Mody University International Journal of Computing and Engineering Research
Vol. 1 Issue 1, 2017, pp.23-27
ISSN: 2456-9607 (Print) 2456-8333(Online)

Performance Evaluation of Indoor Propagation Models

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Received 20 Nov. 2016, Published 31 March 2017

Abstract: In wireless domain, due to attenuation during indoor propagation, performance evaluation of a radio signal is demanded for the design and maintenance of indoor wireless services. As outdoor models are not accurate for indoor scenarios hence models such as ITU Model, Ericsson Multiple Breakdown Model, Partition Model and Attenuation Factor Models can be used to derive satisfying results.

Keywords: Path loss, ITU model, Ericsson multiple breakdown model, indoor propagation,wireless communication

1. INTRODUCTION

Wireless Communication is a very important field of research for development of technology in recent times. During transmission of a signal, path loss occurs which means the power density of a signal reduces with distance as it propagates through space. Path loss is the main factor whose analysis further leads to proper designing of link budget in a telecommunication system. Two types of propagation may occur during transmission of a radio signal, outdoor and indoor. Our prime focus in this paper is to show the results of computed values of various types of indoor propagation which would help us to understand the difference in path loss using each model for the same distance. Indoor Propagation follows the same mechanism such as reflection, scattering and diffraction, just like outdoor propagation system. What mainly differs in the indoor environment is, whether the doors or windows are open or not, the antenna is mounted on desk or ceiling, level of floors in the building, the wall used for partition between rooms is concrete or wooden or any other soft material. Excessive path loss within indoors can prevent units from communicating with one another. Thus, it is useful to attempt to predict path loss as a function of distance. Both theoretical and measurement based propagation models indicate that average received signal power decreases logarithmically with distance. Empirical models help in reducing computational complexity as well as increasing the accuracy of the predictions. [1]

2. TYPES OF INDOOR PROPAGATION

A. *ITU Model*

International Telecommunication Union (ITU) model is applicable for small range of communication where T-R separation is smaller. The radio propagation is affected by the layout inside the building. It is best suited in residential and office environment. The use of this indoor transmission loss model assumes that the base station and portable are located inside the same building. . It is based on both an average path loss and its associated shadow fading states. . The distance power loss coefficient given below includes an indirect allowance for communication through walls and over or through obstacles, and for any other loss mechanisms that may occur within a single floor of a building.

The basic model has the following form:

$$L= 20 \log f + N \log d + P_f (n) – 28 \quad \text{dB} \qquad [2]$$

Where, N is the distance power loss coefficient, f is the frequency (MHz), d is the separation distance (m) between the base station and portable, P_f is the floor penetration factor (dB) and n is the number of floors between bas and portable. The ITU model has limitations to frequency being 900 MHz to 5.2 GHz, floorsfrom 1 to 3 and distance more den 1 meters.

Typical parameters, based on various measurement results are given in Table 1 and 2. [3]

Table1: Power Loss coefficients, for indoor transmission loss calculation

Frequency	Residential	Office	Commercial
900 MHz	-	33	20
1.2-1.3 GHz	-	32	22
1.8-2 GHz	28	30	22
4 GHz	-	28	22
60 GHz	-	22	17

Table 2: Power loss coefficients,N,for indoor transmission loss calculation

Frequency	Residential	Office	Commercial
900 MHz	-	9(1 floor) 19(2 floors) 24(3 floors)	-
1.8-2 GHz	4n	15+4(n-1)	6+3(n-1)

B. Ericsson Multiple Breakdown Model

This is a radio propagation model that predicts the path loss a signal encounters inside multiple floors of office buildings or such indoor environment. The model has four break points and are based on measurements conducted at 900 MHz [4]. The graph derived is dB attenuation vs distance graph shows how the path loss exponent increases with increase in distance between the transceivers. When we are closer to the transmitter in a building environment, we have more probability of sightline and less barrier. One disadvantage is that one single path loss exponent is not sufficient to characterize the path loss within an office environment. The model assumes that at d_o= 1 m, there will be an obvious 30 dB attenuation, which is mainly when f=900MHz and unity gain antennas. The Ericsson model provides a deterministic limit on the range of path loss at a particular distance. A uniform distribution was used by Bernhardt to generate the path loss values within the maximum and minimum range as a function of distance for in-building simulation. [5]

