick and concrete walls for 900MHz band” in which the author estimate the wall attenuation using single ray transmission and mod. Friss equation. The attenuation value at ϵ_r=4 and δ=0.022 S/m was 5.2dB and at ϵ_r=4 and δ=0.024S/m was 5.6dB for a brick wall of 27 cm.

Also Khan,M.Z.,Mohammod,A .(2007) conducted a research on the wireless power transmission to a buried sensor in concrete. They studied the feasibility of sending power to a buried sensor in concrete using a signal generator as to transmit wireless microwave power and received by antenna buried in concrete The return loss characteristics of a stacked microstrip patch antenna were measured to be 10dB at frequency between 6 to 6.2GHz both in free space and within dry and wet concrete. Muzaiyanah,H.,AbdulHalim,A. and Khairul Bariah, A. (2009) publish their paper on Wifi signal propagation at 2.4GHz analyzing the signal propagation at 2.4GHz based on 3 type of environment scenarios :indoor, outdoor & within building graphical results shows that, the measured data and path loss prediction model gives almost similar curvature even though there are scattered signal occur due to obstruction and surrounding environment.

Similarly, B.R.Jadhavar,T.R sontakke (2012) present their paper titled “2.4GHz propagation prediction models for indoor wireless communication Within building” The measurement shows that the standard deviation between measured and predicted path loss is 12.4124 dB for all locations in one building and as small as 8.0948 dB on same floor. And in other building it is 10.2854 dB and minimum 8.5454 dB for same floor measurements. NNEBE S.U (2014) Path loss prediction model of a wireless sensor development of a Network in an Indoor environment indoor channel prediction model of wireless sensor network based on log- distance model and practical measurement The path loss prediction parameters obtained using the log-normal shadowing model reveals that the path loss exponent value and the standard deviation caused by the shadowing effect are 2.77, 2.44dB respectively. To my knowledge no known existing system uses Weiner II model for the study of path loss through concrete wall. None of the model has addressed the limitation for communication indoor, identification means of wi-fi device user is not considered in most of the literature review. This research uses the Weiner II model because is a model that is use to determine the path loss for different environment scenario.

TABLE 2.2 SUMMARY OF RELATED LITERATURE

S/N	AUTHOR/YEAR	TITLE OF WORK	METHODOLOGY	RESULT	RESEARCH GAP
1	Daniel P. et-al (2003)	Measurement and modeling of propagation losses in brick and concrete walls for 900MHz band	Estimate the wall attenuation using single ray transmission and mod. Friis Equation.	The attenuation value at ϵ_r=4 and δ=0.022S/m was 5.2dB and at ϵ_r=4 and δ=0.024S/m was 5.6dB for a brick wall of 27cm.	The research is based on single ray model different from the model use (Weiner II model at 2.4Ghz)and did not prove the possibility of communication indoor
2	Kedar, N.S, Challa, D.N. and Sankar,K.J (2014)	Study of RF propagation loses in homogeneous Brick and Concrete wall using Analytical Frequency Dependent models	Estimate the attenuation of different types of concrete and brick walls using the electromagnetic method of general solution of wave equation using boundary condition	The path loss of 20cm concrete wall was estimated to be 10dB less than the one obtained due to difference in wall thickness	The research only estimate the loss imposed by concrete wall using different approach from my research. However, limitation of communication indoor is not addressed
3	Khan,M.Z.,Mohammod,A .(2007)	Wireless power transmission to a buried sensor in concrete	Studied the feasibility of sending power to a buried sensor in concrete using a signal generator as	The return loss characteristics of a stacked microstrip patch antenna were measured to be	The research measured power loss while this research focuses on determination of path loss of the signal through concrete wall

			to transmit wireless microwave power and received by rectenna buried in concrete	10dB at frequency between 6 to 6.2GHz both in free space and within dry and wet concrete.	
4	Muzaiyanah,H.,AbdulHalim,A. and Khairul Bariah, A. (2009)	Wifi signal propagation at 2.4GHz	Analyzing the signal propagation at 2.4GHz based on 3 type of environment scenarios :indoor, outdoor & within building	Graphical results shows that, the measured data and path loss prediction model gives almost similar curvature even though there are scattered signal occur due to obstruction and surrounding environment.	The research compare measured data with log-distance, AFC and ITU model all which are different from the model use in this research and did not consider positioning information.
5	B.R.Jadhavar,T.R sontakke (2012)	2.4GHz propagation prediction models for indoor wireless comm. Within building	Predicted the effect of wall partitions base on log - distance model	The measurement shows that the standard deviation between measured and	Path loss is estimated to be 12dB using same frequency but different model only that position information is not considered.

				predicted path loss is 12.4124 dB for all locations in one building and as small as 8.0948 dB on same floor. And in other building it is 10.2854 dB and minimum 8.5454 dB for same floor measurements	
6	NNEBE S.U (2014)	Path loss Prediction Model of a Wireless Sensor Network in an Indoor Environment	Development of an indoor channel prediction model of Wireless Sensor Network based on log- distance model and practical measurement	The path loss prediction parameters obtained using the log-normal shadowing model reveals that the path loss exponent value and the standard deviation caused by the shadowing effect are 2.77, 2.44dB respectively.	The research compared theoretical with measured result to predict attenuation based on log distance model but did not take into consideration different environment scenario

CHAPTER THREE

MATERIALS AND METHODS

3.0 INTRODUCTION

In this chapter, Wi-Fi access point and laptop computer was used to study the effect of path loss due to concrete wall by measuring the strength of the signal received at 10m distance interval from the access point to the Wi-Fi devices (laptop computer) running inSSIDer software. Section 3.1 presents and analyses the mathematical model of RF signal path loss in free space. Section 3.2 present's experimental setup and other empirical measurements, section 3.3 the path loss mathematical model with concrete wall in consideration; section 3.4 presents a graphical user interface for interacting with the path loss simulation tool in a friendly manner.

3.1 MATHEMATICAL MODEL (PATH LOSS MODEL)

In this section, the Weiner-II path loss model (3.1) and (3.2) was transformed into Matlab code to predict signal strength passing through concrete wall. This model has been chosen for its simplicity and its effectiveness at modeling signal propagation over several frequencies and its ability to predict path loss for different environment scenario.

3.2 WEINER-II PATH LOSS MODEL

In simple terms the path loss is the difference between the transmitted power and the received power of a wireless communication system. This may range from tens of dB to more than a 100 dB.

