Characterization of Fading and Path Loss on WiMAX at 2.6GHz Frequency Band for Cell Planning.

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***Abstract* - Statistical characterization of fading is a key aspect for the analysis and simulation of wireless communication systems. Links are usually obstructed by buildings, trees and moving traffic such as car, taxi etc. such links are susceptible to fading. In present study, characterization of fading on such links on WiMAX at frequency band of 2.6 GHz is carried out. Based upon received signal strength collected in a typical suburban environment which takes care of LOS and Non-LOS propagation based on diffraction and scattering consist of moderate height trees, single storied buildings and open field area with transmitting site located at 35 m above ground level, the increase in fading with distance is plotted on graphs. Result shows how signal fading in this band vary with distance. The evaluation of fading and path loss help to create properly the determination of cell size.**

***Index Terms* - OFDM, WiMAX, IEEE 802.16, Path Loss exponent, Large-scale fading and Small-scale fading, RSSI.**

I. INTRODUCTION

Channel characterization, deals with the fidelity of received signal, and has to do with the nature of the waveform received at a receiver. OFDM technology has been implemented through WiMAX at frequency bands of 2.6 GHz and 3.3 GHz in India. The wavelength in these cellular bands is thus a fraction of a meter. With a limit on the transmit power (either at the base-station or at the mobile), the largest distance between the base-station and a mobile at which communication can reliably take place is called the coverage of the cell. For reliable communication, a minimal received power level has to be met and thus the fast decay of power with distance constrains cell coverage. On the other hand, rapid signal attenuation with distance is also helpful; it reduces the interference between adjacent cells. The path loss is associated with the design of base stations, as it tells us how much a transmitter needs to radiate to service a given region.

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The received power decreases with distance there are several obstacles between the transmitter and the receiver, the obstacles might also absorb some power while scattering the rest. At large distances the power can even decay exponentially with distance.

The general term fading is used to describe fluctuations in the envelope of a transmitted radio signal. However, when speaking of such fluctuations, one must consider whether the observation has been made over short distances or long distances. For a wireless channel, the former case will show rapid fluctuations in the signal's envelope, while the latter will give a more slowly varying, averaged view [1]. For this reason, the first scenario is formally called small-scale fading, while the second scenario is referred to as large-scale fading. The propagation factors that affect the strength of the received signals in wireless communication systems are the path loss, large-scale fading and small-scale fading. The path loss is basically a drop in signal power as a function of distance. When a mobile receiver moves away from the base station, i.e. when the distance increases, the signal will become weaker because of power loss in the transmission medium. For free-space propagation, the signal strength is inversely proportional to the distance squared (i.e., $1/d^2$ where d is the distance between the transmitter and receiver). The path loss has the lowest rate of change of the three factors and the attenuation normally reaches 100-120 dB in the coverage area.

The large-scale fading varies faster than path loss and is normally described as a log-normal distributed stochastic process around the mean of path loss. This type of fading is introduced because of the shadowing from buildings and other structures in the environment. The large-scale fading introduces attenuations of about 6-10 dB[2].

The small-scale fading is, as the name implies, the fastest varying mechanism. It is introduced as a consequence of the multipath propagation together with the time-varying nature of the channel. The small-scale fading attenuates the signal with up to 40dB when the mobile moves as short as half a wavelength [3].
This paper presents characterization of fading parameters of wireless channel. Section II gives the introduction of large scale fading, small scale fading

and path loss. The various studies already conducted on several mobile communication technologies and results obtained has been stated in Section III. Base station setup, Subscriber Station location arrangements and methodology of data collection has been elaborated in Section IV. Processing of data and results obtained has been given in Section V. followed by discussions and conclusion has been drawn in Section VI.

II. SMALL SCALE FADING, LARGE SCALE FADING AND PATH LOSS

Large-scale fading is more relevant to issues such as cell-site planning. Small-scale multipath fading is more relevant to the design of reliable and efficient communication systems.

• Large-scale fading, due to path loss of signal as a function of distance and shadowing by large objects such as buildings and hills. This occurs as the mobile moves through a distance of the order of the cell size, and is typically frequency independent [4].

