GEOMETRY DEPENDENCE OF VEGETATION ATTENUATION ON ISOLATED SINGLE TREES

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ABSTRACT

The dependence of vegetation attenuation on propagation geometry has been experimentally investigated at SHF band for isolated single trees. Two measurement heights (Trunk and Canopy) have been used in these experiments that involve three fully foliated trees, Common Whitebeam (Sorbus aria), Silver Maple (Acer Saccharinum) and Common Hazel (Corylus Avellana). Result shows that apart from frequency (f) and depth of penetration into vegetation (d), measurement geometry is another key parameter that determines the extent of signal loss in vegetation.

Keywords: Vegetation attenuation, propagation geometry, isolated trees, trunk, canopy.

INTRODUCTION

The determination of propagation algorithm that estimates excess attenuation due to vegetation is critical for effective wireless planning. However, the complex nature of vegetation parameters is a key hindrance to this. So, getting a generic model that can accurately predict well in all scenarios is relatively difficult due to these inexhaustible complex parameters of vegetation. Several empirical loss prediction models have been proposed (Lagrone, 1960; Weissberger, 1982; COST 235, 1996; Al-Nuaimi et al. 1998; Seville et al. 1995; Meng et al. 2009). Most of these empirical loss prediction models agree to the dependence of vegetation loss on signal frequency (*f*) and depth of penetration (*d*). But beyond this, several other factors play a key role in the determination of excess loss e.g Propagation geometry, density of tree foliation etc. In their work, Ndzi et al (2012) carried out an investigation in a forest grown with mango and oil palm plantation in order to determine the dependence of vegetation attenuation on measurement geometry. These authors recorded different attenuation values at different paths within same plantation. They succeeded by suggesting different prediction models for used based on the geometry involved for use in Wireless Sensor Network (WSN). This points to the fact that propagation geometry has a strong influence on the extent signal loss in trees.

MEASUREMENT DETAILS

The experimental site used for this work is the University of Leicester campus in the United Kingdom. The transmitter section consists of an Anritsu signal generator MG3692B with an operating frequency from 2 GHz to 20 GHz. It can generate a continuous wave RF signal up to a maximum power of +30dBm (1watt). This signal generator was configured to a ‘step sweep’ mode so as to sweep across the selected frequency band (3.5 GHz and 5.4 GHz) with a dwell time of 70 seconds on each frequency and a step size of 50 MHz. An auto trigger option was enabled to guarantee automatic transition of frequency across the band. A Westflex WF103 low loss 50 Ω coaxial cable was used to connect the transmit antenna to the signal generator. The antenna is directional and was mounted on an extensible telescopic mast. This mast has a maximum height of 12 m and is supported by a tripod stand to guarantee stability during use, and can withstand moderate wind force. The receiver is made up of the Agilent E4440A PSA series spectrum analyzer with a working frequency range of 3.0 Hz – 26.5 GHz. It has a RF input impedance of 50 Ω and a maximum power of +30 dBm. During measurements, the analyzer was set to a span of 50 MHz. As the signal is being sent by the transmitter, the receiver has a function ('Tracking Signal Key') which enables it to track the incoming signal. This key was normally set to 'ON' mode and the RSS in dBm with the corresponding transmitted frequency would be tracked and displayed onto the screen. Synchronization between transmitter and receiver is normally done by the equipment. In order to get a more stable display, the 'peak hold' key is pressed and the data (RSS) could be recorded while the signal is being held by the analyzer for a dwell time of 70 seconds. For frequency selection that sweeps across selected band, the receiver's display automatically changes in accordance with the transmitted signals' frequency values. The antenna type used here was directional and identical to that in the transmitter section. This is to ensure maximum power transmission in the required direction by the main lobe. Typical screen shot (trace) of the spectrum analyzer is as shown in Figure 1.0 which reveals a high noise floor level.

