Path Loss and Fading Characterization at 2.4 GHz for Indoor Scenario

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ABSTRACT
A measurement exercise is undertaken to determine path loss and fading behavior of the propagation channel through RF level measurements. Path loss exponent is computed for LOS and NLOS antenna positions in a building that predicts effect of wall partitions, number of floors at 2.4 GHz. Further, the channel fading is derived to understand the exact fading behavior by virtue of obtaining CDF of the fading distribution of the received data. The fading distribution of the received signal is compared to standard distributions mainly Rayleigh, Rician and Lognormal.

Keywords
CDF , BER , Rayleigh distribution.

1. INTRODUCTION
To have satisfactory operation of mobile system in indoor environment there is desire to predict radio coverage within buildings so that optimum location of base stations can be chosen which maximizes capacity and minimizes co-channel interference. In next generation system more stress is given on indoor environment because there is requirement of other services like position information of the mobile user inside large buildings, malls, hospitals, air ports, public places, factories and emergency services [1]. It has been found that the mechanisms behind electromagnetic wave propagation are diverse and characterized by certain phenomena such as reflection, refraction and diffraction of waves [2]. These phenomena induces signal scattering, fading and shadowing along the signal path and their effects can best be described (in a large scale) by the path loss exponent which defines the rate of change of attenuation that the signals suffers as it propagates from the transmitter to the receiver.

For all measured data sets, a single-slope model was employed in order to determine the path-loss exponent, where d represents the T-R separation distance and relates to path loss in terms of an empirical path loss exponent, n. The dn path loss model is generally used to predict the power transfer between a transmitter and a receiver .The dn model predicts that the mean path loss, PL (d), measured in dB, at a T-R separation d will be [3, 4]

$$P_L(d) = P_L(d_0)+10 \ n \log10 \ (d/d_0) \ (dB) \qquad (1)$$

Where PL(d0) is the mean path loss in dB at close-in reference distance d0, and n is the empirical quantity - the "path loss exponent".

"Path loss" is the term used to quantify the difference (in dB) between the transmitted power, Pt (in dBm), and received power, Pr (in dBm). (The gains of the transmitting and receiving antennas may be implicitly included or excluded in these power quantities).

2. FADING MODELS - THEORITICAL CONSIDERATIONS
Radio waves arrive at a mobile receiver from different directions with different time delays and the signal is subjected to fading. Fading is a significant part of any wireless communication design and it is important to predict what type of fading may occur in a scenario. Fading distribution is the probability distribution of the value of signal fading relative to a specified reference level [5]. The major fading models are presented in the following section.

2.1 Rayleigh Fading
Small-scale fading is also known as Rayleigh fading since the fluctuation of the signal envelope is Rayleigh distributed when there is no predominant line of sight between the transmitter and receiver and its probability density function (pdf) is given by

$$f_{Rayleig\ h}(r) = \frac{r}{\sigma^2} e^{\left(\frac{-r^2}{2\sigma^2}\right)} 0 \le r < \infty \qquad (2)$$

Where σ is the root mean squared value of the received signal before detection and σ^2 is the average power of the received fading signal [6].

2.2 Rician Fading
Rician fading occurs when there is dominant stationary signal component present (such as LOS) .It degenerates to Rayleigh when dominant component fades away. [7]

$$f_{Rician}(r) = \frac{r}{\sigma^2} e^{\left(\frac{-r^2+A^2}{2\sigma^2}\right)} I_0\left(\frac{Ar}{\sigma^2}\right) \quad (0 \le r < \infty, 0 \le A < \infty \qquad (3)$$

Where A is the Peak amplitude of the Dominant Signal & I_0 is the first order Bessel's Function. The Rician distribution is often described in terms of parameter
$K = Ar/ 2\sigma^2$.

