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Propagation Measurements in a Wide Range of Elevation Angles Using a Remote-Controlled Airship

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1. Introduction

Using a remote-controlled airship (Fig. 1) to simulate a satellite, high altitude platform (HAP) or unmanned aerial vehicle (UAV) is very advantageous when corresponding propagation channels are to be addressed. For example, in case of building penetration loss or vegetation attenuation measurements for high elevation angles, the use of an unmanned airship can dramatically reduce the costs of the measurement campaign while providing almost equal measurement possibilities compared to the case when e.g. a helicopter or an aircraft is used as a pseudo-satellite. However, one significant constraint is given simply by the weather conditions as the airship cannot be operated under rainy, snowy, foggy or windy conditions.

During the period from 2008 to 2012, we successfully carried out three different types of propagation measurements with a remote-controlled airship [1]-[6]. These campaigns covered satellite-to-indoor channel and attenuation by vegetation measurements for high elevation angles as well as UAV channel measurements for low elevation angles. Different types of measurement systems were utilized to address single-input single-output (SISO), single-input multiple-output (SIMO), multiple-input single-output (MISO) and combined SIMO/MISO propagation channels for frequencies ranging from L- to C-band. The aim of this paper is to present in detail the measurement methods applied during the corresponding propagation measurements and to provide general guidelines and understanding that can be useful when such measurements are carried out.

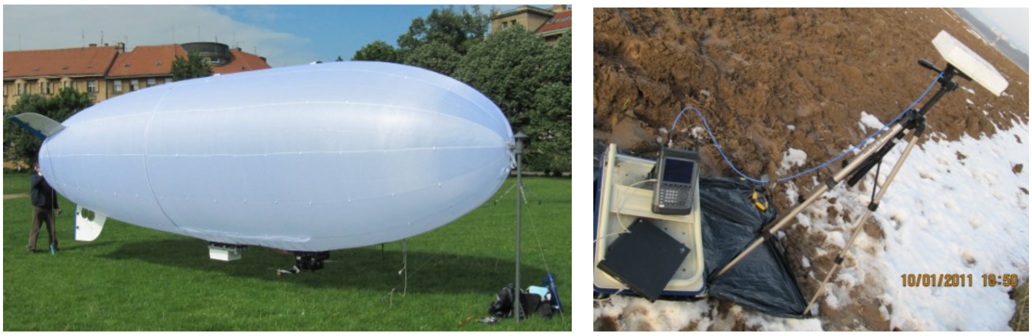

Figure 1: The remote-controlled airship (left) and the receiver station (right)

2. Remote-Controlled Airship

The remote-controlled airship used for the measurements (Fig. 1) is a nine-meter-long airship filled with Helium and powered by batteries. It can be easily deflated and transported to a selected location. Apart from take-offs and landings, the airship follows semi-automatically the flight paths that are pre-defined based on GPS coordinates. It is equipped with a number of sensors tracking its pitch, roll, GPS position and others in order to synchronize the flight data and the signal levels recorded by the receiving station. The batteries enable the airship to operate in the air for approximately 25 minutes and its design allows attaching a payload of a weight of up to 7 kg to its bottom part. The altitude of the airship is kept during the flight typically around 200 meters above the ground level while its speed is approximately 3 m/s.

3. Building Penetration Loss Measurements

During the years 2009 and 2010, we performed building penetration loss measurements at 2.0 GHz, 3.5 GHz, 5.0 GHz and 6.5 GHz using the remote controlled airship. Based on the experimental data, we derived elevation-dependent penetration loss models valid for these four frequencies, a wide range of elevation angles and satellite-to-indoor scenarios [1].

3.1 Measurement Setup

A transmitter station with continuous wave generators and left-handed circularly polarized spiral antennas was placed at the bottom part of the airship. A receiver station (Fig. 1) was equipped with an antenna of the same type and was placed always at a one-meter distance from a window during the measurements. These measurements were performed at 52 measurement sites inside five different representative types of buildings (A–E) typical for an urban area. The receiving station comprised a sensitive portable radio receiver powered by batteries with a sampling rate of approximately 1 Hz at each of the four frequencies.

For these measurements, a wide range of elevation angles from 25 to 90 degrees was required to be covered at different azimuths. To meet such goals, four flyovers of the airship forming a star-shape pattern were carefully planned above each of the case-study buildings (indicated by red lines in Fig. 2 on the left). Respecting the altitude of the airship, each flyover had a length of about 1 km. At the end of the flyover, the airship was manoeuvred to follow the next flight path, as indicated in Fig. 2 on the right. In this way, all the considered elevation angles for different azimuths were covered in a reasonable time, meaning that experimental data for one building were usually obtained within one day. The flyovers were planned respecting the building orientation, i.e. always one flyover was parallel and one was perpendicular to the building facade.

