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Study of Measurements and Attenuation in Vegetation at Microwave Frequencies

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Abstract – This paper presents the First report of an ongoing to study the effects of trees on radio signals at microwave frequencies. Measurements have been made to determine the extent of attenuation when propagated through vegetation and also have been carried to be conducted on selected vegetation with various degree of foliation to determine the dependence of losses on vegetation. also, path geometry and tree geometry are among other parameters under consideration. The results from these experiments compared with standard ITUR-P empirical models and to reflect the dependence of vegetation attenuation on the input parameters under observation.

Index Terms – Vegetation. Attenuation, Foliage Depth.

1. INTRODUCTION

Vegetation and trees planted at strategic places all over the Italy and at the same time maintain a greener environment. However, their presence may have an adverse effect on telecommunication services as they may cause blockages to radio path by obstructing the line of sight between transmitter and receiver.

As a result, propagating radio waves are forced to follow different paths to the receiver and this situation leads to signal degradation. Removing all trees obstructing line of sight is an impractical solution, but fade mitigation techniques such as adaptive coding and path modulation, path diversity etc. can be adapted to mitigate the effect. So, for radio planners whose aim is to achieve effective communication with high reliability, link availability and good quality of service (QoS), the effect of vegetation has to be taken into consideration during the planning and design work.Trees, either singly or as a group influence the level of the signal directly by providing an additional attenuation over free space loss. They act as obstacles causing absorption and scattering to radio signals. When a single tree appears along radio path, it introduces a partial blockage to a line of sight resulting in loss of signal at the receiver end. Considerable efforts have been made in the recent past by various authors Al-Nuaimi et al. (1994, 1998)[1][2], Ndzi et al. (2005)[3], and Meng et al (2009) [4] to properly estimate the influence of vegetation on radio waves. This has actually stimulated and attracted series of experimental campaigns which led to models for the prediction of attenuation. Apart from signal attenuation, fading is another phenomenon commonly encountered by radio waves propagating through vegetation. Fading in a wireless channel is simply a variation in amplitude and phase level of the received signal. The variation can be due to multipath propagation. When radio signals encounter clutter (e.g vegetation) it may lead to diffraction, reflection, and scattering along the propagation path. Such signals are then forced to follow different (multiple) paths to the destination. So, various sub-components of the waves would arrive at the receiver at different times. Vegetation plays a significant role in fading a phenomenon in wireless communication. Concerted efforts have been made in the past by Song Meng et al. (2009)[5] and Cheffena et al. (2009)[6] to model path loss at various frequencies both analytically and empirically.

In a more general term, radio waves obstructed by vegetation are decomposed into various sub-component parts and each forming a propagation mechanism. These are :

Reflection from ground

Diffraction around edges

Diffraction over the tree top

Diffusion and scattering through vegetation.

Reflection from other nearby obstacles

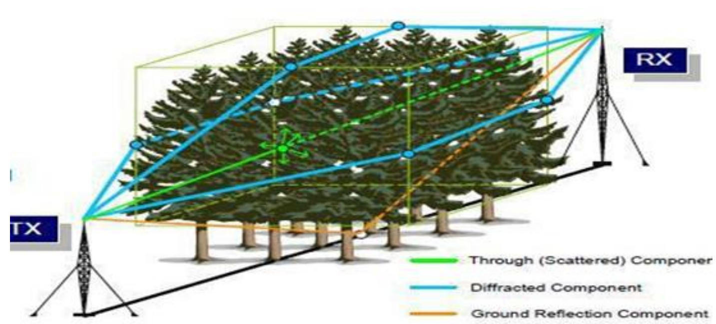


Figure (1) Generic propagation mechanism

2. EMPIRICAL ATTENUATION MODELS

An empirical model is known as the exponential decay (EXD) model was generally in use to predict excess propagation loss in vegetation.

From the 1960s, work has been done to discuss the effect of vegetation on Radio waves. Tamir (1967)[7] proposed a half-space model to deal with radio wave propagated in the forest over a large depth of more than 1000 m. Weissberger (1982)[8] proposed the modified exponential decay model (MED) for propagation path blocked by dense, dry, leafed trees found in a temperate climate. The model covers frequencies from 230 MHz - 95 GHz. The predicted loss is as

$$L(dB) = \begin{cases} 1.33 f^{0.284} d_f^{\ 0.588}, 14 < d_f \leq 400m \\ 0.45 f^{0.284} d_f \quad 0 < d_f \leq 14m \end{cases} \quad (1)$$

