ISSN : 0976-8491 (Online) | ISSN : 2229-4333 (Print)

A Survey on the Atmospheric Effects on Radio Path Loss in Cellular Mobile Communication System

[1]C S Hanchinal, [2]Dr. K.N.Muralidhara
[1]PET Research foundation, University of Mysore, Mysore, India
[2]Dept. of ECE, PES College of Engineering, Mandya, India

Abstract
Radio propagation is essential for emerging technologies with appropriate design, deployment and management strategies for any wireless network. It is heavily site specific and can vary significantly depending on terrain, atmospheric effects, frequency of operation, velocity of mobile terminal, interface sources and other dynamic factor.
Accurate characterization of radio channel through key parameters and a mathematical model is important for: Predicting signal coverage, achievable data rates, network planning, Quality of service, hand over performance, etc.
Efficiency of present path loss models for cellular communication system suffers when they are used in the environment other than for which they have been used. Accurate path loss can be determined by measuring strength of signal through site specific field measurements.

Keywords
Radio Propagation; Path Loss; Characterization; Quality of Service; Planning; Atmospheric Effects

I. Introduction
The last decade, motivated a great development in field of telecommunications which has shrink the globe into a small village. The mobile communication had a key breakthrough from analog to digital communication. The advancement in wireless communication systems with exponential growth in number of subscribers, motivated to a great journey from 1G (First generation) to 4G (Fourth Generation). This allowed peak data rates up to 1 Gbps (Gigabits per second) in the downlink for low mobility (pedestrians), up to 100 Mbps (Megabits per second) for high mobility (vehicular speed), dynamically shared and the use of network resources to support more simultaneous users per cell, high spectral efficiency, scalable bandwidth, enhanced coverage up to 31 miles (50 kms), low latency level, high reliability, system capacity, robustness and better Quality of Service (QOS) compared to previous wireless broadband generations.
Mobile communication is the fastest growing segment of the wireless industry. As such, it has captured the attention of the media and imagination of the public. The vision of the wireless network communications supporting information exchange between people or devices is the communications frontier of the next few decades and much of it already exists in some form. However, many technical challenges remain in designing of wireless networks that deliver performance necessary to support emerging applications.

II. Cellular Concept
The cellular concept was a major breakthrough in solving the problem of spectral congestion and user's capacity. It offered high capacity with a limited spectrum allocation without any major technological change. The cellular concept is a system level idea in which a single, high power transmitter (large cell) is replaced with many low power transmitters (small cells). The area serviced by a transmitter is called a cell. Each small powered transmitter, also called a base station provides coverage to only a small portion of the service area. The power loss involved in transmission between the base station (BTS) and Mobile Station (MS) is known as the path loss and depends particularly on the antenna height, carrier frequency and distance. At higher frequencies the range for a given path loss is reduced. So more cells are required to cover a given area. Base stations close to one another are assigned different groups of channels. So that all the available channels are assigned to a relatively small number of neighboring base stations [3]. Neighboring base stations are assigned different groups of channels so that the interference between base stations or interactions between the cells is minimized. As the demand for service increases, the number of base stations may be increased thereby providing additional capacity with no increase in radio spectrum. The key idea of modern cellular systems is that it is possible to serve the unlimited number of subscribers, distributed over an unlimited area, using only a limited number of channels, by efficient channel reuse.

III. Radio Propagation
There is an exponential increase in the number of subscribers over the last decade. The evolution of new mobile broadband technologies has led to increase in coverage and capacity to adopt new ITU (International Telecommunication Union) standards. This has led to a revolution in radio planning and requirement for either new propagation models or expansion of existing propagation models to meet the requirement of the technology. Moreover it is highly important to understand propagation characteristic of radio wave through the air medium (transmission medium) to analyse the coverage parameters and deploy a wireless broadband system more accurately.
Radio propagation based on path loss models, helps us to predict coverage with precise placing of base stations in any given terrain. As radio waves have the feature of reflection, diffraction and scattering, it is more important to understand a wireless and mobile environment for proper transmission and receiving of signals. As the lower part of the spectrum is mostly occupied and evolving technologies are working on higher part of the spectrum (ultra high and super high frequencies) with lower wavelength, coverage planning with radio propagation models is mandatory to meet CAPEX and OPEX

IV. Path Loss
The reduction in power density of an electromagnetic wave between transmitter and receiver is called as path loss or path attenuation as it propagates through free space.

