Experimental Analysis of Cellular Outdoor Propagation at 1800 MHz over Dense Urban Regions of Ghaziabad

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Abstract—The basic task in the designing of future generation wireless mobile communication systems is to forecast the coverage of the area using the available forecasting path loss models before the actual implementation of the design. Forecasting path loss models are mathematical equations which are used to predict the coverage and the performance of the system. The forecasting models are designed for specific terrain conditions and can give varying results when applied to a different terrain type. To analyze the behaviour of the radio frequency channel, experimental data collection was performed in the 1800 MHz band for five GSM cell sites in the densely populated areas of Ghaziabad city with high rise buildings. In this paper the experimental results are compared with the four forecasting models namely, Cost 231 Hata, Cost 231 Walfisch Ikegami (WI), ECC, SUI. Their Average errors and Standard Deviations are compared which reveals that Cost 231 Hata model has the least values and is selected as the best model.

Keyword- Forecasting models, Received field strength, Path loss, Average Error, Standard deviation,

I. INTRODUCTION

In wireless communications the prime concern is to achieve an efficient network performance. When the radio waves propagate from the base tower they undergo attenuation as a result of many factors like, absorption, reflection, scattering, diffraction. This results into path loss which restricts the coverage area. Prediction of path loss is hence an important primary step in the planning of the network. Forecasting models are hence necessary for determining the correct location of the base tower and predicting the coverage area of the network. Forecasting models are designed for specific terrain conditions, hence selection of the correct forecasting model is of utmost importance in the network designing process. In order to analyse the characteristics of the propagating signal in the 1800 MHz band, experimental campaign was conducted in the dense urban areas of Ghaziabad (India) city. The experimental results are applicable to the 3G systems as the characteristics of their propagation are quite similar to the 1800 MHz band [1]. In [2] the authors performed measurements in the urban and suburban areas of Stockholm at 900 MHz and 1800 MHz. Their study revealed a difference of 6.9 dB in path loss for urban areas and 9.3 dB for suburban areas between the two frequencies. Their results suggest that the path loss due to the presence of vegetation is higher at 1800 MHz than at 900 MHz. In [3] the authors present a three dimensional model for predicting the indoor and outdoor coverage in dense urban areas. The study requires exact building data which is to be stored in raster format. In [4] the authors achieved greater accuracy but with increased analytical complexity.

In the current paper experimental analysis of the field data is performed in the 1800 MHz band for five base towers located in the densely populated areas of Ghaziabad city (India). The area comprises of high rise buildings built in close proximity. The paper compares the experimental path loss with the well known forecasting models. The error metrics like average errors and standard deviations are compared between the experimental path loss and the forecasted path loss. These results provide the basis for selection of the suitable model for the area under study.

II. RESEARCH METHODOLOGY

In this paper the radio signals for five GSM base towers operating in 1800 MHz band of Idea Cellular Networks have been measured using Sony Ericson receiver (W995 model). A GPS receiver was also used in the process to find the latitude and longitude of the receiving mobile. During the data collection period from April to September 2015, data signals were collected on dry days with no rain. The measurements were usually taken during the day time. The van used to carry the measurement set up was driven at a speed of nearly 20 Km per hour on pre determined routes [5]. The Ghaziabad city is located at Latitude of 28.6697856 and Longitude of 77.449791 and at an altitude of 214 meters above sea level. The measurements of the radio signals were performed in the dense urban areas of Indirapuram region of Ghaziabad city which is situated at Latitude 28.641485 and Longitude 77.371384 and at an altitude of 206 meters above sea level. The region under study consists of high rise buildings which result in sharp signal degradations and limit the coverage area within 1 Km. The vegetation present is minimal and there are many shopping complexes which further add to the signal degradation. The power transmitted by all the base towers is +30dBm and the gain of all the base towers is 17 dBi. The details of the five base towers under study are presented in Table 1.

