Determination of Path Loss Model based on Measurements for IEEE 802.11n in Large Rectangular Room

Ekta Khurana
ECE
SBSSTC
Ferozepur, India

Jaswinder Kaur
A.P,ECE
SBSSTC
Ferozepur, India

Varun Nayyar
A.P,ECE
RBCENTW
Hoshiarpur, India

ABSTRACT
In this paper, path loss (PL) model for IEEE 802.11n in large rectangular room is determined on basis of PL measurements. It is found that PL model can be described by a TGn channel model and free-space model at small distances with PL exponent of 2.67 and 2. At large distances PL model can be described by one-slope model with PL exponent of 1.6. Further, it is determined PL exponent increases in the presence of humans. Finally we investigate that our PL model has less PL so it is better than one-slope model, free-space model and TGn channel model.

Keywords
IEEE 802.11n, One–slope model, Free-space model, TGn channel model

1. INTRODUCTION
The IEEE 802.11n is the latest amendment to IEEE standards that aims to provide higher throughput and increased range of reception with PHY and medium access control(MAC) enhancements. The most important new MAC layer features in IEEE 802.11n are frame aggregation and enhanced block ack. It operates on both 2.4 GHz and the lesser used 5 GHz bands. It is based on Multiple Input Multiple Output (MIMO) technology along with Orthogonal Frequency Division Multiplexing (MIMO-OFDM) [5]. This technology is used in this standard to exploit multipath signal propagation and increase throughput via spatial multiplexing [4].

Spatial Divison Multiplexing (SDM) is another valuable feature of the MIMO technology. There is increase in data throughput by SDM as the no of resolved spatial data streams is increased [3]. In IEEE 802.11n OFDM modulation is used in the 20 MHz band [6].

In this paper, a PL model for large rectangular rooms is determined, based on PL measurements. Further the path loss exponent of measured PL model is compared with path loss exponent of one-slope, Free-space model and TGn channel model.

The Outline of this paper is as follows. Section 2 describes the PL measurements. In Section 3 different path loss models are introduced and discussed. Section 4 describes the effect of humans on the PL model. Section 5 includes the results of measured model with all other models. Conclusion is given in Section 6.

2. PATH LOSS MEASUREMENTS
The path loss measurements were taken in a large rectangular room (college computer lab). In this room, seating arrangement consists of uniform distribution of student desks. This room has a rectangular geometry. The room is divided into four parts by the soft partitioning of the glass. The measurements were done at frequency 2.4GHz.

The access point was positioned in the middle of the room (Tx in Fig.1). The area of the room is 18m×21m. As measurement equipment at the transmitter side, we used access point CISCO WAP 4410N which provides longer range by using multiple antennas to transmit and receive data streams in different directions.

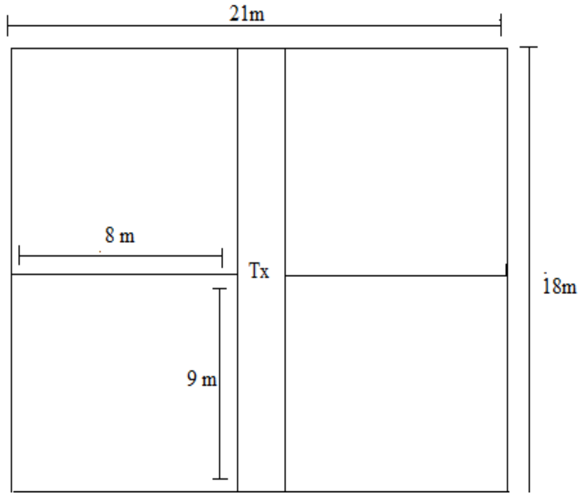

Fig.1. Plan of a large rectangular room where PL measurements were carried out.

The access point has three detachable 2dBi omni-directional antennas. At the receiver side, the equipment included a laptop, equipped with inbuilt Wireless USB Adapter and Xirrus Wi-Fi Inspector tool. The receiver was moved diagonally in four directions, starting from the Tx position.

During the measurements, no people were present in the room.

3. PATH LOSS MODEL
3.1 Determination of PL model
From the measurement data, the path loss is calculated by [7]:

$$PL= - (P_R) + P_T + G_T + G_R – L_T – L_R, \quad (1)$$

where - (P_R) is the average received power [dBm] , P_T is the transmit power [dBm], G_T (G_R) is the transmitter (receiver) gain [dBi], and L_T (L_R) is the transmitter (receiver) feeder loss[dB].