Figure 2: Flyovers of the airship above a selected building (left), five actual flight paths above building A including airship manoeuvres (right)

3.2 Reference measurements

To calculate penetration loss, experimental data were simply subtracted from reference signal levels obtained on a flat open field for matching azimuth and elevation angles [2]. To obtain a set of reference signal levels for various combinations of azimuth and elevation angles, the airship was used with a great advantage. Its flyovers above the flat open field covering the considered range of elevation angles were planned for azimuths separated by only approximately 15 degrees. All the recorded signal levels were recalculated to a uniform distance of 20 km to deal with different distances between receiving (Rx) and transmitting (Tx) antennas during the measurements.

4. Vegetation Attenuation Measurements

Since 2009, vegetation attenuation measurements have been performed using the setup described in Section 3.1. Selected scenarios were studied at the same four frequencies for the same wide range of elevation angles. The trials were carried out for the in and out of leaf conditions. Based on the experimental data for six scenarios consisting of various kinds of deciduous and coniferous groves, empirical models for the frequency dependence of the additional vegetation loss for satellite links at L-, S- and C- band were derived for the summer and winter seasons [3], [4].

4.1 Measurement Method

The flyovers of the airship were during these measurements planned with respect to the selected scenario: Rx at pre-defined distances from a single isolated tree, Rx inside a tree alley, or Rx inside a forested area with LOS always fully blocked, see Fig. 3.

For the single tree scenario, the flight paths were performed in a line defined by the positions of the Rx and the tree. Thus, it was possible to address the attenuation due to vegetation as a function of vegetation depth. Considering a tree alley, flyovers perpendicular to the direction of the alley were performed resulting in different vegetation depths as well. For the case of forested areas, the flyovers followed the star shape pattern above the Rx, the same as during the penetration loss measurements. In this way, results statistically independent on the azimuth were obtained. By selecting adequate scenarios in a given location, various measurement configurations were addressed during one measurement day simply by changing the airship flight paths.

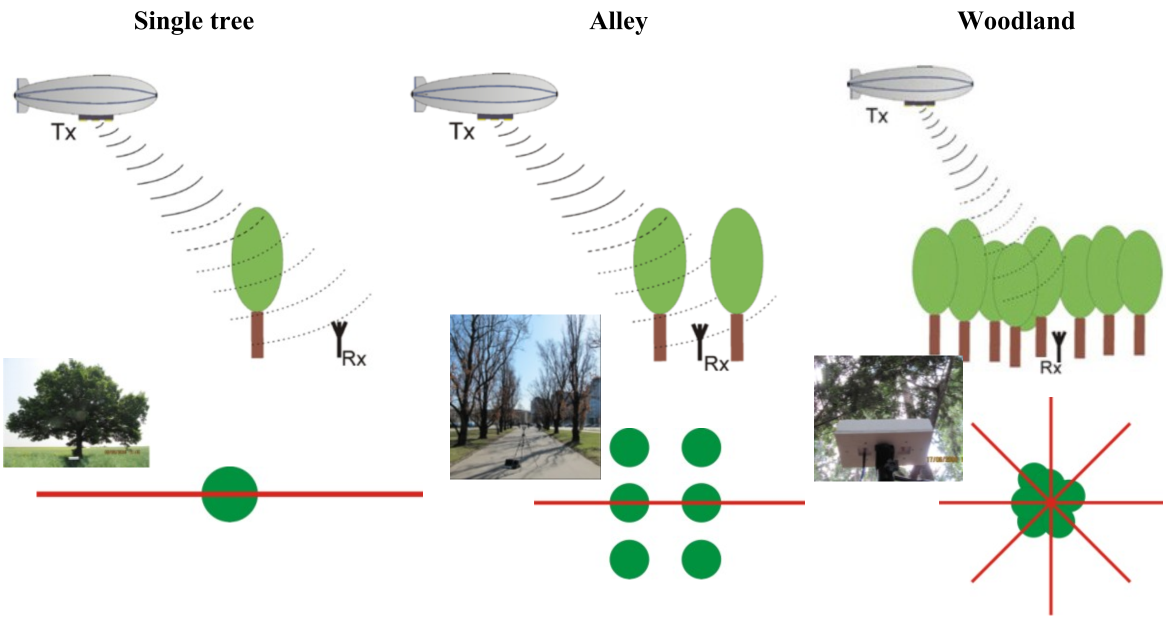

Figure 3: Case-study scenarios and corresponding flight paths

5. UAV Link Measurements

Since 2009, the UAV channel measurements have been performed in an urban area at the frequency of 2.0 GHz for very low elevation angles. During these trials, a four-channel receiver (Fig. 4) with 100 Hz sampling rate was utilized and connected to four quarter-wavelength monopoles (Fig. 4). One Tx antenna of the same type was used as well enabling to address a SIMO channel. A simplified excess loss model was successfully verified by using the obtained experimental data [5].

