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Outdoor Propagation Models-Comparison Literature Review

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Abstract - **The aim of comparing different outdoor propagation models is to study the earlier introduced models in the present environment of RF technology and requirement. In the present era of telecom services coverage is not enough but we need to introduce cellular network with high quality parameters. In this comparison review we will focus on the type of terrain/ environment which will best suit the different outdoor propagations models.**

Keywords - **Pathloss, Attenuation, Optimization, Antenna Gain, Interference.**

I. Introduction

The ability to communicate with people on the move has evolved remarkably since Guglielmo Marconi first demonstrated radio's ability to provide continuous contact with ships sailing the English Channel. That was in year 1897, and since then new wireless communications and services have been enthusiastically adopted by people throughout the world. Specially during the past ten years, the radio communications industry has grown by margins, fuelled by digital and RF circuit fabrications, new large-scale circuit integration, and other modern technologies which make portable radio equipment smaller in size , cheaper, and reliable. Digital switching techniques have evolved the mass deployment of affordable, more friendly radio communication networks. These trends will develop at an even greater pace during the next decade.

Wireless communications is enjoying its rapid growth period in past decades, due to development in technologies which permit huge deployment. Historically, growth in the mobile communications field came slowly, and has been coupled closely to technological improvements. The capacity to provide wireless communications to an entire population was not even a matter of thought until Bell Laboratories came with the cellular concept in the 1960s and 1970s. With the development of reliable and solid-state radio frequency hardware in the 1970s, the wireless communications era was actually born. The recent exponential growth in cellular radio and personal communication systems throughout the world is directly attributable to new technologies of 1970s, which got mature today. The future growth of mobile and portable communication systems will be tied more closely to radio spectrum allocations and regulatory decisions which affect or support new services, as well as to consumer needs and technology advances in the signal processing and mobile network areas.

Nowadays we find a totally different outlook of radio communications, which encompasses recent developments in different fields & even more creation of newer fields like: adhoc wireless network, wireless sensor network, mobile communications etc. Between the two extremes of present & past times, the mid-time arena have seen development of various propagation models like: Line of sight, okumura-Hata, cost etc. In order to facilitate better planned & resource specific developments for the bet HHHterment of QOS. This period of time also noticed several developments in the field estimation path loss in different propagation scenario profiles deploying variable modelling strategies.

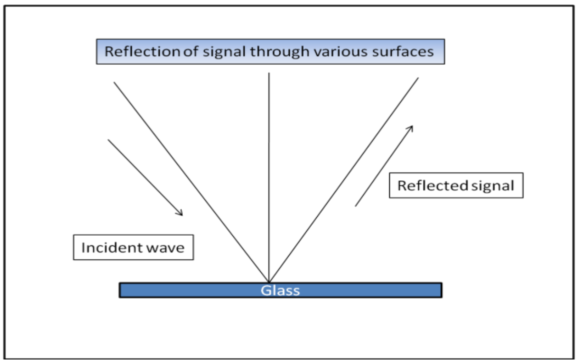
II. Radio Propagation

A. Types of Radio wave propagation mechanisms

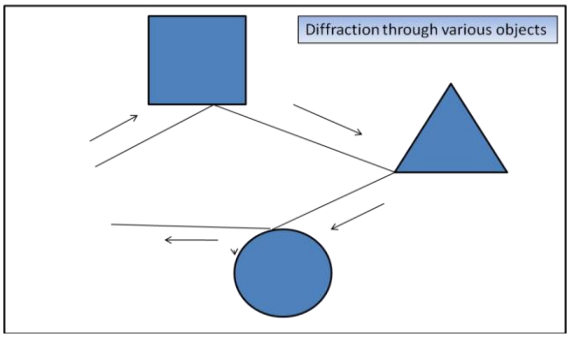
To study and understand the modelling of radio wave propagation, it is first required to know the basics of its propagation mechanism. There are three basic mechanism of propagation:

1. Reflection
2. Refraction
3. Diffraction

We will discuss them in very short with the help of fig.1.(a),(b) & (c) [4],[3]