Path loss is a major component in the analysis and design of the link budget of a telecommunication system [6]. This term path loss is commonly used in wireless communications and signal propagation. Path loss may be due to many effects, such as free-space loss, refraction, reflection, aperture-medium, coupling loss, and absorption [1].

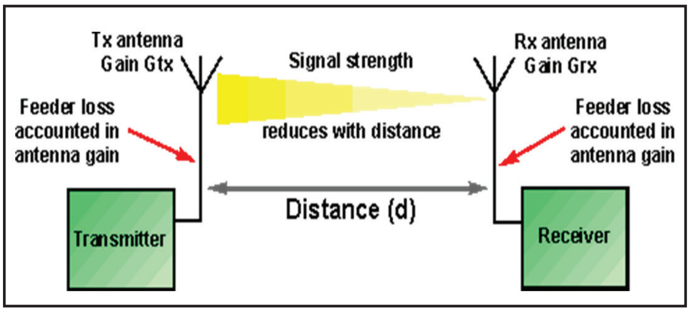

Fig. 1:

Path loss is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and receiver, and height and location of antennas [2].

V. LOS and NLOS

The expansion and advancement in technology promised to provide coverage for longer distances up to 50 kms (31 miles) in mobile communication system. There exists a condition where signal transmitted undergoes multipath fading before attaining the receiver. This feature is called NLOS (Non Line of Sight). Conversely a signal may travel without any obstruction between the transmitter and receiver. This feature is called LOS (Line of Sight). LOS conditions prevail in flat lands such as rural and open areas. Urban and suburban terrains experience most of NLOS conditions for data transfer.

VI. Radio Propagation Models

Radio propagation models are empirical mathematical procedure for the depiction of radio wave propagation as a "function of distance, frequency or any specific conditions". Radio waves help in communication of a wireless network, both in short and long range which is based on radio transmission. The geographical environment (mountains, water area, plains and hills) or propagation environment along with physical parameters of the medium like temperature, pressure, terrains, humidity, and environmental noise affects the radio wave propagation. Path Loss (PL) happens when electromagnetic waves interact with environment when transmitted between the source antenna (transmitter) and destination antenna (receiver). The signal undergoes reflection, diffraction, scattering and absorption before hitting the receiver. This is because, the signal transmission channel includes buildings, obstacles, trees, foliage, vegetation and moist air. This reduces the amplitude and phase of the signal.

Propagation models are basically classified into theoretical propagation models and empirical models.

A. Theoretical Propagation Models

The propagation models are divided into two basic types, namely, free space propagation and plane earth propagation model [3].

1. Free Space Propagation Model

In free space, the wave is not reflected or absorbed. Ideal propagation implies equal radiation in all directions from the radiating source and propagation to an infinite distance with no degradation [6]. Spreading the power over greater areas causes the attenuation. Equation (1) illustrates how the power flux is calculated.

$$P_d = P_t / 4\pi d^2 \qquad (1)$$

Where P_t is known as transmitted power (W/m²) and P_d is the power at a distance d from antenna. If the radiating element is generating a fixed power and this power is spread over an ever expanding sphere, the energy will be spread more thinly as the sphere expands.

By having identified the power flux density at any point of a given distance from the radiator, if a receiver antenna is placed at this point, the power received by the antenna can be calculated. The formula for calculating the effective antenna aperture and received power are shown in equations (2) and (3) below. The amount of power captured by the antenna at the required distance d, depends upon the effective aperture of the antenna and the power flux density at the receiving element. Actual power received by the antenna depends on the following:

- The aperture of receiving antenna A_e
- The wavelength of received signal λ.
- And the power flux density at receiving antenna P_d.