C. Partition Model

Real world hardly follows this simple model. There are mainly two kinds of partition loss, one being in the same floor while the other between different floors. When it is in the same floor, partition which are part of the structure of the building is called hard partition while partitions which are movable and do not span to the building is called soft partition. The material used for making the partition has an effect on the loss of signal. While in case of partition between floors of a building, it is highly dependent on the materials and external dimensions of the building and all its surroundings. The presence of doors and windows and the tinting can impact the loss within floors. The value generally used for Floor Attenuation Factor (FAF) for various types of buildings, are tabulated and considered by the researchers.

Two office buildings were taken into consideration by the researchers and an Average Floor Attenuation factor in dB was tabulated as follows [1]:

Table 3

Buildings	FAF(dB)	σ (dB)	Number of locations
Office Building 1:			
Through One floor	12.9	7.0	52
Through Two Floors	18.7	2.8	9
Through Three Floors	24.4	1.7	9
Through Four Floors	27.0	1.5	9
Office Building 2:			
Through One Floor	16.2	2.9	21
Through Two Floors	27.5	5.4	21
Through Three Floors	31.6	7.2	21

D. Attenuation Factor Model

This is type of radio propagation model which can predict the path loss a signal confronts due to building types and obstacles. The collected information by Seidel was later developed to accurately install indoor and campus networks. Primary ray tracing technique was used in this method to draw single ray between the transceivers in 3-D, hence Partition Attenuation Factor (PAF) was calculated for specific type of obstruction. By summing the cumulative partition losses along the primary ray was seen to yield perfection with the aid of immense computing efficiency. The model has shown to have reduced upto 4 dB of path loss between measured and predicted values, as compared to 13 dB or so when another model was used in two different buildings. [6]

The attenuation factor model is represented using the following equation:

$$L = L(do) + 10\ nsf \log(d/do) + FAF + \sum PAF$$

Where, do is the reference distance, nsf is the same floor path loss exponent, d is the distance between the transmitter and receiver, FAF is the Floor Attenuation Factor and PAF is the Partition Attenuation Factor. Apparently the value of FAF can be replaced in the above equation by an exponent which already considers the effect of multiple floor separation. Hence, the equation could be as below:

$$L(dB) = L(do) + 10\ nmf \log(d/do) + \sum PAF$$

Where nmf represents the path loss exponent based on measurements through multiple floors.

The Table below gives an idea of the variety in value of n for several locations in many buildings and also the way standard deviation decreases as the average region gets smaller and more site specific [1].

Table 4

All buildings	n	σ (dB)	Number of locations
All locations	3.14	16.3	634
Same floor	2.76	12.9	501
Through One floor	4.19	5.1	73
Through two floors	5.04	6.5	30
Through three floors	5.22	6.7	30
Grocery Store	1.81	5.2	89
Retail Store	2.18	8.7	137
Office Building 1			
Entire Building	3.54	12.8	320
Same Floor	3.27	11.2	238
West wing 5th floor	2.68	8.1	104
Central wing 5th floor	4.01	4.3	118
West wing 4th floor	3.18	4.4	120
Office Building 2			
Entire building	4.33	13.2	100
Same floor	3.25	5.2	37

3. Result and Discussion

A. Results of ITU Model

In Mat lab, path loss was estimated using ITU Model which has been graphically represented for both f =900MHz and f=5200MHz. The difference in values of path loss is easily noticeable. The values for the computation of the equation using variables such as N and P_f was used from table 1 and 2 as mentioned earlier in this paper.

