A Review on Empirical Data Collection and Analysis of Bertoni's Model at 1.8 GHz

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ABSTRACT
In any kind of network planning it is the central task to estimate and thus analyze propagation characteristics of a radio system through a medium in order to state accuracy in signal parameters for efficient network planning. The system must necessarily incorporate in itself the ability to predict the accurateness of radio propagation behavior. The site measurements each and every time are no doubt expensive & costly, so these models are a better alternative to that and even a lot less costly along with better suitability. Path loss thus is now a major consideration while laying down any network of base stations that can be used to estimate transmission requirements for a particular region thus offering better Quality of Service. Thus it is an important aspect to know the features of environment of operation of such a system along with the location of base station and mobile.

General Terms
TEMS, Data collection, Measured data, Scenario-profile

Keywords
Path loss data, Empirical models, Bertoni's model, Comparison

1. INTRODUCTION
In order to study the nature of radiation pattern and quality of signal persisting in a particular region we definitely require certain kind of modeling to bring out the natural characteristics of the environment in to machine coordinated implementation and for the same we deploy radio propagation models. Radio propagation models can be broadly classified in to: Outdoor propagation models and Indoor propagation models. But as the work solely deals with Outdoor propagation models, we shall restrict ourselves only up for discussion on Outdoor propagation models.

2. REVIEW OF PROPAGATION MODELS
The following different kinds of outdoor models deployed in radio propagation are as:

2.1 Empirical Models
2.2 Deterministic Models
2.3 Stochastic Models

2.1 Empirical Models
An empirical model is simply based on observed and measured data alone [14]. It can be further classified in to two sub heads, time-dispersive and non-time-dispersive [14]. The SUI (Stanford University Interim) model is one of the perfect examples of time-dispersive models. The models like COST-231 Hata model, Hata model and ITU-R models are examples of non-time dispersive models.

2.2 Deterministic Models
These kinds of models deploy laws of electromagnetic wave propagation for determination of received signal strength in a definite region of concern. Today the radio propagation studies are more concerned with site-specific propagation modeling as we can use these models for the purpose of both outdoor & indoor scenarios in deterministic form. Here actual 3-D designs of buildings or concerned environment like foliage equivalent to some dielectric slab etc. are made based on some database. There after ray tracing techniques are used to associate representation with the software being used, representing fundamental phenomenon of reflection, diffraction and scattering [19][20]. It is more of computerized form of comparative analysis and is becoming increasingly important with advent of high-speed computational technologies coming in.

2.3 Stochastic Models

Stochastic models are used in terms of random variables being deployed for representation of some or the other factors influencing the behavioral nature of radio waves in action. These models have a concern of correctness and accuracy. These are mostly used for prediction at and above 1.8 GHz.

3. FREE SPACE PATH LOSS MODEL
Path loss in free space can be defined as losses in strength of the signal in free air i.e. no object or any entity lies middle to propagation from transmitter to receiver. Free Space Path Loss is diverse on frequency and distance. The free space path loss is given as:

$$PL=32.45 + 20\log10 (d) + 20\log10 (f) \quad (1)$$

Where,

f=frequency of operation [MHz]

d=transmitter and receiver separation [m]

Power is usually expressed in decibels (dB-m)

3.1 OKUMURA MODEL

The Okumura Model is a well-known classical empirical model to measure the radio signal strength in built up areas. This model was framed on the basis of accumulated data from Tokyo city of Japan. This model is perfect for using in the cities having dense and tall structure, like Tokyo. While dealing with the areas, the urban area is sub-grouped as big cities and the medium city or normal built cities. The region of Tokyo is an urbanized area with high buildings. In our work we have considered medium built buildings with heights less than 15-20 meters. Moreover Okumura gives a crystal clear scenario with respect to correction factors for sub-urban and rural or open areas. By using Okumura model we can predict path loss in urban, sub-urban and rural areas up to frequencies less than 3 GHz. Our work is on 1.8 GHz. We provide this model as a base of Hata-Okumura model.

