Initial Results of Foliage Attenuation Measurements of a Tree-lined Passage at L, S and C Bands for High Elevation Angle Links

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Abstract

This paper presents the initial results of a series of measurements to investigate the vegetation attenuation for a terminal of a high elevation link inside a tree alley passage at 2.0, 3.5, 5.0 and 6.5 GHz. The measurements were performed over the course of two seasons at two positions using a 9-meter-long remote-controlled airship as a pseudo-satellite.

Keywords: Propagation measurements, Vegetation attenuation, Satellite communications

1. Introduction

In satellite communication systems, the local environment has a significant impact on received signal quality as signal attenuation is caused by obstructions located midway along the propagation path. The presence of trees in urban and suburban settings is one such obstacle and this paper explores the relationship of trees and signal quality in greater detail.

Radio wave propagation through wooded areas or single trees has been studied by a number of investigators. Many of these works, focuses to satellite services, utilized aircrafts, helicopters or roofs of high buildings to carry the transmitting site [1-3]. Some of available works in the literature are focused to terrestrial services [4]. In addition, there are number of theoretical works to investigate the vegetation attenuation [5,6].

This paper presents the initial experimental results of an investigation into frequency dependence of vegetation attenuation as caused by tree alley over two seasons for high elevation angels at L, S and C frequency bands. The organization of the paper is as follows. Section 2 describes the measurement equipment, scenario and location with a brief description of data processing provided as well. Results from the summertime and wintertime measurements and subsequent data analyses are presented in Section 3. The paper concludes with a brief section of conclusions drawn in Section 4.

2. Measurement campaign

2.1 Measurement equipment

The equipment utilized was identical to that used in the measurement referenced in [3]. A 9-meter-long remote-controlled airship was used to carry a transmitting station consisting of a CW generator at 2.0, 3.5, 5.0 and 6.5 GHz, a power amplifier and planar wideband spiral antennas with left-handed circular polarization (LHCP). Helium filled the airship hull thus allowing for a maximum payload of 7 kg and an operating speed of about 2 – 6 m/s. The receiving station was located on the ground inside the tree alley using a single broadband spiral, circular, polarized antenna (LHCP) as a receiving antenna which was attached to a tripod at a default height of 1.5 m above the ground. The received signal strength was measured by a sensitive, portable receiver controlled by computer via its LAN interface. In addition, the airship was equipped with a number of sensors to track position, flight direction, pressure, temperature, and the pitch and roll of the airship.

2.2 Measurement scenario and location

The aim of this work was to investigate vegetation attenuation inside tree alley passage at high elevation angles. A schematic diagram of the measurement scenario is depicted in Fig. 1. As mentioned earlier, an airship controlled from the ground was used as a pseudo-satellite to carry the transmitter station while the receiver station was located on the ground at two different positions to account for vegetation variability. The airship performed perpendicular flyovers, in one direction only, above the receiver on both sides in order to obtain attenuation data for elevation angles ranging from 40 to 90 degrees. The tree-lined city square in question is situated in Fleming Square, Prague (GSP: 50°6'18.558"N, 14°23'30.587"E). The tree-lined area is composed of two parallel lines of trees consisting of 16 deciduous trees with an average height of 21 meters, Fig. 2.