Effective area A_e of an isotropic antenna is:

$$A_e = \lambda^2 / 4\pi \qquad (2)$$

While power received is:

$$P_r = P_d \text{ X } A_e$$
$$= P_t \text{ X } \lambda^2 / (4\pi \text{ d})^2 \qquad (3)$$

While equation (4) illustrates the path loss (L_p):

$$L_p = \text{Power transmitted } (p_t) - \text{Power received } (P_r) \qquad (4)$$

When substituting equation (3) in equation (4), it yields equation (5) :

$$L_p(\text{dB}) = 20\log_{10}(4\pi)+20\log_{10}(d)-20\log_{10}(\lambda) \qquad (5)$$

Then substituting (λ in km) = 0.3 / f (in MHz) and rationalizing the equation produces the generic free space path loss formula, which is stated in equation (6).

$$L_p(\text{dB})=32.5+20\log_{10}(d)+20\log_{10}(f) \qquad (6)$$

2. Plane Earth Propagation Models

The free space propagation model does not consider the effects of propagation over ground. When a radio wave propagates over ground, some of the power will be reflected due to the presence of ground and then received by the receiver. Determining the effect of the reflected power, the free space propagation model is modified and referred to as the 'Plane Earth' propagation model. This model better represents the true characteristics of radio wave propagation over ground. The plane earth model computes the received signal to be the sum of a direct signal and that reflected from a flat, smooth earth. The relevant input parameters include the antenna heights, the length of the path, the operating frequency and the reflection coefficient of the earth. This coefficient will vary according to the terrain type (e.g. water, desert, wet ground etc). Path loss equation for the plane Earth model is illustrated in equation (7).

$$L_{pe}= 40 \log_{10} (d) - 20 \log_{10} (h_1) - 20 \log_{10} (h_2) \qquad (7)$$

Where d represents the path length in meters and h1 and h2 are the antenna heights at the base station and the mobile, respectively. The plane earth model is not appropriate for mobile GSM systems as it does not consider the reflections from buildings, multiple propagation or diffraction effects. Furthermore, if the mobile height changes as it will in practice then the predicted path loss will also be changed.

B. Empirical Propagation Models

The two basic propagation models (free space loss and plane earth loss) would require detailed knowledge of the location, dimension and constitutive parameters of every tree, building and terrain feature in the area to be covered. This is far too complex to be practical and would yield an unnecessary amount of detail. One appropriate way of accounting for these complex effects is via an empirical prediction models among them are: Okumara-Hata model, Cost 231-Hata model, Cost 231 Walfish-Ikegami model. These models depend on location, frequency range and clutter type such as urban, sub-urban and countryside.

Radio propagation models are empirical mathematical procedure for the depiction of radio wave propagation as a "function of distance, frequency or any specific conditions". The geographical environment (mountains, water area, plains and hills) or propagation environment along with physical parameters of the medium like temperature, pressure, terrains, humidity, and environmental noise affects the radio wave propagation. Path Loss (PL) happens when electromagnetic waves interact with environment when transmitted between the source antenna (a) transmitter and destination antenna (a) receiver. The signal undergoes reflection, diffraction, scattering and absorption before hitting the receiver. This is because; the signal transmission channel includes buildings, obstacles, trees, foliage, vegetation and moist air. This reduces the amplitude and phase of the signal. The two basic propagation models (free space loss and plane earth loss) would require detailed knowledge of the location, dimension and constitutive parameters of every tree, building and terrain feature in the area to be covered. This is far too complex to be practical and would yield an unnecessary amount of detail. One appropriate way of accounting for these complex effects is via an empirical prediction models among them are: Okumara-Hata model, Cost 231-Hata model, Cost 231 Walfish-Ikegami model. These models depend on location, frequency range and clutter type such as urban, sub-urban and countryside.

1. Okumara-Hata Model

Okumara carried out extensive drive test measurements with large clutter type, frequency, transmitter height and transmitter power. It states that the signal strength decreases at much greater rate with distance than that predicted by free space loss.

Hata model was based on Okumara's field test results and predicted various equations for path loss with different types of clutter. The limitations on Hata model due to range of test results from carrier frequency 150 MHz to 1500 MHz, the distance from the base station ranges from 1 Km to 20 Km, the height of base station antenna (h_b) ranges from 30 m to 200 m and height of mobile antenna (h_m) ranges from 1 m to 10 m. Hata created number of representative loss mathematical models for each of the urban, suburban and open country environments as illustrated in equations below respectively.