(a)Reflection at shiny surfaces



(b)Diffraction at the edges

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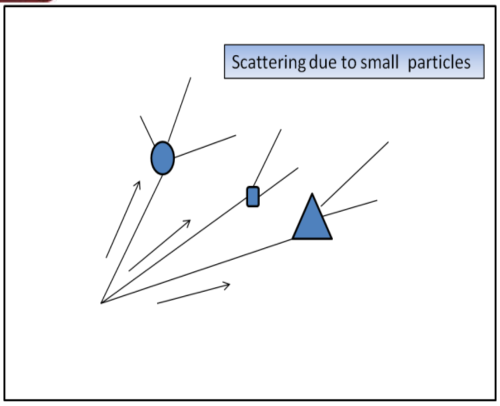


(c) Depiction of scattering

Fig.1 (a), (b), (c)-Various propagation mechanisms.

B. Radio Propagation Models

Radio propagation model defines the behaviour of transmitted radio wave in the environment selected for transmission. Broadly we have two types of environment for radio waves i.e. outdoor and indoor. So there are broadly two types of radio propagation models:

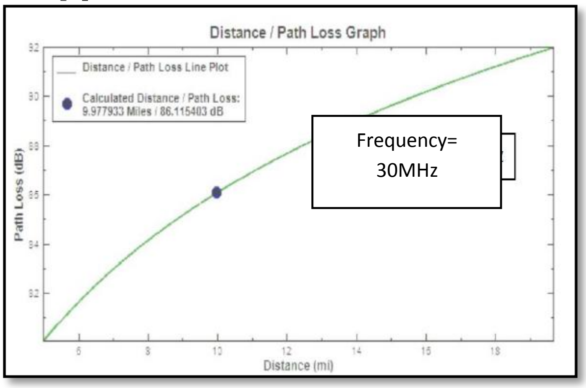
1. Outdoor propagation models.
2. Indoor propagation model.

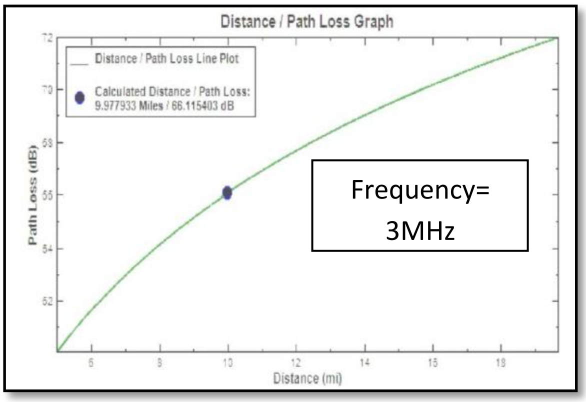
Here in this paper we will focus on Outdoor propagation models as it is our topic of interest

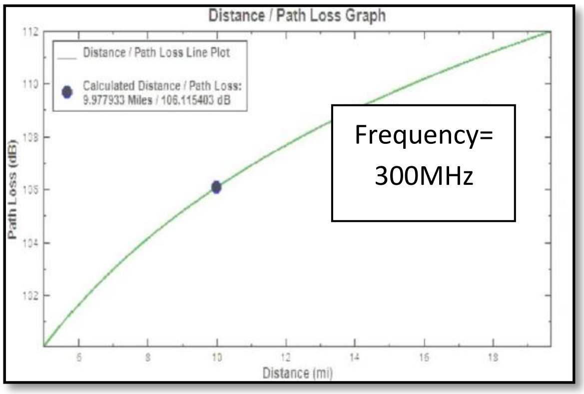
III. Outdoor Propagation Models

These models correspond to prepare model for RF waves travelling in outside environment comprising of buildings, trees, mountains and vehicles. There is some important work done and some important model prepared under this category:

Free Space Model- In this modelling the received power depend upon transmitted power, antenna gains & distance between transmitter and receiver. The logic is that "the received power is inversely proportional to square of the distance between transmitter & receiver" [1]. This model holds true only when there is only single path without any obstruction between transmitter & receiver. Below equation is employed for calculation of received power for distance of separation 'I' between transmitter & receiver.[4]







$$P_r(I) = \frac{P_t\, G_t\, G_r\, \alpha^2}{4\pi^2\, I^2\, L} \quad \ldots\ldots\ldots\ldots\ldots\ldots (a)$$

Where Pt is the transmitted power. Gt & Gr are the transmitting & receiving antenna gains respectively. L (L≥1) is the system loss & α is the wavelength of transmitted wave.