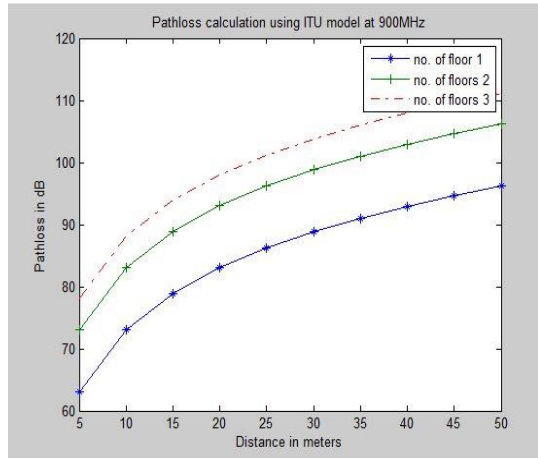

Fig 1: Path loss calculation using ITU model at 900 MHz

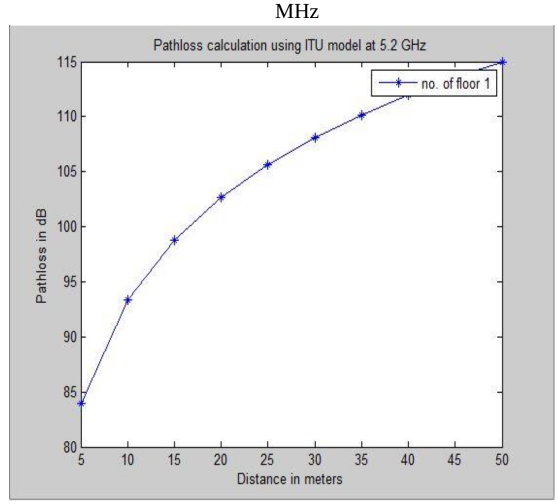

Fig 2: Path loss calculation using ITU model at 5.2 GHz

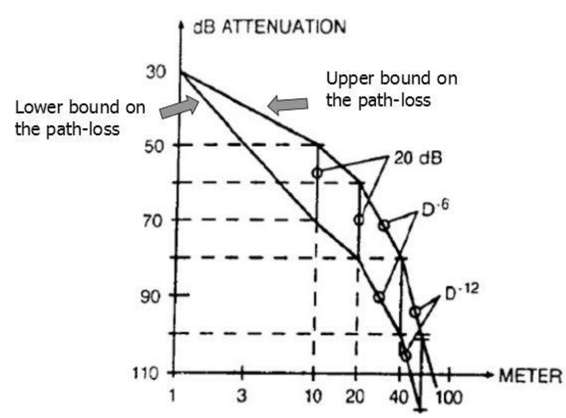

Fig 3: Ericsson in-building path loss model

While at d=50m, for f=900 MHz the path loss is seen to be 94 dB for 1 floor, 105 dB for 2 floors and 110 dB for 3 floors, whereas for f=5.2 GHz the path loss for 1 floor is 115 dB . This clearly shows how path loss depends on number of floors, distance and frequency of the signal generated.

B. Results of Ericsson Model

The figure above is the Ericsson model which shows path loss starting from d = 1m to 100m. Using uniform distribution, path loss was generated between minimum and maximum range, relative to distance. The four breakpoints consider upper and lower bound on path loss. It was assumed to have 30dB attenuation at d_o= 1m and frequency value was taken to be 900 MHz. This model is deterministic in nature. At around d =50m, the path loss is shown to be around 100 dB which is close to the value obtained in ITU model. [7]

C. Results of Partition Model

In case of this model, uniform values were obtained by researchers on the basis of their experiments conducted for different office buildings. Certain parameters were assumed during their research work, hence the following graphical model was obtained. This is the oldest model used for path loss calculation, hence with time advancement, there has been better models designed for accurate results. However the graph below gives an idea about the estimated values of partition model in different floors of an office building. [8]

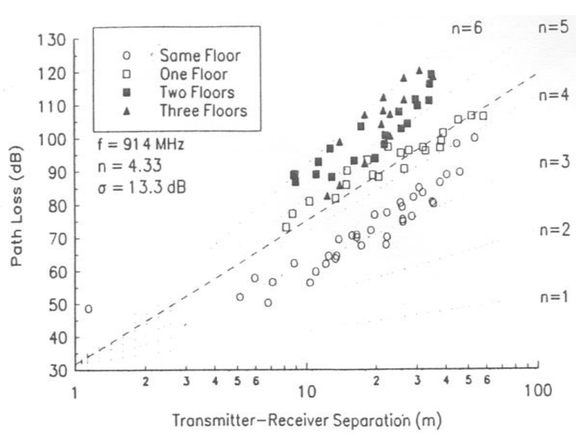

Fig 4: Path loss in an Office Building at f =914MHz

D Results of Attenuation Factor Model

This model was used to plot a graph in Matlabcomparing between 5 floors of a building with concrete walls when the frequency was 900 MHz.

