OUTDOOR PROPAGATION MODELS A LITERATURE REVIEW

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***Abstract*— The major focus of this review is based on earlier & present day developments encompassing the field of radio transmission & propagation. It covers a wide area of radio communication in a more subtle & elastic manner, the leading aspects of the review involves an overall discussion of different models & techniques developed so far, facilitating radio propagation. A more penetrating aspect of mobility lead communications & associated software developments along with recent advancements also forms an important part of it.**

Keywords- pathloss, models,attenuation.

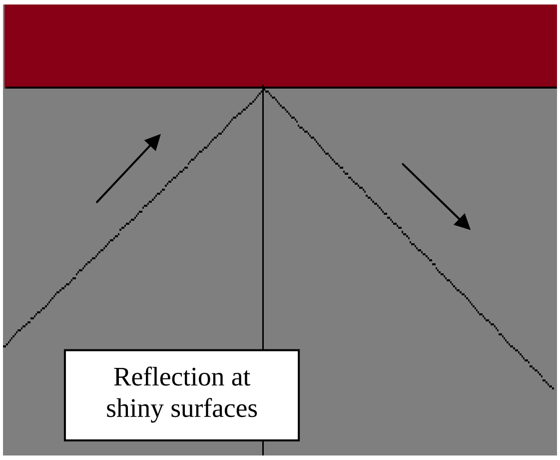
I. INTRODUCTION

The initial study in the field of radio communications began with Maxwell's mathematical explanations of relationship between the two major fields involved rigorously in the sector of communication i.e. the magnetic & electric fields during 1884. Later in 1888 Heinrich Hertz demonstrated experimentally the generation of electromagnetic waves from electricity & suggested that these waves travel with the speed of light. The entire electromagnetic spectrum is composed of many sub spectra's indicating different nature waves. Radio waves are also a part of this electromagnetic sub-spectrum. In 1896 the first telegraphing machine based on the concept of radio waves was built by Guglielmo Marconi, it employed the fundamentals of spark gap transmission/reception. This was later followed by transmission of letter 'S' across English channel by him. All this was a great success initially but a lot was to be done, even more the earlier means of transmissions attempted were discrete & damped by nature. There, after in 1900 Reginald Fessenden showed that the continuous radio-waves are necessary for the transmission of speech & music signals. On December 23, 1900 first wireless voice message was transmitted & in 1906 first radio broadcast was made. There, after the golden period of radio based transmission & it's applications in a variety of fields begun. 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 communications, wireless sensor communications, mobile communications etc. Between the two extremes of present & past, the mid-time arena visualized development of various propagation models like: Line of sight, okumura-hata, cost etc. in order to facilitate better planned & resource specific developments for the betterment in, majority of all the aspects i.e. the QoS. This period of time also noticed several developments in the field of path loss estimation in different propagation scenario profiles deploying variable modeling stratergies.In parallel to all this, simultaneously many software platforms were also being developed for analytical study of radio propagation models & different networking topologies in deployment such as: omnet++,opnet,ns-1&2,glomosimm,qualnet4.5&5.0 etc. Even more many scholars were also deploying 2-d & 3-d designs for study of real-time propagation characteristics via. Actual indoor building modeling.[8]