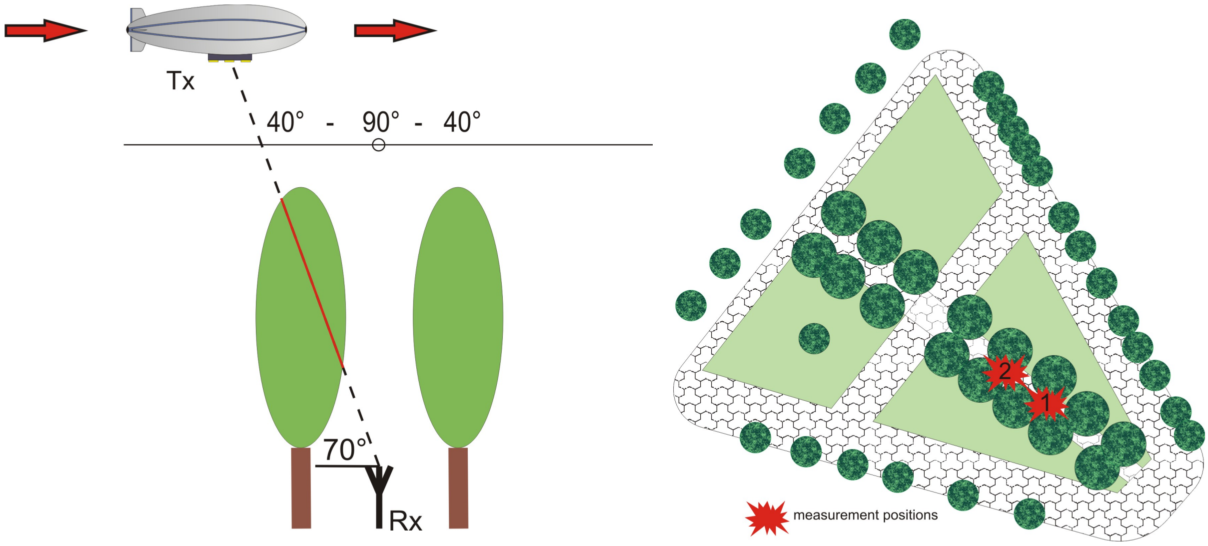

Figure 1: Schematic diagram of the measurement setup and location.

Figure 2: Measurement position 1: summer and winter.

2.3 Data processing

The additional attenuation due to vegetation shadowing was defined as the difference between a measured signal level and a reference signal level at the same elevation and azimuth in the reference site. For our measurements a large, open, flat field was chosen as the calibration site to obtain the reference data. There were two datasets to be synchronized and studied: 1. Received signal strengths, and, 2. Flight data from the airship sensors. Consequently, potentially invalid data (indentified from the airship sensors) were omitted. For further processing, measured data were processed as a function of elevation angle. The influence of multipath was eliminated using an averaging window of 10 degrees in the elevation angle.

3. Results

3.1 Summer and winter trials

The measured data, for summer and winter measurements at both positions, were processed in identical ways. Fig. 1 clearly shows two distinct settings at the time of the flyovers. Firstly, almost line-of-sight (LOS) occurred when the airship achieved an elevation angle of approximately 90 degrees and the link was not shadowed by the vegetation. And secondly, non-line-of-sight (NLOS), when the elevation angle was lower and the link was shadowed by the forested area. The layout of the trees is symmetrical along the alley so the received signal strength was calculated as a function of elevation angle ranging from 40 to 90 degrees regardless of when the airship was on the right or left side of the alley. Fig. 3 and 4 present additional attenuation dependencies at the four frequencies during summer and winter measurements. Looking at Fig. 3, significant frequency dependence is apparent for summer measurements while approximately difference between 2.0 and 6.5 GHz was found to be 3.5 dB. As predicted, lower addition attenuation was observed due to the absence of leaves during winter measurements as seen in Fig. 4, with only insignificant frequency dependence being identified during these measurements.