During the measurements, a transmit power of 15.5dBm, transmit (receiver) gain of 2 dBi and zero transmitter (receiver) feeder loss is used.

From the measurement data, the P_R samples and their corresponding position are obtained. From these P_R samples Path loss values are calculated by (1).

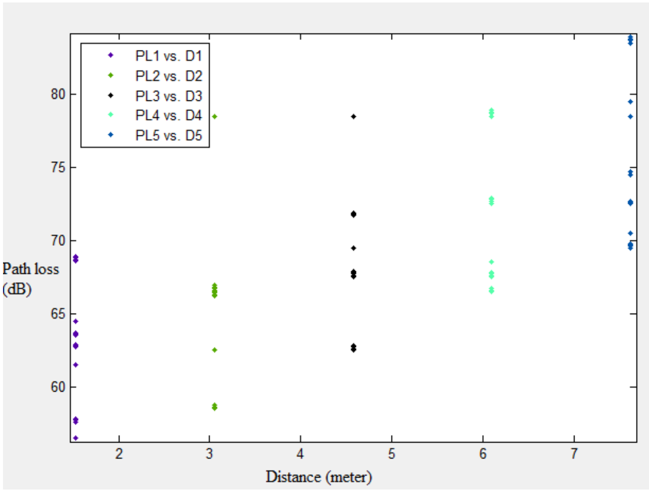

Fig.2. Measured Path Loss at different distances in large rectangular room.

In Fig.2. PL1,PL2,PL3,PL4,PL5 are calculated path loss from the P_R measurements in four directions at different distances. The PL median of measured PL model is shown in Fig.3.

3.2 One-slope model

One-slope model describes the path loss [dB] for large rectangular room [8]:

$$PLx=PL_o+10n\log(d) + X_\sigma, \quad (2)$$

where PL_o is the mean path loss at a distance of 1 m, n is the PL exponent, and X_σ [dB] is a normally distributed variable with 0 dB median and standard deviation σ .The parameters n and σ are determined by the method of least squares.

Fig.4. shows median of one-slope model with PL exponent of 1.6. The determined PL exponent is lower than the free-space PL exponent of 2. This can be described by the reflections at the walls, ceiling and the floor.

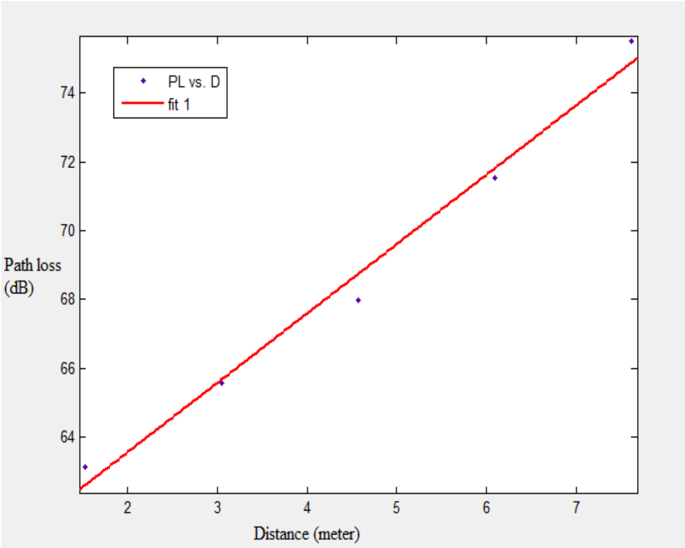

Fig.3. Measured Path Loss model in a large rectangular room.

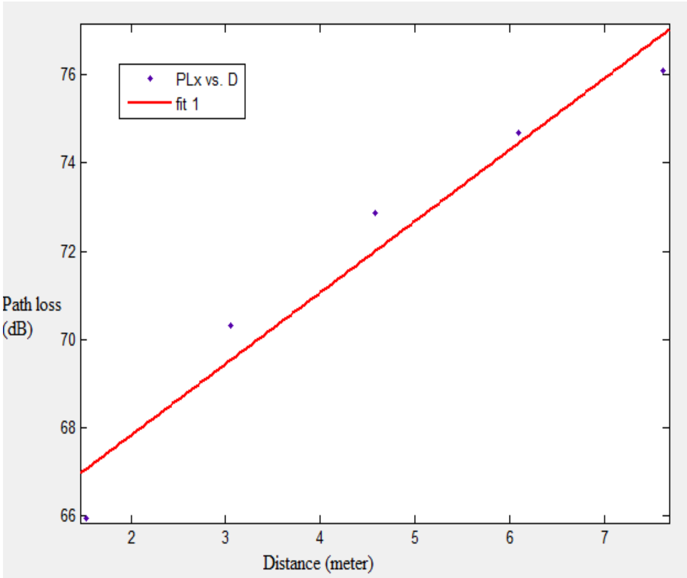

Fig.4. One-slope model in a large rectangular room.

