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Radio Measurements in the WiMAX Band of 2.3 GHz, in Coastal Zone for Different Transmitting Antenna Heights

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Abstract— In this paper, comparison of propagation prediction models for WiMAX at 2.3 GHz for different transmitting antenna height is presented and path loss for different models such as COST-231 Hata model, SUI model, the ECC model, ITU-R(NLOS) model for different transmitting antenna height is computed. The obtained path losses are graphically plotted for the better conclusion using the MATLAB. The paper studies the path loss models of the wideband channels at 2.3GHz for WiMAX.

Index Terms— Pathloss; path loss exponent; propagation model; WiMAX, propagation.

I. INTRODUCTION

Signal Propagation models are used extensively in network planning, particularly for conducting feasibility studies and performing initial system deployment. The path loss propagation models have been an active area of research in recent years. Path loss is unwanted signal strength reductions that signal suffers when propagating from transmitter to receiver. The losses present in a signal during propagation from base station to receiver may be classical and already existing. Also to increase the robustness of the transmitted information, it is needed to estimate the path loss introduced by a terrain over which the signal will propagate to sufficiently compensate for the power lost during signal propagation. The tremendous development in wireless communications leads to the emergence of new ideas and techniques to increase capacity and improve the QoS. The general trend in the development of wireless communication is the use of higher data rates (broader frequency band), propagation in more complex environments, employment of smart antennas, and use of multiple-input multiple-output (MIMO) systems with smaller cell sizes. Before implementing designs and confirming planning of wireless communication systems, accurate propagation characteristics of the environment should be known. Recent developments in the telecom sector of India showing the Government's initiative for the coverage of rural and urban areas with broadband systems spurred lots of activity in the WiMAX systems based on IEEE 802.16 standard. In the WiMAX technology, spectrum managers in India are allocating either 2.3 or 3.5 GHz band depending on availability. WiMAX carries the promise of ubiquitous broadband wireless access enabling real-time and multimedia applications. WiMAX networks are being deployed worldwide to bridge the digital divide and to help countries with no previous infrastructure provide broadband access to users.

This paper studies path loss and propagation models using deployed WiMAX network operating at a frequency of 2.3 GHz**.** The first major study reporting the comparison of different models with measurements taken at Cambridge, was reported by Abhayawardhana *etal*. [1] at 3.5 GHz. Similar studies were also conducted by Rial *etal*. [2] and Belloul *etal*. [3]. Path loss measurements in sea port for WiMAX is done for deploying wireless broadband communication in sea ports [4]. In present study, experiments were conducted in an urban zone with one side coastal region of Mumbai in western India. The signal levels have been converted into path loss values using antenna gain, feeder loss etc., and these have been compared with models like COST-231Hata [5], ECC [6], SUI [7] and ITU-R (NLOS) [8] for different transmitting antenna heights. For different transmitting antenna heights prediction errors and standard deviations are compared for those urban coastal zones.

In Section II, experimental set up and field set up have been provided. In Section III, measurements locations and routes are described. In Section IV, different path loss models are presented and in Section V, we analyzed the path loss of existing prediction methods for different transmitting antenna heights. The conclusions are presented in Section VI.

II. EXPERIMENTAL SET UP

The details of the base stations are shown in Table II. The transmitting antenna used in the present study was the omni-directional antenna TW2.3/OMNI/8dBi [9]. The transmitter and receiver used for experiment were Tortoise dual-band transmitter and Coyote dual-band receiver [10] at 2.3 GHz. The averaging of 512 samples per second in temporal and spatial zone (40 Lambda) has been done. The omni-directional receiver antenna with 2dBi gain was used for the present study.

III. MEASUREMENT LOCATIONS AND ROUTES

All four sites Electric Mansion (ETM), Gangasagar (CHS-GSC), Geetanjali (GTL) and Mistry Chambers (MCB) situated in urban coastal region of Mumbai, India as shown in Fig. 1. The clutter environment of these sites is shown in different colors as indicated in legend part of Fig. 1.