• Small-scale fading, due to the constructive and destructive interference of the multiple signal paths between the transmitter and receiver. This occurs at the spatial scale of the order of the carrier wavelength, and is frequency dependent.

In this paper, we will concern ourselves with small scale fading and large-scale fading. Received power or its reciprocal, path loss, is generally the most important parameter predicted by large-scale propagation models. The three main propagation mechanisms that determine path loss are refraction, reflection and scattering.

Path loss is defined as the difference between transmitted power and received power,

$$\text{Path loss} = \text{Transmitted power} + \text{gain} - \text{Received power} \quad (1)$$

Here, we have used the transmitting power of 40 dbi and transmitting antenna gain of 17 dbi.

Path loss is the reduction in signal strength when it propagates from Tx to Rx. Various parameters reduces the signal strength such as height of antenna, distance between Tx and Rx, obstacles such as trees, buildings, etc. transmitted power and antenna gain.

A general model which includes path loss exponent and shadow fading factor is given as

$$PL(dB) = PL(d_0) + 10\,\gamma \log(d/d_0) + \sigma \quad (2)$$

Where, $PL(d_0)$ is the path loss at the reference distance d_0 usually taken as 100 m, γ is the path loss exponent, σ is the standard deviation of received signals and d is the distance between Tx and Rx [5]. Losses are measured in dBm and d is in meters. We evaluate all the above three terms to calculate fading.

For small scale and large scale fading

$$\sigma = \sqrt{(\sigma_s^2+\sigma_l^2)} \quad (3)$$

Where, σ_s and σ_l are the standard deviations for small scale and large scale fading respectively. A plot of Received Signal Strength Indicator (RSSI) with distance from transmitter may be considered as radial coverage.

III. RELATED WORKS

Deployment of mobile wireless communications systems in suburban environments has attracted considerable interest in recent years as: common carriers seek methods for providing network access services to residential households without the expense of deploying wire line connectivity over the last mile [6]. In suburban environments, wireless links are usually obstructed by intervening obstacles and most of the signal that reaches the receiver does so as a result of scattering and diffraction by objects in the environment. During the past decade, groups in Canada, the United States, the United Kingdom, Chile, Australia and elsewhere have conducted measurement campaigns aimed at characterizing the manner in which signal fading occurs on non-line-of-sight (NLOS) paths in macrocell environments, e.g., [7,8].A study was conducted in 2007 to estimate the coverage of WiMAX based on IEEE 802.16 D at Kalyani, a suburban area of Kolkata City, for estimation of both line of sight(LOS) and Non Line of Sight (NLOS) performance [9]. RSSI and CINR were thoroughly measured for WiMAX coverage in desert and hilly areas deploying an outdoor CPE having 13db gain at a height of 3m up to a distance of 9 km [10].Such studies have variously sought to characterize: (1) the first-order statistics of the fading signal envelope over time and location, (2) the rate at which the signal fades, either through direct estimation of the Doppler spectrum or through estimation of the average fade duration ,(3) the effect of the height and beam width of the receiving antenna,(3) local density trees, buildings and high speed moving traffic in the vicinity, and (4) the distance between the base station or the receiver terminal. Regulators are increasingly designating multiple primary allocations within individual frequency bands, as well as proposing more flexible licensing schemes, in an attempt to accommodate different users and services in the same spectrum. RF spectrum above 2 GHz that has traditionally been used for broadcasting and fixed point-to-point applications is increasingly being transferred to mobility and fixed point-to-multipoint applications. Thus, the amount of radio spectrum, and the choice of frequency bands available for fixed point-to-multipoint applications, will almost certainly increase in coming years. The manner in which path loss, or its reciprocal, path gain, is affected by the carrier frequency, the heights of and separation between the base station and mobile terminal in suburban environments over the range from 200 MHz to 2 GHz has been well-studied over the years and has been captured by several standard models [11]- [13]. However, existing channel models do not provide a description of the depth of signal fading that wireless channels will experience over this frequency range in suburban environments. Ref. [14] describes fading on UHF links within a tropical rain forest but the link configuration was quite different from that encountered in suburban macrocells. This lack of information places those charged with planning, simulating or deploying fixed wireless systems in suburban macrocell environments at a severe disadvantage when asked to predict system coverage and outage probabilities.