Two Ray Ground Model- Total received power at the receiver includes powers due to two paths : first, the direct path between transmitter and receiver, second the path by one ground reflection between the transmitter & receiver separated by same distance I as in case first case. Additional parameter in this model is the height of receiver & transmitter from ground surface. Received power at a distance I using this model is given by following equation:

$$P_r(I) = \frac{P_t\, G_t\, G_r\, h_t^{\,2} h_r^{\,2}}{I^4\, L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (b)$$

ht & hr are the heights of locations of receiving & transmitting antennas with respect to the ground.

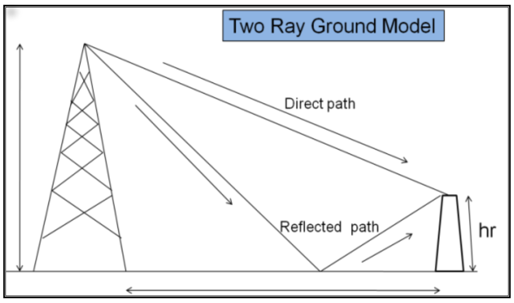


Fig.1. depiction of two ray ground reflection model

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Ricean and Rayleigh Fading Models - When there are multiple indirect paths between transmitter and receiver and no direct path exist between them, Rayleigh fading is said to occur but if there are multiple indirect paths along with one direct path between transmitter & receiver then Ricean fading happens. So shows that the multipath propagation give rise to another feature of propagation which is called fading. Due to fading effect signal received with some time delay and thus in order to get an idea of measure of fading.[5]

Shadowing Model - this model says "Received power is a logarithmic function of distance between transmitter and receiver". This model also involves a random variable which accounts for path loss due to variable habitats. It also assumes a close in distance Io taken as a reference point, with respect to which received power is calculated at different distances i.e. a relativistic measurement is carried out as:

$$P_r(I_0) = \frac{\left(\frac{I}{I_0}\right)^{\mu}}{P_r(I)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(c)$$

μ is the factor for path lost and it is calculated using empirical formulae for measurement. Some of the typical values as per niche specificity are listed as in table:

Habitat (niche characteristics)		μ (Path Loss exponent)
Outdoor Environments	Frees pace	2
	Urban area cellular radio	2.7-3.5
	Obstructed in factories	2-3
	Shadowed urban areas	3-5

[9] & [10]

Table.1 various path loss exponent values at different frequencies of measurement & variable environment profiles.

Longley Rice Model - this model is applicable to point to point communication in frequency range 40MHz-100MHz over different kind of terrains. Media transmission loss is predicted using path geometry, diffraction losses and scattering losses. This model works in two modes, when path specific parameters are available then it is point to point prediction and when they are not available that mode is called Area mode prediction.

Okumura Mode l- An empirical model developed by Japanese radio scientist Okumura as a part of extensive measurement campaign conducted in 1968. It is the mostly used model for urban area. It is applicable for frequency range from 150 MHz to 1920 MHz but can be extrapolated up to 3GHz, and can be deployed for a distance range of 1Km to 100Km. It is applicable for base station height ranging from 30m to 1000m. Path loss in Okumura model is expressed as:

$$L_{50}(I)[d\,|\,B] = L_F(I) + A_M(f,I) - G(h_t) - G(h_r) - G_{area} \quad \ldots\ldots(d)$$

L_{50} = 50th percentile of path loss or median value.

$L_F(I)$ = Free space propagation path loss.

$A_M(f,I)$ = Median attenuation relative to free space.

$G(h_t)$ = base station antenna height gain factor.