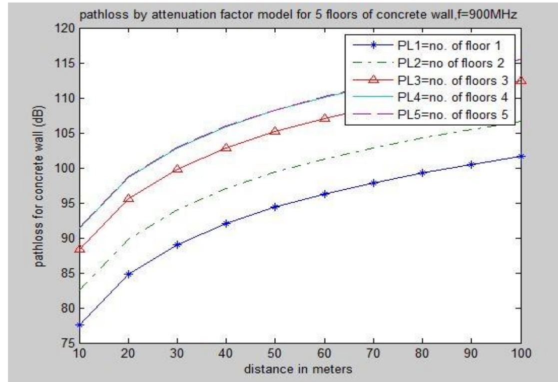

Fig 6: Pathloss calculation for 5 floors at f=900 MHz

Also having taken Soft and Hard partition into consideration, graphs were plotted for four floors of a building taking frequency as 900 MHz, as shown below:

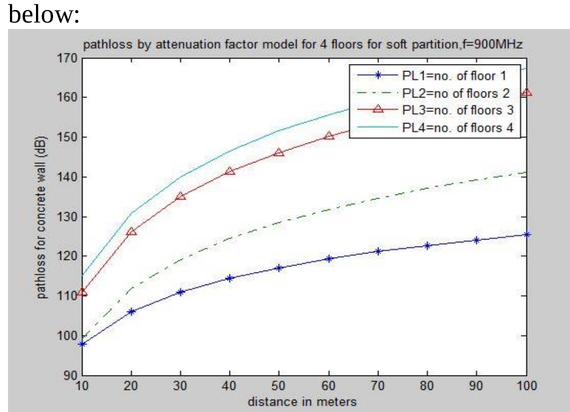

Fig 7: Pathloss calculation for soft partition atf=900 MHz

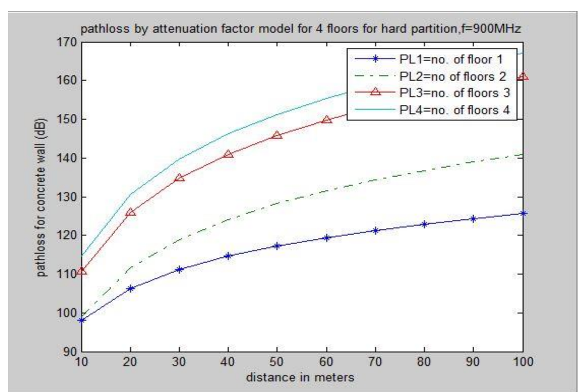

Fig 8:Pathloss calculation for soft partition at f=900 MHz

4. CONCLUSION

The indoor propagation model is important for analysis so as to design communication devices used as transceiver within an indoor environment. In this paper, four types of models were compared for performance evaluation to give a brief idea about the indoor propagation loss that may occur with change in some parameters, which differs from outdoor propagation in spite of following same mechanism such as reflection, refraction and scattering. [9] Using Mat lab, having seen the graphical representation for ITU model and Attenuation partition model, an exact value is obtained for a distance of 50 and 100 meters respectively. Ericsson model and partition model was deterministic in nature and estimated a wide range of values of path loss depending on types of buildings and obstacles encountered by the signal transmitted. The use of wireless system for indoor use is seen to pose one of the biggest design challenges; hence it is suggested to use latest models such as ITU model and Attenuation factor model for path loss prediction. The free space path loss was taken into consideration during calculation for all the types of models discussed in this paper. Thus, it can be concluded by saying that all the models are useful for various purposes.

ACKNOWLEDGMENT

I would like to express my gratitude of thanks to my honorable advisor Dr. Partha Pratim Bhattacharya for his encouragement, support and guidance which helped me to enhance my ability and make an attempt to succeed in completion of this paper.

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