CHS-GSC lies in urban region and surrounded by high density vegetation at western side while at eastern and southern side, it has coastal region which starts at 0.2 Km. GTL and ETM shows presence of urban region and coastal area. Eastern side of MCB is water while urban area is present at western side. MCB lies at sea port.

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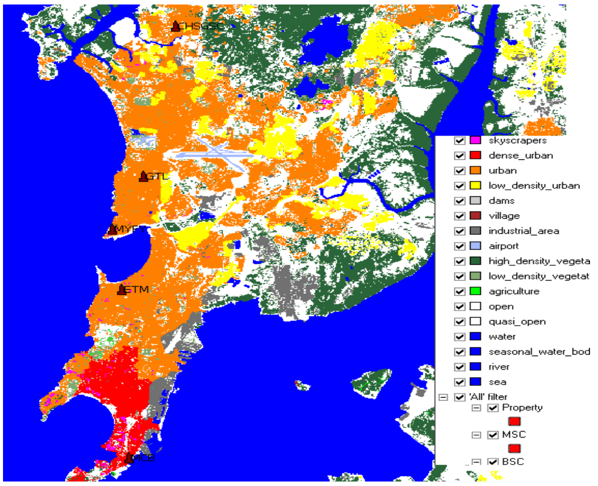

Fig. 1.Clutter environment for experimental sites (ETM, CHS -GSC, GTL, MCB)

IV. PROPAGATION PATH LOSS MODELS

A. *SUI Model*

The SUI model was developed under the Institute of Electrical and Electronics Engineers (IEEE) 802.16 working group for prediction of path loss in urban, suburban and rural environments [7]. The applicability of this model in the higher frequency has not been validated. However, due to the availability of correction factors for the operating frequency, this model is selected for this study. The path loss in SUI mode [1] is calculated using (1)

$$L = A + 10\,\gamma \log_{10}\left(\frac{d}{d_0}\right) + X_f + X_h + s \quad \text{for} \quad d > d_0 \tag{1}$$

where, d is the distance between the base station and the receiver antenna in metres, d_0 = 100 m and s is a lognormal distributed factor that is used to account for the shadow fading owing to trees and other clutter and has a value between 8.2 dB and 10.6 dB . The other parameters are defined as,

$$A = 20\log_{10}\left(\frac{4\Pi d_0}{\lambda}\right) \tag{2}$$

$$\gamma = a - bh_b + c/h_b \tag{3}$$

where, the parameter h_b is the base station height above ground in meters and should be between 10 m and 80 m .The constants used for a, b and c are given in Table I.

TABLE I SUI MODEL PARAMETER

Model	Terrain	Terrain	Terrain
a	4.6	4	3.6
b	0.0075	0.0065	0.005
c	12.6	17.1	20

B. *COST-231 Hata Model*

This model has been developed based on experimental measurements conducted by Okumura in Tokyo (Japan) region [1], [5].

Experimental formula for propagation path loss L in dB by Hata [5]

$$L\{urbanarea\} = 69.55 + 26.16\log_{10} f - 13.82\log_{10} h_b - c(h_m) + (44.9 - 6.55\log_{10} h_b)\log_{10} d \tag{4}$$

where f is the frequency (in MHz) from 150 MHz to 1500 MHz, h_b is the effective transmitter (base station) antenna height (in meters) ranging from 30m to 200m, h_m is the effective receiver antenna height (in meters) ranging from 1m to 10m, d is the T-R separation distance (in km) ranging from 1 to 10 km, and $c(h_m)$ is the correction factor depending on the mobile station antenna height which is function of the size of the coverage area. For small to medium sized city, the mobile antenna correction factor is defined as

$$c(h_m) = (1.1\log_{10} f - 0.7)h_m - (1.56\log_{10} f - 0.8)\,dB \tag{5}$$

and for a large city, the correction factor $c(h_m)$ is defined as

$$c\,(h_m) = 8.29(\log_{10} 1.54h_m)^2 - 1.1 \quad for\ f \le 300\,MHz \tag{6}$$

$$c\,(h_m) = 3.2(\log_{10} 11.75h_m)^2 - 4.97 \quad for\ f \ge 300\,MHz \tag{7}$$