Median path loss model can be expressed as [20]:

$PL\ (dB) = L_f + A_{mn}(f, d) - G\ (h_{te}) - G\ (h_{re}) - G_{AREA}$ (2)

Where,

PL: Central tendency path loss [dB]

L_f: Free space path loss [dB]

$A_{mn}(f, d)$: Median attenuation relative to free space [dB]

$G\ (h_{te})$: Base station antenna height gain factor [dB]

$G\ (h_{re})$: Mobile station antenna height gain factor [dB]

$G_{AREA:}$ Gain due to type of environment [dB]

and parameters

f: Frequency [MHz]

h_{te}: Transmitter antenna height [m]

h_{re}: Receiver antenna height [m]

d: transmitter and receiver separation [Km]

Attenuation and other gain terms are as given in [1]

3.2 COST 231 HATA MODEL

The Hata model is introduced as a mathematical expression to mitigate the best fit of the graphical data provided by the classical Okumura model. Hata model is used for the frequency range of 150 MHz to 1500 MHz to predict the median path loss for the distance d from transmitter to receiver antenna up to 20 Km, and the transmitter antenna height is considered 30m to 200m and receiver antenna height is 1 m to 10 m. To predict the path loss in the frequency range 1500 MHz to 2000 MHz. This model is worked as an extension to Hata model. It is used to calculate the path loss in three different environments like urban, sub-urban and rural. This model establishes subtle way for the calculation of the path loss. Although this model is outside our range but near to it and thus the introduced correction factors still allowed to predict path loss in this frequency range. The basic path loss equation for this COST 231 Hata model is expressed as:

$PL = 46.3 + 33.9\log10\ (f) - 13.82\log10\ (h_b) – ah_m + (44.9 – 6.55\log10\ (h_b))\ \log10 d + c_m$ (3)

Where,

d: Distance between transmitter and receiver antenna [Km]

f: Frequency [MHz]

h_b: Transmitter antenna height [m]

The parameter c_m has different values for different environments like 0 dB for sub-urban and 3dB for urban areas and the remaining parameter ah_m is defined in urban areas as:

$ah_m = 3.20(\log10(11.75\ h_r))^2 – 4.79$ for f > 400 MHz

The value for ah_m in sub-urban and rural areas is given as:

$ah_m = (1.11\ \log10 f – 0.7)h_r – (1.5\ \log10 f – 0.8)$

Where,

The h_r is the antenna height in meters.

3.3 STANFORD UNIVERSITY INTERIM (SUI) MODEL

IEEE 802.16 Wireless group proposed this standard for the frequency range below 11 GHz. This model has been derived as an extension to Hata Model with frequency band greater than 1900 MHz. The correction parameters are permitted in model up to 3.5 GHz. The base station antenna height supported up to a range of 10 m to 80 m. The most important feature of this model is the terrain based classification based on foliage distribution along with.

The fundamental path loss expression for the SUI Model along with correction factors is as:

$PL = A + 10\gamma\log 10\ (\frac{d}{d_0}) + X_f + X_h + e$;for $d > d_0$ (4)

Where the parameters are

d: Distance between BS and receiving antenna [m]

d_0: 100 [m]

λ: Wavelength [m]

X_f: Correction factor for freq. > 2GHz [MHz]

s: Correction factor for shadowing effect [dB]

X_h: Correction factor for receiving antenna height [m]

γ: Path loss exponent

The factor s is Log-normally distributed and accounts for shadowing relative to foliage & other hindrances of similar classifications having a value of 8.2 dB and 10.6 dB.