TABLE I Detail Description of Base Towers

Site Id	**1881**	**219**	**4330**	**4525**	**2477**
Terrain Type	Dense Urban				
Latitude	28.6413	28.6425	28.64339	28.64556	28.645
Longitude	77.3803	77.3746	77.37062	77.36	77.376
Channel Number	814	522	815	812	528
BCCH Frequency (MHz)	1865.6	1807.2	1865.8	1865.2	1808.4
Transmitter Height (meters)	19	16	21	20	25
Azimuth (degrees)	280	240	220	120	70
Tilt	4 ET, 0 MT	3 ET, 0MT	4 ET, 0 MT	4 ET, 0 MT	4 ET, 0 MT

The height of the receiving mobile unit is 1.5 m. The satellite image of the area under study is shown in Fig 1 which can be easily obtained from Google Maps.In Table 1 ET represents electrical tilt and MT represents mechanical tilt.

Fig. 1 Satellite Image of Indirapuram

The research methodology is described in Fig 2 in the form of a block diagram.

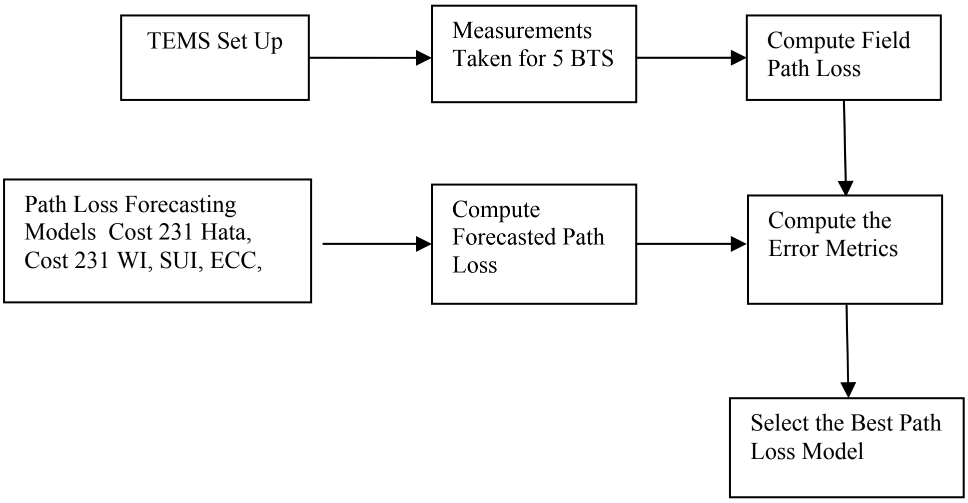

Fig. 2 Research Methodology Block Diagram

The error metrics used in the paper for comparing the field path loss and the forecasted path loss are Average Error and Standard Deviation. During the processing of data, few steps were followed [6], Filtering of the data so that any incomplete data is removed, Averaging of the data to provide a precise path loss value at a point. Path loss is obtained as in [5].

The comparisons reveal, Cost231 Hata model is the best model for the area under study as it has the minimum values of the error metrics.

III. FORECASTING MODELS

This paper compares the field path loss with the path loss forecasted by the four traditional path loss forecasting models, Cost 231 Hata, Cost 231 Walfisch Ikegami (WI), ECC and SUI. By using suitable correction factors these models can easily be accommodated to any environmental terrain like metro cities, medium cities and open areas [7].

A. The Cost 231 Hata

This model is actually an extension to the existing Okumura Hata model [8]. It applies to frequency ranges from 500 MHz to 2000 MHz. The model can be made to suit different environmental conditions varying from flat open areas to densely populated metropolitan areas by using appropriate correction factors. The path loss (dB) for this model is computed by the following equation

$$PL_{Cost\ 231} = 46.3 + 33.9\log_{10}(f_c) - 13.82\log_{10}(h_b) - ah_m + (44.9 - 6.55(\log_{10}(h_b) * \log_{10}(d) + c_m \quad (1)$$

Where f_c is the BCCH frequency in MHz of the base tower, h_b is the height of the base tower in meters. The term ah_m is the correction factor for the terrain type. In this paper as the terrain is a dense urban area so its value used as per [8] is

$$ah_m = 3.2\,(\log_{10}\,(11.75\,h_R))^2 - 4.97 \quad (2)$$

where h_R is the height of the mobile receiver and it is fixed as 1.5m. The value for c_m used for the dense urban area under study is 3dB.