According to the WEINER-II model the path loss can be calculated as:

$$PL = 20\log_{10}(d[m]+6.4 + 20\log_{10}(\frac{fc[GHz]}{5.0}) + \mathrm{X} \qquad (3.1)$$

$$PL = 20\log_{10}(d)+46.4 + 20\log_{10}(\frac{fc}{5.0}) \qquad (3.2)$$

Here d is the separation between the transmitter and receiver in meters f_c is the frequency in GHz, A is the path loss exponent, B is the intercept i.e path loss in dB reference to 1m distance and C is the frequency dependent parameter. X is the environment specific parameter such as path loss due to a wall.PL_{free} is the path loss in a free space line of sight environment (here A=20, B=46.4 and C=20).Refer to the table 2.1 which describes the different environments defined in the WEINNER-II model. Once an environment is selected the path loss parameters A, B and C can be selected from the table.

Table 3.1 Calculated Path Loss Based on Wiener-II Model

Distance (m)	Free space path loss(dB)	Path loss (dB) concrete wall (one wall)
10	60.0248	72.0248
20	66.0454	78.0454
30	69.5672	81.5672
40	72.0660	84.0660
50	74.0042	86.0042
60	75.5878	87.5878
70	76.9268	88.9268
80	78.0866	90.0866
90	79.1097	91.1097
100	80.0248	92.0248

3.3 EXPERIMENTAL SET UP:

The measurements are done using one access point and which is IEEE 802.11b compliant and operates on 2.4 GHz. It also provides a transmit power of 17dBm and a bandwidth of 11 Mbps. The signal measurements were done using the software ‘inSSIDer’’ which is a tool that allows one to identify and measure the signal strength of WLANs. Using this software the measurements were taken. The signal strength was measured at 10m distance interval from access points. At each interval signal measurements were taken and recorded. Measuring tape was use for distance measurement. Table 3.3 shows the values for the measured received power/signal strength at 10m distance interval. And the path loss is calculated using equation (3.3)

$$\frac{P1}{P2} \equiv 10log_{10}\left(\frac{P1}{P2}\right)\text{dB} = 10log_{10}\left(\frac{P1}{1mw}\right) - 10log_{10}\left(\frac{P1}{1mw}\right)$$

$$= P1|dBm - P2|dBm \qquad (3.3)$$

Table 3.2 Measured Received Powers and Corresponding Path Loss

Distance (m)	Transmit power(dBm)	Measured power (dBm) free space	Measured power (dBm) with wall obstruction	Path loss free space (dB)	Path loss with wall (dB)
10	17	-44	-56	61	73
20	17	-50	-62	67	79
30	17	-54	-65	71	82
40	17	-56	-68	73	85
50	17	-58	-70	75	87
60	17	-59	-72	76	89
70	17	-61	-73	78	90
80	17	-62	-74	79	91
90	17	-63	-75	80	92
100	17	-64	-76	81	93

Table 3.3 Comparison between the Theoretical Path Loss and Empirical Path loss Values

Distance (m)	Measured path loss (dB) free space	Measured path loss(dB) with wall	Predicted path loss(dB) free space	Predicted path loss(dB) with wall
10	61	73	60.0248	72.0248
20	67	79	66.0454	78.0454
30	71	82	69.5672	81.5672
40	73	85	72.0660	84.0660
50	75	87	74.0042	86.0042
60	76	89	75.5878	87.5878
70	78	90	76.9268	88.9268
80	79	91	78.0866	90.0866
90	80	92	79.1097	91.1097
100	81	93	80.0248	92.0248

3.4 CONCRETE WALL MODEL

The wall is represented by an infinite homogeneous flat plate; the transmitted wave is assumed to be uniform therefore the multiple reflections inside the wall can be ignored. The wave reflection and transmission by the flat plate can simply be represented by single ray model since the wall is assumed to be a homogeneous wall. Figure 3.1 below show the wall model for the wave propagation. The total through wall amplitude transmission coefficient designated by

$$\check{T}=T_{12}\mathrm{A} \qquad (3.4)$$

WhereT_{12}=$T_1 T_2$. T_1Is the Fresnel transmission coefficient at the boundary z=0 and equal to$T_1^{\dot{}}$ or$T_1^{''}$ for perpendicular (vertical) or parallel polarization. T_2 is the Fresnel transmission coefficient at Z=d plane, equal to $T_2^{\dot{}}$ or $T_2^{''}$ respectively. $T_1 and\, T_2$ account for the mismatch attenuation or simply attenuation, and $A = e^{-\alpha t}$is the amplitude attenuation factor or simply attenuation due to only the medium absorption losses.

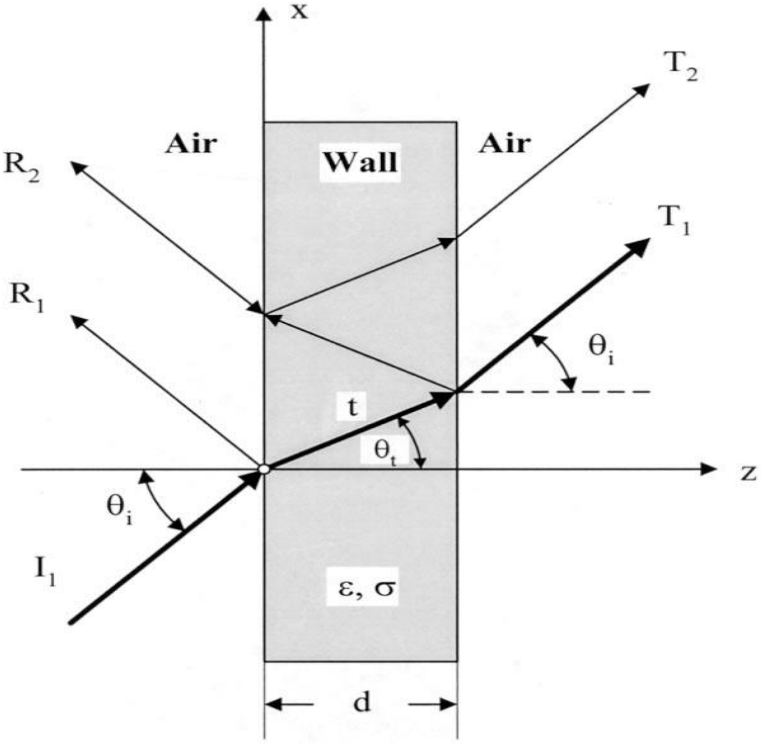


Figure 3.1 Representation of the wall model

$$T_{12}^{\perp} = T_1^{\perp} T_2^{\perp} = \frac{4COS\theta i\sqrt{\epsilon r - sin^2\theta i}}{(cos\theta i + \sqrt{\epsilon r sin^2\theta i})^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

$$T_{12}^{\parallel} = T_1^{\parallel} T_2^{\parallel} = \frac{4\varepsilon rCOS\Theta i\sqrt{\varepsilon r - \sin^2\theta i}}{(4\epsilon rcos\theta i + \sqrt{\varepsilon r - sin^2\theta i})^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