3.4 HATA –OKUMURA EXTENDED MODEL or ECC-33 MODEL

It is the most used of empirical propagation models is the Hata-Okumura model, which is based on the Okumura model. This model is well established model for the UHF band. Recent recommendation of ITU-R i.e. P.529, encouraged the use of this up to 3.5 GHz but data greater than 3 GHz is not yet provided. Based on guidelines proposed by earlier Okumura model & recommendations made by ITU-R a new model referred to as ECC-33 model came to existence. In this the Path loss is expressed as:

$PL = A_{fs} + A_{bm} – G_t - G_r$ (5)

A_{fs}: Free space attenuation [dB]

A_{bm}: Basic median path loss [dB]

G_t: Transmitter antenna height gain factor

G_r: Receiver antenna height gain factor

3.5 COST-231 WALFISCH-BERTONI'S MODEL

This model was contribution of J. Walfisch and F. Ikegami suggested physical modeling based on ray traced physical models. Now it is known as COST-231 Walfisch-Bertoni model based on suggestions & work done by Bertoni regarding low roof top buildings. This model is most suitable for flat sub-urban & urban areas with uniform building height. Among other models this COST-231 model gives a more precise path loss. This is a result of additional parameters introduced which characterize different environments. It also covers distinguishing on basis of terrain features. The path loss equation for the same is given as:

For LOS condition

$PL_{LOS} = 42.6 + 26\log(d) + 20\log(f)$ (6)

For N-LOS condition

$PL_{LOS} = \{ L_{FSL} + L_{rts} + L_{msd}$ for urban & sub-urban

L_{FS}if $L_{rts} + L_{msd} > 0 \}$ (7)

Where,

L_{FSL} = Free space loss

L_{rts} = Roof top to street diffraction

L_{msd} = Multi screen diffraction loss

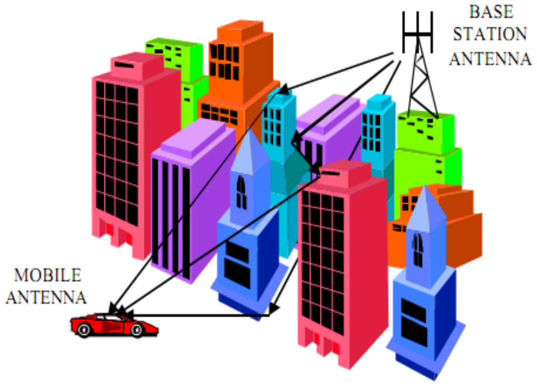

Figure.1. Problem of interest depicted as layout.

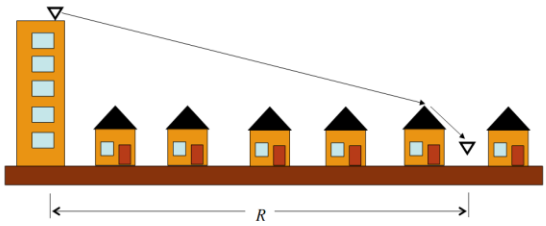

Figure.2. Depiction of Walfisch-Bertoni COST-231 model.

The above figure shows uniform height buildings with equal separation which is core feature of walfisch-ikegami model but the main concern is if the building is low roof top what should be the route for analysis and there comes Walfisch-Bertoni or Bertoni's model for uniform lower height consideration based on ray tracing technique considering each building block as a diffraction screen. The Bertoni's model is a better model for our concerned frequency range as here from analysis point of view but still there are certain concerns regarding the same in terms of mobile station height being variable.

3.6 PROCEDURE

the purpose of model to be chosen that best suits our analysis & work has been presented in this context. We have deployed MATLAB based coding approach facilitation to compare the results obtained from each of the following models discussed above.

At this point it is to be understood that for the region of interest [21] i.e. where we do have low-roof top buildings in the scenario Bertoni's model is the preferred choice. The major feature of Bertoni's model is that it deals with path gain instead of path loss parameter which is a common trait in other models, although related to the later as:

$$\textbf{PG} \equiv \textbf{Path Gain} = \frac{\textit{recieved power}}{\textit{transmitted power}} \quad (8)$$

(PG is always less than 1)

$$\textbf{PL} \equiv \textbf{Path Loss} = \frac{\textit{transmitted power}}{\textit{received power}} \quad (9)$$

(PL is always greater than 1)

When expressed in dB, PG dB = 10logPG = −L where L ≡ 10logPL

If $P = P_T A / R^n$, then PG dB = 10log A − 10nlog R and L = −10log A +10nlog R.