B. The Cost 231 Walfisch Ikgami (WI)

This model is a result of the combinations of the Walfisch and Ikegami models. It is applicable to frequency ranges from 800 MHz to 2000MHz. The path loss (dB) forecasted by this model is given as in [8], as follows

$$PL_{WI} = L_{FS} + L_{RT} + L_{MS} \quad (3)$$

Where L_{FS} is the free space loss and is given in [6] as

$$L_{FS} = 32.45 + 20\log_{10}(d) + 20\log_{10}(f) \quad (4)$$

L_{RT} is the roof top of the building to the street diffraction and is given in [8] as

$$L_{RT} = -16.9 - 10log_{10}(w) + 10log_{10}f + 20\log_{10}h_{mobile} + L_{orit} \qquad \text{for } h_{rooftop} > h_R \quad (5)$$

Where h_R is height of mobile receiving unit of 1.5 m, w is the width of the road and L_{orit} is in degrees

L_{orit} is expressed as

$$L_{orit} = -10 + 0.354\Delta \qquad \text{for } 0 < \Delta < 35$$

$= 2.5 + 0.075(\Delta - 35)$ for $35< \Delta<55$ (6)

$= 4 - 0.114(\Delta - 55)$ for $55< \Delta<90$

Where Δ is the angle between the direct radio signal path and the orientation angle of the road.

L_{MS} is the multi-screen diffraction loss and is given by

$L_{MS}= L_{BS} + K_a + K_d \log_{10}(d) + K_f \log_{10} f_c - 9\log_{10} f_c - 9\log_{10}(B)$ for $L_{MS} > 0$ (7)

$= 0$ otherwise

The parameters L_{BS}, K_a, K_d, K_f, can be read in detail from [8]. Here d is the distance between base tower and the receiving mobile, B is the distance between buildings. In the present study the model is used for road widths of 10m and 20 m, and the roof heights of 12m to 20m as the area consists of high rise buildings.

C. The ECC

This model has been developed by The Electronics Communication Committee. The path loss (dB), expressed by this model is given in [9] as

$$PL_{ECC}= A_{FS} + A_{BM} - G_B - G_R \quad (8)$$

here A_{FS} is free space signal loss, A_{BM} is median path loss, G_B is the base tower's correction factor for height gain and G_R is correction factor for the receiver. The parameters discussed above are defined in [9] as,

$$A_{FS} = 92.4 + 20 \log_{10}(d) + 20 \log_{10}(f_c) \quad (9)$$

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

$$G_B = \log_{10}(h_b/200)(13.958 + 5.8\{\log_{10}(d)\}^2) \quad (11)$$

For medium city the value of G_R is given as in [9],

$$G_R = \{42.57 + 13.7 \log_{10}(f_c)\}\{\log_{10}(h_R) - 0.585\} \quad (12)$$

For large city G_R is given as,

$$G_R = 0.759h_R - 1.862 \quad (13)$$

Here, h_b is base tower height in meters, h_R is mobile receiver height and is fixed as 1.5m, f_c is base tower's radiating frequency in GHz and the spacing between base tower and the mobile receiver is defined as d in Km.

D. The SUI

This model was developed by the Stanford University's, IEEE 802.16 broadband wireless access working group [9], [10].This model is presented for three different terrain conditions category A,B and C. In the present study the category with the maximum loss is selected which is the category A.