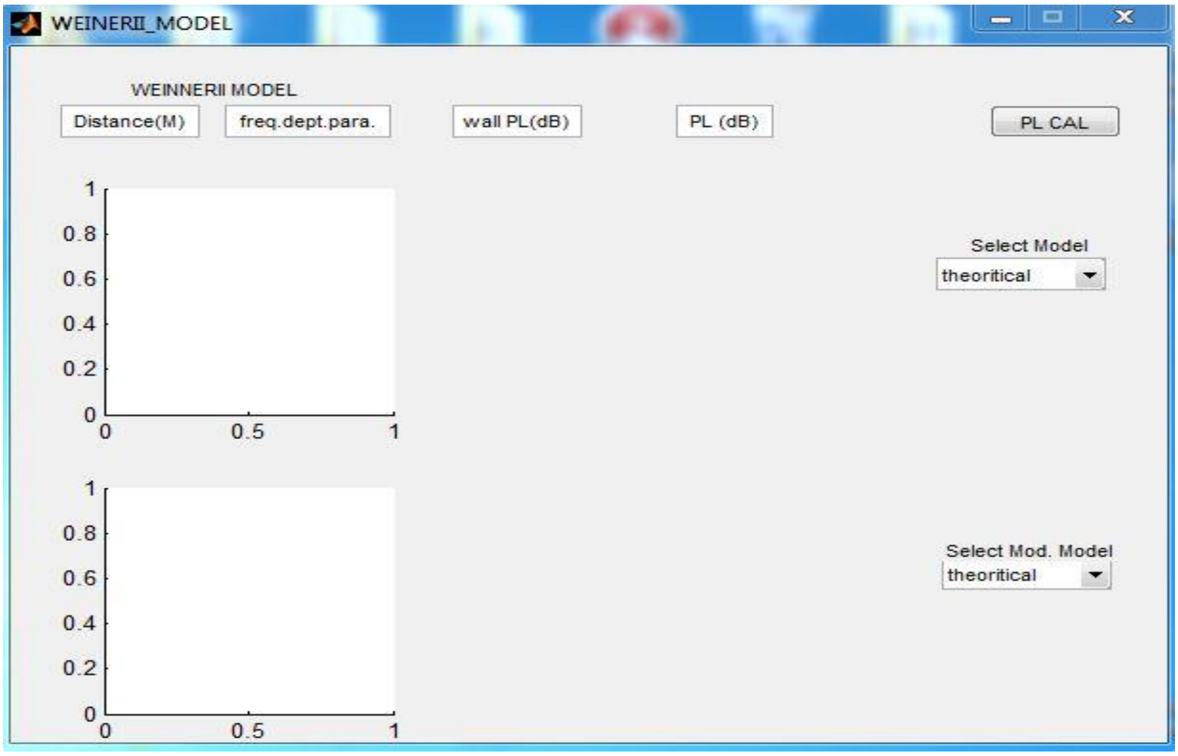
The equivalent medium attenuation coefficientα ($^S/_m$) is given by

$$\alpha = \omega\sqrt{\mu\varepsilon/2[\sqrt{1+(\frac{\delta}{\omega\varepsilon}}}\,)^2+1]$$

To calculate the transmission coefficient, it is necessary to determine the proper electrical parameters of the concrete $\boldsymbol{\delta}$ and$\boldsymbol{\varepsilon_r}$. The parameters are first unknown but their values was obtained by “fitting” the calculated results to the measured ones. Doing this results in the set of parameters $\boldsymbol{\delta}$=0.05S/m and $\boldsymbol{\varepsilon_r}$=4.6 and wall thickness = 30cm.

3.5 GRAPHICAL USER INTERFACE

In order to provide easy and interactive way of determining the path loss of Wi-Fi signal in both free space and obstructed medium, a graphical user interface is developed to permit determination of Wi-Fi signal attenuation in a building complex.

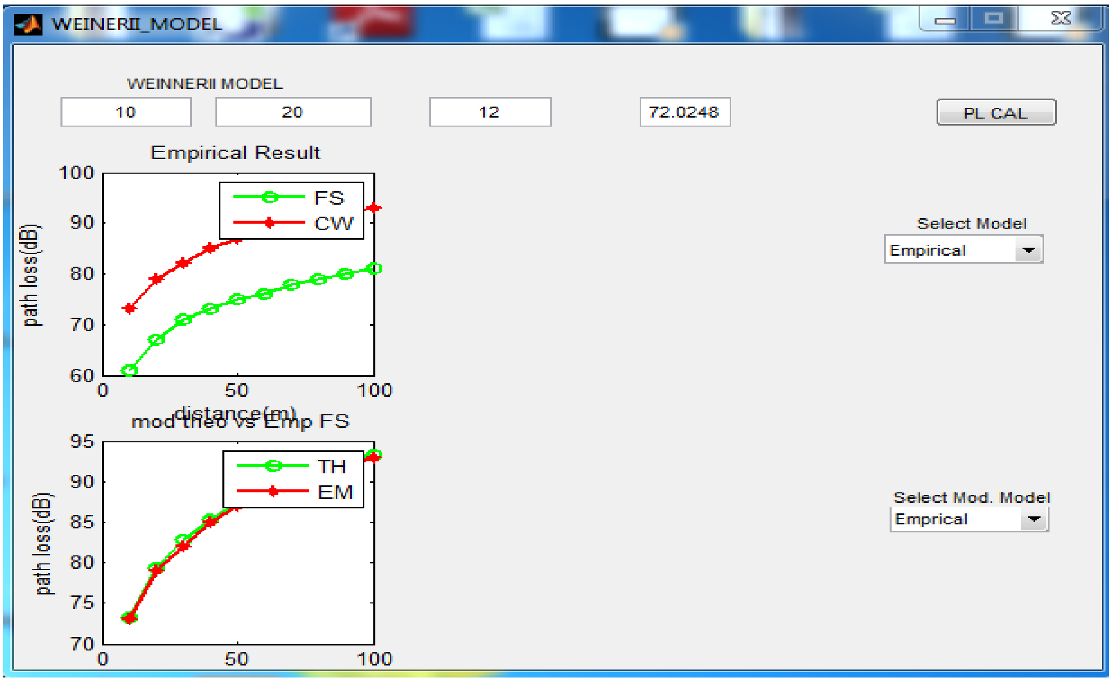


Select Model: theoritical

Select Mod. Model: theoritical

Figure 3.2 Layout of the matlab Graphical user Interface for path loss Calculation and Graph Plotting

