RF COVERAGE ESTIMATION OF CELLULAR MOBILE SYSTEM

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ABSTRACT

In the design of any cellular mobile system, the fundamental task is to predict the coverage of the proposed system. A wide variety of approaches have been developed over the years to predict coverage using propagation models. Propagation models are useful for predicting signal attenuation or path loss which may be used as a controlling factor for system performance or coverage so as to achieve perfect reception. In this paper Asset's path loss model for macro cells has been used and then the received signal strength is calculated to determine coverage. Section 1 introduces the cellular mobile system. Section 2 describes the propagation model. Path loss formula is discussed in section 3. Problem formulation and effects of variation in antenna height, antenna power and antenna tilt on RF coverage area are described in section 4. Finally the best configuration to achieve largest coverage area is concluded in section 5.

KEYWORDS

Cellular Mobile System, RF Coverage, Asset's Path Loss Model, Received Signal Strength.

I. INTRODUCTION

Wireless telecommunications is the transfer of information between two or more points that are physically not connected. Distances can be short as a few meters as in television remote control or long ranging from thousands to millions of kilometres for deep-space radio communications.

Since the early days of GSM development, GSM system network planning has undergone extensive modification so as to fulfil the ever-increasing demand from operators and mobile users with issues related to capacity and coverage. Coverage in a cell is dependent upon the area covered by the signal. ASSET is a planning and analysis tool that provides a complete range of functionality for the design and simulation of cellular networks.

II. PROPAGATION MODEL

Propagation models are mathematical attempts to model the real radio environment as closely as possible. Most propagation models need to be tuned (calibrated) by being compared to measured propagation data; otherwise we will not be able to obtain accurate coverage predictions. Carrier Wave measurements (survey data) help to produce an accurate propagation model that functions correctly. The validity of a propagation model will depend on the validity and significance of the survey data. Propagation models are used extensively in network planning particularly for conducting feasibility studies and during initial deployment. These models can be broadly categorized into three types; empirical, deterministic and stochastic. Empirical models are those based on observations and measurements alone. The deterministic models make use of the laws governing electromagnetic wave propagation to determine the received signal power at a particular location. Deterministic models often require a complete 3-D map of the propagation environment. An example of a deterministic model is a ray tracing model. Stochastic models, on the other hand, model the environment as a series of random variables. These models are the least accurate but require the least information about the environment and use much less processing power to generate predictions [1]. Deterministic Methods of Propagation Prediction includes Free Space Model and Plane Earth Model [2]. Standard Empirical model includes The Lee's model-This model was based on empirical data chosen as to model a flat terrain and The Walfisch – Ikegami model : This model is useful for dense urban environments[3] Okumara Hata's Propagation Model [4-7] COST- 231 Hata Model[8]

III. PATH LOSS FORMULA

Standard Macro cells are of three types: 1, 2 and 3. In this standard macro cell 3 is used. Following shows the general path loss formula for the Macro cell models:

Path Loss (dB) = k1 + k2log (d) + k3 (Hms) + k4log (Hms) + k5log (Heff) + k6log (Heff)log(d) +k7Diffn + C_loss

Where: d = Distance from the base station to the mobile station (km).

Hms = Height of the mobile station above ground (m). This figure may be specified either globally or for individual clutter categories.

Heff = Effective base station antenna height (m).

Diffn = Diffraction loss calculated using Epstein, Peterson, Deygout or Bullington equivalent knife edge methods.

k1 and k2 Intercept and Slope. These factors correspond to a constant offset (in dBm) and a multiplying factor for the log of the distance between the base station and mobile.

k3 = Mobile Antenna Height Factor. Correction factor used to take into account the effective mobile antenna height.

k4 = Okumura-Hata multiplying factor for Hms.

k5 = Effective Antenna Height Gain. This is the multiplying factor for the log of the effective antenna height.

k6 = This is the Okumura-Hata type multiplying factor for log (Heff) log (d).

K7 = Diffraction. This is a multiplying factor for diffraction loss calculations.

C_loss = Clutter specifications such as heights and separation are also taken into account in the calculation

The propagation model can be tuned by modifying the k-factors. For improved near and far performance, dual slope attenuation can be introduced by specifying both near and far values for k1 & k2 and the crossover point.