3.3 Free-space model

It is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed line of sight path between them [2]. Path loss for free space is calculated by [9]:

$$PLy=32.4+20\log(f_c) + 20\log(d), \quad (3)$$

where f_c is the carrier frequency (hertz), d is the distance between transmitter and receiver (meter).

Fig.5. shows median of free-space model with PL exponent of 2.

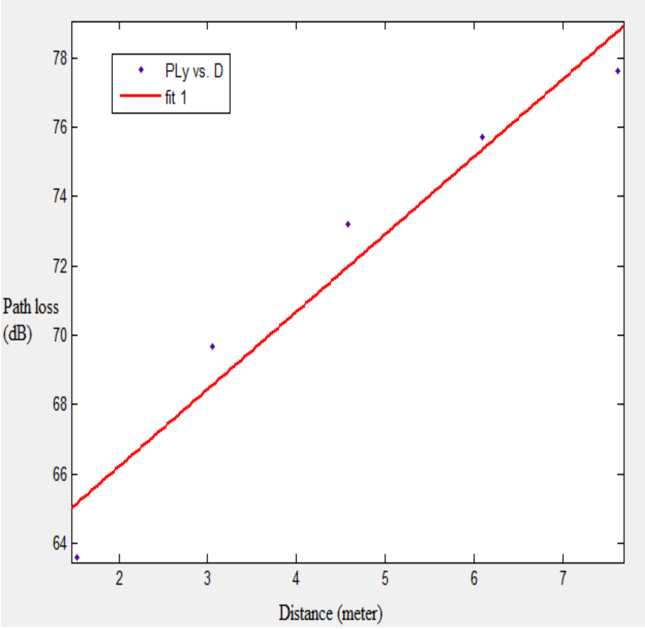

Fig.5. Free space model in a large rectangular room

3.4 IEEE 802.11 TGn channel model

Path loss for IEEE 802.11 TGn channel model is given by [1]:

$$PLz = PLy \qquad d <= d_{BP}$$

$$PLz = Ply(d_{BP}) + 35\log_{10}(d / d_{BP}) \qquad d > d_{BP} \qquad (4)$$

where Ply is the free space path loss (dB), d_{BP} is the breakpoint distance (meter) between transmitter and receiver.

According to the IEEE 802.11 TGn channel model , the PL can be modeled by the free space PL for $d < d_{BP}$, and by a one-slope model with exponent 3.5 for $d > d_{BP}$. The TGn model predicts a breakpoint of 5m for 'Small environment' (type of environment 'C') and a breakpoint of 10m for 'Large environment' (type of environment 'D').

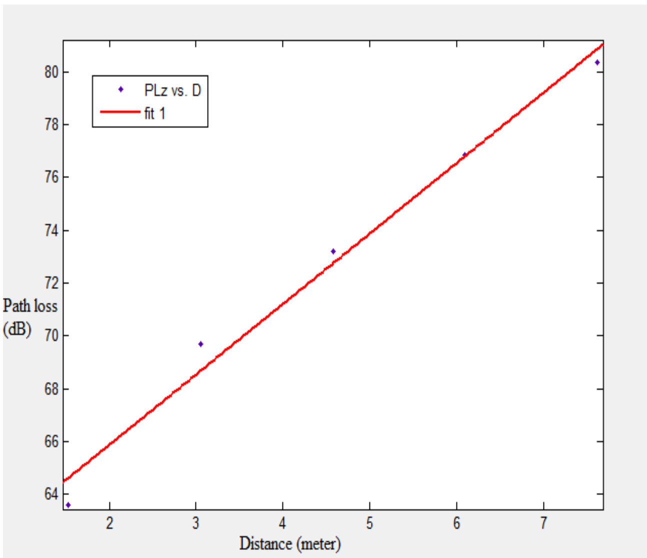

Fig.6. TGn channel model in a large rectangular room.