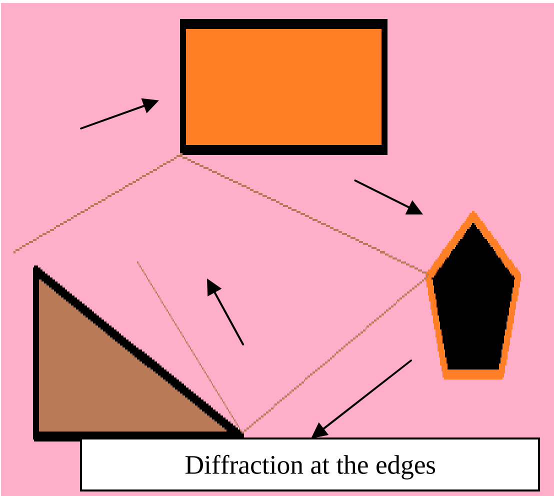
II. RADIO PROPAGATION

A. Types of Radio propagation mechanisms

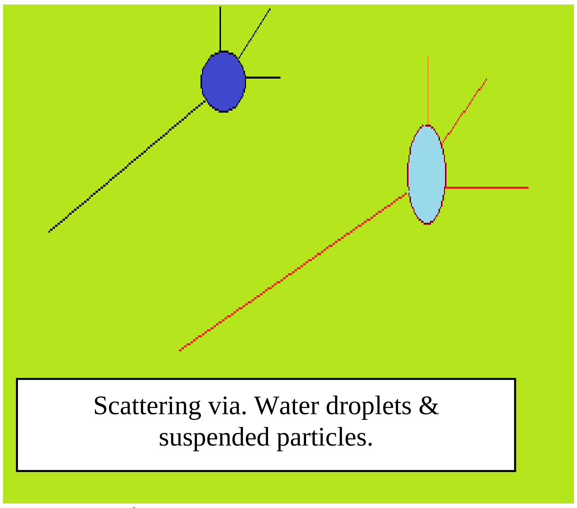
The 3 very basic radio propagation mechanisms are actually the key to analysis of any radio propagation modeling based study. These are: reflection, diffraction & scattering. Now, we analyze some basic different profiles based on all these three mechanisms as shown in fig.1.(a),(b) & (c) [4],[3]



(a)Reflection at shiny surfaces



(b)Diffraction at the edges



(c) Depiction of scattering

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

B. Different Radio Propagation Models

Radio propagation models facilitate studies of radio transmissions under different environments of implementation of the radio system. In all radio propagation models, macroscopically can be classified in to two categories: 1-Outdoor Propagation Models 2-Indoor Propagation Models. We focus only on type 1.[2]

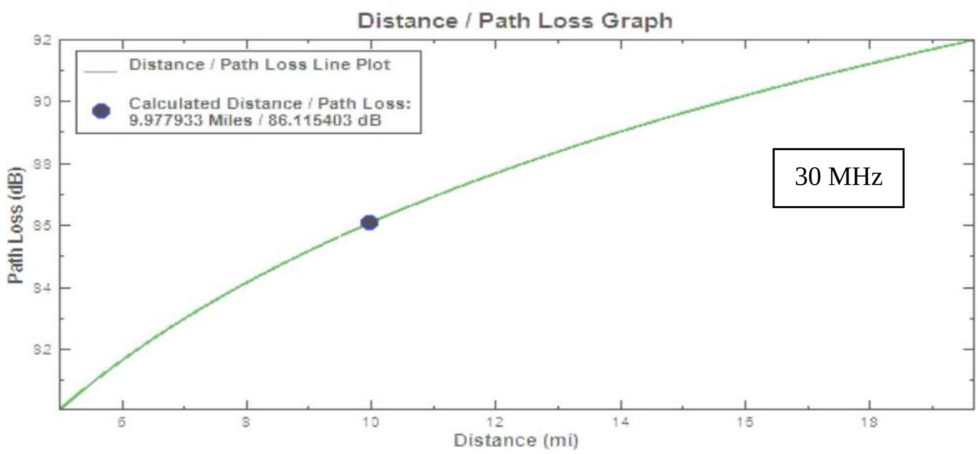
OUTDOOR PROPAGATION MODELS:

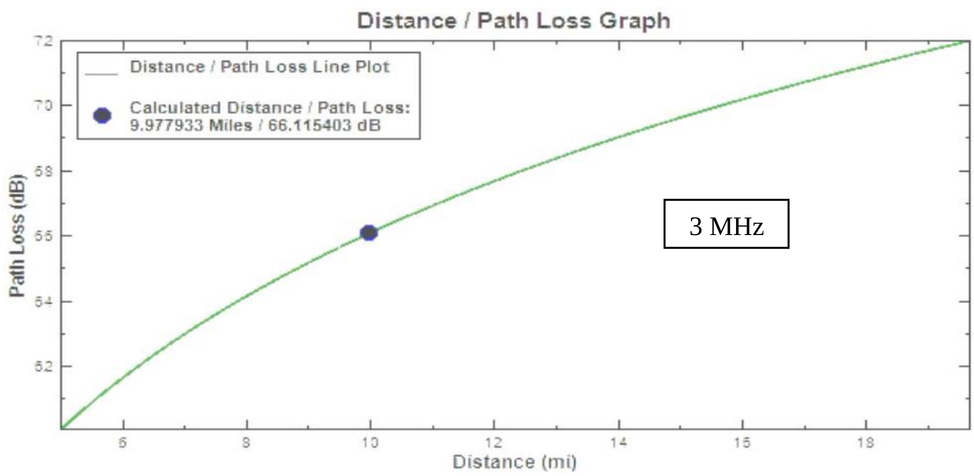
These models correspond to the building environment modeling for radio propagations. Under them following models are studied as:

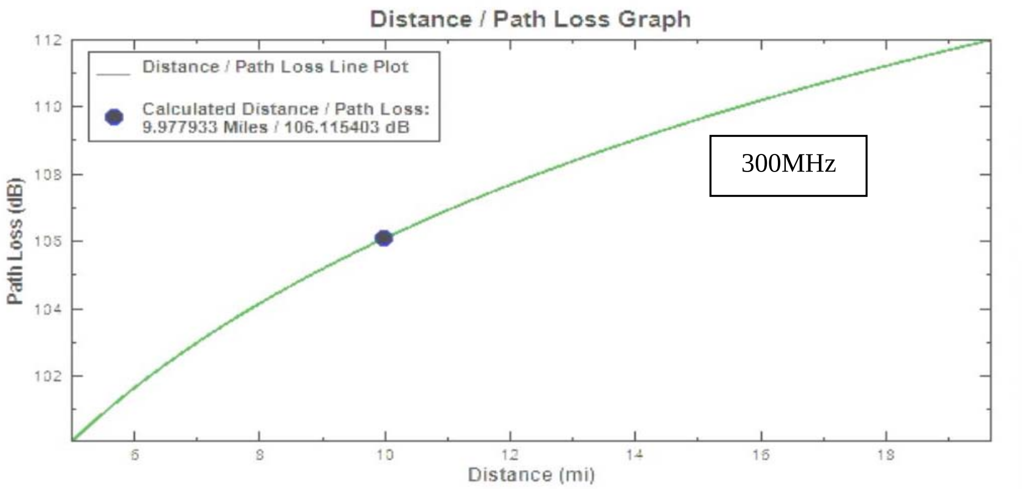
Free Space Model- In this kind of modeling the received power is a function of transmitted power, antenna gains & distance between transmitter and receiver. The logic behind it is that “the received power decreases as the square of the distance between transmitter & receiver” [1]. Major assumption of this kind of modeling is that there can only be single path without any obstruction between transmitter & receiver. The following equation is employed for calculation of received power for distance of separation ‘I’ between transmitter & receiver.[4]

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

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 the concerned entity.







Two Ray Ground Model- Here it is assumed that the total received power at the receiver end is the sum of powers due to two paths : first, the direct path between transmitter & receiver ;second, the path obtained by one ground reflection between the same transmitter & receiver separated by same distance as in case first. Another important parameter in this model is the height of location of receiver & transmitter with respect to the ground surface. The formula used for calculating received power at a distance' I' using this model is as:

$$\mathbf{P_r(I) = \frac{P_t\ G_t\ G_r\ h_t^2 h_r^2}{I^4\ L}} \qquad \text{………………..(b)}$$