The path loss (dB), given by this model is

$$PL_{sui}(dB) = \mathbf{A} + 10\upsilon \log_{10}(\mathbf{d}/d_{Ref}) + \mathbf{Y_f} + \mathbf{Y_h} + \mathbf{S} \quad (14)$$

Where **d** is the distance in meters between the radiating base tower and the receiving mobile unit, 100 m is the reference distance d_{Ref}, υ is the path loss exponent, $\mathbf{Y_f}$ is the correction factor for frequency, $\mathbf{Y_h}$ is the correction factor for height of receiving mobile unit and **S** is the shadowing factor. In the present research the value of **S** taken is 10.6dB as the area is a dense urban region and faces maximum clutter loss.

$$\mathbf{A} = 20\log_{10}(4\pi d_{Ref}/\lambda) \quad (15)$$

$$\upsilon = a - bh_b + (c/h_b) \quad (16)$$

$$\mathbf{Y_f} = 6\log_{10}(f_c/2000) \quad (17)$$

$$\mathbf{Y_h} = -10.8 \log_{10}(h_R/2000), \quad \text{for Terrain A and B} \quad (18)$$

Here λ is wavelength in meters, f_c is frequency of the radio signal in MHz, h_b is height in meters of the radiating base tower and h_R is height in meters of the mobile unit. The terrain specific parameter values taken in the present study are

$a = 4.6$, $b = 0.0075/m$, $c = 12.6m$

The area under study is a dense urban region with multistoried buildings resulting into large path loss due to multipath fading and hence category A is chosen[10].

IV. RESULTS and DISCUSSIONS

The instantaneous field strength recorded experimentally is used to calculate the field path loss. The field path loss has been computed for distances from 50 m to 1km.The forecasting models discussed in the above section have been compared to the field results and their Matlab simulations have been presented .The Average error and the Standard deviation is also discussed between the various forecasting models and the field path loss.

A. *Simulation Results*

The Figures 3 to 7 show the Matlab simulations of the comparisons between the path losses forecasted by various models and the actual path loss, obtained from the field data measurements performed for the five base towers with specific Site Ids. The area under study is a microcellular dense urban region of Indirapuram located in Ghaziabad city.

The figures reveal that the field data is obtained for distances as close as 50 m in case of site Ids 1881, 4330, 4525, for the site Ids 219 and 2477 the field data is obtained at nearly 100 m. The field data for all the base towers has been obtained within 1Km distance which suggests that these are the microcellular dense urban areas.

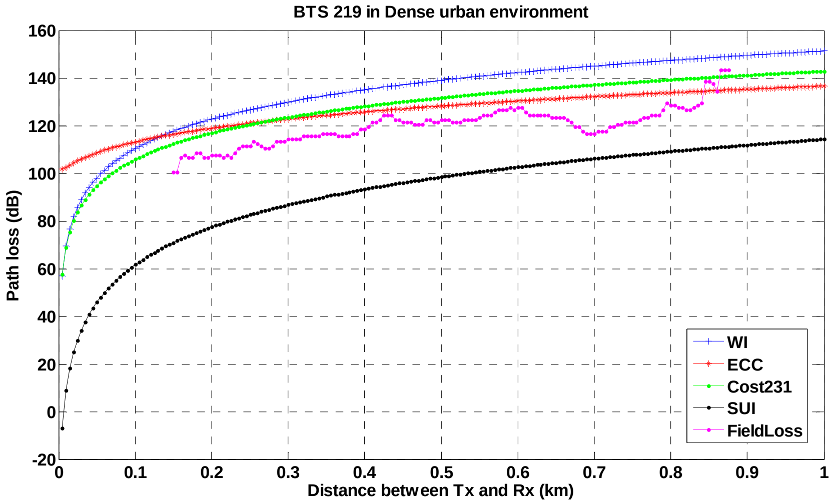

Fig. 3 Comparison of forecasting models and field path loss for Site Id 219.