Fig.6. shows median of TGn channel model with PL exponent of 2.6 .

4. EFFECT OF HUMANS ON THE PL MODEL

In Table 1, the parameter of PL model is given for the case of the vacant room and the room with lecture at 2.4 GHz.

Table1. Parameters of PL model in vacant room and during lecture.

Vacant room	n =1.4	σ (dB) = 1.6
Lecture	n =1.8	σ (dB) = 0.9

The PL exponent increases towards 2 in the presence of humans at 2.4 GHz. Due to high PL exponent, the PL during a lecture intersects with the PL in the vacant room.

Due to multipath propagation, the PL exponent of the vacant room is lower than free-space exponent. During lecture, the PL exponent increases towards 2 due to absorption by the human body.

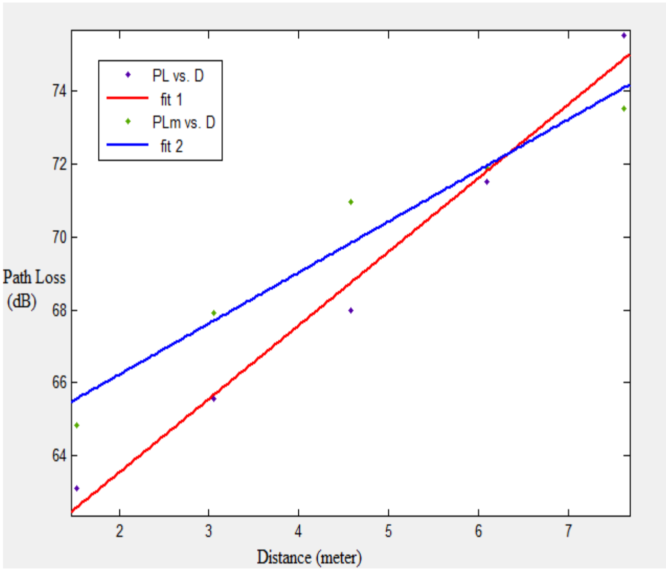

Fig.7. Median of PL model in the vacant room and during lecture.

In Fig.7 PL shows the median of PL models in vacant room and PLm shows the median of PL models during lecture. For large rectangular room we expect that the attenuation increases which results in increase in PL exponent.

5. RESULTS

It is found that the PL model described by one-slope model gives path loss exponent of 1.6, which is lower than free space. Further it is determined from the Fig.8. that the measured model has lower breakpoint and path loss exponent compared to TGn channel model. The path loss median of measured model is lower than path loss median of TGn channel model at 2.4 GHz.

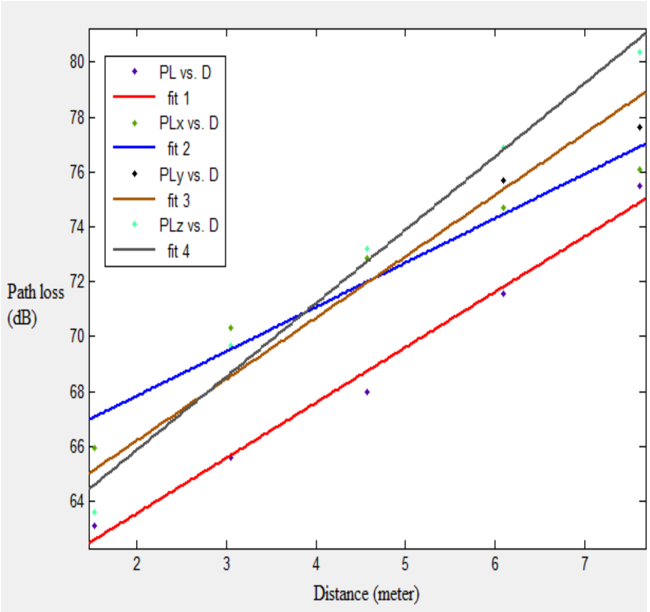

Fig.8. Measured result of different path loss models in a large rectangular room.

6. CONCLUSION

We determine a PL model for IEEE 802.11n in a large rectangular room based on PL measurements. It is found that measured model can be described accurately by TGn channel model at small distances and by one-slope model at large distances. It is determined that PL exponent increases towards 2 in the presence of humans. Future research will consist of simulation of this prediction model in MATLAB simulink.

7. REFERENCES

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