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

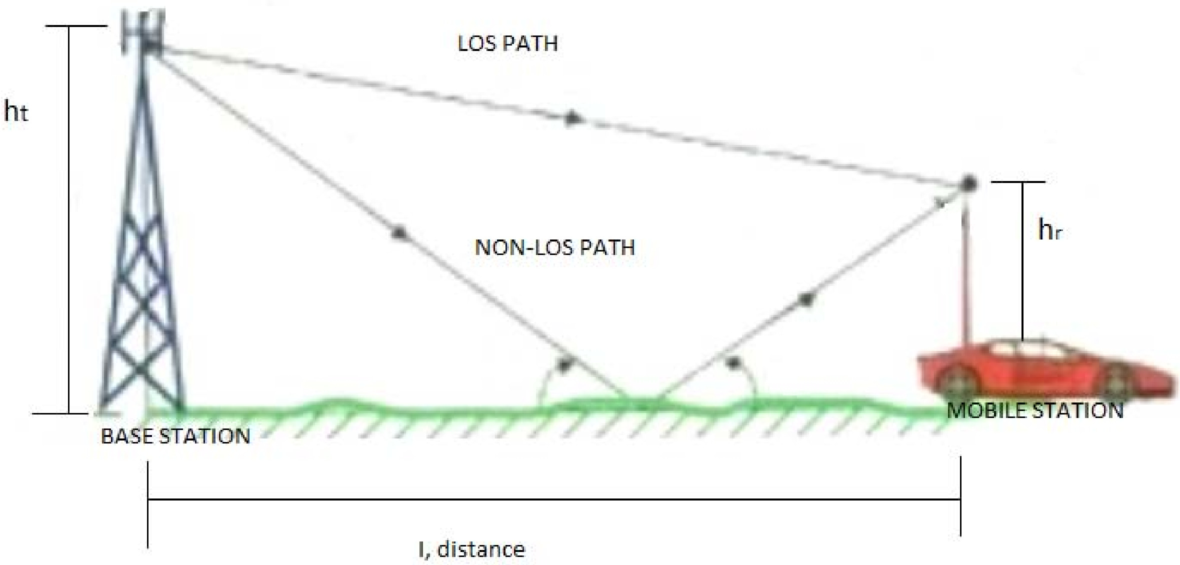


FIG.1 DEPICTION OF TWO RAY GROUND REFLECTION MODEL

Ricean & Rayleigh Fading Models- These are used when multiple propagation paths exist between a transmitter & receiver. If there are multiple indirect paths between transmitter & receiver and no direct path exist between them than Rayleigh fading is said to occur but if there are multiple indirect paths along with one direct path between transmitter & receiver Ricean fading is said to occur.

This implies that the phenomenon of multipath propagation gives rise to another feature in radio propagations called as fading. Due to fading effect, signals transmitted from the same transmitter are received at the same receiver with some time delay & thus in order to get an idea of measure of fading it is needed to correlate different signals received at the receiver in time-domain known as time-correlation.[5]

Shadowing Model- In this model it is assumed that the received power at the receiver end varies logarithmically with the distance between transmitter & receiver or in other words it can be quoted as: "received power is a logarithmic function of distance between transmitter & receiver. This model also involves a normalized random variable which accounts for path loss encountered for variable habitats.
It also assumes a close in distance I_o 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:

$$\mathbf{P_r}(\boldsymbol{I_0}) = \frac{(\frac{\mathbf{I}}{\mathbf{I_0}})^{\mu}}{\mathbf{P_r}(\mathbf{I})} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(c)$$

Where μ is the factor which accounts for the path loss & is generally determined using empirical methods using realistic field measurements. Some of the typical values as per niche specificity is 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 only applicable in case of point to point communications & not of use for mobile communications. This covers 40 MHz – 100 MHz band of operation. It takes in to account wide range of terrain profiles along with path geometry of terrain & refractivity of troposphere .Fundamentally; it deploys geometrical optics along with two-ray ground reflection model. One major limitation of the model is that it does not take any account of building & foliage.

Okumura Model- An empirical model developed by Japanese radio scientist Okumura as a part of extensive measurement campaign conducted in 1968. He discovered that a good model for path loss profile is a simple power law relationship, where exponent μ is a function of frequency & antenna height.

It is applicable for frequency range from 150 MHz to 1920 MHz but can be extrapolated up to 3GHz, equivalently deployed for a distance range of 1Km to 100Km. Path loss in Okumura model is expressed as:

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

[6]

L_{50} : 5o th 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.

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

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

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

h_t = transmitter antenna height.

h_r = receiver antenna height.

Hata Model-It is simply the empirical formulation of the graphical path loss data produced by Okumura & is valid for frequency range of 150 MHz -1.5 MHz.[7]

Median path loss for the Hata model is given by:

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

fc: frequency in MHz.

h_t: base station antenna height.

h_r: mobile station antenna height.

I: tx-rx separation [in Km].

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

Where:

1. For Urban Area-

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

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.