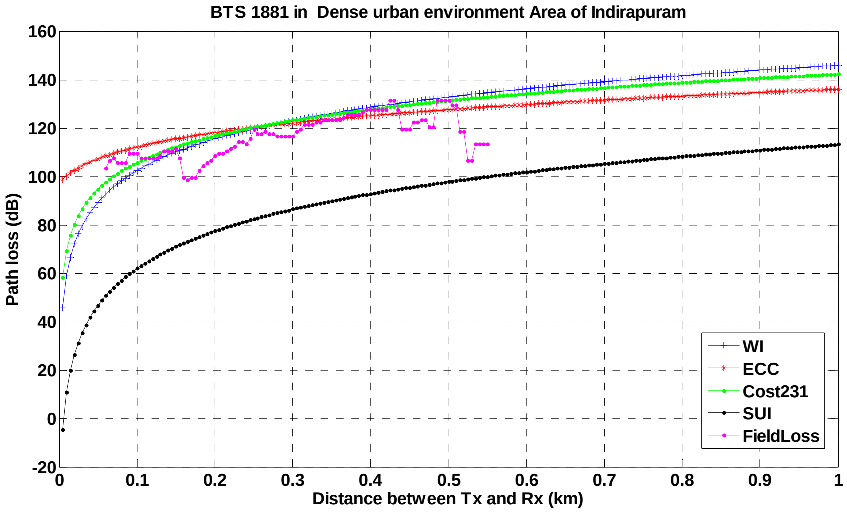

Fig. 4 Comparison of forecasting models and field loss for Site Id 1881.

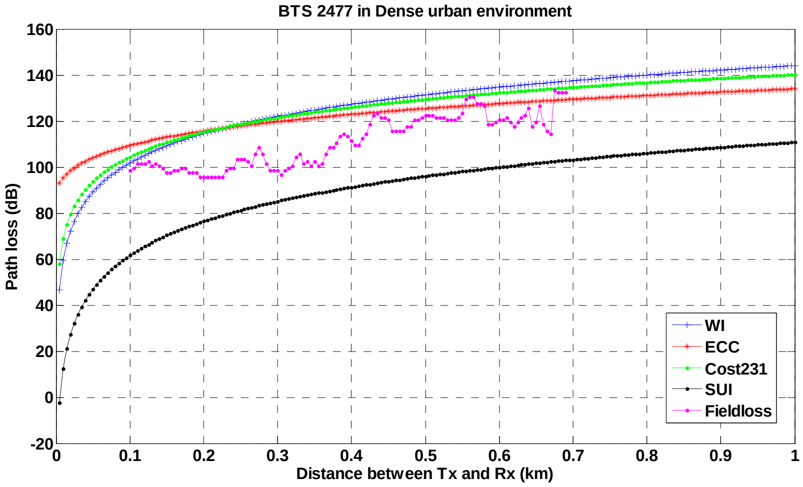

Fig. 5 Comparison of forecasting models and field loss for Site Id 2477.

The values of field path loss at points very near to the base towers had significant values in the range from 95 to 120 dB. Figures 3 and 5 show forecasting models ECC, Cost 231 Hata, Cost WI overestimates whereas SUI underestimates the path loss. In Figures 4 and 7, the field path loss has values very close to ECC and Cost 231 Hata. In [11] the authors observed that propagation of signal takes place by two mechanisms, vertical and horizontal propagation. Near the base tower the horizontal propagation takes place and at far away distances from the tower the vertical propagation comes into play.

In Fig 6 the field path loss values are in close agreement to Cost 231 Hata and WI forecasting models. In all the Figures the SUI model underestimated the field path loss with large values. The curves obtained have significant rise and fall of values which can be explained as a result of high rise buildings which are not uniformly spaced. At times there are gaps in buildings and a strong signal is obtained which is due to the presence of Line of Sight.