The path losses L_S and L_O in dB for suburban and open areas are given in equations (8) and (9) respectively.

$$L_S = L\,\{urbanarea\} - 2\{\log_{10}(f/28)\}^2 - 5.4 \tag{8}$$

$$L_O = L\{urbanarea\} - 4.78\{(\log_{10} f)^2\} + 18.33\log_{10} f - 40.94 \tag{9}$$

This model is well suited for large cell mobile systems, but not personal communications systems (PCS) which have cell on the order of 1 km radius.

C. *ECC Model*

The original Okumura experimental data were gathered in the suburbs of [11]. The author refers to urban areas as subdivided into large city and medium city categories. Correction factors for suburban and open areas were also given. Since the characteristics of a highly built-up area such as Tokyo are quite different to those found in typical European suburban areas medium city model is recommended for European cities [12].

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Although the Hata Okumura model is widely used for UHF bands, its accuracy is questionable for higher frequencies [11]. The COST-231 model extended its use up to 2GHz but it was proposed for mobile systems having Omni-directional CPE antennas sited less than 3m above ground level. A different approach was taken by the Electronic communication Committee (ECC) which extrapolated the original measurements by Okumura and modified its assumptions. The path loss equation for ECC-33 model [6] is defined as

$$L = A_{fs} + A_{bm} - G_b - G_r \quad (10)$$

where Afs, Abm, Gb and Gr are the free space attenuation, the basic median path loss, the BS height gain factor and the terminal (CPE) height gain factor. They are individually defined as

$$A_{fs} = 92.4 + 20\log_{10}(d) + 20\log_{10}(f) \quad (11)$$

$$A_{bm} = 20.41 + 9.83\log_{10}(d) + 7.894\log_{10}(f) + 9.56[\log_{10}(f)]^2 \quad (12)$$

$$G_b = \log_{10}(h_b/200)\{13.958 + 5.8[\log_{10}(d)]^2\} \quad (13)$$

and for medium city environments

$$G_r = [42.57 + 13.7\log_{10}(f)][\log_{10}(h_r) - 0.585] \quad (14)$$

where f is the frequency in GHz
d is the distance between AP and CPE in km
hb is the BS antenna height in meters
hr is the CPE antenna height in meters

The medium city model is more appropriate for European cities whereas the large city environment should only be used for cities with tall buildings. It is interesting to note that the predictions produced by the ECC-33 model do not lie on straight lines when plotted against distance having a log scale. For the sake of completeness, the path loss gradient at 2km will be compared with the path loss predicted by other models [13]. The predictions using the ECC-33 model with the medium city option are compared with the measurements taken in suburban and urban environments.

D. ITU-R (P.1411-1)

NLOS [8] signals can arrive at the BS or MS by diffraction mechanisms or by multipath which may be a combination of diffraction and reflection mechanisms. In the model for transmission loss in the NLOS for roof-tops of similar height, the loss between isotropic antennas is expressed as the sum of free-space loss, L_{bf}, the diffraction loss from roof-top to street L_{rts} and the reduction due to multiple screen diffraction past rows of buildings, L_{msd}. In this model L_{bf} and L_{rts} are independent of the BS antenna height, while L_{msd} is dependent on whether the base station antenna is at, below or above building heights. In the non-LOS case the basic transmission loss comprises the free space path loss L, the multiple screen diffraction loss L_{msd} and the rooftop to street diffraction and scatter loss L_{rts}. Thus the path loss L_b in non LOS is defined as

$$L_b = \begin{cases} L_B + L_{rts} + L_{msd} & L_{rts} + L_{msd} > 0 \\ L_B & L_{rts} + L_{msd} < 0 \end{cases} \quad (15)$$