3.7 FACTORS JUSTIFYING THE CHOICE OF MODEL

The major usability of any model is to deal efficiently with prediction of signal strength for different residential environments and Bertoni's model facilitates this as it involves:

(A) Low building environment facilitation by deploying uniform radio absorbers array in place of rows of buildings.
(B) Street grid organization made aptly suitable by accounting for intra-building spacing and back-to-back spacing.
(C) Use of simple geometric techniques for lower building scenario and ray-tracing techniques for high-rise building scenario both.
(D) Considering propagation as a roof-top phenomenon.

Classification of path loss i.e. path gain in to three subtle factors each accounting for free-space loss, diffraction loss due to edges etc. as shown:

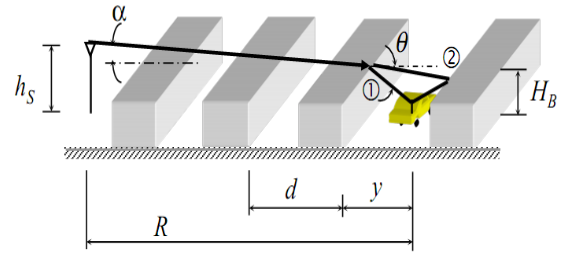

Figure.3. Path gain for propagation over buildings

Path Gain

$$PG = (PG_0)(PG_1)(PG_2) \qquad (10)$$

Where,

$PG_0 = \frac{\lambda}{4\pi r^2}$ [free-space path gain]

$PG_1 = Q^2$ [Reduction in the field at the roof top just before the mobile due to propagation past previous rows of buildings given by a factor Q].

$PG_2 = 1/2\pi k\rho_1 \{[1/|\Theta_1| - 1/(2\pi - |\Theta_1|)]^2 + |\acute{\Gamma}|^2/2\pi k\rho_2 \{[1/|\Theta_2| - 1/(2\pi - |\Theta_2|)]^2$

which accounts for the roof top field down to mobile i.e. summing the ray powers to get the small average.

Where, ρ_1 and ρ_2 have their usual meanings as in electromagnetics.

3.8 PHYSICAL APPROXIMATION DEPLOYED IN BERTONI'S MODEL

Reduction of rooftop fields for a spherical wave incident on the rows of buildings is the same as the reduction for an incident plane wave after many rows. Reduction in the field strength occurs due to multiple forward diffractions past an array of absorbing screens for a plane wave with unit amplitude that is incident at glancing angle α as represented in physical analogy below:

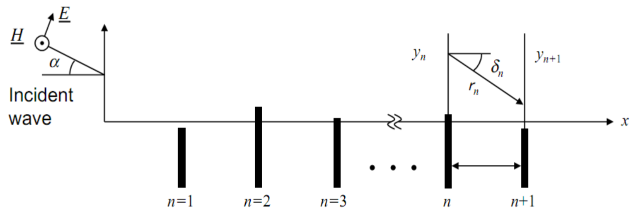

Figure.4. Physical optics approximation for roof-top field reduction

The physical analogy depicts replacing buildings by parallel absorbing screens. For parallel screens, the reduction factor is found by repeated application of the Kirchhoff integral. Going from screen n to screen n+1, the integration is as:

$$H(x_{n+1}, y_{n+1}) = \int_{-\infty}^{\infty}\int_{h_n}^{\infty}(\cos\alpha_n + \cos\delta_n)H(x_n, y_n)\frac{jk\,e^{-jkr}}{4\pi r}\,dy_n\,dz_n \qquad (11)$$

3.9 MODEL TUNING MEASUREMENT COLLECTION

Normally, propagation model tuning measurements are carried out if planning is done for a new network and, if there is an area with changes in the propagation environment such as new buildings, new roads, or else a new frequency band is taken into consideration [4][6]. It was mentioned in the previous chapter that statistical models are based on measurement data and have high computational efficiency as opposed to deterministic models. Practically, the accuracy of statistical models depends not only on the accuracy of the measurements, but also on the similarities between the propagation environments of the area where the measurement campaign is performed and the environment that the calibrated model is to be applied. To obtain such data, radio frequency (RF) measurements campaigns were performed in sub-urban region of Dehradun for various sites that contained buildings and vegetation.

