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# Measurement of the Horizon Elevation for Satellite Tracking Antennas Located in Urban and Metropolitan Areas Combining Geographic and Electromagnetic Sensors

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ABSTRACT

In urban and metropolitan areas presence of nearby obstacles and signal interference sources surrounding tracking antenna locations reduces satellite communication times. In low orbit missions these obstructions are even more relevant due to a few minutes per satellite pass. In this scenario a best estimation of the antenna elevation mask in the mission frequency band is proposed to test the antenna design for a given site by applying mission simulation software before the installation stage. If needed, to improve efficiency in satellite tracking operations, mitigation techniques will be proposed either in the redesign or relocation of the antenna.

This paper describes a methodology for deriving the horizon elevation diagram, which includes a measurement setup when different data capturing sensors are used: geographic and electromagnetic. Application results which have contributed in the selection of the antenna location can be seen in the case study of the new CubeSat-LEO tracking antenna at Cal Poly University.



## 1. Introduction

Emergence and increase in the number of LEO (Low Earth Orbit) nano-satellite projects such as the QB50 project [1] and their development at universities and research centers in the last years, have conditioned the geo-location of the satellite tracking antennas in urban and metropolitan areas. Despite the great advantage of LEO orbits being the short distance the radio signal must pass through which in turn reduces transmission power requirements and minimizes the propagation delay [2], it is becoming necessary to increase the operational quality of the antenna. Critical points identified are: visibility times of a few minutes in each satellite pass per day, assembly adaptability to any direction in azimuth and elevation, accuracy of the initial orientation derived from the position of the satellite and the antenna, and effectiveness of satellite tracking through a continuous system in order to avoid possible signal losses. To improve the performance of the antenna design there are several solutions: the use of azimuth-elevation pedestals to minimize tracking losses [3], the antenna size selection to achieve the desired gain margin [4], and the antenna positioning system using stepper motors [5]. Moreover, in urban and metropolitan areas obstructions caused by buildings and interference sources become another critical point as they reduce the FOV (Field of View) and disturb the signal communication between the satellite and the antenna. In particular AOS (Acquisition of Signal) and LOS (Loss of Signal) along the horizon in certain azimuth directions, since above mentioned critical points in the tracking antenna operations increase. In this scenario for LEO tracking antennas, mission analysts must take into account the quality link and the mission concept when analyzing the link budget. Link budget analysis takes into account in situ analysis of external noise caused by radio electric emissions from the earth and the atmosphere, extraterrestrial sources, and man-made noise [6]. In this sense, measurements presented by Leferink et al. [7] confirm that different interference sources coming from industrial production plants, cars and trains affect radio links in UHF (Ultra High Frequency) and in VHF (Very High Frequency) bands. For LEO tracking antennas locations on building roofs, parameters such as the antenna gain in relation to its size and the noise temperature at in relation to spectrum congested antenna sites [8] are of great relevance in the link budget analysis in order to establish a robust communication link. From the link quality point of view, applying a standard antenna elevation mask with a fixed minimum elevation of 10° would guarantee adequate conditions for the satellite

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communication links, as this would avoid most of the surrounding obstacles and interferences. [9]. However, from the mission concept point of view the above mentioned standard mask reduces the amount of data download per satellite pass in a science mission. This is further reduced as the altitude of the satellite decreases, the opportunities to track or communicate with it from the antenna become more restricted further complicating satellite scheduling [10]. In this scenario, a best estimation of the antenna elevation mask would increase the satellite FOV (field of view) and in consequence would maximize science data download. In this sense, results presented by Gill et al. [11] do not consider the satellite FOV as a link budget parameter but for the amount of telemetry data in downlinks with minimum possible elevations.

This paper analyzes the tracking antenna scenario associated to a new generation of nanosatellites called CubeSat [12]. These small satellites reduce the link budget margin available in LEO missions, adding short lifetime and limitation of available signal power on board as specific link budget parameters. In order to reach an optimal solution, considering the above mentioned points of view, a balance between them and the limited resources in CubeSat missions, a methodology to simulate the horizon elevation from the selected antenna site is proposed.

## 2. Methodology

This methodology has been developed taking into account the data set required by the satellite tracking software from the antenna location point of view. From the measurement data analysis, a measurement setup has been designed to finally select the most adequate equipment for data capturing processes.