The term L_{rts} describes the coupling of the wave propagating along the multiple-screen path into the street where the mobile station is located. It takes into account the width of the street and its orientation. The values of L_{rts} are as follows

$$L_{rts} = -8.2 - 10\log_{10} w + 10\log_{10} f_{MHz} + 20\log_{10}(h - h_m) + L_{ori} \quad (16)$$

where w, h and h_m are gap between buildings, height of building and height of mobile stations respectively. L_{ori} is the street orientation correction factor, which takes into account the effect of roof-top-to street diffraction into streets that are not perpendicular to the direction of propagation and same as (16). The multiple screen diffraction loss from the BS due to propagation past rows of buildings depends on the BS antenna height relative to the building heights and on the incidence angle. The relevant equations are same as given above. The details of simulation parameters are given in Table III.

V. PATH LOSS ANALYSIS

Figure 2 to Figure 5 show the comparison of path losses predicted by COST-231 Hata, ECC, SUI (terrain B), and ITU-R (NLOS) methods for different transmitting antenna heights. In these figures, close to transmitter observed path losses varied from 100-120 dB and at distances beyond 500 m, path loss was confined in the range of 110-160 dB. In Table III the corresponding error statistics in terms of mean prediction error μ, and the standard deviation σ, of the prediction errors, are given for each model for different base stations. Here the error is taken as the difference between observed and predicted loss. While evaluating the path loss exponent for ECC model the standard practice of taking path loss gradient at 2 km has been followed. The parameters n and σ can be determined using linear regression of the path loss values against the log of normalized distance d/d_o in a minimum mean square error (MMSE) manner. Path loss exponent for dense urban region and mixed urban environment region [14] is 3.0 to 4.1 and 2.8 to 4.4 respectively. For urban coastal region, value of path loss exponent is less as compared to its value in dense urban region and mixed urban environment region. Path loss exponents found by the SUI and ITU-R (NLOS) methods are around 3.8 respectively for all the base stations. Standard deviation ECC and the COST-231 Hata varied from 6.0 to 7.3 (Figs. 2-5).

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This variation could be attributed to the degree of urbanization and geometrical configuration of buildings, which varies from base station to base station. In Figures 2-5, path loss values for 40m antenna height is less as compared to 31m, 35m, 38m. The COST-231 Hata model has mean prediction error varies from 0.2 to 4.9 dB. For CHS-GSC base station with transmitting antenna height 40m, mean prediction error is less as compared to 38m, 35m, 31m transmitting antenna heights. ITU-R (NLOS) and SUI predicted higher values of standard deviation for all the different transmitting antenna heights.

VI. CONCLUSION

An experimental campaign was conducted in the urban, coastal region of Mumbai using WiMAX transmissions at 2.3 GHz for four base stations with different transmitting antenna heights. The signal levels have been converted into path loss values for prediction methods like COST-231 Hata, ECC, SUI (Terrain B), ITU-R (NLOS). Path loss exponents, mean errors and standard deviations of all the methods have been deduced and compared for different transmitting antenna heights. From the following analysis, it has been observed that the prediction error of SUI, ITU-R (NLOS) is considerably higher than COST-231 Hata.

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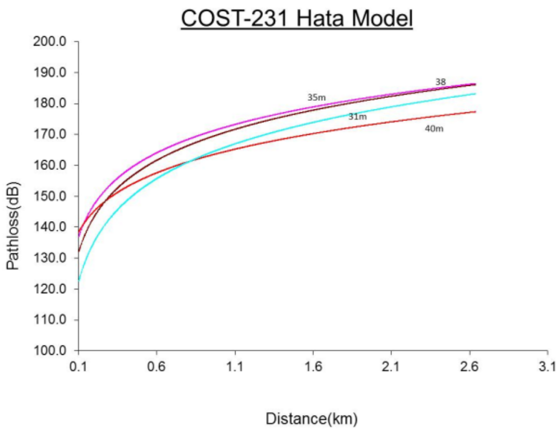