2.3 Log Normal Fading
The log-normal fading model is widely used to characterize indoor non-LOS propagation path loss, especially when the signal will penetrate through walls, windows (especially with steel frames), partition boards and other large obstacles. The log-normal distributed random variable in fact obeys a normal or Gaussian distribution when the values are measured in decibels. If x is a Gaussian random variable with its mean μ

and variance σ2, then x is a log-normally distributed random variable with its probability density function as [8]

$$p(x) = \frac{1}{\sqrt{2\pi\sigma}}\, e^{-(x-\mu)^2/\sigma} \qquad (4)$$

3. SYSTEM SETUP

The measurement setup used is presented in figure 1. RF Signal generator is connected to Transmitting Antenna (Sector Antenna) via coaxial Cable. The signal is received through Omni directional antenna and analyzed using Agilent's Handheld Spectrum Analyzer .The frequency used for the measurements is 2.4 GHz. In order to enhance the antenna positioning accuracy, an antenna carriage is used in the RX-end. During the measurements, the RX antenna carriage is moved along the path with one wavelength (12.5 cm) steps. Transmitter antenna is kept fixed at an effective antenna height of about 3 meter.

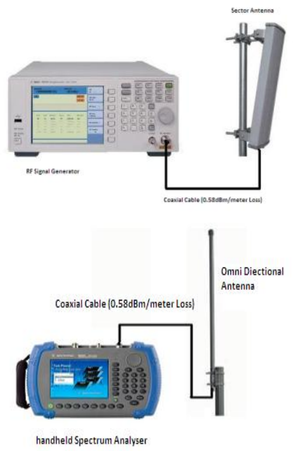

Fig. 1 : Transmitter and Receiver Configuration

The Indoor and outdoor measurement are conducted in the building premises of the Department of Electronics & Communication Engineering, C.T.A.E. Maharana Pratap University of agriculture & technology Udaipur; Rajasthan, India (Fig. 2).The measured environments were research lab, corridor and First Floor. The measurements also considered the effects of LOS and NLOS path across the lab (Fig. 3) . The attenuation of signal is measured due to fading effects caused by various surrounding things like tables, chairs, fans and other instruments kept inside the lab.

Table 1: System Parameters

Parameters	Specifications
Transmitting Antenna	3 Sector (16 dBi)
Receiving Antenna	Omni directional (16 dBi)
Frequency	2.4 GHz
Modulation Scheme	16QAM (½ Code rate)
Channel Bandwidth	10 MHz
Transmit Power	0 dBm
Transmitter Height	3 meters
Receiver Height	2 Meters

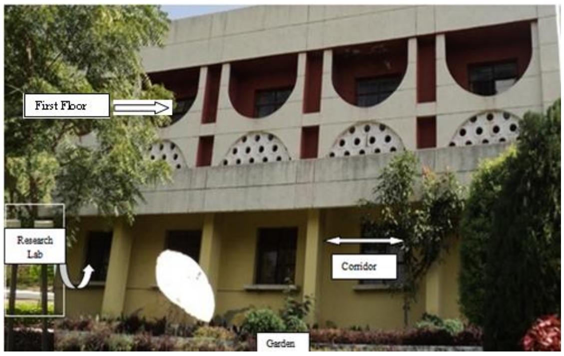

Fig. 2: Measurement Scenario

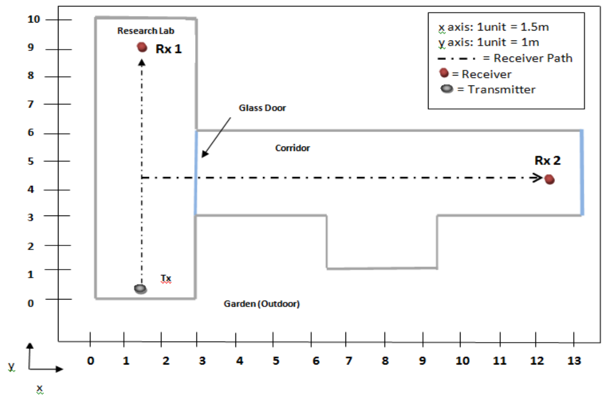

Fig 3: Geometry of Indoor LOS and NLOS Scenario

4. RESULTS & DISCUSSIONS

4.1 Indoor NLOS Scenario (Ground Floor)

The transmitter is kept at fixed position in research Lab and receiver carriage is moved along the building corridor.