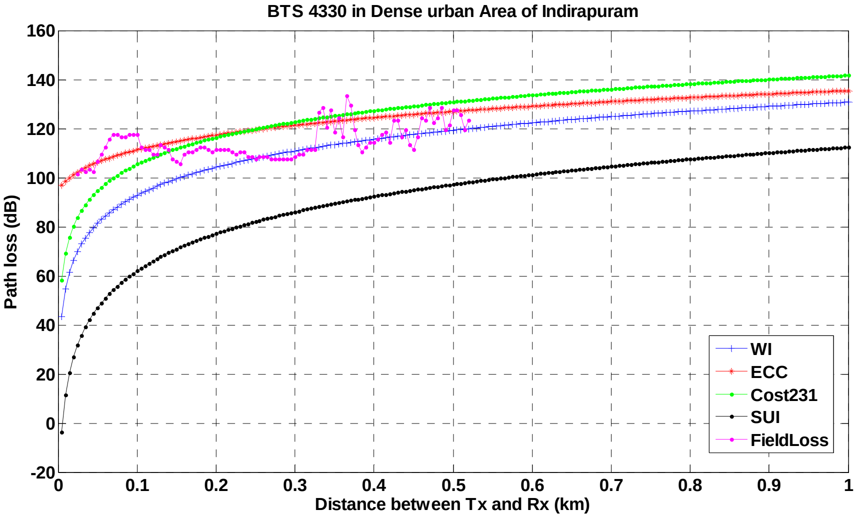

Fig. 6 Comparison of forecasting models and field loss for Site Id 4330.

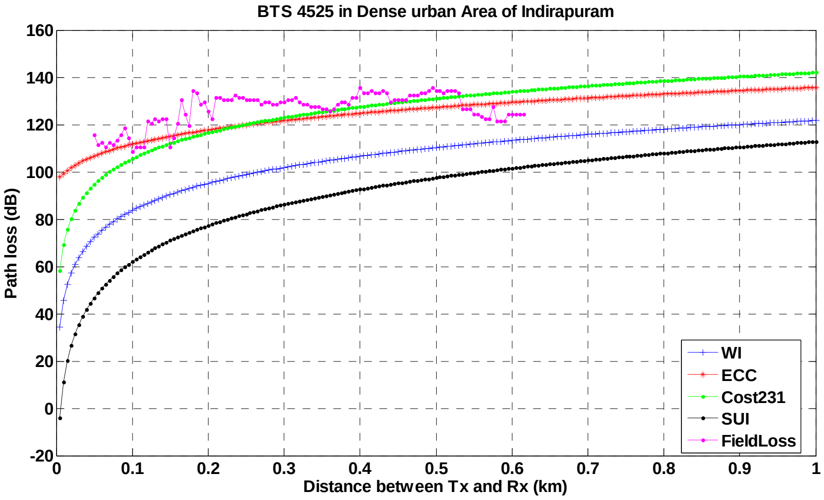

Fig. 7 Comparison of forecasting models and field loss for Site Id 4525.

B. *Average Errors and Standard Deviations*

The comparisons discussed above were used to compute the forecasting errors, which is the difference between the field path loss and the forecasted path loss by the four forecasting models. The Average Error and the Standard Deviation for the five base towers are given in Tables II and III.

TABLE II Comparison of Average Error for the four models

Site Id	**Cost 231 Hata**	**ECC**	**SUI**	**Cost 231 WI**
219	10.46737776	25.71116	23.29759	17.6205582
1881	4.665021763	22.81764	32.91938	4.89719558
2477	12.90376957	28.78571	22.58279	13.7818026
4330	3.604047661	22.72962	34.96544	8.48903806
4525	4.607076453	13.12942	41.74966	25.7997704

TABLE III Comparison of Standard Deviation for the four models

Site Id	**Cost 231 Hata**	**ECC**	**SUI**	**Cost 231 WI**
219	4.236855596	4.525525	5.812989	4.46768061
1881	6.51965988	7.924846	8.780586	7.4497543
2477	6.114618776	7.015874	6.584506	6.36005945
4330	9.638212381	10.59058	13.52106	10.0909984
4525	7.395545169	7.682288	10.66467	7.72851681

Average error and standard deviation is computed as follows

$$\text{Average Error} = \frac{1}{n}\sum_{x=1}^{n}|Z_x - P_x| \quad (19)$$

$$\text{Standard Deviation} = \sqrt{\frac{1}{n}\sum_{x=1}^{n}(|Z_x - P_x| - \text{ Average Error})^2} \quad (20)$$

Where Z_x is the field path loss and P_x is the forecasted path loss by the four models at a distance x from the base tower. The term ‘n’ denotes the number of samples collected.