4. SITE AND SCENARIO SELECTION

Since the measurement campaign was required to establish the effect of vegetation and buildings on radio signal propagation, the sites for measurement were selected to ensure that the sites were representative of the clutter types being considered. At first, built areas were considered. The sites chosen were initially analyzed using MATLAB code based on Bertoni's model and some other important models. The cell characteristics were analyzed to verify that the cell contained over 80% of built clutter.

Figure.5. Building Topology of Area Studied.

One of the typical built-type clutters in the area studied is shown in Figure.6. For the vegetation type clutter, the same procedure was considered. However, only trees in a straight line were considered as it was evident that in such areas, trees were almost always along streets except for those in parks and a few in individual compounds.

Figure.6. Foliage Pattern of Area Studied.

The base stations had antennas located at a height 35m above the ground while some were located on masts and few others were on rooftops. The signal transmitted had a bandwidth of 806-880MHz/880-960MHz and 806-960MHz respectively. The type of modulation used was Gaussian minimum shift keying (GMSK)[10] with time division multiple access (TDMA)/frequency division multiple access (FDMA). This was chosen as a compromise between fairly high spectrum efficiency (1 bit/Hz) and a reasonable demodulation complexity.

5. MEASURMENT CAMPAIGN

5.1 Data Collection and Validation

The TEMS Investigator handset and software versions 5.0, 8.1, 10.1& 13.1 were used to collect samples of the measured signal. The handset was used with precaution as it is known to have a typical accuracy of ± 4 dBm. The calibrated power was -100≤ - <-40dBm. The device used was TEMS handset given time to settle on a particular range of values. The readouts were made on software in pre-defined format. A geographical positioning system (GPS) receiver was used to collect the location information. The data captured included: logical channel 1 with information on BCCH, serving cell BCCH ARFCN, Base station identity code, received signal strength (Rx Lev), Traffic channel, Timeslot number, Transmit power-graphic, carrier-to-interference ratio in dB, Timing advance, cell identity and the neighbor list. The GPS had an accuracy of ± 15m. This accuracy is much better compared to previous values of ±200-300m. This is due to the fact that selective variability was switched off in the recent past which improved the accuracy of the GPS dramatically [12][4][9].

The network cells within the area being studied were measured for model tuning since all relevant parameters such as effective isotropic radiated power (EIRP), antenna type, direction and height were known. The drive routes were selected for the sites that had over 80% of the clutter type under consideration. The data was recorded manually as there was no available interface to the computer. An average value of the range within which the handset settled was recorded. The data is available after slight modification as a CSV (Comma Separated Values) file which can also be modified to KML (Google earth map file) via. csv to kml converter tool. Each measurement run was analyzed for trends and errors to satisfy that the available data correctly maps the targeted area. Below we have presented pictures of tools and allied equipment's used during real-time measurement campaign as Figure.7 (a) & (b).