Running the matlab GUI shown above in matlab environment will display the result as shown in figure 3.3



10 20 12 72.0248

Select Model
Empirical

Select Mod. Model
Emprical

Figure 3.3 Result of matlab GUI

CHAPTER FOUR

RESULT AND DISCUSSION

4.0 INTRODUCTION

This chapter presents the result that was obtained from practical measurement and path loss prediction model both in free space and obstructed medium. Section 4.1 presents the result from practical measurement, Section 4.2 present the result obtained from the model in consideration section 4.3 discusses the result obtained and section 4.4 summarized the result findings.

4.1 MEASURED RESULT

Table 4.1 below summarizes the results obtained from measurement by transmitting power of 17dBm at 10 meter distance interval. The measured signal strength in free space and obstructed medium is recorded and the corresponding path loss at each distance is calculated and recorded in the table.

Table 4.1: Empirical Power and Corresponding Path Loss

Distance (m)	Transmit power(dBm)	Measured power (dBm) free space	Measured power (dBm) with wall obstruction	Path loss free space (dB)	Path loss with wall (dB)
10	17	-44	-56	61	73
20	17	-50	-62	67	79
30	17	-54	-65	71	82
40	17	-56	-68	73	85
50	17	-58	-70	75	87
60	17	-59	-72	76	89
70	17	-61	-73	78	90
80	17	-62	-74	79	91
90	17	-63	-75	80	92
100	17	-64	-76	81	93

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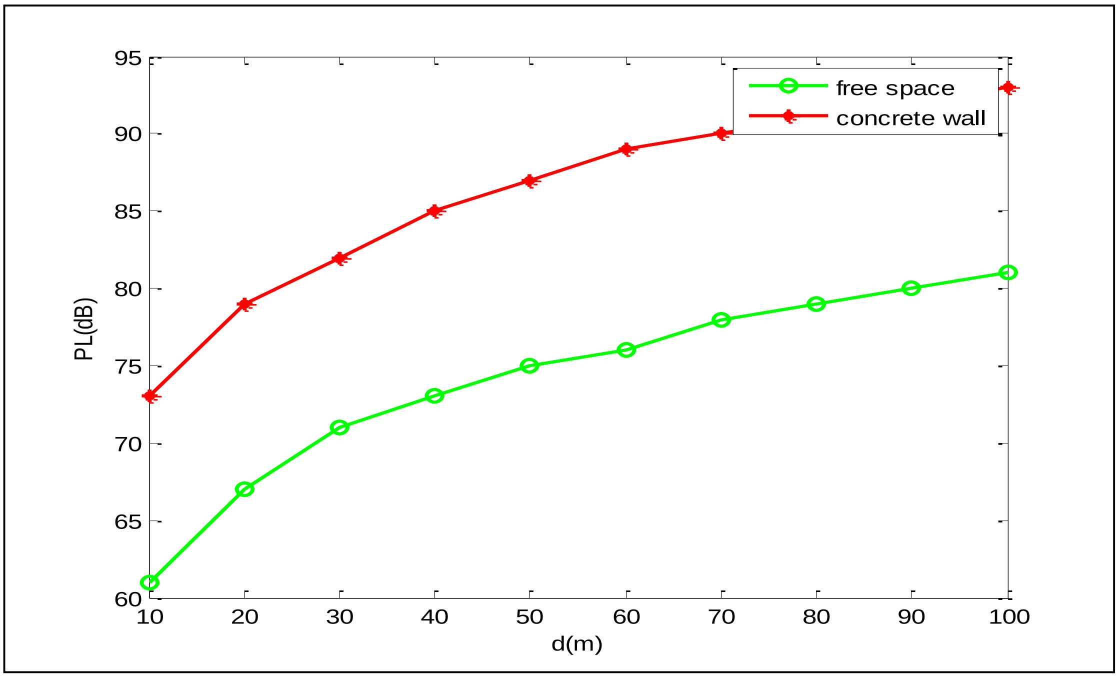

Figure 4.1 Empirical Result in free space and obstructed Medium

4.2 RESULT FROM THE MODEL IN CONSIDERATION

Path loss prediction model is basically an empirical mathematical formulation for the characterization of radio wave propagation. The models are usually developed to predict the behavior of how the signal is propagated in several environments and places. Based on Wiener II Model the path loss is calculated and tabulated as shown in table 4.2

Table 4.2: Calculated Path Loss Based On Wiener II Model

Distance (m)	Free space path loss(dB)	Path loss (dB) concrete wall
10	60.0248	72.0248
20	66.0454	78.0454
30	69.5672	81.5672
40	72.0660	84.0660
50	74.0042	86.0042
60	75.5878	87.5878
70	76.9268	88.9268
80	78.0866	90.0866
90	79.1097	91.1097
100	80.0248	92.0248

The graph showing the relationship between theoretical free space path loss and loss due to concrete wall is shown below

