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Path loss Determination Using Hata Model and Effect of Path loss in OFDM

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***Abstract*—The aim is to adopt a modified propagation model for the Chennai area in which examine the applicability of Okumura-Hata model for LTE frequency band 3 (1800 band) and then analyze the performance characteristics of OFDM which is used in LTE. The performance of wireless communication systems is mainly governed by the wireless channel environment. In the investigation the variation in path loss between the measured and predicted values has been analyzed. Due to the growing interest of high data rate and bandwidth constrains, the new technology is adopted as OFDM, in the latest generation communication system 4G. The performance comparison of the OFDM is evaluated by considering the effect of path loss. The goal of the paper is to evaluate the performance of OFDM through HATA model**

***Index Terms*— Drive test, OFDM, Okumura-Hata, Optimization, Path loss.**

I. INTRODUCTION

Since the mid 1990's the cellular communications industry has witnessed rapid growth. Wireless mobile communication networks have become much more pervasive than anyone ever imagined when cellular concept was first developed. From the beginning of the 20th century onwards researches has been going on to provide new methods and products for wireless communication in order to exchange of the multimedia information. High quality and high capacity network are in need today, for that estimating coverage accurately has become exceedingly important. Therefore for more accurate design coverage of modern cellular networks, measurement of signal strength must be taken into consideration, thus to provide efficient and reliable coverage area. The nature of the radio channel affects the transmission of information through it. One of the major challenges facing engineers in mobile radio design has been modeling an accurate radio channel and its characteristics. The electromagnetic wave propagation can generally be attributed to scattering, diffraction and reflection. Because of multiple reflections from various objects, they travel along different paths of varying lengths. Most cellular radio systems operate in urban areas where there is no direct line-of-sight path between the transmitter and receiver and also there is presence of high rise buildings causes severe diffraction loss. The more commonly used propagation data for mobile communications is Okumura's measurements and this is recognized by the International Telecommunication Union (ITU). OFDM is seen as a possible candidate for Fourth Generation (4G) wireless systems that demand higher data rates in order to support the anticipated multi-media intensive applications for voice and data transmissions. The demand for high data rates in 4G systems causes the transmitted signals to be subjected to frequency-selective fading.

II. RELATED WORK AND AIM OF RESEARCH

Radio propagation is essential for emerging technologies with appropriate design, deployment and management strategies for any wireless network. It is heavily site specific and can vary significantly depending on terrain, frequency of operation, velocity of mobile terminal, interface sources and other dynamic factor. Accurate characterization of radio channel through key parameters and a mathematical model is important for predicting signal coverage, achievable data rates, BER and Antenna gain. Wireless system has high Bit Error Rate (BER) and poor performance without equalization. Fading is not same for every communication system and inter Symbol Interference (ISI) is also one of the main problem in our communication systems. This project presents the detailed study on model, Hata Model and this is the most popular model that being used widely for Urban Areas. The Radio propagation model that was built using the data collected in the city of Tokyo, Japan and analyzed mathematically. The nature of the radio channel affects the transmission of information through it. The interaction between the electromagnetic waves and the environment reduces the signal strength send from transmitter to receiver that causes path loss [1]. One of the major challenges facing engineers in mobile radio design has been modeling an accurate radio channel and its characteristics. If there is no line of sight (LOS) communication between transmitter and receiver, generally there are very many particles to cause scattering in this region, the Rayleigh fading statistical model may usefully predict behavior and performance in this kind of systems.

Propagation models are broadly classified into two categories namely Large Scale Propagation and Small Scale Propagation models. They have been studied extensively to assess the effects of channels on the transmission and reception of signals in wireless conditions. Some common properties to be considered for channel design include fading, Doppler Effect, diffraction, line of sight and propagation delay. Also the environmental properties affect the radio channel includes Urban/Hilly/Rural terrain, indoor/outdoor environment and weather conditions including humidity factor. The choice of system architecture and optimization of system parameters for communications are dependent on the channel conditions. Now days there are different models to calculate the path loss such as empirical and semi deterministic models.