$G(h_r)$ = Mobile station antenna height gain factor.

G_{area} = Gain due to type of environment.

$G(h_t) = 20\log(h_t/200)$ $1000m > h_t > 30m$

$G(h_r) = 10\log(h_r/3)$ $h_r \le 3m$

$G(h_r) = 20\log(h_r/3)$ $3 < h_r < 10m$

h_t = transmitter antenna height.

h_r = transmitter receiver height.

It is considered as simplest and best in terms of accuracy for path loss prediction for mature cellular & land mobile Radio system in clutter environments. its major disadvantage was slow response to rapid changes in terrain therefore model is fairly good in urban and sub urban areas but not for rural areas. Common standard deviation between predicted and measured path loss is 10-14dB.

Hata Model - It is simply the empirical formulation of the graphical path loss data provided by Okumura & is valid for frequency range of 150 MHz -1.5 MHz.[7]. It provide urban area propagation loss as a standard formula and supplied correction equation for application to other situations.

Median path loss for the Hata model is given by:

$$L(dB) = 69.55 + 26.16\log(fc)[MHz] - 13.82\log(h_t) - a(h_r(m)) + (44.99 - 6.55\log(h_t)[m])(\log(I[Km])) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (e)$$

Where,

fc = frequency in MHz

h_t = transmitter antenna height.

h_r = transmitter receiver height.

I = tx = rx separation [in Km]

$a(h_r)$ = antenna height correction factor of the mobile antenna as a function of coverage area.

1. *For Urban Area*

$$L_{70}(dB) = 69.55 + 26.16\log(fc)[MHz] - 13.82\log(h_t) - a(h_r(m)) + (44.99 - 6.55\log(h_t)[m])(\log(I[Km])) \quad \ldots\ldots\ldots\ldots (f)$$

2. *For Sub-Urban Area-*

Cost 231 model - This model is sometimes also known as Hata Model pcs extension which is an enhanced version of Hata Model and is valid from 1500-2000MHz. Base station height ranges 30-200m and receiver antenna height 1-10m and distance between two antennas from 1-20km. The Cost231 median path loss is given by:

$$L_{50}(dB) = 46.3 + 33.9\log(fc) - 13.82\log(h_t) - a(h_r) + [44.96.55\log(h_t)]\log(I) + C \quad \ldots\ldots(g)$$

fc = is the frequency in MHz.

ht = is the base station height in meters.

hr = is the mobile station height in meters.

$a(hr)$ = is the mobile antenna height correction factor defined earlier.

I: is the link distance in km

C = 0dB for medium cities or suburban centre with medium tree density.

C = 3dB for metropolitan centers.

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The Cost 231 model is used only for applications where the base station antenna is above certain roof tops. Hata & Cost 231 models are used widely in radio planning in mobile telephony.

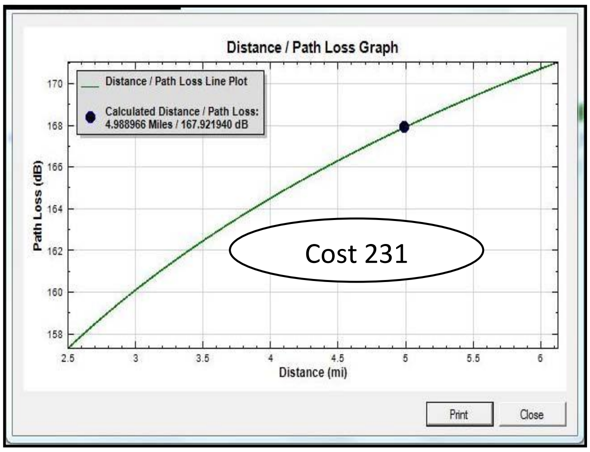


Fig.4. path loss profile for cost231model

IV. Near Earth Propagation Models

They are used for various applications involve point to point propagation near earth surface. Such models are based on phenomenon of scattering, reflection, diffraction, absorption etc caused by terrain, buildings and foliage. Some of the proposed & listed models for this category are:

Foliage Models - These models approximates extra attenuation loss caused due to dense foliage attenuating the LOS path of signal. Generally, the foliage depth is expressed in Meters & frequency of operation in GHz. The model covers a frequency range of 230 MHz to 95 GHz. [8]

Weiss Berger's Model - this model is based on exponentially decay model and it is expressed in the form of given below path loss equation. I

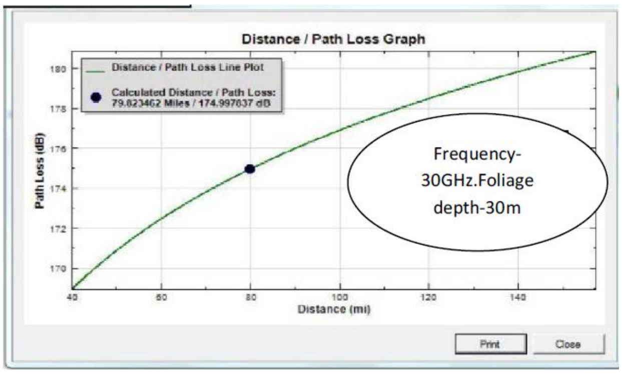
$$L(dB) = \begin{Bmatrix} 1.33F^{0.284} I_f^{0.588}, 14 < I_f < 400m \\ 0.45F^{0.284} I_f, \quad 0 < I_f < 14m \end{Bmatrix} \quad ....(h)$$

Where,

I_f = Depth of foliage in meters.

F = frequency in GHz.

This model covers a frequency range of 230 MHz to 95 GHz.



Early ITU Vegetation Model - This model generates results in fine coincidence with Weiss Berger's model, also known as Early ITU Model. It is also said that that this model is the round off version of Weiss Berger's model. This is given by:

$$L(dB) = 0.2F^{0.3} I_f^{0.6} \quad ....(i)$$

F = frequency in MHz

I_f = Depth of foliage in meters along line of sight.

Updated ITU Vegetation Model - Mostly early ITU models were profile specific so it was not possible to fix particular model everywhere. In this updated model, Above 5GHz the model depends on type of foliage, depth of foliage & area of concern. Therefore, the excess attenuation due to vegetation is given as:

$$A_{veg} = R_\infty I + C\left\{\left[1 - e^{-(R_0 + R_\infty)}\right] I / C\right\} dB \quad ....(j)$$

Terrestrial path with one terminal in woodland - it covers the situation when one terminal is on free space and other terminal is in the middle of woodland i.e. dense foliage or vegetation. Access attenuation in this kind situation can be calculated using below mentioned expression:

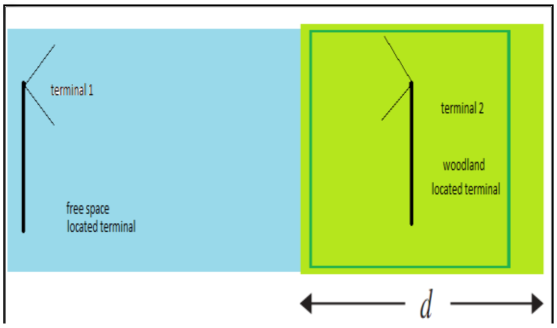


Fig.2. Propagation path with single terminal in woodland.

The model is mathematically depicted as:

$$A_{ev} = A_m \left[A e_\alpha^1 / A_m \right] \quad ....(k)$$

I = length of path within the woodland in meters.

α = attenuation specific to short vegetative path (dB/m)

A_m = maximum attenuation for single terminal within specific vegetation type (dB).

Single Vegetation Obstruction - it is for the situation when neither of the terminals is in vegetation but still there exist vegetation in between them. This model stands for single type of vegetation. For frequency = 3 GHz or below the vegetation loss model is:

$$A_{e-1} = I.\alpha \quad ....(l)$$

Where,

α = specific attenuation for short vegetative paths (dB/m).

I = Length of path within the vegetation in meters.

A_{e-1} =Lowest excess attenuation for any other path (in dB) [12]

The equation shows that if the vegetation loss is very large, an alternate path is used to determine the path loss such as diffraction path.

