Vegetation Attenuation by a Single Tree for High Elevation Angles at 2.0 and 6.5 GHz

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1. Introduction

With the new requirements imposed on wireless satellite services, such as a wide range of services, mobility, availability, etc., the need has arisen to investigate the propagation channel for high elevation angles under vegetation blockage conditions. The appearance of a forested medium in the path of a satellite, terrestrial or any microwave communication link has a significant effect on the quality of the received signal.

Over the past fifty years a number of measurement campaigns and theoretical works focused on investigating vegetation attenuation have been carried out [1-6]. In addition, a number of models describing the influence of vegetation blockage on electromagnetic wave propagation have been developed. The measurement trials can be broken down according to several aspects; as a measurement scenario, in terms of frequency, elevation angle or vegetation arrangement, etc.

This paper presents some of the initial results of an ongoing, extensive measurement campaign focusing on shadowing by vegetation for mobile satellite services. Results for the frequency dependence of vegetation attenuation in forested environments have already been introduced in [7]. This paper addresses vegetation attenuation by a single tree. Empirical data obtained in both the summer and winter seasons for wide range of elevation angles are analyzed at two different frequencies.

The paper is organized as follows. In Section 2 the measurement setup, scenario and data processing are presented. Section 3 describes the results from the summer and winter trials and a brief summary concludes the paper in Section 4.

2. Measurement trials

2.1 Measurement setup

A 9-meter long remote-controlled airship was used as a pseudo-satellite carrying a transmitter. The airship was filled with the inert gas helium with a maximum payload of 7 kg and an operating speed of about 20 km/h. The airship was equipped with a number of sensors to track its GPS position, as well as its pitch, roll and altitude. The transmitter consisted of continuous wave generators at 2 and 6.5 GHz, power amplifiers and left hand circular polarized (LHCP) planar antennas. The transmitting spiral antenna was a self-complementary structure that had an input impedance close to the theoretical value of 60π. The back volume of the antenna was filled with a polyamide carbon absorber in order to attenuate the cross polarization component. The power supply was provided from a battery pack in the drive unit gondola. The receiving site contained a portable receiver (PR100 made by Rohde&Schwarz) which was controlled via its LAN interface by a computer and a single LHCP broadband antenna with a similar design to the transmitting antenna.

2.2 Measurement scenario and location

The goal of the measurement trail was to investigate the single tree vegetation attenuation for satellite communications, i.e. high elevation angles. As was mentioned above, the remote-controlled airship was utilized to carry the transmitter station while the receiving site was located at three different distances from a tree - 5, 10 and 15 meters - as depicted in Fig. 1. During the measurement process the airship flew at an average height of approximately 200 meters above the ground in order to achieve a sufficiently broad range of elevation angles, from 20 to 90 degrees. The flyovers were planned so that the receiver, the tree under investigation and the airship were kept in one line (Fig. 1). At least three flyovers were accomplished in order to obtain statistically relevant data for a sufficient range of elevation angles for each measurement position. The single tree under investigation was situated in a park in the city of Prague. The tree is of the deciduous kind, approximately 12 meters high and 8 meters wide. The data were obtained during two different seasons, in summer when the tree was in full leaf and in winter when the tree was bare. The measurement scenario and positions were exactly the same for both seasons.

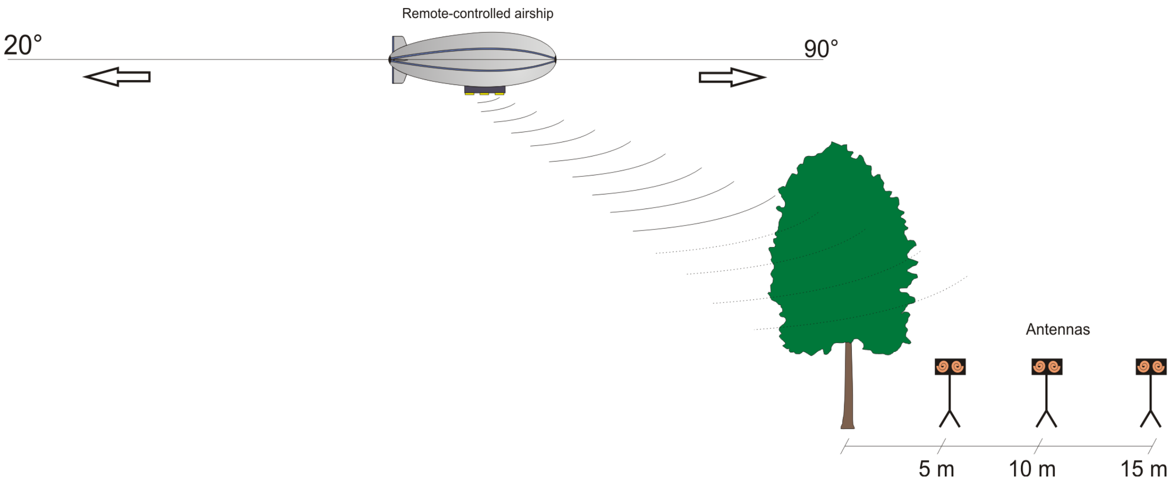

Figure 1: Schematic diagram of the measurement setup

2.3. Data processing

The received signal strength was measured as a function of the elevation angle. The additional attenuation due to vegetation is defined as the difference between an actual measured signal level and the level measured for the same elevation angle and mutual orientation of both transmitter and receiver antennas at a calibration location. A large open field was chosen as the calibration location where extensive measurement flyovers were performed to obtain the calibration data.