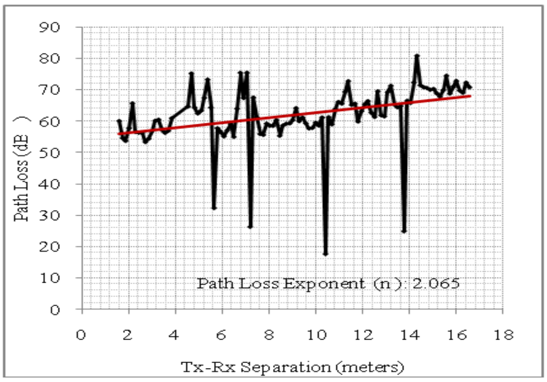

Fig 4: Plot of path Loss v/s Tx-Rx Distance

Figure 4 shows the path loss characteristics in Receiver path for NLOs position. It was found that model gives a good prediction to the theoretical data with the path loss exponent of 2. Basically the exponent varies from 1.4 to 2.6 and is closed to one slope model explained in theory

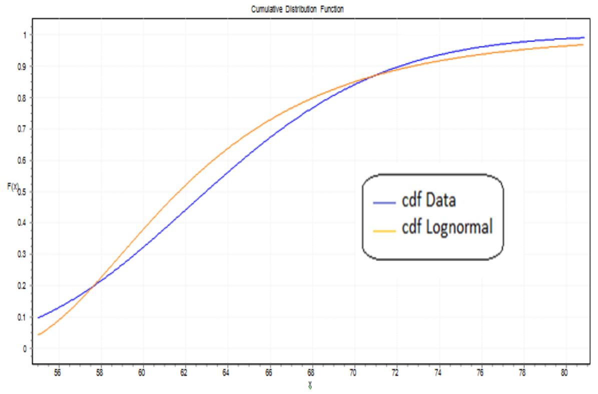

Fig 5: Comparison of experimental data Distribution with Lognormal Distribution

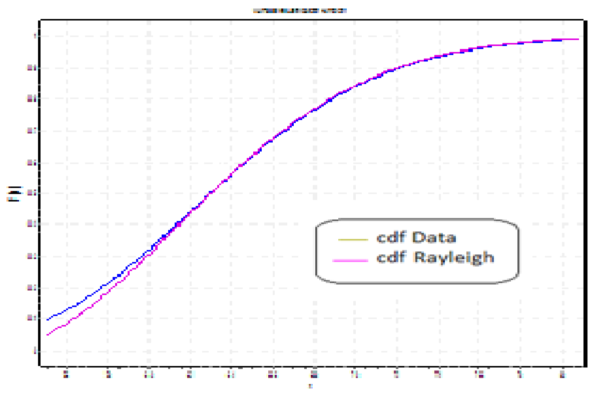

Fig 6: Comparison of experimental data Distribution with Rayleigh Distribution

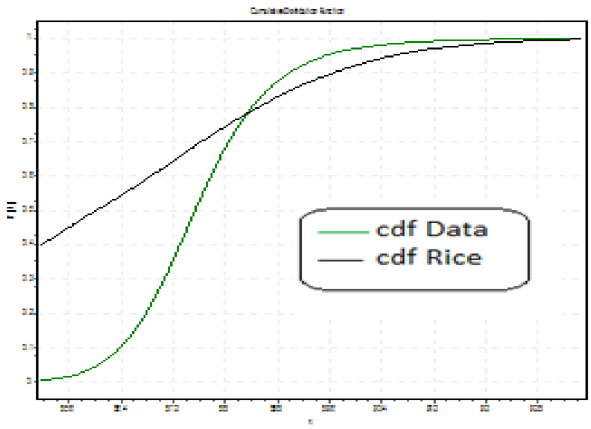

Fig 7: Comparison of experimental data Distribution with Rice distribution

In Fig 5, 6, and 7 measured path profile was compared with theoretical curves like Rayleigh, rice and log normal. Above observation reveals that Rayleigh seems to fit best to the data but Log Normal is very close to the same. Measurement made in corridor front indicated less penetration loss then in other part of buildings. The curve fits rice fading near the gate of research Lab and Rayleigh elsewhere.

4.2 Indoor LOS Scenario (Ground Floor)

The transmitter is kept at fixed position in research Lab and receiver carriage is moved along the Lab in LOS direction.