V. Terrain Modelling

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Terrain modelling involves the preparation of model which will include effects of manmade objects, terrain variations and vegetation effects. Some models that incorporate Terrain modelling are discussed below:

Egli Model - This can be used as a first basic model for calculation of path loss over non-regular terrain. It is given as:

$$L_{50} = G_b G_m \left(h_b h_m / I^2\right)^2 \beta \qquad ....(m)$$

Where,

G_b = gain of base station antenna.

G_m = gain of mobile antenna.

h_b = height of base station antenna.

h_m = height of mobile antenna.

I = propagation distance

$\beta = (40/f)^2$, f is in MHz.

Longley-Rice Model - it is important model and it covers following parametric conditions such as: terrain, climate, subsoil conditions and ground shape. It is implemented in the form of an algorithm which accepts different parameters to give the path loss data because of much detailed outlook it poses. It is implemented in two configurations: point-to point & area configuration This model is based on measurements made in the frequency range of 40 MHz -100GHz in the range from 1 -2000 km.

ITU Terrain Model - It is based on phenomenon of diffraction studied under wave optics & is a quicker methodology for computing median path loss. ITU Terrain Model loss is given as:

$$A_d = -\frac{20h}{F_1} + 10dB \qquad ....(n)$$

h = height difference between most concerned path blockage & LOS between transmitter & receiver.

F_1 = Radius of first Fresnel Zone

Where F1 is given as:

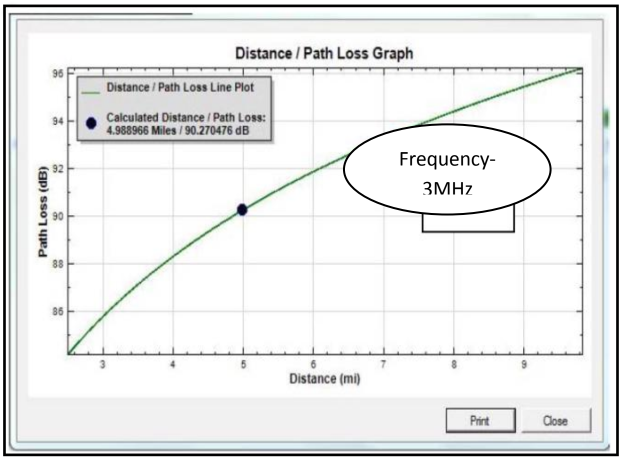
$$F_1 = 17.3\sqrt{\frac{d_1 d_2}{fd}}\, m \qquad ....(o)$$

Where,

d_1 and d_2 = distances from each of the terminal to the obstruction in km.

d = distances between in km

f = frequency of operation in GHz.



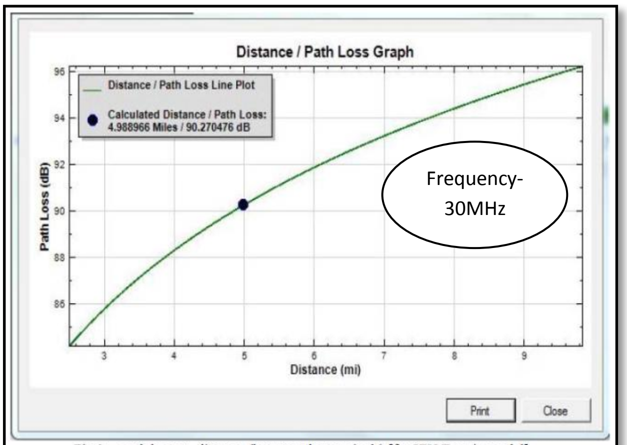


Fig.3 –path loss vs. distance (between the terminals) [for ITU Terrain model]

VI. Conclusion

From the survey of important models discussed, it gives a clear insight in to the fact that for an analysis to be drawn out regarding specific model with respect to any data set the median values of attenuation or path loss is calculated specific to the kind of environment, terrain & other such factors. As my interest is in study of RF propagation in urban area; Okumara model is the best suited and I continue my work based on this model.

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