The Cost231 median path loss is given by:

$$L_{50}(dB)=46.3+33.9\log(fc)-13.82\log(h_t)-a(h_r)+[44.9-6.55\log(h_t)]\log(I)+C \quad \text{..................}(g)$$

[1]

Where,

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 centers with medium tree density.
C : 3dB for metropolitan centers.

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.

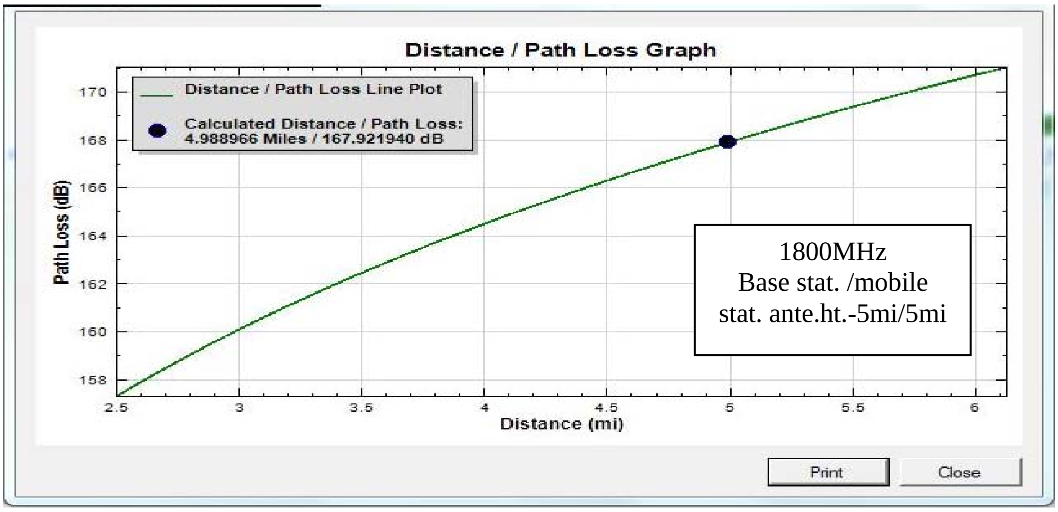


Fig.4 path loss profile for cost231model

III. NEAR EARTH PROPAGATION MODELS

Many applications require radio wave propagations near the earth surface for point-point communication link in presence of various obstacles. Such models incorporate significantly the effect of terrain profile, foliage, buildings etc. attributed to variety of phenomenon's like: scattering, reflection, diffraction, absorption etc. these models are of significance presently in VHF band accounting to ample amount of data being collected for this range. Some of the proposed & listed models for this category are:

FOLIAGE MODELS- These models give an idea about extra attenuation loss attributed to dense foliage hindrance in signal's LOS path of propagation.

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- It is based on exponential decay model & is a modification to exponential decay model. It is given as:

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

Where,

I_f = Depth of foliage in meters.
F = Frequency in GHz.