### 2.1. Measurement data

The tracking software with information of the satellite orbit is engaged to the antenna rotor controller to start the tracking process when the satellite is in view (satellite entry) over a predefined elevation. The rotor controller governs the operation of the antenna rotors to generate the required voltages to steer the antenna in the correct angular position. Then, the antenna comes to stow position once the satellite goes below the minimum elevation (satellite exit). These programs, such as Orbitron [13] used to predict when and in which direction the satellite is available to communicate with it, or STK (Satellite Tool Kit) [14] used to analyze the satellite missions, require a data set from the antenna location point of view; first, to simulate and analyze the satellite mission, and; second, to control the positioner to point the antenna in the satellite direction during the tracking mission. [15]. The data set contains both the geographic coordinates and the orthometric height of the antenna rotor center, and the antenna elevation mask or altimetry profile surrounding the antenna site. In urban and metropolitan areas, this mask should also contain information about antenna minimum elevations to avoid physical and electromagnetic obstructions caused by nearby obstacles and signal interference sources which affect the communication links in certain azimuth directions from the antenna location site. Fig. 1 shows the simulation of this scenario in which nearby obstacles (white dots) surrounding the antenna site reduce the satellite FOV, and a radio amateur antenna that emits in the same frequency band also reduce the communication time between the satellite and the antenna in the azimuth direction of the satellite entry.

This required measurement data is twofold: geographic and electromagnetic. Considering the STK file required to create the scenario the data must be exported with the same parameters (azimuth, elevation) from each software used. In addition, the electromagnetic and geographic data fusion requires data capture in the same coordinate reference system.

### 2.2. Measurement setup

Considering that the purpose is to in situ simulate the tracking antenna elevation mask and the measurement data required, a measurement setup has been designed when using different data capturing sensors to provide in situ quick results by a swift process of data fusion. Data capturing sensors for each procedure have been selected for each procedure analyzing the data set required. Fig. 2 shows the scheme of the measurement setup designed which contains the procedures followed to obtain each mask, geographic and electromagnetic. In the first procedure, the *Geographic study*, the main purpose is to establish the spatial position of the antenna rotor center as the center of the coordinate reference system by using GNSS (Global Navigation Satellite System) technology. This reference system will be used for the acquisition of the altimetry profile data by using topographic instrument. The reference system will also be used in the second procedure, the *Electromagnetic*

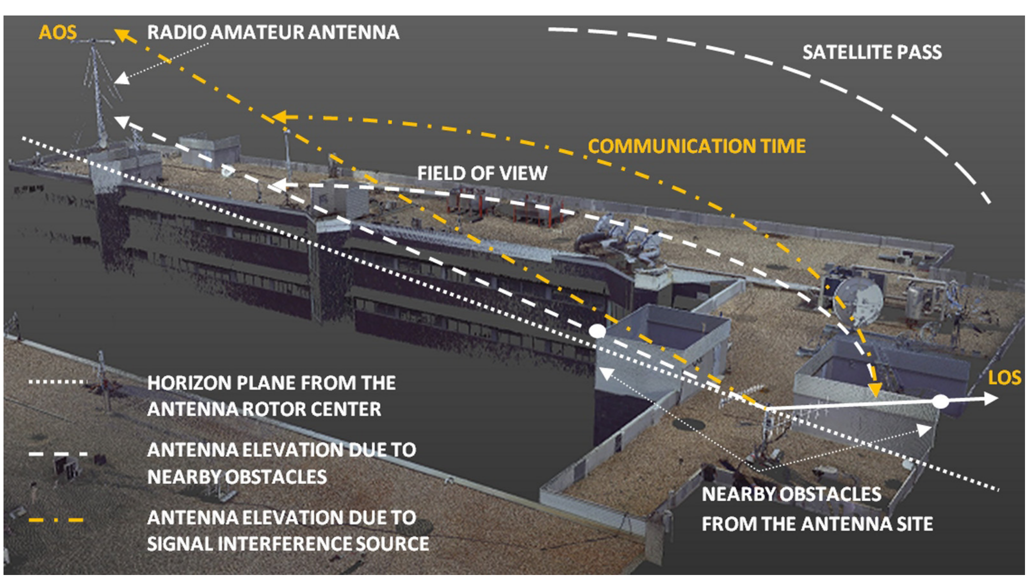


**Fig. 1.** Simulation of a tracking antenna scenario in a particular satellite pass.