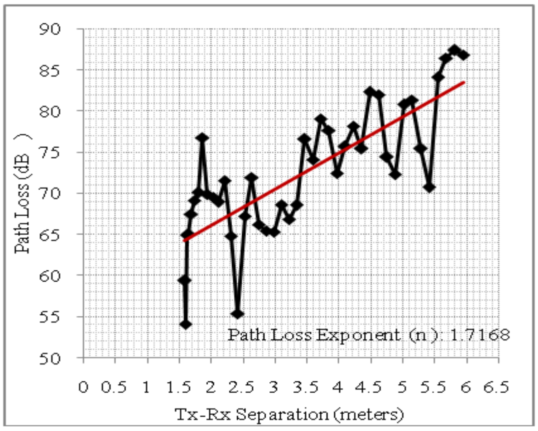

Fig 8: Plot of path Loss v/s Tx-Rx Distance

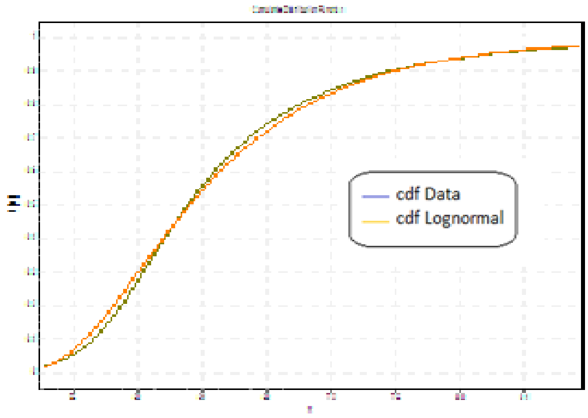

Fig 9: Comparison of experimental data Distribution with Lognormal Distribution

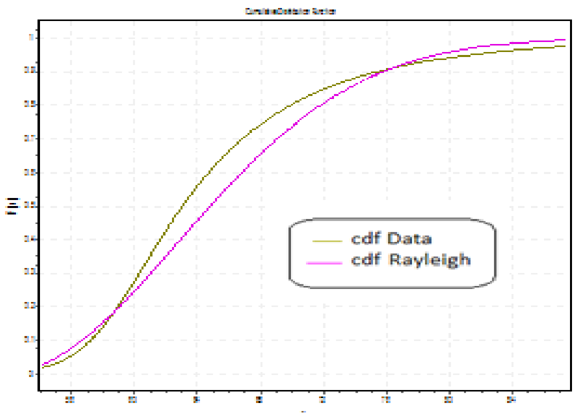

Fig 10: Comparison of experimental data Distribution with Rayleigh Distribution

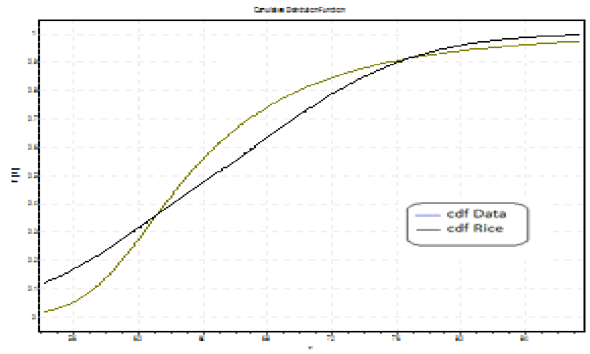

Fig 11: Comparison of experimental data Distribution with Rice distribution

Figure 8 shows the path loss characteristics in Receiver path for LOS position. It was found that model gives a poor prediction to the theoretical data with the path loss exponent of 2. Basically the exponent varies from 1.2 to 1.9and does not justify one slope model explained above. Measured path profile was also compared with theoretical curves like Rayleigh, rice and log normal. Above observation reveals that log normal seems to fit best to the data but rice is very close the same.

4.3 Indoor Scenario (Ground to First Floor)

The transmitter is kept at fixed position in research Lab and receiver carriage is moved along first floor corridor.