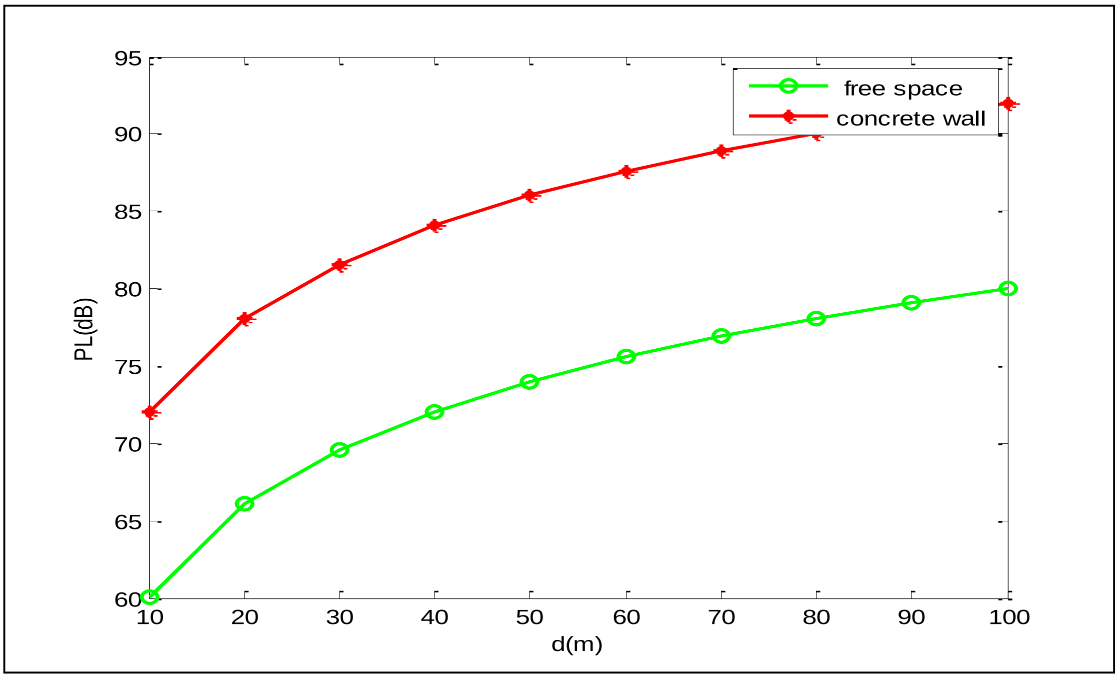

Figure 4.2 Theoretical Result in free space and obstructed Medium

From the table 4.3, comparing the values of theoretical and empirical path loss, the values of the model is averagely 2dB different to that of the measured. This proves the previously obtained result. In order to obtain a more accurate prediction model, path ;loss model parameters were tuned which yield a better model as shown in equation 4.1 and 4.2 respectively.

Table 4.3 Theoretical and Empirical Path Losses in Free Space and Obstructed Medium

Distance (m)	Measured path loss (dB) free space	Measured path loss(dB) with wall	Predicted path loss(dB) free space	Predicted path loss(dB) with wall
10	61	73	60.0248	72.0248
20	67	79	66.0454	78.0454
30	71	82	69.5672	81.5672
40	73	85	72.0660	84.0660
50	75	87	74.0042	86.0042
60	76	89	75.5878	87.5878
70	78	90	76.9268	88.9268
80	79	91	78.0866	90.0866
90	80	92	79.1097	91.1097
100	81	93	80.0248	92.0248

$$PL = 20\log_{10}(d[m] + 46.4 + 16\log_{10}(\frac{fc[GHz]}{5.0}) + \mathrm{X} \qquad (4.1)$$

$$PL_{free} = 20\log_{10}(d) + 46.4 + 20\log_{10}(\frac{fc}{5.0}) \qquad (4.2)$$

Mean square error (MSE) describes how good the propagation model matches the experimental data and is used for the comparison between the empirical and modified model. Mean square error formula is given by

$$\mathrm{MSE} = \sqrt{\frac{1}{N}\sum_{1}^{N}(Pm - \mathrm{Pr})^2} \qquad (4.3)$$

Table 4.4 Mean Square Error Calculation of the Theoretical Model

Dist(m)	MFSPL	MCWPL	PPLFS	PPLCW	$(Pm-Pr)^2$ free space	$(Pm-Pr)^2$ wall
10	61	73	60.0248	72.0248	0.95	0.951
20	67	79	66.0454	78.0454	0.91	0.911
30	71	82	69.5672	81.5672	2.053	0.187
40	73	85	72.0660	84.0660	0.872	0.872
50	75	87	74.0042	86.0042	0.992	0.992
60	76	89	75.5878	87.5878	0.17	1.994
70	78	90	76.9268	88.9268	1.152	1.152
80	79	91	78.0866	90.0866	0.834	0.834
90	80	92	79.1097	91.1097	0.793	0.7926
100	81	93	80.0248	92.0248	0.951	0.9510

From table 4.4, the mean square error for the theoretical model of measured and predicted path loss is 0.984dB in free space and 0.982dB in the presence of concrete wall.

Table 4.5 Mean Square Error Calculation of the Modified Model

Measure PLFS	Measured PLCW	Predicted PLFS	Predicted PLCW	$(Pm-Pr)^2$ free space	$(Pm-Pr)^2$ wall
61	73	61.2999	73.2999	0.09	0.090
67	79	67.3205	79.3205	0.103	0.103
71	82	70.8423	82.8423	0.025	0.709
73	85	73.3411	85.3411	0.116	0.116
75	87	75.2793	87.2793	0.078	0.078
76	89	76.2018	88.8639	0.041	0.019
78	90	78.8629	90.2018	0.744	0.040
79	91	79.3677	91.3617	0.131	0.131
80	92	90.3847	92.3847	0.148	0.148
81	93	81.2999	92.2999	0.090	0.49

From table 4.5 the mean square error for the measured and predicted path loss of the modified model is 0.39dB in free space and 0.14dB in the presence of concrete wall