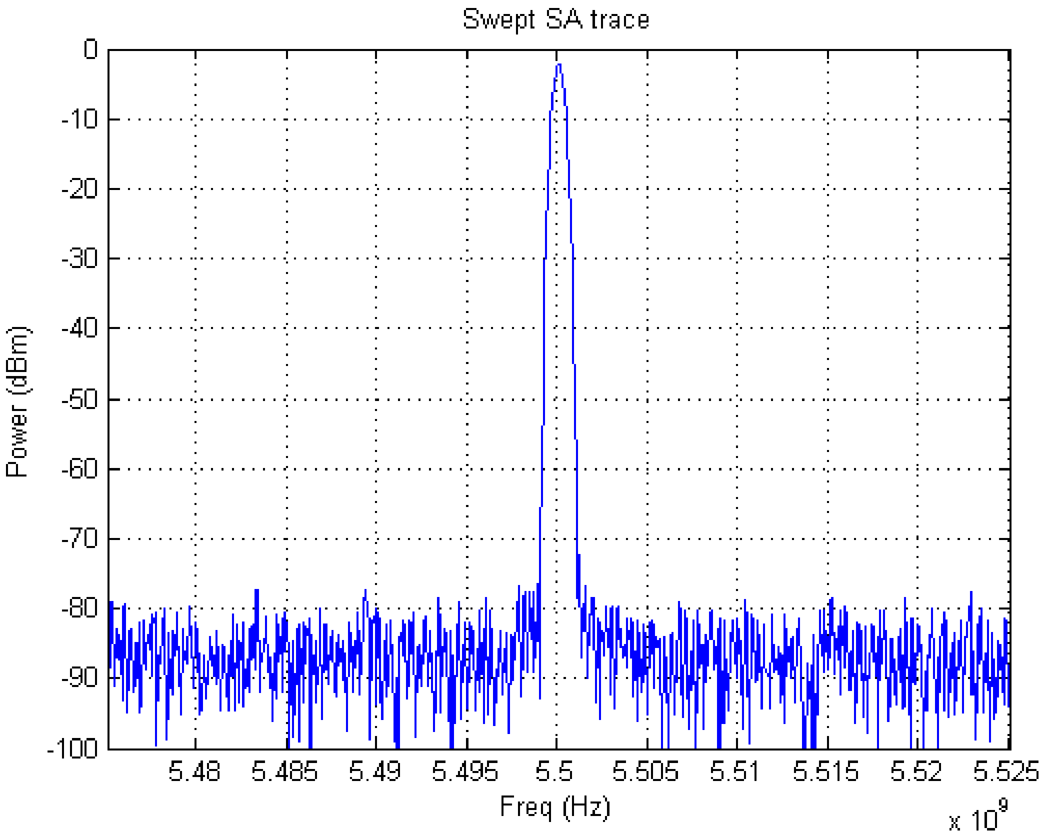


Figure 1.0 Typical screen shot (Trace) at 5.5 GHz.

In order to realise the objective of this investigation, two measurement heights (Trunk and Canopy) have been used which involves three isolated trees with varying heights of between 10 m to 15 m. These are Common Whitebeam (Sorbus aria), Silver Maple (Acer Saccharinum) and Common Hazel (Corylus Avellana). The land terrain around the silver maple and common hazel is uneven. But efforts were made in ensuring that both antennas maintained same altitude while the line of axis were perfectly established. For all the trees, separation distance between transmit antenna and tree trunk is 8 m while observation point was located 7 m away from the tree and directly facing the transmit antenna. The antenna heights were adjusted accordingly in each case to match up with trunk and canopy levels in order to realise the desired geometries. In each case, 50 data samples were logged in at an interval of 10 seconds in succession for every frequency. Average values were then estimated during post experimental processing exercise.

RESULTS, ANALYSIS AND DISCUSSION

	Common whitebeam tree		Silver maple tree		Common hazel tree	
	3.5 GHz	5.4 GHz	3.5 GHz	5.4 GHz	3.5 GHz	5.4 GHz
Trunk mean loss (dB)	8 ± 0.5	11 ± 0.4	5 ± 0.2	6 ± 0.5	3 ± 0.2	6 ± 0.4
Canopy mean loss (dB)	20 ± 2.1	30 ± 2.2	16 ± 0.7	21 ± 1.7	13 ± 2.4	22 ± 2.2
Loss difference (dB)	12	19	11	15	10	16

Table 1.0 Average measured values across the trees.