Path loss for urban clutter:

$$L_p(\text{urban}) = 69.55 + 26.16 \log_{10}(f) - 13.82 \log_{10}(h_b) - a(h_m) + (44.9 - 6.55 \log_{10}(h_b)) \log_{10}(d)$$

$$a(h_m) = (1.1 \log_{10}(f) - 0.7)h_m - (1.56 \log_{10}(f) - 0.8)$$

Path loss for suburban clutter:

$$L_p(\text{suburban}) = L_p(\text{urban}) - 2(\log_{10}(f/28))^2 - 5.4$$

Path loss for open country is:

$$L_p(\text{open country}) = L_p(\text{urban}) - 4.78(\log_{10}(f))^2 + 18.33\log_{10}(f) - 40.94 \quad (10)$$

Hata model is not suitable for micro-cell planning where antenna is below roof height and its maximum carrier frequency is 1500 MHz. It is not valid for 1800 MHz and 1900 MHz systems.

2. COST 231-Walfish-Ikegami Model

It is based on considerations of reflection and scattering above and between buildings in urban environments. It considers both line of sight (LOS) and non line of sight (NLOS) situations. It is designed for 800 MHz to 2 GHz, base station heights of 4 to 50 m, and cell sizes up to 5 km, and is especially convenient for predictions in urban corridors.

The case of line of sight is approximated by a model using free-space approximation up to 20 m and the following beyond:

$$L_{LOS} = 42.6 + 26 \log(d/1\text{km}) + 20 \log(f/1\text{ MHz}) \quad \text{for } d >= 20\text{m}$$

The models for non line of sight takes into account various scattering and diffraction properties of the surrounding buildings:

$$L_{NLOS} = L_0 + \max\{0, L_{rts} + L_{msd}\}$$

where L_0 represents free space loss, L_{rts} is a correction factor representing diffraction and scatter from rooftop to street, and L_{msd} represents multiscreen diffraction due to urban rows of buildings. These terms vary with street width, building height and separation, angle of incidence.

VII. Problem Statement

Both the above empirical models are widely used for network optimization. But it is observed that variation of signal strength due to environmental changes are not taken into account for signal prediction and network planning.

The refractivity of the atmosphere, N is defined as follows [19,20]:

$$N = (n-1)*10^6$$

For example, when n=1.000350,N=350.

A well known approximation for refractivity N is given below:

$$N = 77.6/T(P + 4810*e/T)$$

Where, P= total atmospheric pressure in mb;
T= atmospheric temperature in K;
e=water vapour pressure in mb.

All the three terms, P,T and e have been observed to fall with height in an exponential manner, resulting in a corresponding decrease in N with height.

VIII. Observations

The received signal strength recorded with the help of drive test tool on a particular winter day at a fixed place transmiitted by fixed BTS of the control channel at different times is as shown below:

Table 1:

S.No.	Time	Signal strength in dBm:
1	7:44 AM	-53
2	7:58 AM	-60
3	8:22 AM	-57
4	8:29 AM	-60
5	8:34 AM	-61
6	8:45 AM	-58
7	8:56 AM	-61
8	9:00 AM	-57
9	9:02 AM	-61
10	9:10 AM	-56
11	9:15 AM	-58
12	9:18 AM	-61
13	9:23 AM	-63
14	9:30 AM	-59
15	9:37 AM	-56
16	9:45 AM	-60

IX. Conclusions

From the above readings, we can conclude that changes in atmosphere at different time has an impact on the received signal strength of mobile communiction system.

There is a need for considering the atmospheric factor in propagation prediction models, to achieve optimum design of next generation communication systems.

References

[1] Mukesh Kumar, Vijay Kumar, Suchika Malik, "Performance and analysis of propagation models for predicting RSS for efficient Handoff", International Journal of Advanced Scientific and technical research. Issue 2, Vol. 1, Feb 2012.

[2] V.S.Abhayawardhana, I.J.Wassell, D.Crosby, M.P.Sellars, M.G.Brown,"Comparision of Empirical propagation path loss models for fixed wireless access systems."

[3] Zia Nadir, Member IAENG, Muhammad Idrees Ahmad, "Pathloss determination using Okumara-Hata model and cubic regression for missing data for Oman", Proceedings of the international multi conference of Engineers and computer scientists, Vol. II. IMECS 2010, March 17-19, 2010, Hong Kong.

[4] K.Ayyappan, P.Dananjayan,"Propagation model for Highway in mobile communication system."

[5] Vishal Gupta, S.C Sharma, M.C. Bansal,"Fringe area path loss correction factor for wireless communication", International journal of recent trends in Engineering Vol. 1, No. 2, May 2009 poster paper.