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

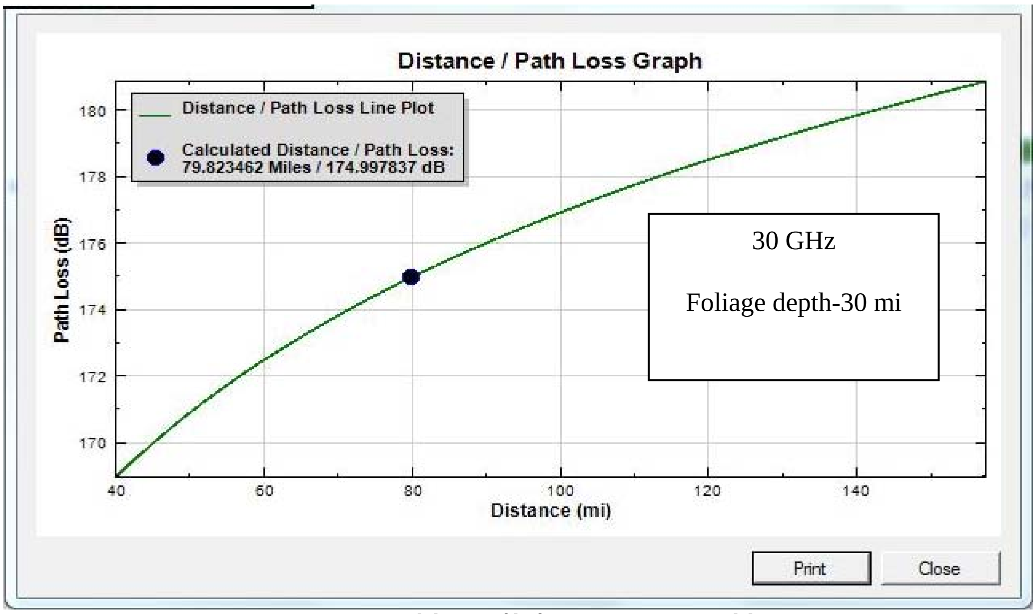


Fig.3Path loss profile for Weiss Berger's model.

Early ITU Vegetation Model- This model generates results in fine coincidence with Weiss Berger's model, also known as Early ITU Model. This is given by:

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

F= Frequency in MHz.

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

Updated ITU Vegetation **Model-** Due to the specificity based approach of all earlier ITU models most of the models were not suitable for all different profiles but still all the models are efficient in one or another point of view. In this updated model it is important to note that "there is a limit to attenuation magnitude because of foliage considerations along with diffraction paths present near & close to actual vegetation."[2] 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:

$$A_{Veg}=R_{\infty}I + C\{[\ 1-e^{-(R_0+R_{\infty}}]I/C\}\ \ dB \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(j)}$$

Terrestrial path with one terminal in woodland- It covers the scenario depicting excess attenuation loss due to one terminal located midst woodland or vegetation as shown as fig.2
[11]

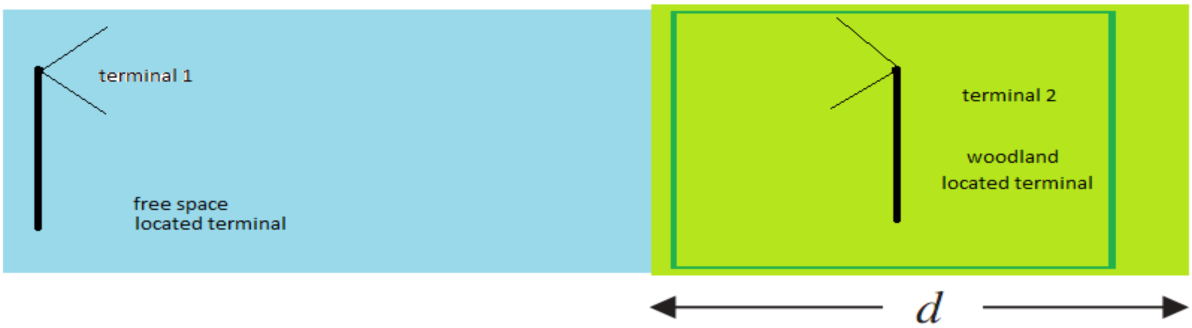


Fig.2- Propagation path with single terminal in woodland.

The model is mathematically depicted as:

$$A_{ev}=A_m\,[1 - e^{I}{}_{\alpha} / A_m\,] \qquad \text{..................(k)}$$

I=length of path within the woodland in meters.

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

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

Single Vegetation Obstruction- If neither of the terminals is within a vegetation zone but still there exists some vegetation in between the two terminals than the given model is used. This model can be employed but with single type of vegetation. When the frequency is 3 GHz or below the vegetation loss model is:

$$A_{e\text{-}l}= I\ .\ \alpha \qquad \text{..................(l)}$$

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

I=length of path within the vegetation in meters.