Large scale path loss modeling plays a fundamental role in designing both fixed and mobile radio systems. Predicting the radio coverage area of a system is not done in a standard manner. For proper selection of Base Trans receiver Station (BTS) parameters needs the proper selection of the particular communication model which show good result by considering these parameters [1].

Propagation models can be classified mainly into two extremes, i.e. fully empirical models and Deterministic models. There are some models which have the characteristics of both types. Those are known as Semi-empirical models. Empirical models are based on practically measured data. Only few parameters are used in these models. So it is simple but not very accurate. The empirical models are mainly used to analysis the behavior of macro cellular environment. These include Hata model, Okumura model. On the other hand, deterministic models are very accurate. Some of the examples include Ray Tracing and Ikegami model. Semi-empirical models are based on both empirical data and deterministic aspects. All these models estimate the mean path loss based on parameters such as antenna heights of the transmitter and Receiver, distance between them, etc. These models have been extensively validated for mobile networks. Most of these models are based on a systematic interpretation of measurement data obtained in the service area.

Okumura model is the most popular model that being used widely. The Okumura model for urban areas is a radio propagation model that was built using the data collected in the city of Tokyo, Japan. The model is ideal for using in cities with many urban structures but not many tall blocking structures. The model served as a base for Hata models. Okumura model was built into three modes which are urban, suburban and open areas. The model for urban areas was built first and used as the base for suburban and open areas. Clutter and terrain categories for open areas are there are no tall trees or buildings in path, plot of land cleared for 200-400m. The examples for open areas are farmland and open fields. For suburban area the categories is village or highway scattered with trees and houses which contain few obstacles near the mobile. Urban area categories is built up city or large town with large buildings and houses with two or more floors or larger villager with close houses and tall, thickly grown trees.

The response from Okumura model with respective the terrain is slow .There for a new model is proposed by Hata which is make use of Okumuras plots. Hata established empirical mathematical relationships to describe the graphical information given by Okumura. Hata's formulation is limited to certain ranges of input parameters and is applicable only over quasi-smooth terrain.

To improving the accuracy in predicting propagation models it has to consider path loss over irregular terrain, various methods, which are often computationally intensive. These models are being increasingly used for radio network planning. The prediction of field strength in a terrestrial environment is a complex task, e.g., when obstruction by terrain and/or scattering from objects is involved. Various modeling methods have been proposed for each correction factor, which have been incorporated in different versions of the Recommendation.

Here the Hata model is redefining with the clutter in Chennai for LTE frequency band 3 (1800 MHz band). Then compare the characteristics of OFDM which is used in the existing LTE with and without effect of path loss.

III. Methodology and Discussion

In this proposed work contains the study of path loss in the Chennai area for LTE. The study is conducted in Bharthi Airtel and it is using 1800 Mhz band which is having the LTE band number as Band 3.The uplink frequency used is 1710 – 1785 and the down link frequency is 1805 -1880. Then OFDM is analyzed with different modulation schemes. The analysis is based on the presence of path loss and without considering the path loss.

The Okumura Model is commonly used to predict the path loss. But Okumura Model is having the disadvantage as the response with respective terrine change is slow. Hata redefined a model in which Okumura's plots are modified in to an empirical model and correction factors added which gives good response when the clutter is having changes. The existing model is based on the field measurement taken in Japan. The terrine conditions are different from Japan and the clutter density is different and it is decreased. In this work the Hata model is redefining with real field optimization in Chennai for the LTE sites.