As follows from the above, there were several sources of measured raw data. The received signal strength was measured by the receiver on the ground, the GPS position and sensor data such as pitch, roll, altitude, compass, pressure, wind speed and temperature were recorded on the airship. Following this, these data sets needed to be processed and synchronized. In the first stage the GPS data were assigned to measured data based on time stamps. Then, potentially invalid data, e.g. those identified by the extreme pitch and roll of the airship due to wind gusts, were then discarded. In addition the data for elevation angles lower than 25 degrees were cancelled to avoid excessive turns of the airship. For further processing of the additional attenuation as a function of the elevation angle, the measured data were averaged using an averaging window of 10 degrees moving along the elevation angle axis.

3. Results

3.1 Summer trials

In Fig. 2 the received signal strength is presented as a function of the elevation angle for all three positions of the receiver antenna at 6.5 GHz. It is obvious that two situations occurred during the measurement, see Fig. 3. The line-of-sight (LOS) situation, when the link is not shadowed by the tree (marked as “1”in Fig. 2), and the non-line-of-sight (NLOS) situation, when the link is shadowed (mark “3”). An evident threshold (marked as “2”) is visible for an elevation angle of

approximately 48 degrees in Fig. 2 for a receiver distance of 15 meters from the tree. This threshold is different for each measurement position according to the geometrical arrangement.
The results were subsequently analyzed as a function of the vegetation depth. Figs. 4 and 5 present the measurement data as well as its polynomial fit for better clarity As follows from the figures, the additional attenuation was found to be between 11-13 dB and 15-20 dB for vegetation depths of 10 m at 2.0 and 6.5 GHz, respectively. Subsequently, the average increase of the additional attenuation with the vegetation depth was approximately 1.0 dB/m at 2.0 GHz and 1.8 dB/m at 6.5 GHz.