4.1 Measurement Method

To achieve low elevations, approximately from 1° to 5°, in an urban area, the flight paths of the airship were planned in the directions from and toward the receiver at distances of 1.2 km to

6.5 km at different altitudes up to 300 meters above the ground level (Fig. 4). Two opposite scenarios were addressed during the measurements simply by changing the Rx location: as far as possible from the nearest building in the direction of the UAV and very close to the nearest building in the direction of the UAV. The flyovers were carried out in a direction that was perpendicular to the orientation of the street with the Rx.

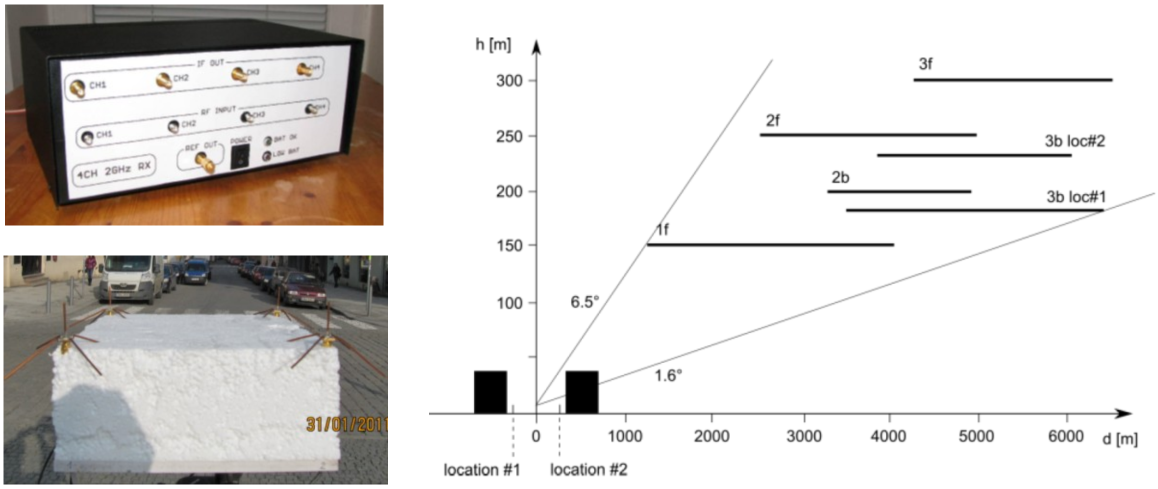

Fig. 4 From left to right: The new 4-channel receiver and the four Rx antennas, flight paths in detail

5. Conclusion

We have presented a variety of methods for different types of propagation measurements carried out using a remote-controlled airship. Based on the experimental results, a number of valid propagation models have been derived [1]-[5]. For a future work, outdoor-to-indoor and vegetation attenuation measurements for satellite navigation and communication services are planned to be carried out addressing SIMO, MISO and SIMO/MISO channels as preliminary measurements have were already performed [6].

Acknowledgments

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References

[1] M. Kvicera and P. Pechac, “Building penetration loss for satellite services at L-, S- and C-Band: measurement and modeling,” IEEE Trans. Ant. and Prop., Vol. 59, No. 8, pp. 3013-3021, 2011.
[2] M. Kvicera, P. Horak, P. Pechac, F. Perez-Fontan, “On a definition of building penetration loss for high elevation angles,” IEEE Trans. Ant. and Prop., Vol. 58, No. 12, pp. 4115-4118, 2010.
[3] P. Horak, M. Kvicera, P. Pechac, “Frequency dependence of attenuation due to vegetation for satellite services,” IEEE Antennas and Wireless Propagation Letters, Vol. 9, pp. 142-144, 2010.
[4] P. Horak, P. Pechac, “Seasonal additional attenuation in woodlands for satellite services at L-, S- and C-bands,” IEEE Trans. Ant. and Prop., Vol. 59, No. 12, pp. 4865-4867, 2011.
[5] M. Simunek,P. Pechac, F Perez-Fontan, “Excess loss model for low elevation links in urban areas for UAVs,”. Radioengineering, Vol. 20, No. 3, pp. 561-568, 2011.
[6] M. Kvicera and P. Pechac, “Antenna diversity measurements at 2.0 GHz for satcom services,” in Proc. ESA Workshop on Radiowave Propagation, Noordwijk, the Netherlands, 2011.