The experiments conducted in a cluster of sites and the observations are made. For the reference, here it is consider only one site. The site or cluster under observation will optimize first. Optimization is a procedure which is used to identify and rectify the performance affecting problems within the constraints of an existing network infrastructure. Then received signal code power (RSCP) will be collected which will give the measure of received power in the mobile handset or user equipment (UE). In some UE it will be displayed. Here we are collecting the received signal code power using the software Huawei GENEX Prob and the procedure of collecting the received signal code power is called drive test which is explained later.

The collected signals are saved in the personal computer where the software is installed and it is analyzed using Huawei GENEX Assistant, and MapInfo. From Huawei GENEX Assistant it is possible to export the different all the mobile and mobile network related parameter in the air interface ie between mobile and enodB which is able to collect by Huawei GENEX Prob which is the drive test tool. The Transmitting power will be constant for each operator thus it is able to calculate the path loss. Then plot the path loss vs. distance. Then analysis is done in OFDM with and without path loss which is used in the existing LTE

In the present LTE system is used Orthogonal Frequency Division Multiplexing (OFDM) and it is seen as a technique that uses parallel transmission of data through different sub channels that are orthogonal to each other thereby lowering the bit rate per carrier. The path loss is calculated by using Okumura-Hata Model and the existing model is developed long back and the data used to develop the plots are collected from the Japan terrine. The terrine condition here in Japan and in Chennai is different. The characteristics such as vegetation, building, clutter density etc.. are different and it also plays major role in the signal propagation. For the analysis we took a LTE site in Chennai and conducted drive test. The drive test process is explained in detail in the next section. From the test we can observe the signal strength .The transmitted power set for LTE 1800 FDD used is 43 dbm in Bharathi Airtel. A processing tool is used to obtain the received signal strength at each point of time and position. Then we can calculate the path loss.

The observed path loss and the theoretical path loss compared by using Matlab and the correction factor will be applied and the present model will change to the customized model for Chennai clutter.

The basic Okumura –Hata model is the most famous and commonly used model and it is made by extensive measurements .Hata transformed Okumura's plots to an empirical model and it is valid for 150-1500 MHz .

Model takes the effect of Transmitter height (hb) in m, receiver height(hm) in m, frequency (fc) in MHz, distance (d) in km and different environments

$$L = \begin{cases} A + B\log d & Urban \\ A + B\log d - C & Suburban \\ A + B\log d - D & Open \end{cases}$$

$$A = 69.55 + 26.16\log|fc| - 13.86\log|hb| - a|hm|$$

$$B = 44.19 - 6.55\log|hb|$$

$$C = 5.4 + 2[\log|fc/28|]^2$$

$$D = 40.94 + 4.78[\log|fc|]^2 - 19.33\log|fc|$$

$$a|hm| = \begin{cases} 1.1\log|fc - 0.7hm - 1.56|fc| - 0.8| & Medium \\ 8.28[\log|1.54hm|^2] - 1.1 & Largecity \\ 3.2\log[|11.75hm|^2] - 4.97 & fc \le 400 largecity \end{cases}$$

The path loss can be calculated from the transmitted and received power. The received power can be computed from the real field measurement and the transmitted power is fixed for each mobile operator. In this case the transmitted power is set as 40 dBm.

$$PL(dB) = 10\log[Pt/\Pr]$$

Pt and Pr are the transmitted and received power in Watts respectively. Then mean square error (MSE) was calculated between measured path loss value and those predicted values by Hata model.

$$MSE = \sqrt{\frac{\sum (Pm - \Pr)^2}{(N-1)}}$$

Where Pm is measured path loss
Pr is predicted path loss
N is number of measured data points

The mean square error is calculated and it is subtracted from the basic Hata model equation which is derived for the area Japan

The terrain in Chennai area (the observed area) can be considered as a suburban area and the difference is subtracted form the original Hata model equation and the modified result of Hata equation in sub-urban area for Chennai area is