Study of all above reference reveals that there is very little approach to evaluate channel characterization in suburban environment. Indian people live majorly in suburban areas for which little, or even none, channel characterization exists. Here, we calculate fading parameters for the frequency range of 2.6 GHz. The received signal strength observed at different locations at ranges from 1 to 3.5 km. We reduced the data in order to determine the manner in which path gain and signal fading vary with distance, and carrier frequency. The resulting measurement-based model allows one to compare the coverage and outage probability that links at different frequencies would experience in a typical suburban environment.

IV. STUDY SETUP AND OBSERVATION

A. Base Station:

Base Station is installed at Kariapatti in Tamil Nadu province of India. Kariapatti is located around 24 Km in Tamil Nadu. It is situated near Madurai-Thuthookudi National Highway 45B. Kariapatti tower is just 2 Km from National Highway in east direction. The tower also shares other Antenna assemblies and Radio Resource Unit (RRU). The antenna assembly is located at a height of 35m.The output power at antenna connector is set at 40 dBm and antenna used has dual element system (2 Rx/1 Tx) with gain of 17 dbi. The antenna orientations are set at 60^0-180^0-300^0 respectively. The frequencies used are in of 5 MHz bandwidth each and from 2.6 GHz. The system uses Time Division Duplexing, convolution turbo code and Adaptive Multiple Antenna.

B. Measurement environment:

In near zone (fig1), the measurement passed through very close range of tower towards North-West direction which has a clear line of sight situation. It is observed that path-loss steadily increases after a distance of 0.232km after which direct signal from BS and reflected signal from road starts to combine constructively resulting in reduction in path loss. The combining continued up to a distance 1.95km after which fading due to distance factor starts to dominate and hence positive slope for path loss. The observation continued up to 3.25m on line of sight.

The data was collected up to a distance of 3.25km from the BTS. At around 0.232 km the Rx is in a close proximity to BTS results in a fall of signal. Around 0.54 km the way is surrounded by few populated area comprising of maximum single storey buildings LOS exist between Tx and Rx and allow the signal to propagate with little suffering from diffraction, reflection, absorption and scattering. Around 0.659 km on the left side of the way having many buildings stops the signal to reach the receiver results in fall of signal. From 1km to 1.2 km, Rx is inside the city even if LOS is available, the received signal undergoes deterioration/ improvement due to additional reflections and scattering by road and local moving traffic e.g. bus, taxi. At the distance around 1.65 km to 1.92 km again having number of buildings on the left side causes poor LOS. From 1.95km towards National Highway on the right side of the way are having a few populated areas the signal is reflected from the buildings and reaches the Rx. On the way around 2.03km is a regular terrain with a few medium height trees which causes ups and down of signal. At 3.25 km towards Madurai the Rx is on the National Highway45B. Field strength of signal decreases with increase in distance between BTS and Rx.

C. Subscriber Station (SS) Setup

An outdoor SS was chosen for the measurements. The SS, laptop, dongle and GPS all were mounted inside a vehicle. The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. A dongle is a small piece of hardware that attaches to laptop and that enables additional functions such as audio, video, data, or other services. On the roof of the vehicle an outdoor antenna was mounted to get maximum signal strength. The total height of the antenna was at 3 m which, on an average, was equal to height of average buildings in suburban areas and line of sight signal was mostly obtained. The output at the antenna connector was 23 dBm and had a gain of 3 dBm. The laptop was loaded with driver software for measurement of signal parameters and attached to a server. RF performances were also monitored at Access Service Network (ASN) Gateway for uplink parameters.

V. RESULTS AND DISCUSSIONS

Fig(1) shows the graph of Received signal strength which is plotted against distance, observations for small scale fading with an average of 0.5 λ and an average of 50 λ for large scale fading are calculated and results are plotted on graphs are shown in fig(2) and (3), and further the graph for signal strength distribution is shown in fig(4) and (5).