A. Calculation of Signal Strength

For the Standard Macro cell models, the received signal strength is calculated using the following equation:

$$\mathbf{P_{Rx}(dBm) = EiRP_{Tx} - LMASK\ (\theta,\varphi) - Lp}$$

where:

P_{Rx}(dBm) is the received power in dBm.

$EiRP_{Tx}$ is the maximum Effective Isotropic Radiated Power of the cell in dBm (that is, at the peak gain point of the antenna).

LMASK (θ,φ) is the antenna mask loss value for azimuth and elevation angles respectively in the direction of the path being calculated in dB. When the received signal is directly on the main beam of the antenna, this value will be zero.

Lp is the path loss in dB.

B.Calculation of EiRP

EiRP = PAPower + antennaG

where:

AntennaG = antennaGain + 2.14 (if the gain is in dB)

IV. PROBLEM FORMULATION

In this section the coverage of GSM network is evaluated on the basis of Rx level using the Standard Macro cell Model 3 Propagation model in Asset. ASSET is a planning and analysis tool that provides a complete range of functionality for the design and simulation of cellular networks. The basic network topology consists of a BTS and varying its various parameters like Antenna Height, Antenna Power and Antenna Tilt. The various other parameters are set as follows:

Propagation Model: Standard Macrocell Model 3

Antenna Type: NPX310M-E4

Effective Site Antenna Height Calculation Methods: Relative Method

Diffraction Loss Calculation Techniques: Epstein-Peterson Diffraction Loss Technique

Clutter: Dense Urban

A. IMPACT OF ANTENNA HEIGHT ON COVERA

1) Relation of Antenna Height with Path loss / Received Signal

The antenna height is the basis of base station coverage area. If the antenna height is increased path loss is lessened and on decreasing the antenna height path loss increases. The relation of path loss with antenna height is as-

$$\mathbf{Ploss = k1 + k2log\ (d) + k3\ (Hms) + k4log\ (Hms) + k5log\ (Heff) + k6log\ (Heff)\ log\ (d) + k7diffn + C\_loss}$$

Also path loss is related to received power as-

$$P_{Rx}(dBm) = EiRP_{Tx} - LMASK(\theta,\varphi) - Lp$$

So, if path loss increases then received power will decrease. If path loss decreases then received power will increase so the signal from the BTS will cover more distance.

2) Impact on received signal level (coverage area) by varying the antenna height from 20 m to 25m.

Category	**20 m**	**21 m**	**22 m**	**23 m**	**24 m**	**25 m**
Category 1:-68.00 <= x dBm	20.03%	20.44%	20.74%	21.16%	21.47%	21.73%
Category 2:-72.00 <= x < -68.00 dBm	7.46%	7.66%	7.98%	8.16%	8.45%	8.79%
Category 3:-77.00 <= x < -72.00 dBm	12.88%	13.42%	13.87%	14.20%	14.50%	14.81%
Category 4:-85.00 <= x < -77.00 dBm	30.31%	30.64%	30.97%	31.39%	31.77%	32.23%
Category 5:-95.00 <= x < -85.00 dBm	27.75%	26.57%	25.35%	24.19%	23.05%	21.77%
Category 6:-105.00 <= x < -95.00 dBm	1.51%	1.25%	1.07%	0.89%	0.76%	0.67%

Table 4.1.1: Impact on coverage area by varying the antenna height

3) Coverage Prediction Plots showing impact of antenna height on Coverage area:

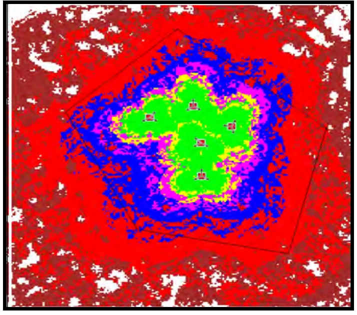

Fig 4.1.1: Antenna Height 20m

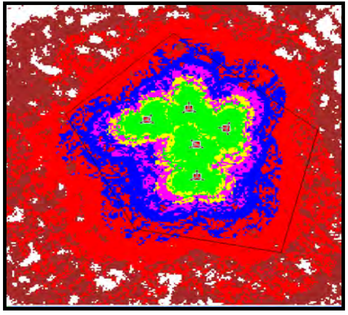

Fig 4.1.2: Antenna Height 21m

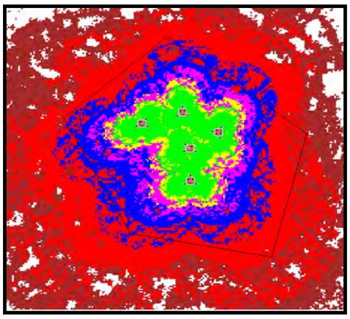

Fig 4.1.3: Antenna Height 22m

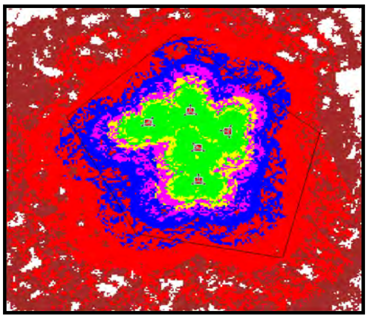

Fig 4.1.4: Antenna Height 23m

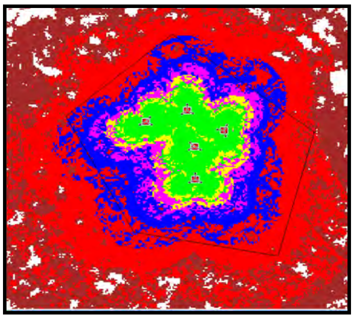

Fig 4.1.5: Antenna Height 24m

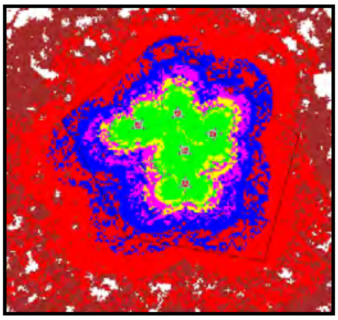

Fig 4.1.6: Antenna Height 25m

B. IMPACT OF TRANSMITTED POWER ON COVERAGE

1) Relation of Transmitted power with received Signal

As the BTS power increases received power also increases.

$$\text{PRx (dBm)} = \text{EiRPTx} - \text{LMASK}(\theta, \varphi) - \text{Lp}$$

2) Impact on received signal level (coverage area) by varying the transmitted power from 38 dBm to 43 dBm.

Category	38 dBm	39 dBm	40 dBm	41 dBm	42 dBm	43 dBm
Category 1:-68.00 <= x dBm	12.56%	14.28%	16.01%	17.74%	19.73%	21.73%
Category 2:-72.00 <= x < -68.00 dBm	7.16%	7.45%	7.86%	8.15%	8.32%	8.79%
Category 3:-77.00 <= x < -72.00 dBm	10.80%	11.33%	11.91%	12.95%	13.90%	14.81%
Category 4:-85.00 <= x < -77.00 dBm	26.37%	27.95%	29.03%	30.04%	31.14%	32.23%
Category 5:-95.00 <= x < -85.00 dBm	36.51%	34.49%	32.49%	29.65%	25.95%	21.77%
Category 6:-105.00 <= x < -95.00 dBm	6.45%	4.46%	2.67%	1.45%	0.96%	0.67%

Fig 4.2.1: Impact on coverage area by varying transmitted power

3) Coverage Prediction Plots showing impact of transmitted power on coverage area:

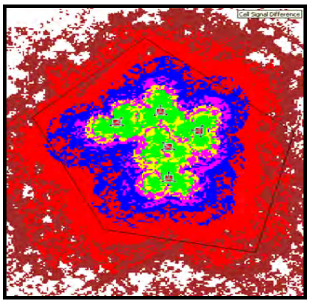

Fig 4.2.1: Transmitted Power 38dBm

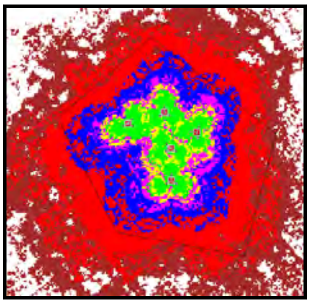

Fig 4.2.2: Transmitted Power 39dBm

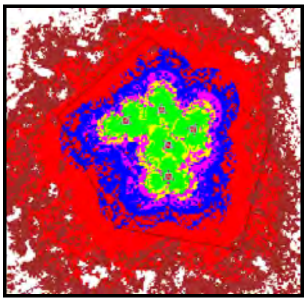

Fig 4.2.3: Transmitted Power 40dBm

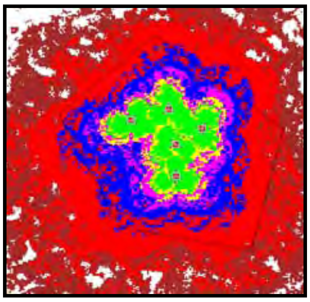

Fig 4.2.4: Transmitted Power 41dBm

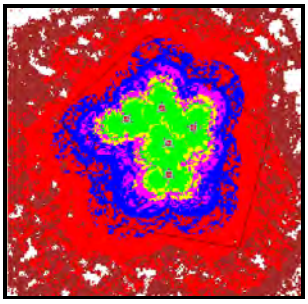

Fig 4.2.5: Transmitted Power 42dBm

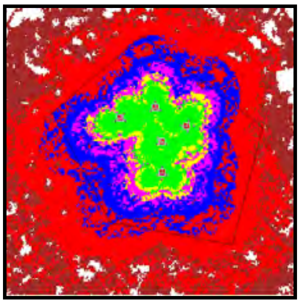

Fig 4.2.6: Transmitted Power 43dBm

C. IMPACT OF ANTENNA TILT ON COVERAGE

1) Relation of antenna tilt on coverage

Network planners often have the problem that the excess height of base station antenna provides over shooting coverage. If the overlapping area between two cells is too large, increased switching between the base stations (handover) occurs, which strains the system. Down tilting is another important parameter in determining optimum coverage. When selecting the optimum tilt angle, the goal is to have as high signal strength as possible in the area where the cell should be serving traffic. Beyond the serving area of the cell, the signal strength should be as low as possible.

When the cell site uses a high-gain antenna, downward tilting can direct the nulls in the antenna pattern towards the horizon to prevent energy from propagating into other cells. A too aggressive down tilting strategy will however lead to an overall loss of coverage. Down tilting the antenna limits the range by reducing the field strength in the horizon and increases the radiated power in the cell that is actually to be covered.

Down tilting can be done in two ways: Electrical down tilt and Mechanical down tilt. Mechanical down tilt alters the antenna's physical position on the tower whereas electrical down tilt changes the phase delivered to the antenna's radiating elements — independently and simultaneously. With electrical tilting, front and back lobes tilt in same direction: for example, an electrical down tilt will make both front lobe and back lobe tilt down. On the contrary, mechanical down tilting will make the front lobe tilt down and the back lobe tilt up. In almost all practical cases, antennas are only tilted down - though tilting up is technically possible. The mechanical and electrical tilt will be used together in order to create greater beam tilt in one direction than the other.

2) Impact on received signal level (coverage area) by varying the Antenna Tilt

Total tilt effect is the sum of both electrical tilt and mechanical tilt. Electrical tilt is constant at 2° as it is manufacturer specific and mechanical tilt is varied from 0° to 5°. So the total tilt is varied from 0° to 7°.

Category	**0°**	**1°**	**2°**	**3°**	**4°**	**5°**
Category 1:-68.00 <= x dBm	20.01%	21.34%	21.73%	21.30%	20.58%	19.58%
Category 2:-72.00 <= x < -68.00 dBm	10.92%	9.88%	8.79%	7.82%	6.87%	6.00%
Category 3:-77.00 <= x < -72.00 dBm	17.07%	16.11%	14.81%	13.56%	11.66%	9.94%
Category 4:-85.00 <= x < -77.00 dBm	34.80%	33.54%	32.23%	30.57%	28.54%	25.79%
Category 5:-95.00 <= x < -85.00 dBm	16.98%	18.75%	21.77%	25.74%	29.83%	34.08%
Category 6:-105.00 <= x < -95.00 dBm	0.22%	0.38%	0.67%	1.00%	2.50%	4.49%

Table 4.3.1: Impact on coverage area by varying Antenna Tilt

3) Coverage Prediction Plots showing impact of antenna tilt on coverage area:

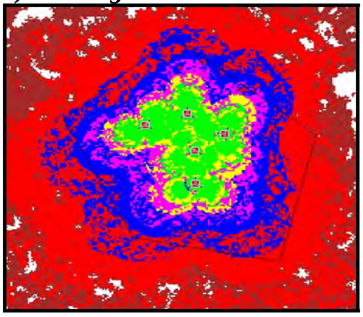

Fig 4.3.1: Antenna Tilt 0°

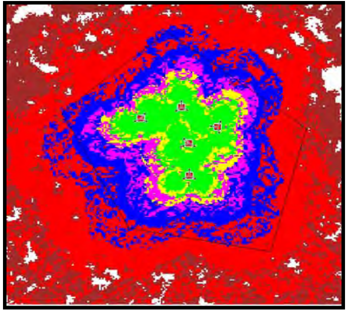

Fig 4.3.2: Antenna Tilt 1°

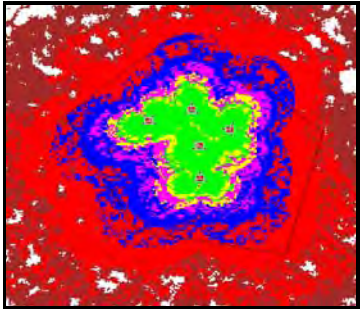

Fig 4.3.3: Antenna Tilt 2°

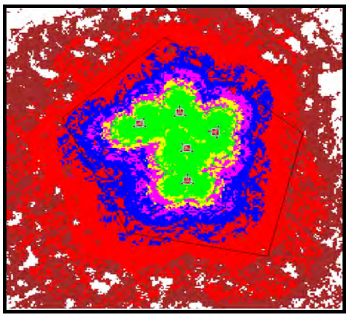

Fig 4.3.4: Antenna Tilt 3°

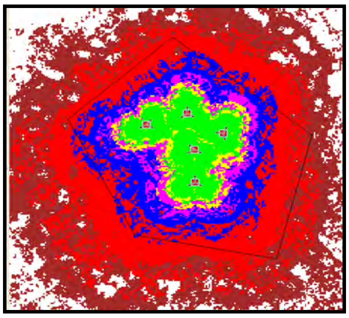

Fig 4.3.5: Antenna Tilt 4°

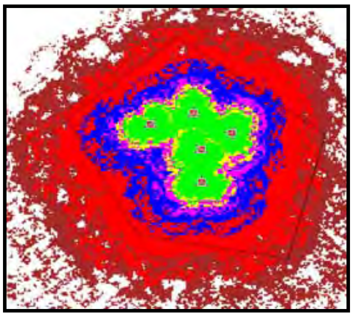

Fig 4.3.6: Antenna Tilt 5°

V. CONCLUSION

This paper depicts the coverage for GSM wireless networks. It can be concluded that coverage is highly influenced by the antenna height, antenna power and antenna tilt. For the better performance of the network it is required that antenna height and power should be high. While antennas tilt should be optimum. Best coverage is obtained at 25m height, 43dBm power and 2° tilt.

REFERENCES

[1] V.S. Abhayawardhana, I.J. Wassell, D. Crosby, M.P. Sellars, M.G. Brown Comparison of Empirical Propagation Path Loss Models for Fixed Wireless Access Systems
[2] Harold P. Stern, JihadG Hermes, and Subrahmanyam Darbha An Adaptive Propagation Prediction Program for Land Mobile Radio Systems IEEE Transactions on broadcasting, VOL 43, NO 1, MARCH 1997.
[3] Geetam S. Tomar, MIEEE and Shekhar Verma Analysis of Handoff Initiation Using Different Path Loss Models in Mobile Communication System
[4] Sylvain Ranvier Path loss models S-72.333 Physical layer methods in wireless communication systems Helsinki University of Technology, SMARAD Centre of Excellence
[5] Nazar. Elfadhil, M.A. Salam, A. Al-Lawati, O. Al-Qasmi, M. Al-Gheithi and Z. Nadir Modification of an open area OKUMURA-HATA propagation model suitable for OMAN.
[6] MASAHARU Hata, Member, IEEE Empirical Formula for Propagation Loss in Land Mobile Radio Services IEEE Transactions on Vehicular Technology, VOL. VT-29, NO. 3, AUGUST 1980 by
[7] Z. Nadir, Member, IAENG , N. Elfadhil, F. Touati Pathloss Determination Using Okumura-Hata Model And Spline Interpolation For Missing Data For Oman Proceedings of the World Congress on Engineering 2008 Vol I WCE 2008, July 2 - 4, 2008, London, U.K.
[8] D.D. DAJAB AND NALDONGAR PARFAIT A Consideration of Propagation Loss Models for GSM during Harmattan in ‘N’djamena (Chad) International Journal of Computing and ICT Research, Vol. 4, No. 1, June 2010