TABLE I: TOOLS USED

Airtel LTE 4G	Specification / Details
1) Test UE model	E392
2) Drive Test Software & version	Huawei GENEX Probe V2R3C02
3) GPS Type / Model	Garmin GPS Spanner
4) Drive Test Analysis Software & Version	Huawei GENEX Assistant V3R3C02/Agilent/Mapinfo
5) Data analysis tool	MATLAB

IV. Drive Test and Radio Network Optimization

The industry is also becoming intensely competitive. Service providers must continually strive to improve their quality of service if they want to keep customers. In this environment, high quality of service is a competitive advantage for a service provider. Quality of service can be characterized by such factors as contiguity of coverage, accessibility to the network, data rate and number of dropped sessions. If too much time is spent simply reacting to customer complaints, there may not be enough time to improve overall service quality. Therefore, service providers need the ability to fix complaint-producing problems quickly by measuring the signal strength and quality of service. The solution for this problem is Drive test and optimization.

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A. *Drive Test*

The primary tool used by most service providers to solve network problems is a drive-test system. Drive test is a Phone-based test and it integrate phone-and-receiver-based solutions A conventional drive-test system is comprised of a test mobile phone or a data card, software to control and a Global Positioning System (GPS) receiver for position information. A test data card gives a customer's view of the network, but can only indicate the type of problem that exists. It cannot show the cause of the problem.

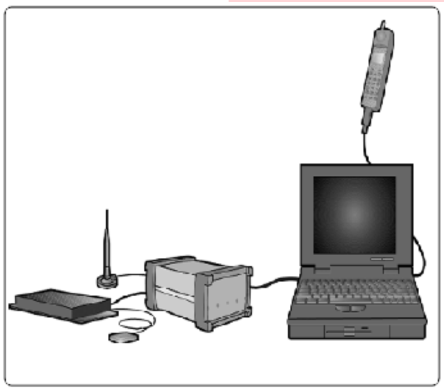

Fig. 1. Drive test set up.

Drive testing consists of test teams driving on pre-defined routes in a network region and periodically initiating calls or data sessions and measuring signal strength. The results are transferred from the MS to a dedicated PC where the various data groups are processed in order to produce graphical and tabular data. A coverage plot of a service area is obtained by placing the test mobile of the drive-test system in the idle mode and driving through the service area measuring the Reference Signal Received Power (RSRP). Reference Signal Received Power (RSRP) is then plotted against GPS information to obtain a coverage plot.

B. *Radio Network Optimization*

The mobile network definition of optimization is 'The identification and rectification of performance affecting problems within the constraints of an existing network infrastructure.' Optimization is an important step in the life cycle of a wireless network. Optimization is a part of the performance management process. The objective of the radio network optimization is to extract the optimum performance from the cellular network, at any given phase of its lifecycle. All cellular systems will be associated with continuous change, with new radio sites being introduced, old sites being enhanced and assigned additional frequencies, Omni-directional sites being sectorised, new frequency plans being implemented in different regions, etc. The initial step in performance management is to define a set of QoS (Quality of Service) parameters such as dropped call rates and session success rates. Key metrics are derived from data collected from sources such as drive tests, statistical data, customer complaints and field engineer reports and are used to measure the performance of the network. These metrics are analyzed and compared to the QoS targets in order to identify any performance degradation in the network. If problematic areas are identified from analysis of the network performance parameters, corrective processes and/or procedures are implemented to rectify the situation using one or a combination of techniques. This process of corrective actions is known as optimization.

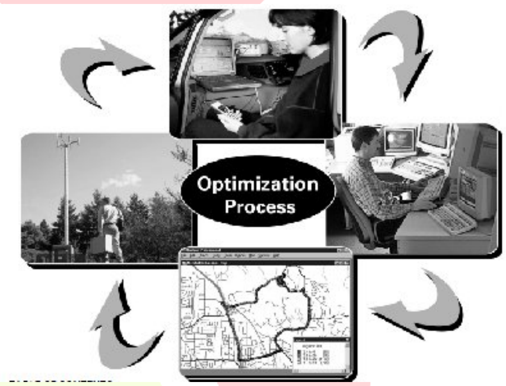

Fig. 2. Optimization Cycle.