(i) Whitebeam tree

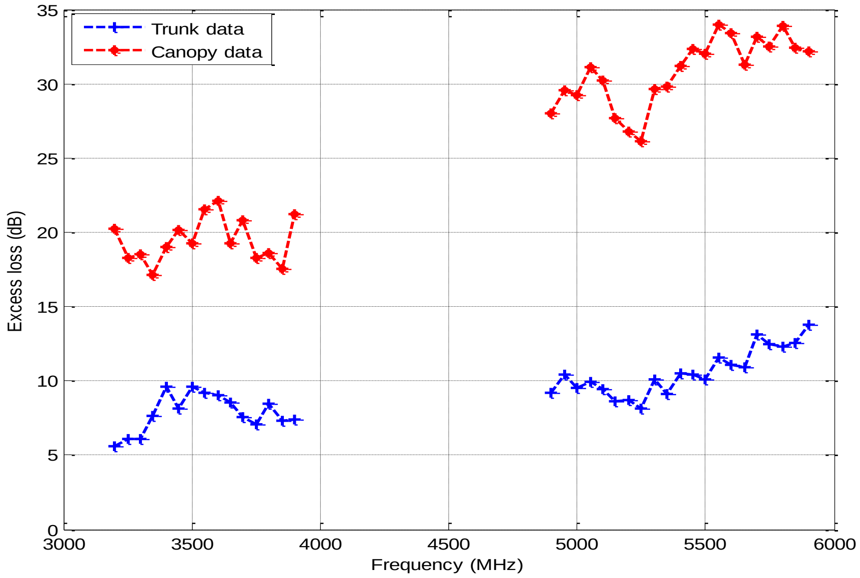


Figure 2.0 Excess loss at trunk and canopy levels at 3.2 – 3.9 GHz and 4.9 - 5.9 GHz

(ii) Silver maple tree

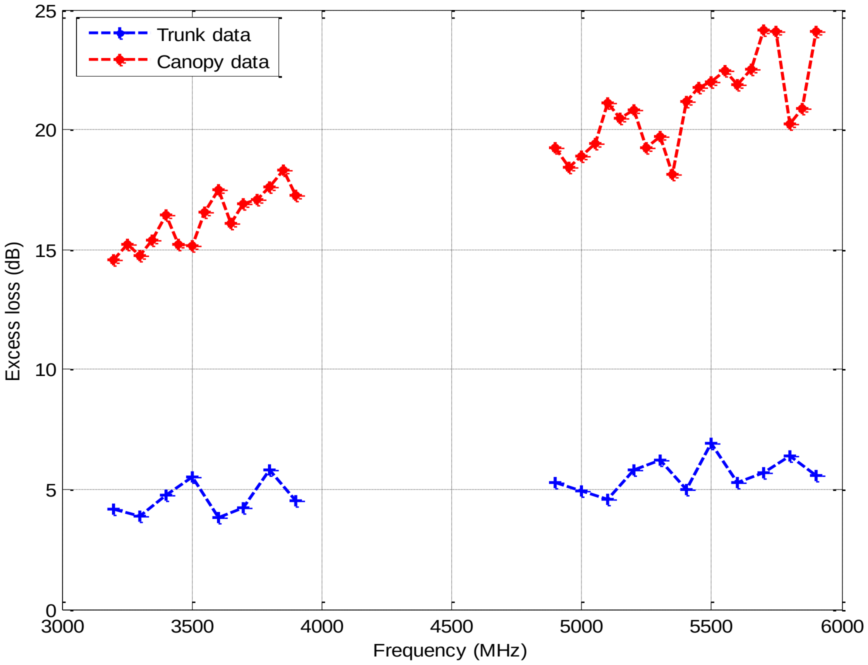


Figure 3.0 Excess loss at trunk and canopy levels at 3.2 – 3.9 GHz and 4.9 - 5.9 GHz