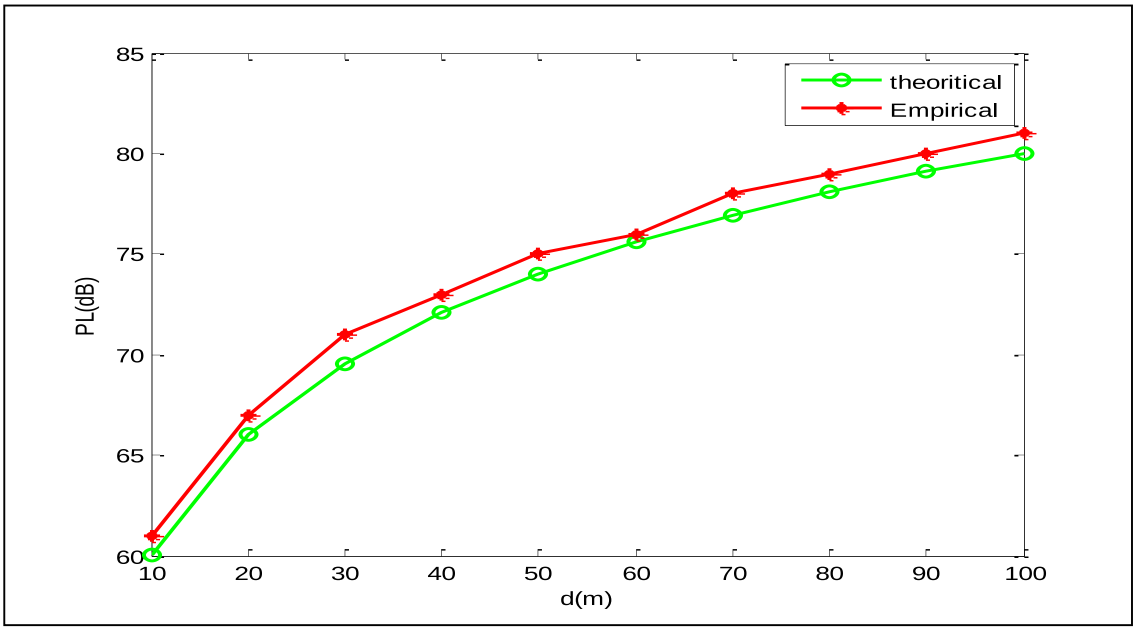

Figure 4.3 Theoretical Wiener II model path loss and Empirical path loss in free space

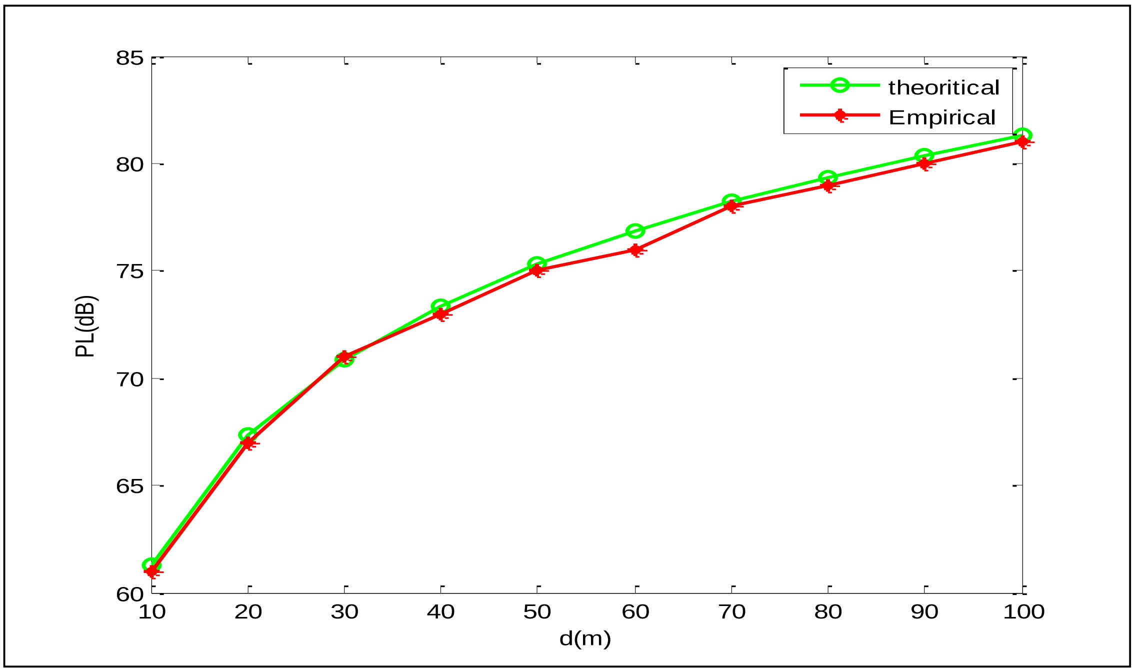

Figure 4.4 Theoretical Modified Wiener II model path loss and Empirical path loss in free space

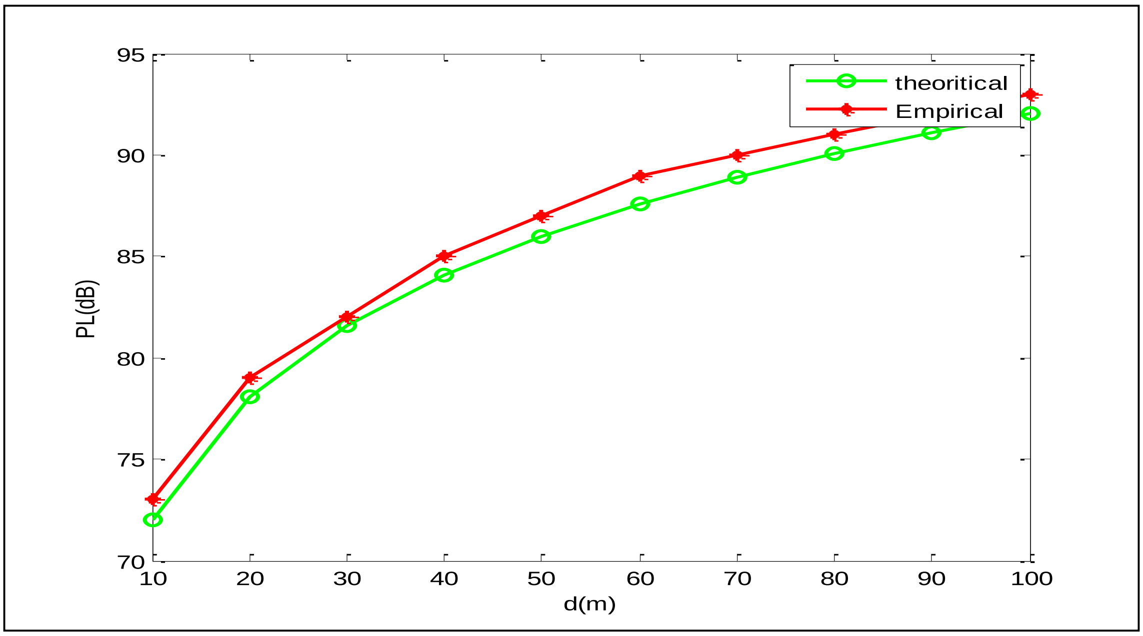

Figure 4.5 Theoretical Wiener II model path loss and Empirical path loss in the presence of Wall