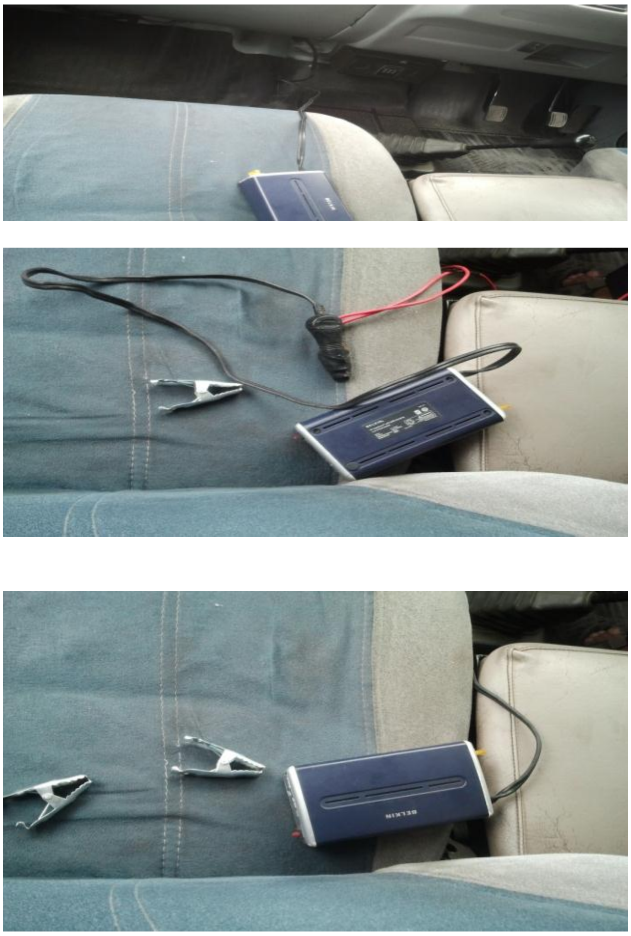

Figure.7(a). Pictures depicting adapter for power supply via, car battery to laptop with TEMS software loaded.

Figure.7(b). Author connecting the device and taking readings at different locations in the region under study over TEMS-8.1

5.2 Measurement and Data Collection

It took almost 6 months of time for visiting different locations within and outside the Dehradun region for GSM data fetch up. The region of concern was the sub-urban region of Patel Nagar, Dehradun and Garhi Cantonment exteriors at 1800 MHz of operating frequency. The data samples taken are for a base station transmitted signal value of 43dBm. The major objective is to measure path loss on the basis of readings obtained.

6. CONCLUSION

The results obtained via, measurements undertaken during the entire 6 months slot are used to obtain path loss values and thereafter these values are compared with respect to Walfisch-Bertoni models findings, state that empirical results generally supersede the modeling based results. Here on the basis of comparative analysis, we obtain an error factor or correction factor which being added to the existing model improves its efficacy for the region of concern.

These on further approximations clearly indicate that the field strength reduction depends not only on distance between the transmitting and receiving entity but also on the objects lying between the two & their geometry along with its outlook. In detailed view it was found that Bertoni also mentioned impact of base station height on signal strength and justified it using ray-trace techniques. Still, there are certain degrees of improvement required in the approach of the model being discussed for the region of our interest and thus a correction factor pertaining to actual measurements made via, drive test need to be compared with theoretical approximations. This would lead to better QoS in the concerned region by re-planning the network as proposed.

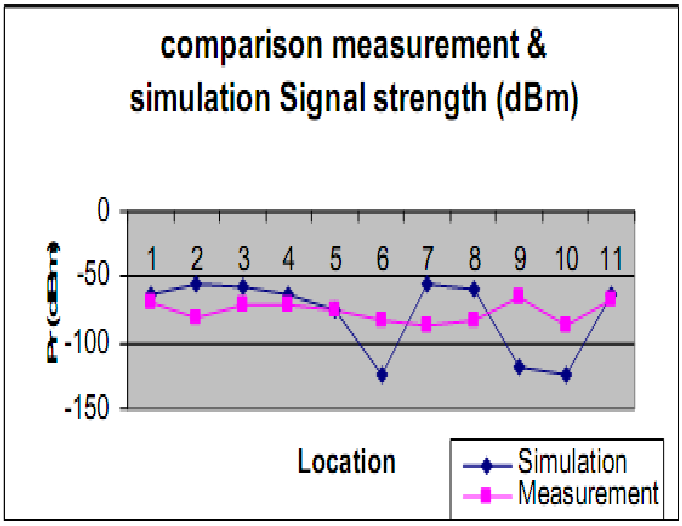

Figure.8. Comparison result of Measurement and simulation of signal strength.

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8. REFERENCES

[1] Rapport, T.S Wireless Communication Principles and Practice. 2nd . Ed.Upper Saddle River, NJ 07458: Prentice Hall PTR. 2002.