$A_{e\text{-}l}$= lowest excess attenuation for any other path (in dB). [12]

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

TERRAIN MODELLING

Terrain is defined as natural geography over which propagation occurs. Specifically, for ground propagations this effects the signal propagation significantly. Terrain profile must not include man-made objects & vegetation. Terrain modeling facilitates computation of median path loss proportional to the distance & terrain variations. Some popular models are:

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

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

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-This model takes in to consideration following parametric conditions such as: terrain, climate, subsoil conditions and ground curvature. 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, namely: 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:

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

[7]

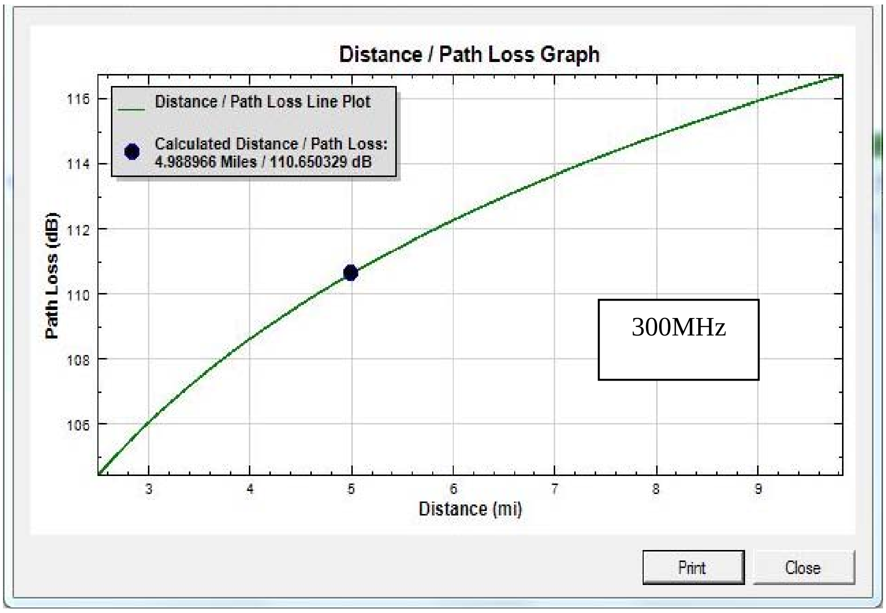
h=height difference between most concerned path blockage & LOS between transmitter & receiver.
F_1= radius of first Fresnel Zone.

Where F_1 is given as:

$$F_1=17.3\sqrt{(d_1d_2/fd)}\ \text{m} \qquad \text{...............(o)}$$

Where,

d_1 & d_2 =distances from each of the terminal to the obstruction in km.
d = distance between terminals in km.
f = frequency of operation in GHz.



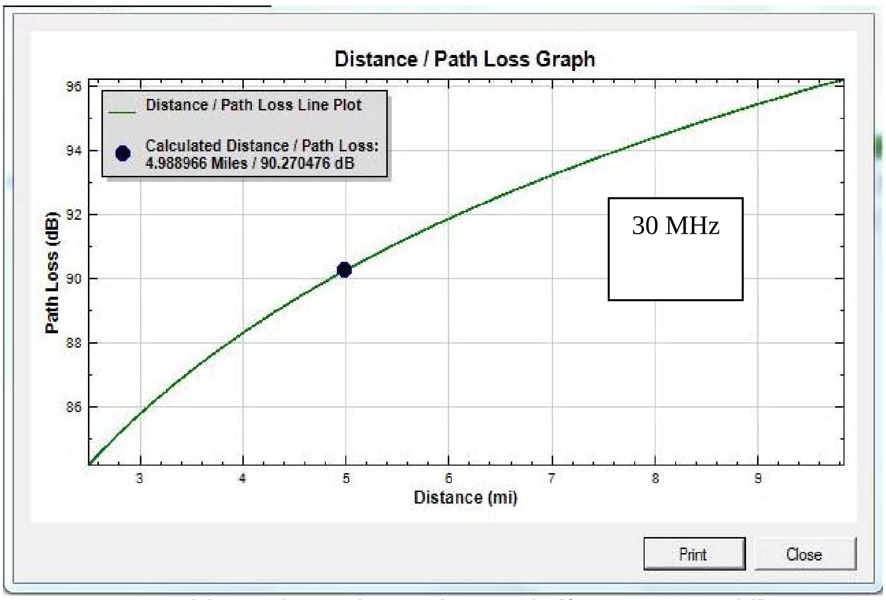


Fig.3 –path loss vs. distance (between the terminals) [for ITU Terrain model]

IV. 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.

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