(iii) Common hazel tree

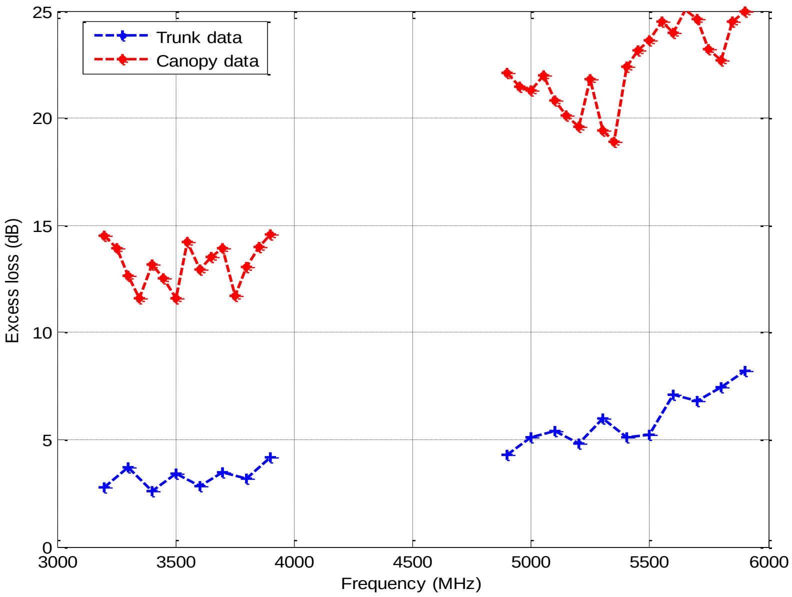
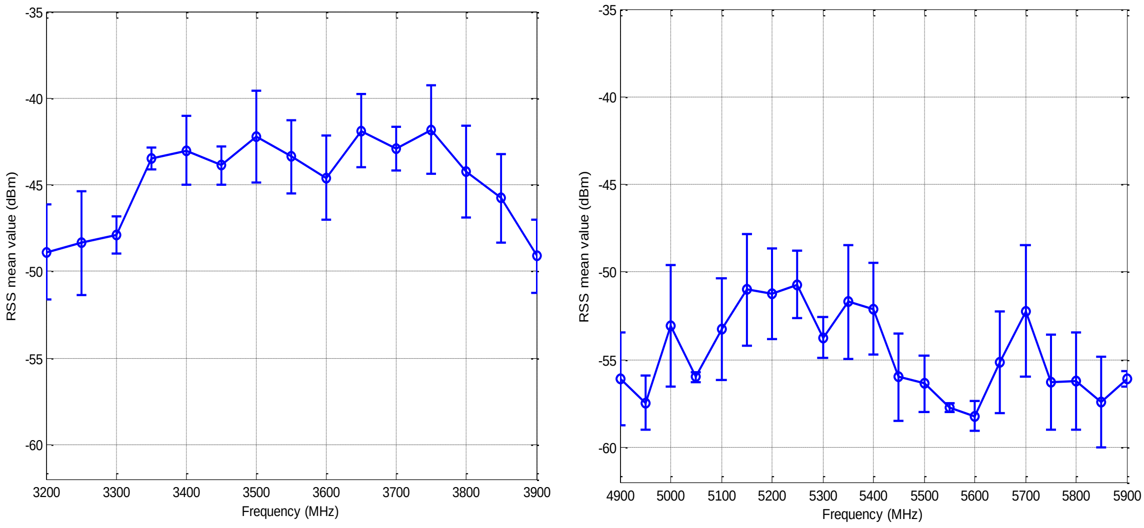


Figure 4.0 Excess loss at trunk and canopy levels at 3.2 – 3.9 GHz and 4.9 - 5.9 GHz