Where f is in GHz and d_f is in meters. This parametric equation is seen to have a general format

$$L\ (dB) = x\ f^{y}\ d_f^{z} \quad (2)$$

Where X, y, and z are variables of fitted values obtained from measurements. Following this trend, the international telecommunication union (ITU) in 1986[9] developed a model for foliage attenuation called early ITU model is given b

$$L\ (dB) = 0.2\ f^{0.3}\ d_f^{0.6} \quad (3)$$

f is in MHz and $d_f$is in meters. Al-Nuaimi et-al (1994) presented a modified version of equation 3 called modified ITU-R model. This caters for both in-leaf and out-of-leaf cases at 11.2GHz and are presented in (4) and (5)

$$L\ (dB) = 15.6\ f^{-0.009}\ d_f^{0.26} \quad \text{in leaf} \quad (4)$$

$$L(dB) = \begin{cases} 1.75 d_f,\ d \leq 31m \\ 28.1 d_f^{\ 0.17},\ d > 31m \end{cases} \quad \text{out of leaf} \quad .(5)$$

A more generalized model to above is the fitted ITU-R model (FITU-R) proposed by same authors (Al-Nuaimi et al 1998). It is applicable in the frequency range of 10-40GHz and presented as

$$L\ (dB) = 0.37\ f^{0.18} d_f^{\ 0.59} \quad \text{In-leaf} \quad (6)$$

$$L\ (dB) = 0.39\ f^{0.39}\ d_f^{\ 0.25} \quad \text{out of leaf} \quad (7)$$

In furtherance of this, COST 235 model [10] was proposed based on measurements conducted on a grove of trees at mill metric frequencies (9.5GHz – 57.6GHz) over a depth of less than 200m for in-leaf and out-of-leaf. The parametric equations are given as

$$L(dB) = \begin{cases} 26.6\ \ f^{-0.2} d_f^{\ 0.5}\ out\ of\ leaf \\ 15.6\ \ f^{-0.009}\ d_f^{\ 0.26}\ in-leaf \end{cases} \quad (8)$$

In the empirical models, it is clear that radio waves obstructed by vegetation suffer some losses in excess of free space which are frequency and foliage depth dependence. Having reviewed these models and observed their drawbacks, possible areas of improvements have been identified.

For example, none of the models has predicted for partial foliation stage. Whereas, three foliation stages have been identified in vegetation(full leaf, out-of-leaf and partial foliation). All existing models predicted for in-leaf and out-of-leaf. This leaves a gap to be filled. Also, empirical models do not include path geometry in their prediction. Measurement geometry and tree geometry are very important in estimating propagation loss in a vegetative channel.

3. PROPOSED METHODOLOGY

Many numbers of experimental have been designed to be conducted. The important components factored at the experiments are path geometry, different foliation stages, different tree types and antenna heights. Propagation carried out at different scenarios in the presence of vegetation. a repeat of same experiments conducted without vegetation blockage to model free space.

3-1. First MEASUREMENT

Equipment Description

The transmitter section is consists of Anritsu MG3692B signal generator with a maximum operating frequency of 20GHz. a discone broadband antenna and an adjustable antenna mast of up to 6m to realize varying antenna height. The transmitter is powered by a 230V AC taken from a combination of two (2) 12V DC battery source (connected in parallel) and a pure sine wave inverter at 1000W. The signal generator can generate a continuous wave (CW) RF signal up to a maximum power of +30dBm (1w) and be fed through a discone antenna to the receiver. The receiver is made up of Agilent E4440A PSA series spectrum analyzer and a broadband discoune antenna (omnidirectional). This is equally powered by a 230V AC and taken from two (2) 12V DC batteries connected in parallel with a full sine wave inverter. The analyzer has a working frequency range of 3MHz to 26.5GHz.

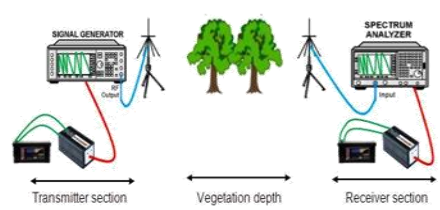


Figure (2) Experimental setup

3-2. TEST SITE

Measurements carried at three different locations for in-leaf, out-of-leaf and partial defoliation states.

Transmitting and receiving types of equipment were each arranged on a separate trolley for easy carry to the measurement site.