Fig.2. Comparison of path loss values of COST-231 Hata model for different transmitting antenna heights

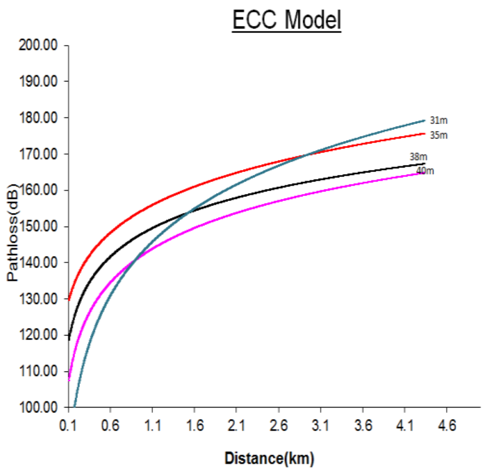

Fig.3. Comparison of path loss values of ECC model for different model for different transmitting antenna height

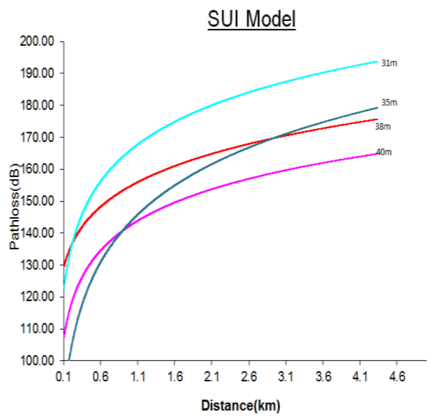

Fig.4. Comparison of path loss values of SUI model for different transmitting antenna heights

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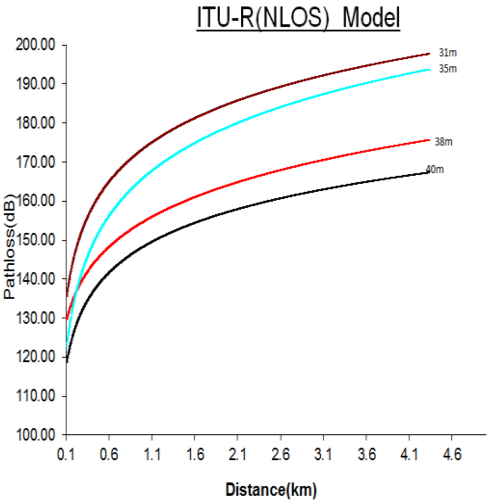

Fig.5. Comparison of path loss values of ITU-R(NLOS) model for different transmitting antenna height for different transmitting antenna heights

Table II Experimental Details of Base Stations

S.No.	Site Name	Height Of Transmitting Antenna	Details	
1.	Electric Mansion(ETM)	35m	Transmitted power	43dBm
2.	Gangasagar(CHS-GSC)	40m	Height of receiving antenna	1.5m
3.	Geetanjali(GTL)	31m	Average street width	15m
4.	MistryChambers(MCB)	38m	Average Height of building	25m

Table III Comparison of Statistical Parameters for Different Transmitting Antenna Heights

Models/height of transmitting antenna	35m			40m			31m			38m		
	n	μ	σ	n	μ	σ	n	μ	σ	n	μ	σ
COST-231 Hata	3.5	4.9	6.7	3.5	0.2	6.8	3.5	14.9	7.1	3.4	1.7	6.8
ECC	3.3	-6.7	5.9	3.4	-19.6	5.9	3.3	-20.1	6.2	3.4	-26.6	6.0
SUI	4.0	14.9	6.8	2.8	1.9	7.9	3.8	-8.1	6.8	3.9	-12.3	6.7
ITU-R(NLOS)	3.8	10.7	7.3	3.8	-2.2	7.6	3.8	-13.2	7.3	3.8	-18.6	7.1

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