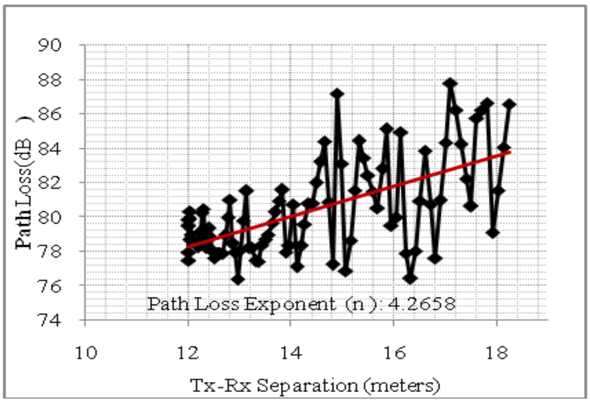

Fig 12: Plot of path Loss v/s Tx-Rx Distance

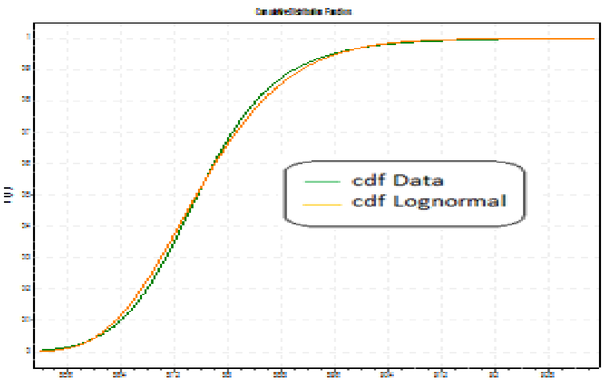

Fig 13: Comparison of experimental data Distribution with Lognormal Distribution

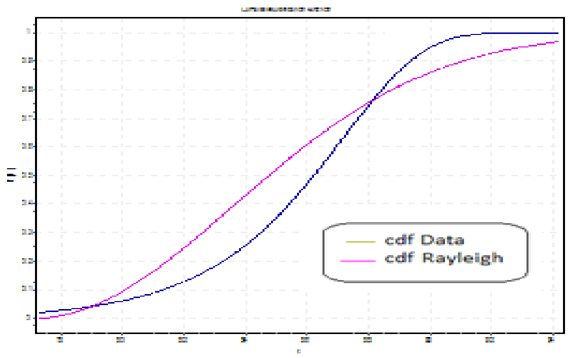

Fig 14: Comparison of experimental data Distribution with Rayleigh Distribution

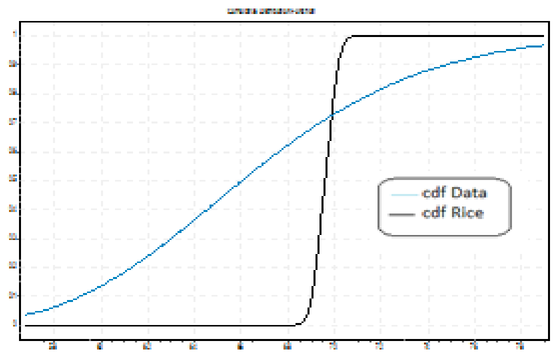

Fig 15: Comparison of experimental data Distribution with Rice distribution

The signal strength received at first Floor inside the building due to transmitter at ground floor is of importance. Fig 12 depicts that mean path loss reaches to 4.26 as the no. of floors between transmitter and receiver increases. The above figure reveals that fading distribution strictly follows Rayleigh distribution.

5. CONCLUSION

We have investigated the data obtained from a series of rigorous measurements at 2.4 GHz. Single-slope propagation models have been derived. Path loss exponent presented proves that indoor LOS radio channel can have path loss exponent below the free space loss, i.e., two. This can be explained by the fact that indoor radio channel is very rich of reflected signals who gains the received signal. The candidate amplitude distributions named Rice, Rayleigh and Lognormal were tested using a Kolmogorov- Smirnov's goodness-of-fit test. Table 2 shows the results of the entire test in all the measured environments.

Table 2: Pass Rates of Multipath Fading Distribution for various scenarios

Distribution In % fit	LOS (Ground Floor)	NLOS (Ground Floor)	NLOS (First Floor)
Lognormal Distribution	93	77	86
Rayleigh Distribution	64	72	82
Rice distribution	78	42	22

From the measurement and simulation analysis , Considering the ray tracing vector summation approach, it was found that for LOS and NLOS cases the results extracted from the ray tracing algorithm follow closely the fluctuations of the measured signal for all examined trajectories. These models will be useful for the rapid deployment and link design for wireless local loops and internet access systems in Indoor scenarios.

6. ACKNOWLEDGMENT

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