[6] Saeed Mohseni, Mohammad A. Matin,"Study of propagation path loss for OFDM mobile systems", International Journal of Computer Science and Network Security, Vol. 12, No. 9, September 2012.

[7] Shveta Sharma, Prof.R.S.Uppal,"RF coverage Estimation of cellular mobile system." International Journal of Engineering and Technology, Vol. 3(6), 2011-2012, pp. 398-403.

[8] Manju Kumari, Tilotma Yadav, Pooja Yadav,"Comparative Study of pathloss models in different Environments", International Journal of Engineering Science and Technology, Vol. 3, No. 4. Apr. 2011.

[9] Mohamed Ouwais Kabaou, Belgacem Rhaimi Chibani, Mohamed Naceur Abdelkrim,"Path loss models comparison in Radio Mobile Communications." International Journal of Soft Computing 3(2): pp. 88-92, 2008.

[10] Magdy F. Iskander, Zhengqing Yun,"Propagation prediction models for wireless communication systems." IEEE transactions on microwave theory and techniques. Vol. 50, No. 3 Mar 2002.

[11] Yasuhiro Oda, Koichi Tsunekawa, Masaharu Hata, "Advanced LOS path-loss model in microcellular mobile communications", IEEE transactions of vehicular technology. Vol. 49, No. 6, Nov 2000.

[12] Scott Y Seidel, Theodore S Rapport,"914 MHz path loss prediction models for indoor wireless communications in multi floored buildings", IEEE transactions on Antenna and propagation. Vol. 40, No. 2 Feb. 1992.

[13] Greg Durgin, Theodore S Rapport, Hao Xu.,"Measurements and models for Radio Path Loss and Penetration Loss in and Around Homes and Trees at 5.85GHz." IEEE transactions on communications. Vol. 46, No. 11, Nov. 1998.

[14] Hazer Inaltekin, Mung Chiang .H. Vincent Poor, Stephen B Wicker," On Unbounded Path-Loss Models: Effects of Singularity on Wireless Network Performance." IEEE transactions on selected areas in communications. Vol. 27, No. 7 Sep. 2009.

[15] Xiongwen Zhao, Jarmo Kivinen, Pertti Vainikainen, Kari Skog,"Propagation Characteristics for Wideband Outdoor Mobile Communications at 5.3 GHz." IEEE journal on selected areas in communications, Vol. 20, No. 3, Apr. 2002.

[16] Vinko Erceg, Larry J Greenstein, Sony Y Tjandra, Seth R Parkoff, Ajay Gupta, Boris Kulic, ArthurA Julius, Rence Bianchi. "An Empirically Based Path Loss Model for Wireless Channels in Suburban Environments," IEEE journal on selected areas in communications. Vol. 17, No. 7 July 1999.

[17] Do-Young KWAK, Chang-Hoon LEE, Scong-Cheol KIM, Jae-Woo LIM, Sung-Soo LEE,"Enhanced Urban Path Loss Prediction Model with New Correction Factors", IEEE transactions on Communication. Vol. E89-B, No. 4. Apr.2006.

[18] Lkhagvatseren. T, Hruska.F.,"Path loss aspects of wireless communication system for sensors." International Journal of computers and communications, Vol. 5, Issue 1, 2011.

[19] J Griffiths,"Radio Wave Propagation and Antennas: An Introduction", Prentice Hall Ltd.1987

[20] J D Parsons,"The Mobile Radio Propagation Channel", II Edition, pp. 26-31, John Wiley and Sons, 2000.

ISSN : 0976-8491 (Online) | ISSN : 2229-4333 (Print)

C S Hanchinal received his B.E. degree in Electronics and Communication Engineering from Gogte Institute of Technology, Belgaum, Karnataka India in 1988, the M.Tech. degree in VLSI Design and Embedded Systems from Visvesvaraya Technological University, Belgaum, India, in 2007. He was a teaching faculty in Regional Telecom Training Centre, BSNL, Mysore from 2001 to 2011. He is presently working as Sub-Divisional Engineer in IT project Circle Pune of BSNL India. His research interests include wireless communication, Telecommunication switching and transmission techniques. At present, He is engaged in mobile communication path loss in varying environmental conditions.