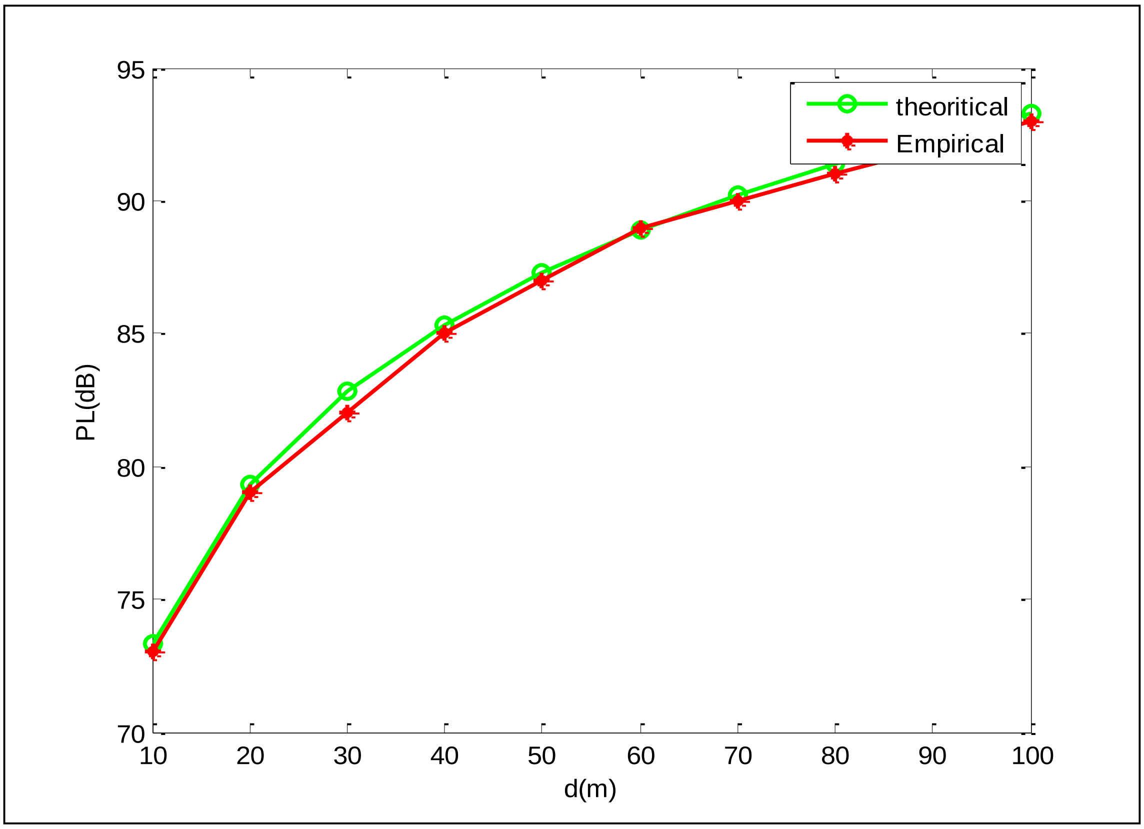

Figure 4.6 Theoretical Modified Weiner II model path loss and Empirical path loss in the presence of Wall

4.3 RESULT DISCUSSION

In order to validate the applicability of the model to predict the measured data, the result obtained from measurement is compared with the simulated result of Weiner II model. Figure 4.1 is a graph of measured path loss both in free space and obstructed medium. The result shows an increase in path loss with increase in distance and path loss in the presence of obstacle has an averagely 12dB difference to that of the free space

($\frac{P1}{P2} \equiv 10log_{10}(\frac{P1}{P2})$ dB =$10log_{10}\left(\frac{P1}{1mw}\right) - 10log_{10}(\frac{P1}{1mw})$). Similar result of 10dB was obtained from an application note www.digi.com (2012) using the sa;me formula but the difference comes from wall thickness of 102mm and frequency of transmission.

Both path loss value obtained is less than the value of 13dB obtained by Michael, T (2011) using simplified path loss model of equation. This discrepancy arises as a result of the frequency of operation which lies between 900-1300MHz as prove by the Friss path loss equation. The path loss decrease with increase in frequency.

$$PL(dB) = 20log_{10}(\frac{4\pi df}{c})$$

While comparing the theoretical and Empirical model result, in free space, the mean square error was 0.984dB in free space and 0.982dB in the presence of obstructed medium. Similarly Figure 4.2, Figure 4.3, Figure 4.4 and Figure 4.6 compare both the result of data obtained from the theoretical Weiner II model and empirical which also proves the result obtained in Figure 4.1 hence the model cannot accurately predict the path loss of the signal passing through the concrete wall. The path loss model parameters were tuned based on the measured result and this yields an improved model with mean square error of 0.39dB between the measured and modified model in free space and 0.14dB in the presence of concrete wall. Theoretical modified Weiner II model proves this by showing a better agreement with measured as shown in Figure 4.5 and Figure 4.6. The model is modified by adjusting the fitting parameter C of the model. The modified result can now accurately predict the measured data.

4.4 SUMMARY

The chapter outlines the result obtained from theoretical and empirical method for the determination of path loss passing through concrete wall. Weiner II model is used as the path loss prediction model and compared with the empirical result. The result obtained from both measurements were plotted and compared, which shows that there is averagely 12dB loss due to the presence of obstructed medium (concrete wall). Similarly the means square error when comparing theoretical and empirical result in free space was 0.984 and 0.982 in the presence of obstacles The path loss model parameters were tuned based on the measured results and this yields an improved model which reduced the mean square error to 0.39dB in free space and 0.14dB with obstacle. The modified model can now be use to predict the measured result, determine the path loss of concrete wall at particular distance and position information of wi-fi devices can be easily identified.

CHAPTER FIVE

CONCLUSION, CONTRIBUTION AND RECOMMENDATION

5.1 CONCLUSIONS

Theoretical Weiner II model is used as the path loss prediction model and compared with the empirical data. The result obtained from both measurements were plotted and compared. The result showed that there is averagely 2dB difference between the measured and calculated path loss in free space and about a 12dB in the presence of obstructed medium (concrete wall). The path loss model parameters were tuned based on the measured results and this yields an improved model with averagely 0.39dB difference between the measured and modified model in free space and 0.14dB in the presence of concrete wall. The modified results can now be used to replace physical measurements for network installations in environment with similar specification.