V. Experimental Results

The existing theoretical Hata model is described in the previous section. The path loss vs. distance is plotted which is derived from the set of equation.

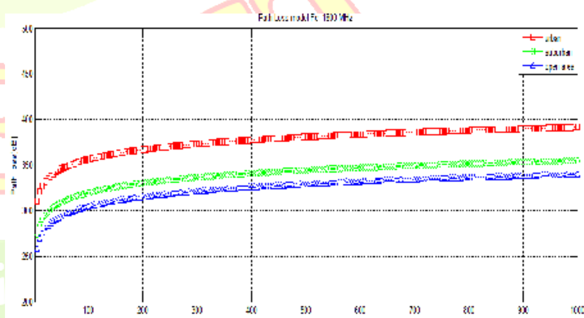

Fig. 3. Hata model.

Genex tool was used to measure the signal strength level for uplink and downlink at coverage areas for a cell in the road of Chennai. The road of Chennai can be considered as sub-urban and therefore equivalent equations of Okumura-hata models were used. Path loss was determined by practical measurement for each distance, and then on that basis a comparison was done between theoretical and experimental values by MATLAB. The physical parameters of the evaluated site is shown bellow.

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TABLE I: PHYSICAL SITE PARAMETERS

Channels	Bandwidth Provision in MHZ	Channel Bandwidth	Lat/Long	Cell ID	PCI
CHN_4G_VELCH	DL: 1833.5-1838.5 UL: 1738.5-1743.5	5 MHZ	12.994/ 80.2175	1	357
				2	358
				3	398

The drive test is conducted in the site CHN_4G_VELCHP and the real field optimization is done. The live display will be provided by the Genex Probe.

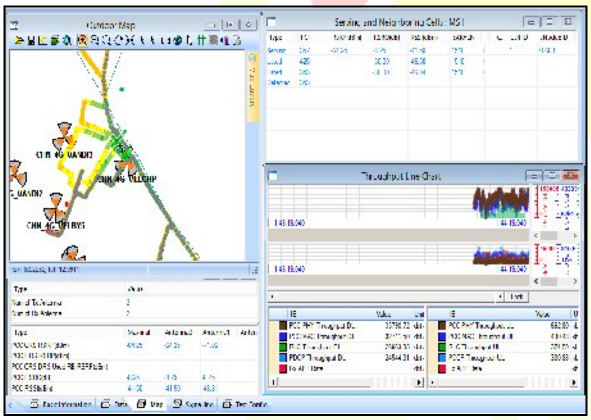

Fig. 4. Genex Probe Output.

The recorded values are processed by Genex assistant and exported as tab file. The Tab files can be analyzed using the MapInfo

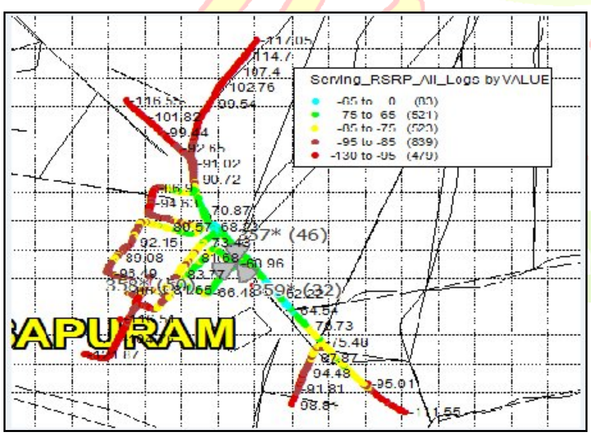

Fig. 5. Mapinfo Output.

For the ease of calculation the values plotted at each 100 meters and the values taken in the main lobe direction. The selected values of received signals are shown in the below figure.

