ISSN 2229-5518

Effect of Foliage on Outdoor Prapagation

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Abstract— This paper focused on effect of the foliage or series of trees on wireless communication system. The paper is based on practical works, done for mobile communication and point to point high speed link at different frequency such as microwave and millimeter wave frequency. Review study of this paper include, prediction of foliage loss and shadowing effect induced by tree.

Index Terms— QoS (Quality of service)

1 Introduction

THE Quality of service (QoS) for wireless communication system has highly affected by the foliage that appear in the path of the communication link. The tree trunk, randomly distributed leaves, wings and branches are different scatters which cause attenuation, scattering and diffraction on radiated signal. Discussion of foliage on wireless communication can be categorized on three terms;
1) A tree
2) Forest
3) Lines of tree
The study of effect induced by forest on radio wave propagation has been done in previous work due to implementation of wireless sensor network. [1] In this case long range forested propagation discussed in VHF and low UHF band. The empirical foliage loss prediction model for isolated foliage effect on a mobile satellite channel studied by Karaliopoulos et al. [2]

Recently thorough understanding of wireless communication link is necessary to develop wireless sensor network [3], Multiple Input Multiple Output (MIMO) [4] and Ultra wideband (UWB) technique. Above mentioned channels are foliage channel in terms of single tree/multiple lines of tree is very common in rural, urban and suburban area[3-7]. Therefore it becomes an interesting topic to investigate foliage channel in terms of single tree/multiple lines of tree at microwave and millimeter wave frequencies.

This paper conducts a comprehensive review of different foliage loss model at microwave and millimeter wave frequencies.

2 Foliage loss prediction model

Here we have empirical method to predict foliage loss in wireless communication link.

2.1 Empirical method

If we consider the ray geometry of propagating wave, classification of foliage loss modeling and prediction with trees/lines of trees can be done as,

- Fig.1; shows horizontal path, if we consider elevation angle below 3^0 the long foliage path through many trees and short foliage path through single tree can be observed.
- Fig2;shows slant path, when the elevation angle is above 10^0 short foliage path through 1 or 2 trees can experienced

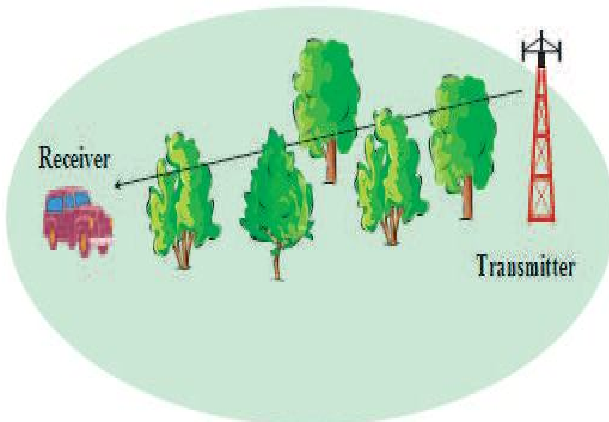
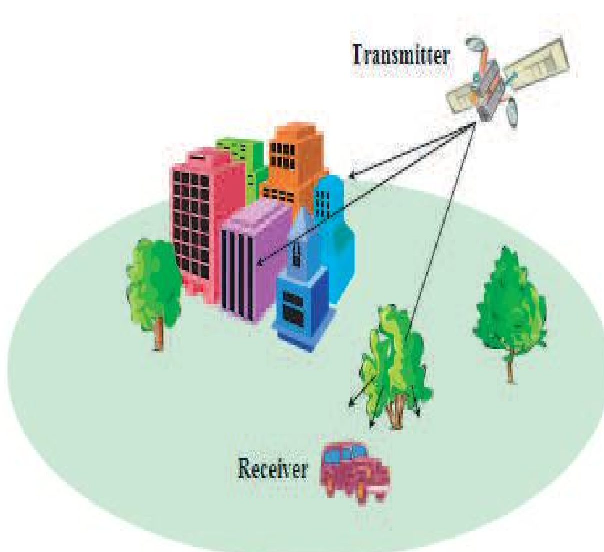