(a) **(b)**

Figure 5.0 RSS values versus frequency for whitebeam tree at canopy level showing spread values at (a) 3.2-3.9 GHz (b) 4.9-5.9 GHz

From the plots of Figure 2.0 (whitebeam tree), 11 dB and 30 dB of excess losses were measured across the tree trunk and canopy levels respectively at 5.4 GHz band. This translates to a loss difference of 19 dB. At 3.5 GHz band, a loss difference of 12 dB was measured between trunk and canopy level. This same trend is noticed in all other trees with wide loss margins between trunk and canopy levels. The difference is due to the composition of the tree structure along the propagation paths. For the canopy geometry, the leaves, twigs and branches all combined to form attenuating elements. So upon signal transmission, the incoming radiated waves are intercepted by these attenuating elements. These canopies provide high obscuration to the incoming signal leading to a partial blockage of direct LOS. The high canopies thickness is another contributing factor to high penetration loss recorded at the canopy geometry. The trunk diameters range between 40 cm to 65 cm, which is so small, compared with canopy thickness and as such, the wave would travel more in lossless air medium which is why a lesser loss is measured across it. On the other hand, the tree trunks contained less of interacting and attenuating elements. A shadow region was observed at this geometry particularly at points very close to the trunks. These points were always avoided. In this experimentation, no ground reflected component is seen. The plots (Figures 5.0) show the range of variability of the measured data for whiebeam tree at canopy geometry. The same observation was noticed in the measured data for other trees. These spread values indicate the degrees of fluctuation in RSS due to multipath. In Table 1.0, very small spread values were calculated for all the trees at trunk level. This is a clear indication of less fluctuation in RSS at trunk level. On the other hand, high spread values were calculated for canopy data. This reveals the extent of multipath due to scattering which is caused by the leaves, twigs and branches. At microwave frequencies, the signal wavelength is of the order of the leaves' dimension. As such, more of the impinging waves are expected to scatter in different directions after leaving the tree. The fluctuation could be more severe in swaying trees which may result in deep fades (nulls) and at extra loss.

Following the trend of loss differences between canopy and trunk levels, it is therefore an indication that for better and efficient point to point radio propagation in trees, adopting trunk geometry is desirable. This will enhance link distance and reduce signal fading due to multipath propagation. For example, in wireless sensor network in agricultural environment and forestry, placing the nodes at trunk level will maximize power with less attenuation (Ndzi et al. 2012).

A good qualitative agreement is seen between our result and observations reported by Savage et al. (2003) when a measurement was conducted on sycamore trees at two receiver antenna heights of 2.5 m and 7.5 m. Their results show higher attenuation value recorded at 7.5 m antenna height than the 2.5 m height. The authors concluded that this is due to increased branch and leaf density at greater antenna heights. Also, Seville et al. (1995) investigated the attenuated fields on sycamore and lime trees at heights of 3 m, 5 m and 7.5 m which correspond to trunk, foliage and tree top levels respectively. Their results show variation in measured attenuation with tree heights. The trunk level gave the least attenuation value while the tree top level gave the highest value. Further demonstration of this is contained in Al-Nuaimi et al. (1994) where the receive antenna height was adjusted to 1.5 m and 3.5 m with transmit antenna fixed at 3.5 m. The penetration loss measured was found to be lower at 1.5 m height which corresponds to trunk level. All these results are in close agreement with our observations which all points to geometry dependence of vegetation attenuation. However, this loss variation with height is subjective as the theory did not hold for some trees (e.g trees with cone-shaped canopies). Further investigations were conducted to verify this and results show that generally, the mid-canopy point measures highest loss values in all cases.

CONCLUSION

It is evident from this investigation that propagation geometry is another key factor (apart from frequency and depth) in the determination of the extent of signal loss in vegetation. In comparison with canopy geometry data, the trunk geometry shows less attenuation values and less variation in RSS. This suggests that for wireless communication in vegetation media, adopting the trunk geometry (i.e placing the communication nodes at trunk level) will reduce the extent of propagation losses, minimize fading due to multipath and enhance coverage distance.

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