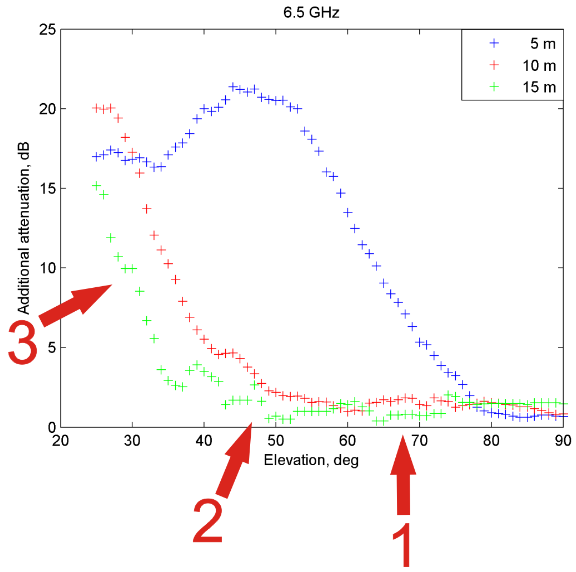

Figure 2: Additional attenuation at 6.5 GHz

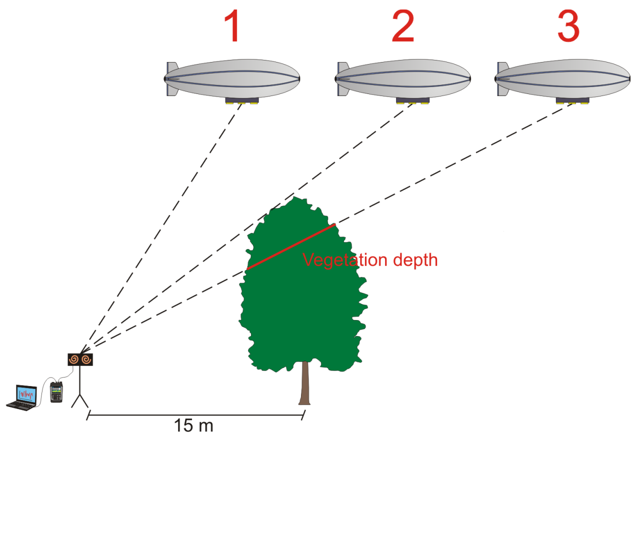

Figure 3: The airship position; LOS vs. NLOS

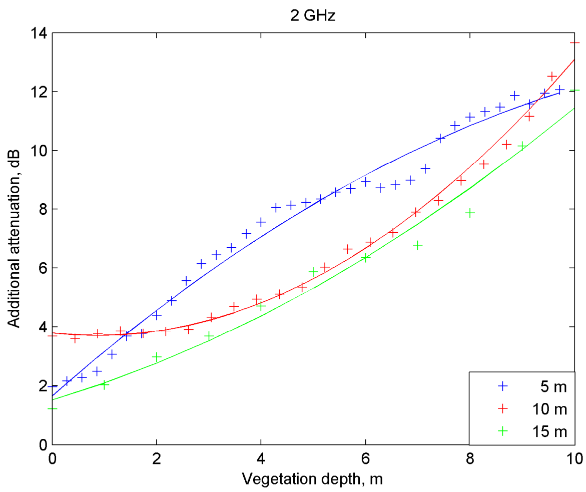

Figure 4: Additional attenuation as a function of vegetation depth at 2.0 GHz

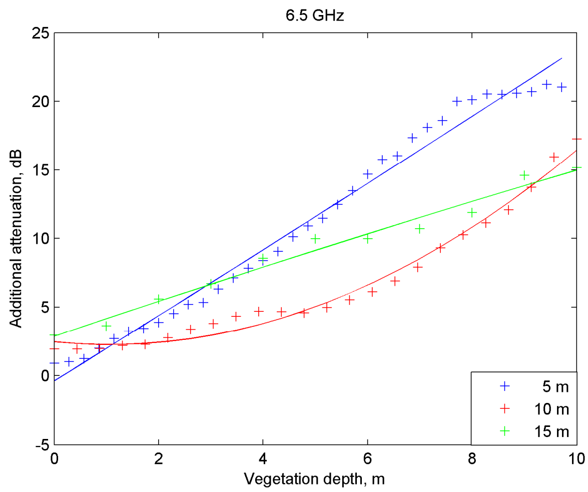

Figure 5: Additional attenuation as a function of vegetation depth at 6.5 GHz

3.2 Winter trials

The data for the winter trial were processed the same way as for the summer measurements. As our intuition tells us, the observed additional attenuation for the winter season was much lower than for the summer season due to the absence of leaves. After the data processing the additional attenuation was found to be between 6-8 dB and 8-13 dB for a vegetation depth of 10 meters at 2.0 and 6.5 GHz, respectively. Subsequently, the average increase of the additional attenuation with the vegetation depth was approximately 0.6 dB/m at 2 GHz and 0.9 dB/m at 6.5 GHz, Figs. 6 and 7.

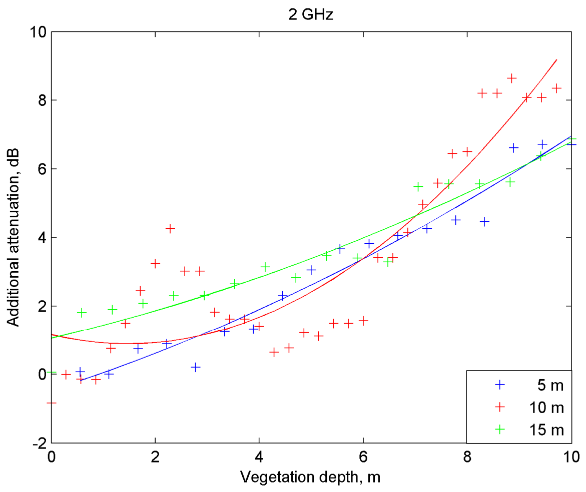

Figure 6: Additional attenuation as a function of vegetation depth at 2.0 GHz

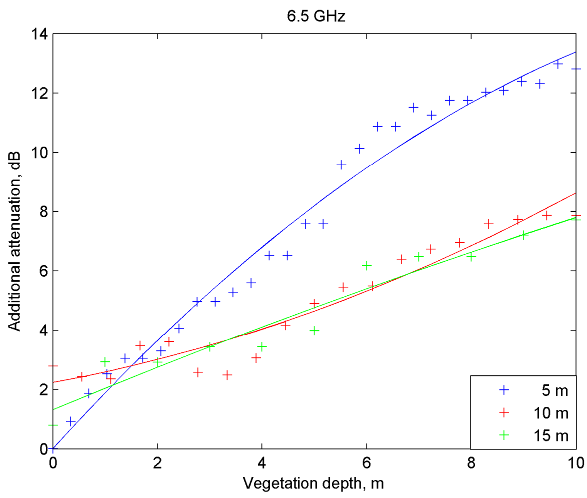

Figure 7: Additional attenuation as a function of vegetation depth at 6.5 GHz

4. Conclusion

The aim of this paper was to present the results from measurement trials focused on investigating the additional vegetation attenuation of a single tree for high elevation angles during two different seasons at 2 and 6.5 GHz, using a remote-controlled airship as a pseudo-satellite. Strong dependencies on the elevation angle and an increasing additional attenuation with vegetation depth were observed for both seasons. The differences between summer and winter measurements were found to be approximately 5 and 7 dB for a vegetation depth of 10 meters at 2 and 6.5 GHz, respectively. Future work will be focused on more detailed analyses of the measured data.

Acknowledgments

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