5.2 CONTRIBUTION

i. Minimization of the theoretical error by 0.39dB in free space and 0.14dB in the presence of obstacle through the improved Weiner II model.

ii. Development of a system that guides network designer in determining best location for network devices without the necessary physical measurement.

iii. Simulation of mathematical model in MATLAB for the determination of path loss at specified distance in graphical user interface

iv. An additional system that determines at various points the strength of Wi-Fi signal for proper placement of repeater in wireless network installations is developed.

v. Making use of the Wi-Fi signal strength in determining the precise location of Wi-Fi device user

5.3 RECOMMENDATIONS

Further research could be carried out to determine the path loss of Wi-Fi signal by considering the properties of different type of materials such as wood, glass, and comparing the effect of the two properties. However, since frequency is a fundamental signal in transmission of signals, further researches should concentrate on monitoring the change in frequency in the presence of obstructed medium. The effect of varying the frequency also is another challenge.

REFERENCES

Ahsan, S, Zeeshan, A. and Iftikhar, A. (2013). Analysis and measurements of WiFi signals in indoor Environment.

Akiwole, B.O.H and Biebuma, J.J. (2013). Comparison analysis of Empirical path loss model for Cellular Transmission in River State. American journal of Engineering Research 2(8): 24-31

Baiya,A.P. and Siladya, S.B (2014). Quantitative Analysis on log-Distance propagation model for Wlan Standard. Indian Journal Research papipex 3(3):2250-1991.

Papapostolou,A. and Chauchi, H. (2011). RFID- assisted indoor localization and the impact of interference on its performance. Journal of Network and Computer Application 34: 902-913

Charlie F.et-al (2006). Value Chain Dynamics Working Group (VCDWG) MIT Communications Futures Program (CFP) Cambridge University Communications Research Network

Dinesh, B.S. (2005) Indoor propagation modeling at 2.4Ghz for IEEE 802.11 Networks (published master’s dissertation). University of North Texas.

Elechi,P. and Otasowes,P.O (2015). Analysis of Developed Building penetration path loss model for GSM wireless Access. International Journal of Engineering Research and General Science 3(6): 2091-2730.

Gary, L.J. (2013). Microwave Attenuation in Concrete wall sections.

Giri, D.V. and Tesche, F.M. (2013). Modeling of propagation losses in common Residential and commercial Building walls. Interaction note

Gupta. D., Sunil, J. (2011), In-building Radio Propagation at 900 MHZ in Multi Storied Building", International Journal of Distributed and Parallel Systems, (2)6 192-201.

Haleh, K. (2011). The integration of IEEE 802.11(WLAN) with RFID systems in ISM (2.45Ghz) frequency Band Environment using framed Sloted Aloha and IEEE 802.15.4 (published master's dissertation).

http://www.digi.com (2012) application note 18/09/16

http://www.searchnetwork.techtarget.com 12/08/2016

IEEE 80211 standard 1999 Edition (2003). "Information technology-Telecommunications and information exchange between systems- Local and metropolitan area networks- Specific requirements- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications,"

Jadhavar,B.R, Sontakke,T.R, (2012). 2.4GHz propagation prediction models for indoor wireless communication within building. International journal of soft Computing and Engineering 2(3):2278-3075.

Jalel,C. et-al, (2013). Comparison Between Measured and Predicted path loss for mobile Communication in Malaysia. World Applied Sciences Journal 21(Mathematical Applications in Engineering):123-128

Japertas, S. and Orzekauskas, E. (2012). Investigation of Wi-Fi indoor signals under LOS and NLOS conditions. International Journal of Digital information and wireless Communication 2(1):26-32.

Khan, M.Z., mohammad, A. (2007). wireless power transmission to a Buried sensor in concrete. IEEE sensors journal (7): 1573-1577

Khan J. and Khwaja, A. (2003). Building Secure Wireless Networks with 802.11.Indianapolis: Wiley Publishing, Inc.

Kedar, N.S.Challa,D.N. and Sankar, K.J.(2014). Study of RF propagation losses in Homogeneos Brick and Concrete walls using analytical frequency Dependent models. Journals of Electronics and Communication Engineering 9(5):2278-2834.

Jim, S.(2005). Article on dB, dBm and Dbw. The University of Kankas

Magdy F. I., Zhengqing, Y. (2002).Propagation Prediction Models for Wireless

Communication Systems. IEEE Transactions on Microwave Theory and Techniques, 50(3)

Matsunaga, M., T. Matsunaga, and M. Nakano, (2011). Modeling and Measurement Techniques for Propagation of Indoor Wireless Communication Considering the Building's Structure and Human Bodies", Loughborough Antennas and Propagation Conference, 1-4.

Magdy,I,Osama,M (2014). Experimental study of wireless sensor Networks for indoor construction operations

Mathuranathan,V. (2013). Simulation of Digital communication systems using Matlab 2nd Edn.,mathuranathan Viswanathan at Amazon.

Mukesh, K.M. (2010). Modeling of losses due to different types of walls and Empirical model for Indoor Wi-fi system. Bahria University. Journal of information & Communication Technology. 3(1).

Omaes, M.O., Ndungus, E.N. and Kibet, P.L. (2015) Comparison of Wi-Fi signal Indoor loss coverage and propagation through walls. proceeding of sustainable Research and innovation (SRI) conference

Pathak, S., S. Ranjani, Ber (2013). Performance Analysis for WiMAX PHY Layer under Different Channel Conditions", International Journal of Information Sciences andTechniques, 3(3): 9-27.

Pekka, K. et-al,(2007) Weiner II Channel models. Information Society Technologies.

Rakesh, N. and Srivatsa,S. K. (2013). A Study on Path Loss Analysis for GSM Mobile Networks for Urban, Rural and Suburban Regions of Karnataka State", International Journal of Distributed and Parallel Systems, 4 (1) :53-66.

Richaot,E. et-al (2000). Electromagnetic propagation into Reinforced- Concrete walls, IEEE Trans. Microw. Theory and Techniques, (48):357-366

Robert, W. (2002). Propagation losses through Common Building materials 2.4Ghz Vs 5Ghz. Magic Network, Inc.

Robert, K. and Dinesh, T. (2011) indoor propagation modeling at 2.4Ghz for IEEE 802.11 Networks. Wireless Network and Emerging Technologies.

Simon, T. (2010). Indoor location Tracking using signal Strength pinpoints (published master’s dissertation) University of Groningen.

Vinko, E. (1999). An Empirically Based Path Loss Model for Wireless Channels in Suburban Environments. IEEE Journal on Selected Areas in Communications, 17 (7)

Yarkoni,N. and Blaunstein, N. (2006). Prediction of propagation Characteristics in Indoor Radio Communication Environments. Progress in Electromagnetic Research. 59 :157-174.