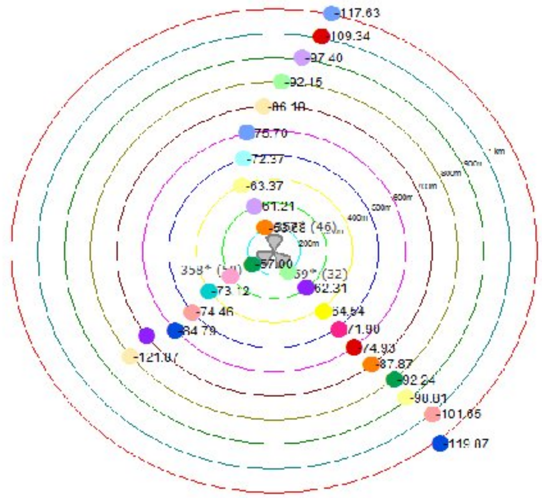

Fig. 6. Segregated MapInfo Output.

The path loss is calculated using the equation. The transmitted power is taken as 43 dbm and it is defined by the operator. The path loss vs distance is plotted in Matlab .

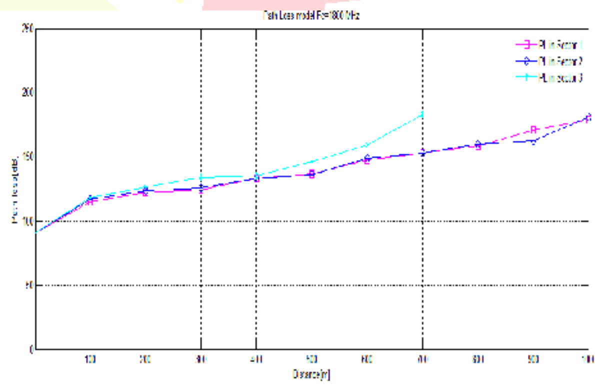

Fig. 7. Practical path loss model.

Then we can compare the theoretical Hata model developed by Hata and the practical values we got in Chennai location.

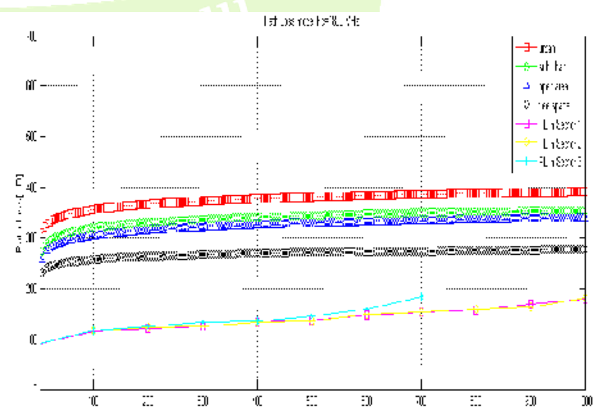

Fig. 8. Hata model and practical model.

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This clearly shows that measured path loss is less than predicted path loss. This difference is because of many reasons one of the reason is the geographical situation of Chennai is different from that of Japan. Now, mean square error (MSE) was calculated between measured path loss value and those predicted by Hata model.

The MSE was found to be around 170 dB. Therefore the MSE was subtracted from the Hata equation .The the modified equation is

$$L = A + B\log d - C - 170$$

The correction factor can be applied for the Chennai suburban area because the same test is repeated in different site in the nearby locations. Then the resulted plot is shown in figure 8

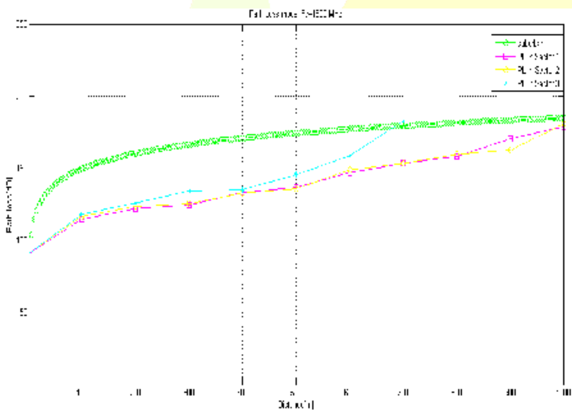

Fig. 9. Hata model with correction factor.