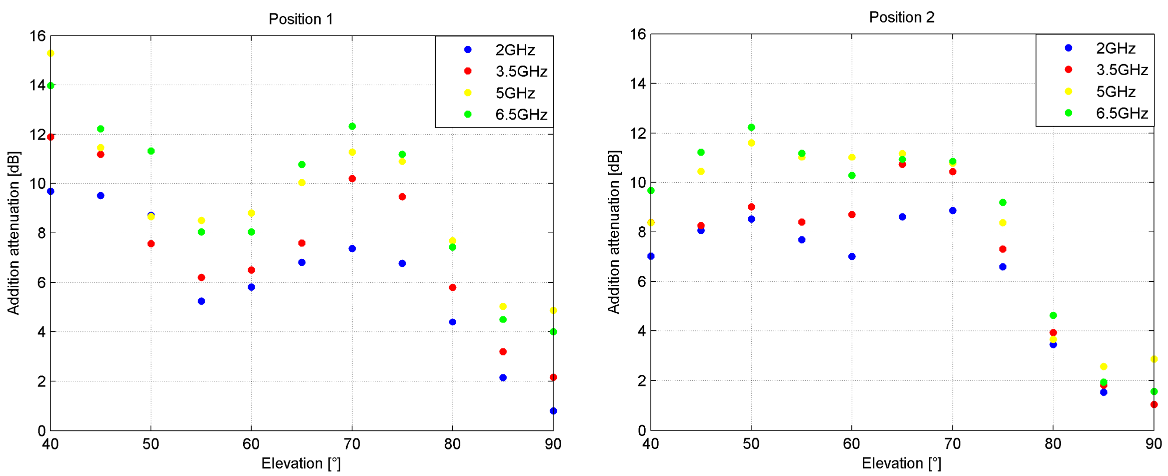

Figure 3: Additional attenuation as a function of elevation angle – summertime.

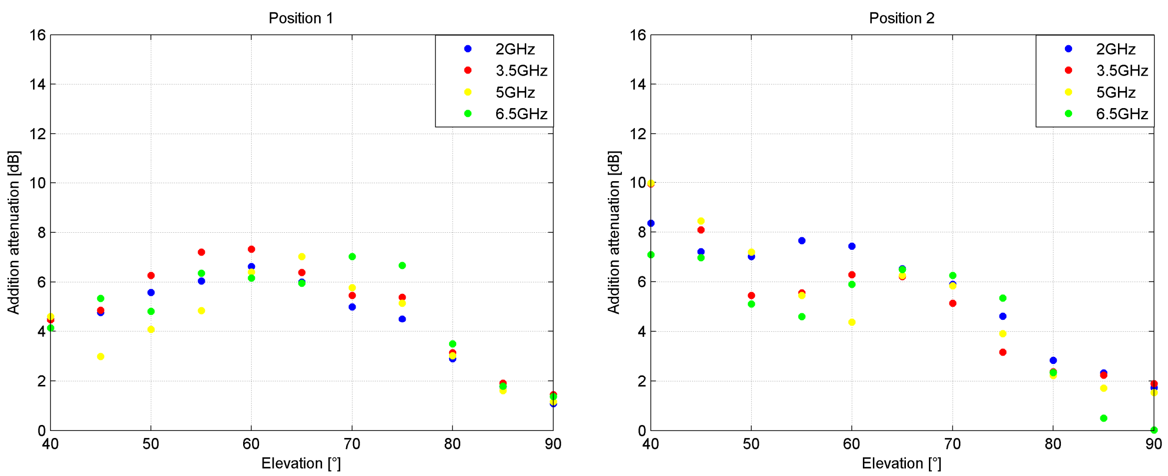

Figure 4: Additional attenuation as a function of elevation angle – wintertime.

3.2 Data analysis

As expected, the additional attenuation depends on a link path length through the canopy: the vegetation depth. The geometry in Fig. 1 suggests that maximum attenuation can be expected at elevation angles of 70 degrees where the vegetation depth is at its greatest. It is interesting to note that the loss never drops to zero at 90 degrees, i.e. for the line-of-sight case there are about 2 dB missing when compared to the calibration measurement. It may have been caused by a system error, or, a different type of ground surface – more investigations are required. The trees under investigation were of the same type and size, however, they are not homogenous mediums hence the additional attenuation behavior is slightly different for position 1 and 2. As follows from Fig. 3, attenuation during summer measurements for an elevation angle of 70 degrees was found to be approximately 8 and 11 dB at 2.0 and 6.5 GHz respectively. Attenuation during winter measurements for the same elevation was observed to be 5.5 dB at 2.0 GHz and 7 dB at 6.5 GHz, Fig. 4.

4. Conclusion

In this paper, we presented the initial results of series of measurements to investigate vegetation attenuation caused by a tree-lined passage. Two different measurement positions were chosen while the received signal strength was measured during summer and winter. The highest additional attenuation was found at the greatest vegetation depth at an elevation angle of 70 degrees which corresponds to our expectations based on the scenario geometry. Only insignificant frequency dependence was observed during winter measurements. Future work will be focused on more detailed analyses of the measured data.

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