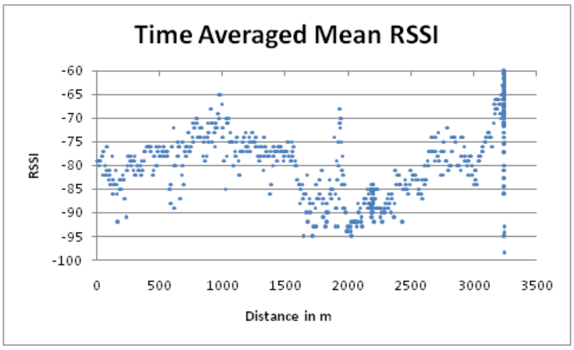

Fig 1: Estimated RSSI versus Distance as a function of Path Loss

As the Receiver (fig.1) is in close proximity to BTS drop of -90 dBm is observed at 0.232 km after which direct signal from BS and reflected signal from road starts to combine constructively resulting in reduction in path loss. From a distance of 1.95km, signal mostly varies between -65 to -85 dBm after which fading due to distance factor starts to dominate and hence positive slope for path loss. Around 0.54 km, -75 to -85 dBm is obtained due to LOS exist between Tx and Rx. No. of buildings on the left side of the way at around 0.6 km results in fall of signal i.e. -88 dBm. From 1km to1.5 km, value of RSSI is between -65 to -80 dBm. Signal reflection from the buildings on the right hand side of the road shows good signal strength of -68dBm at ~1.95km. From 1007 m to 2032 m, is the region where small scale fading is observed. At 2.5 km towards Madurai the Rx is on the National Highway45B. Field strength of signal decreases with increase in distance between BTS and Rx. Large scale fading is observed in the region from around 3240 m to 3242 m which is plotted on the graph. ~3241m, graph showing drop of signal i.e. -93 dBm shown in fig (1).

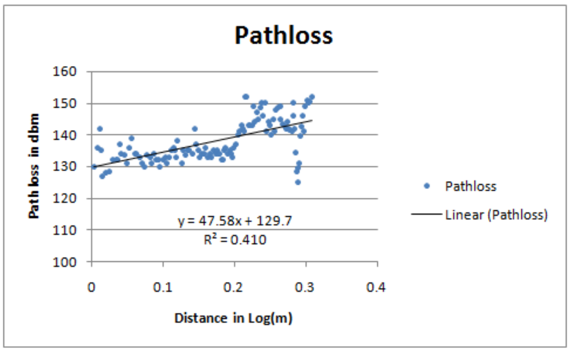

Fig 2: Large scale fading obtained from 1007m to 2032m

The contour covers in-between open field area, moderate height trees, diffraction from single storied buildings, deterioration/ improvement of received signal due to additional reflections and scattering by road and local moving traffic e.g. bus, taxi up to a distance of 3.5 km. The combined environment path loss variation with distance (in log scale) has been shown in fig (2). The observed data is subjected to linear trendline for same distance and plotted. The path-loss exponent is 4.7587 and the fading σ is 6.41013 for a distance of 1007 m to 2032m at 35m antenna height. Fig 2 shows the graph drawn for large scale fading.

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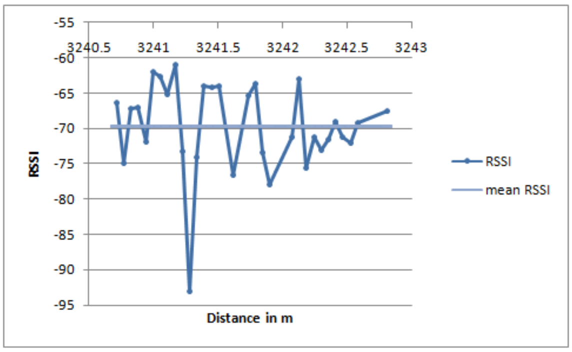

Fig 3: Small scale fading obtained from3240m to 3242m

Fig(3) showing graph for large scale fading. RSSI is mostly observed between -60 to -75 dbm whereas deep fading of -23 dbm is observed at a distance of 3241.3 km. Mean of -69.7665dbm is shown by a line drawn horizontally at the middle of the graph. The wavelength λ of electromagnetic radiation at any given frequency f is given by λ= c/f , where $c = 3\times10^8$m/s is the speed of light. The wavelength λ is taken as 0.5λ for small scale fading whereas for large scale fading it is taken as 50λ.