Figure (3) Site one (Full leaf vegetation)

Figure (4) Site two (Partial foliation vegetation)

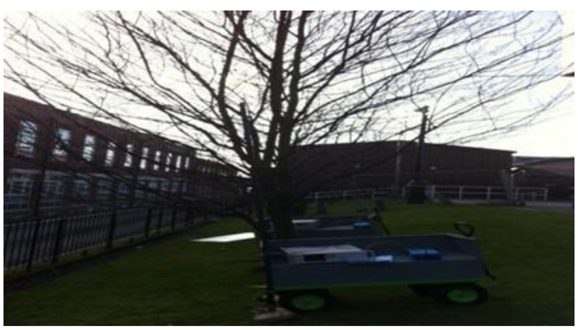


Figure (5) Site three. (out-of-leaf)

4. RESULTS AND DISCUSSIONS

In These measurements interaction of radio waves with vegetation structure going to excess attenuation. dependence of the excess loss on foliage density appears in results shown in figures 6 and 8. The full leaf recorded a loss of 8dB - 16dB even at a shorter foliage depth while the latter for partial foliage recorded a loss of 2.4dB -7dB at a higher depth. Figure 7 shows different antenna height effects relative to the vegetation. Since the research work is still at a First stage, making a concluding remark would be premature for now. It is therefore hoped that upon completion, the contribution of each of these component parts (foliage density, path geometry, antenna height etc) to the excess loss would be well characterized.

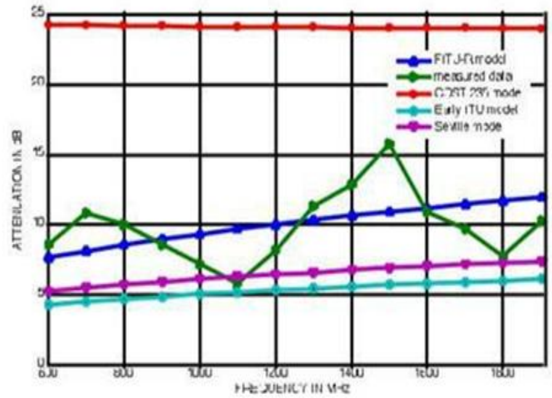


Figure (6) Measured data at foliage depth of 6.8m compared with empirical models. (Full leaf)

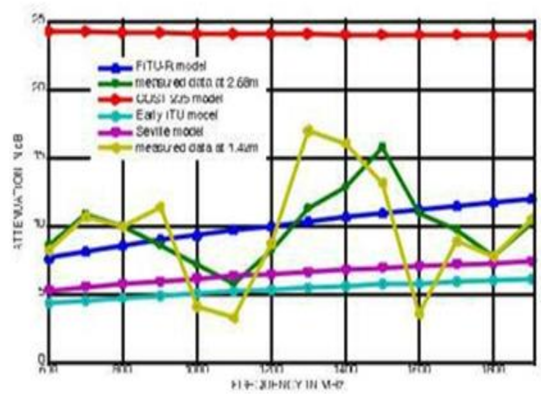
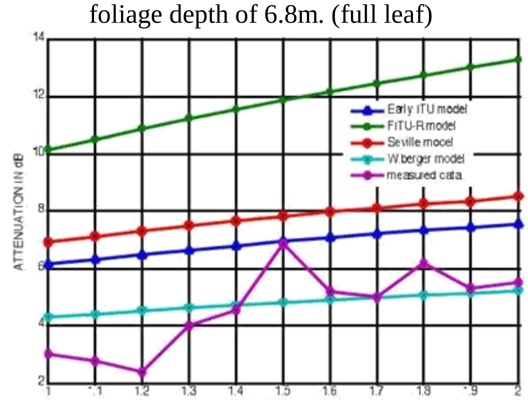


Figure (7) Measured data at two different antenna heights for foliage depth of 6.8m. (full leaf)



Figure(8) Measured data for partial defoliation compared with empirical models. Foliage depth =9.5m

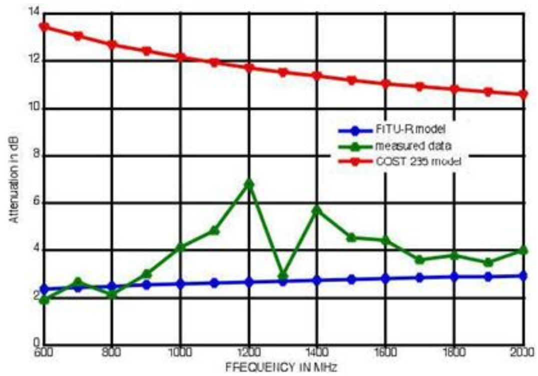


Figure (9) Out of leaf data at a depth of 3.3m

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