In dense urban regions, Cost 231 Hata model forecasted path loss with minimum average error of 3.604 dB for base tower 4330 and the minimum standard deviation of 4.236dB for base tower 219. The maximum average error forecasted by Cost 231 Hata model is 10.467 dB for base tower 219.The maximum deviation estimated by Cost 231 Hata model is 9.638 dB for base tower 4330.

The Walfisch and Ikegami model produced an average error in the range from 4.897 dB to25.799 dB.The deviations produced by the model were in the range from 4.467 dB to 10.090 dB.The ECC model forecasted with an average error ranging from 13.129 dB to 28.785 dB and deviations ranging from 4.525 dB to 10.590 dB.

The deviations of the SUI model were from 5.812 dB to 13.521 dB and the range of average error was from 22.582 dB and 41.749 dB. Taking all the base towers together, Cost 231 Hata gave the average error of 7.249 dB and average standard deviation of 6.780 dB. This shows that comparing either by taking all the towers together or individually the Cost 231 Hata model gave the least values of standard deviation and average error. This analysis hence proves that Cost 231 Hata model is the best model for the area under study.

C. *Received Field Power*

The measured field signal power monitored and recorded in dB by the TEMS software for the five base towers under study is processed and tabulated in the form of a bar chart as shown in Fig. 8. The different bars represent the percentage of the different categories of the received power in the field. This is an efficient way to represent and analyse a large amount of field data of various radiating base towers in a compact form.

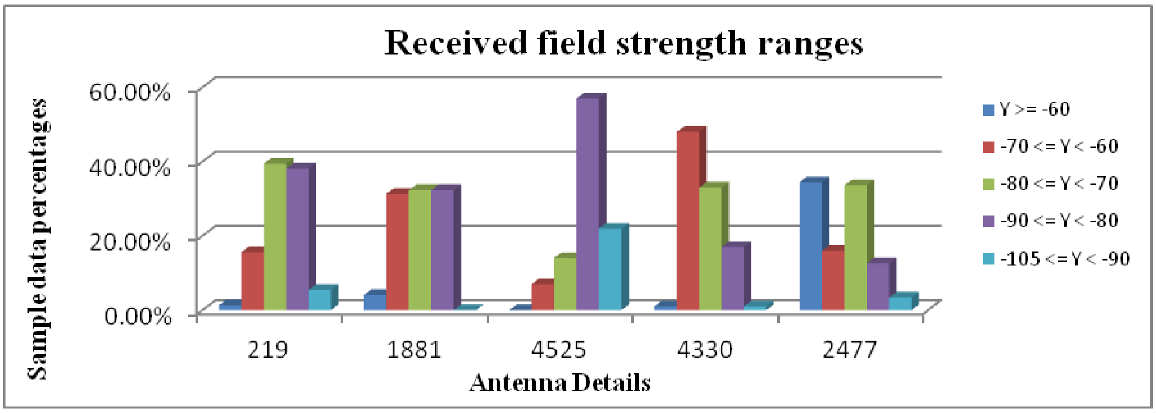

Fig. 8 Comparison of the received power ranges

V. CONCLUSION

In the microcellular dense urban areas of Ghaziabad city, the radio signal power measurements were conducted in the 1800 MHz band for five base towers. The field results were analyzed and compared with the four traditional forecasting models,Cost 231 hata,WI, ECC and SUI. The average errors and the standard deviations have also been analyzed and the study shows that Cost 231 Hata model is the best model as it has the lowest values and has reported to be in better agreement to the field data among the various compared models. This study provides a basis for the selection of the best suitable model which can be further tuned and its parameters optimized to enhance the accuracy of the model as in [4].This study can prove to be useful to the service providers in improving their quality of service and reduce the call drop cases.

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