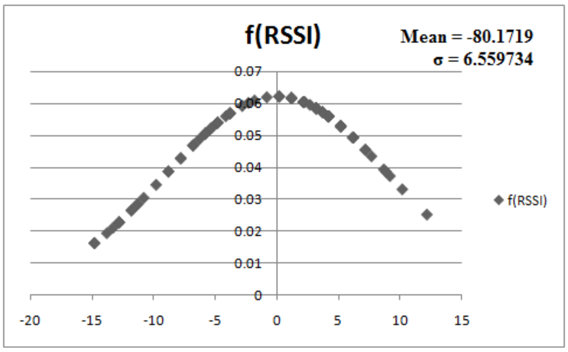

Fig 4: Signal strength distribution and Rayleigh fading factor estimation for the distance of 1007m to 2032m obtained for large scale fading.

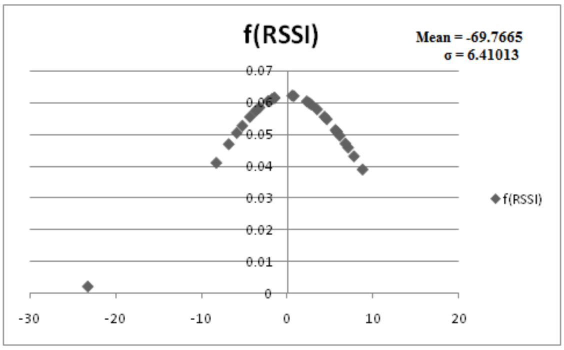

Fig 5: Signal strength distribution and Rayleigh fading factor estimation for the distance of 3240m to 3242m obtained for large scale fading.

Signal strength distribution at the periphery of the cell and Rayleigh fading factor estimation is shown in fig (4) and (5). Hence from graph, we get the loss equation in dbm at a distance d meters as

$$L\ (dbm) = 120.52 + 10*4.758 \log10(d/d_0) + 9.18$$

Where, d and d_0 are in meters and d_0=1000m

VI. CONCLUSION

In this paper we have used 2.6 GHz licensed band with WiMAX technology. Therefore, it is important to study the signal coverage on this band to provide channel data to the operators in order to allow them reach a good coverage planning. Besides this, the determination of some wideband parameters is important to choose, for example, the appropriate data transmission rate in this kind of environment. Indian people live majorly in suburban areas for which little, or even none, channel characterization exists. Hence, this work tries to fill this lack of information to help planners to do a better project. Thus, starting from measurements on the 2.6 GHz band in Kariapatti (a suburban environment), the small scale and large scale fading were estimated for a route of 1 to 3.5km and then, the path loss was determined which is used to predict the signal level in this area.

For large scale fading data is observed from a distance of 1007m to 2302 m. the value of path loss exponent so obtained is 4.758 which indicates better coverage with fading σ of 6.559734.

For small scale fading data is observed from a distance of 3240m to 3242 m and the fading σ is 6.41013. Deep fading of -23dbm is observed at a distance of 3241.3m.

From the statistical analysis of fading, it is observed that, although the signal has a good level, there is the possibility of deep fading, which can fail the communication, due to the multipath acting not only for enhancing the signal level but also reducing it. The extensive data array obtained from the measurements permitted to understand the suburban channel behavior, and to determine the main parameters, providing results that are mainly useful to the planners in order to improve the signal coverage on this kind of environment and the data transmission rate. Our most significant finding is that the depth of signal fading drops off rapidly as frequency decreases (or as wavelength increases).

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