Figure 1



ISSN 2229-5518

FIGURE 2

TABLE I
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Model	Expression
Weissberger model [8]	L_W (dB) =(1:33*$f^{0:284}d^{0:588}$ 14m < d · 400m (0:45 * $f^{0:284}d$ m 0 m d < 14m f is frequency in GHz, and d is the tree depth in meter
ITU-R model [9]	$L_{ITU\text{-}R}$ (dB) = 0:2 * $f^{0:3}d^{0:6}$ f is frequency in MHz, and d is the tree depth in meter (d < 400 m)
COST235 model [10]	L_{COST} (dB) =(26:6* $f^{-0:2}d^{0:5}$ out-of-leaf) (15:6* $f^{-0:009}d^{0:26}$ in-leaf) f is frequency in MHz, and d is the tree depth in meter
FITU-R model [11]	$L_{FITU\text{-}R}$ (dB) =(0:37* $f^{0:18}d^{0:59}$ out-of-leaf) (0:39 * $f^{0:39}d^{0:25}$ in-leaf) f is frequency in MHz, and d is the tree depth in meter
MA model [12]	L_{MA} (dB) = A_m [1-exp(-$R_0 d$=A_m)] A_m is the maximum attenuation, R_0 is the initial gradient of the attenuation rate curve, and d is the tree depth in meter
NZG model [12]	L_{NZG} (dB) = $R_\infty d + k[1-\exp\{-(R_0-R_\infty)/k\}\, d]$ d is the tree depth in meter;R_0 and R_∞ are the initial and final specific attenuation values in dB/m, and k is the final attenuation offset in dB
DG model [13]	L_{DG} (dB) =($R_\infty/f^{\,a}\, w^{\,b)}\, d + k/w^{\,c}[1-\exp\{-(R_0-R_\infty)/\ k\}\, w^c d]$ The same definition for $d;R_0;R_\infty$, and k with NZG model, f is frequency in GHz; w is the maximum effective coupling width between the transmitting and receiving antennas, and a, b, c, are estimated constant.

3 EFFECTS ON PROPAGATION LOSS VARIATIONS

3.1 Antenna Height-gain Effect

An empirical modeling of antenna height gain on path loss in forest was performed by, Tewari et al. [14]. These empirical models are derived on the basis of measurement that conducts on various tropical rainforest, with a foliage depth of 4 Km in India. The transmitting antenna used has a height h_T, varying from 3.95 to 16.45m. and receiving antenna has height h_R varying from 1.5 to 3.5 m. above the ground, with the condition that $h_T.h_R$>10.

Finally derived antenna height gain on the path loss in forest is given as:

G_h (dB) = -12 - 4 $\log_{10}(f)$ + 20 $\log_{10}(h_T)$ + 20 $\log_{10}(h_R)$

Where G_h is the height gain factor in dB, f is the frequency in MHz, and h_T and h_R are the transmit and receive antenna heights in meter, respectively.

3.2 Terrain Effect

Classification of terrain effect for the radio wave propagation in forest can be done as:

- Plain Terrain Effect
- Hill Terrain Effect

The experimental and analytical study for plain terrain effect shows that, on UHF and VHF band ground reflection from a plain forested terrain plays an important role. Meek [15] started the study of hill forested terrain effect. In which he investigate the diffraction due to forested hill at VHF and UHF. In his scenario he reported that two knife edges are sufficient to characterize the terrain diffraction.

3.3 Shadowing Effect

Outdoor propagation is highly affected by the tree shadowing effect. Shadowing effect is focused on the factor such as wind and air which can result in a variation of the shadowing. There are two important factor by which tree shadowing effect is highly influenced are humidity and wind.

A temporal variation in received signal cans results when foliage medium moves due to wind. Humidity effect can cause to vary dielectric parameter (conductivity, permittivity) of tree and then affect the signal propagation.

- **Humidity Effect:**

As humidity of forest changes, correspondingly variation in conductivity and permittivity of forest occur and it affects the propagation of radio wave. In early February Low [16] reported that, when temperature drop below 0^0c the humidity in the tree trunk also decreases. According to the of Low[16] in January of the same year, when humidity in the tree trunk is low, there is an increment of 2-3 db is noticed in received signal power at 457 MHz 914 MHz as compare to power received when temperature is above 0^0c. Evans[17] conduct measurement over a one year period and concluded that, signal strength can fluctuate about 1-1.5db as variation takes place from wet to dry condition including mist. According to reading of changes that occur throughout the year, the most important changes occur in late summer when foliage volume becomes maximum.

Recently Joshi et al.[18] conduct a comparative study over dry and wet foliage condition. They noticed that in wet foliage condition at 1900 MHz, the propagation losses are 29-32 db greater then the loss measured during dry foliage condition.

- **Wind Effect:**

Wind effect can be investigated by implementation of Local Multipoint Distribution Service (LMDS). After analization of four types of wind velocity ranges from low to high, it reported that as wind velocity increases the standard deviation of the attenuation variation about the mean also increases. Hence in rural area a fade margin of 3.4db should allowed for 2 GHz radio service. Petal et al. [19] reported that wind impinging on the trees at velocity below 15Km/h can cause significant fading.

Naz et al.[20] investigate effect of wind on different foliated state at a higher frequency up to 295 GHz. They found that trees with yellow and dehydrated foliage produce more variation as compare to tree with green foliage. Dense tree do not produce much variation while it can cause attenuation.

4 Conclusion

This paper concludes the effect of foliage on outdoor propagation. Here the foliage loss prediction models are defined empirically. From this research review, some possible research area can be proposed. Improvement in reliability of communication link can be done under the consideration of external effect such as wind rain etc.Morever the wideband foliage channel information, required for implementation of UWB technique is needed to investigated in more detail.

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