Then Performance of OFDM with variable M-ary QAM is analyzed. The figure shows that by increasing the value of M, the BER also gets increased as in case of the QAM. Square QAM is normally used to reduce the effect of fading. In the following figure Nfft (N point FFT/ifft) is taken as 64 and with the addition of 25% cyclic prefix it is transmitted and performance is evaluated. M-16,32 and 64 is compared in the following plot.

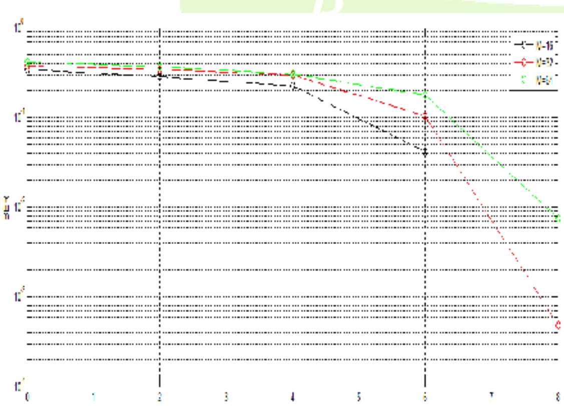

Fig. 10. BER performance of OFDM.

Performance of OFDM using Hata-Okumura Model is plotted with and without path loss. The figure give below is plotted with N point FFT/IFFT is 64 and M=64. The effect of path loss is considered in this simulation result. Hata-Okumura model is having sufficient path loss and here conceded the suburban area for the plot.The path loss is obtained from the test conducted in the on field.

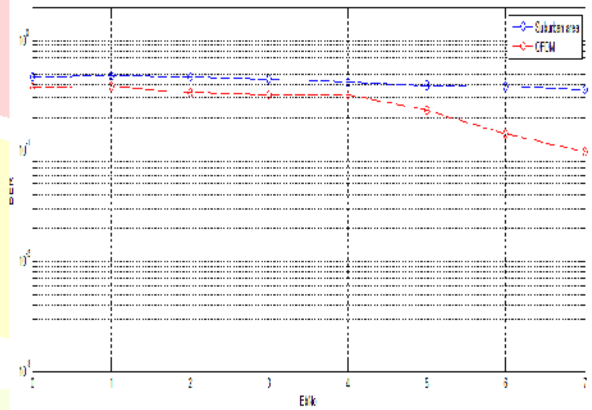

Fig. 11. OFDM With and without path loss.

VI. Conclusion and Future Works

The research work of this thesis is entirely devoted to the investigations of an OFDM downlink multipath fading channel environments along with the circumstance of path loss. This work was aimed on predicting the mean signal strength of Chennai. Today's predictions models differ in their applicability over different environmental and terrain conditions. There are many predictions methods based on deterministic processes through the availability of improved data values, but still the Hata model is most commonly used empirical propagation model. That is because of the ITU-R recommendation for its proven reliability and its simplicity. By using the Okumura-Hata model obtained the path loss and compared OFDM with and without path loss

Throughout this thesis, perfect synchronization and Channel State Information (CSI) is known at the receiver is assumed. With the assumptions, comparative studies of the OFDM is plotted and evaluated.

The future work includes the comparison of OFCDM scheme which combines both the advantages of both OFDM and CDMA with and without the effect of path loss. With sufficient amount of guard intervals, OFDM can wholly remove the effect of ISI. The SNR problem of OFDM is taken care with the help of CDMA.

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