[2] Walfisch, J. and bertoni, H.L. a Theore tical Model of UHF Propagation in Urban.

[3] Liang, G .and Bertoni, H.L.approach to 3-D ray tracing for propagation prediction in Cities. IEEE Transactions on Antenna and Propagation. 1998.

[4] Blaunstein, N. Radio Propagation in Cellular Networks. Boston London: Artech House. 1999

[5] Maciel, L. R., Bertoni , H. L. and Xia, H. N. Unified Approach to Prediction of Propagation Over Buildings

for All Ranges of Base Station Antenna Height. IEEE Transactions on Antennas and Propagation. 1998. 46(12): 1782-1789.

[6] V.S. Abhayawardhana, I.J. Wassel, D. Crosby, M.P. Sellers, M.G. Brown, "Comparison of empirical propagation path loss models for fixed wireless access systems," 61th IEEE Technology Conference, Stockholm, pp. 73-77, 2005.

[7] Electronic Communication Committee (ECC) within the European Conference of Postal and Telecommunication Administration (CEPT), "The analysis of the coexistence of FWA cells in the 3.4 – 3.8 GHz band," tech. rep., ECC Report 33, May 2003.

[8] A. Molisch, L. Greenstein, and M. Shafi, "Propagation issues for cognitive radio," Proceedings of the IEEE, vol. 97, no. 5,pp. 787–804, May 2009.

[9] Vishal Gupta, Sandip Vijay and S.C.Sharma, "Efficient Path Loss Prediction in Mobile Wireless Communication Network", ISN2008, Feb. 22-24, 2008, Pg-271.

[10] W.C.Y.Lee, "Mobile Communication Design Fundamentals", (2nd Ed), John Wiely&Sons, New York, 1993.

[11] T. S. Rappaport, S. Y. Seidel, and K. R. Schaubach, " Site-specific propagation prediction for PCS system design", in Virginia Tech's Second Symp Wireless Personal Comm., Blacksburg, VA, June 17 – 19, 1992, pp. 16.1 – 16.27.

[12] S. Y. Seidel, T. S. Rappaport, "Site specific propagation prediction for wireless in building communication system design", IEEE Transaction on vehicular technology, Vol.43, Nov. 1994, pp. 879 – 891.

[13] Erricolo, D.; Uslenghi, P. L. E. Propagation path loss – acomparison between ray-tracing approach and empirical models. IEEE Trans. Antennas Propagation. 50, 5(2002), pp. 766-768J.

[14] Sarkar, Z.K.; Ji, Z.;Kim,K.;Medouri,A.; Salazar-Palma,M. A Survey of Various Propagation Models for Mobile Communication. IEEE Antennas and Propagation Magazine, 45, 3(2003), pp.51-82N.

[15] Kwak, D. Y.; Lee, C. H.; Kim, S. C.; Lim, J. W.; Lee, S. S.Enhanced urban path loss prediction model with newcorrection factors. IEICE Trans. Commun. E89-B, 4(2006), pp. 1459-1463.

[16] C. Tornevik, J.E. Berg, F. Lotse and M. Madfors, "Propagation Cell Planning and Channel Allocation for Indoor Application of Cellular System", IEEE Veh. Techno, Vol.48, May 1993, Pp. 867-870.

[17] Dharm Prakash Agarwal and Qing-An Zeng, "Introduction to Wireless and Mobile Systems", Thomson and Brooks/Cole, 2003, Pp: 63-87.

[18] COST Action 231; Digital mobile radio towards future generation systems, final report. // Tech. rep. European.

[19] http://www.radioelectronics.com/info/propagation/path-loss/rf-signal-loss-Tutorial.php.

[20] Mr. Sumit Joshi,Outdoor propagation models: A literature Review,IJCSE,Vol.12, Issue2,2012.

[21] Mr. Sumit Joshi,Mr. Rajeev Kumar,A Review On mobility Phillic Communications, IJCSI, Vol.9, Issue.1, 2012.

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