Tracking Quality Measurements Of Ground Station For Low Earth Orbit Satellite.

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Abstract - **The poor quality position tracking of the satellite Ground Station (GS) for the Low Earth Orbit (LEO) satellite is due to the low quality RF signal received. The BRITE-PL team (owner of the first Polish scientific satellite [6]) have had a lot of problems with optimizing the quality of the BRITE-PL-1-Lem satellite down-link. One of the investigated sources of trouble was the quality of the tracking ground station antenna systems. As a result, a procedure for measuring the quality of the tracking was prepared. The BRITE-PL team in co-operation with the Marcin Stolarski Laboratory (MSL) company has prepared an absolute measurement of tracking the antenna using an optical tracking real satellite (such as the International Space Station (ISS)) which reflects a lot of sunlight and can be easily observed in the dark sky. This paper describes what can be measured and how (it does not describe the calibration process) using this method based on the first experiment (which showed an uncalibrated (before calibration) antenna tracking system) at the BRITE-PL ground station located at the Nicolaus Copernicus Astronomical Center of the Polish Academy of Science.**

Index Terms — **satellite tracking; ground station, ISS;**

I. INTRODUCTION

Tracking errors can be delivered from (Fig. 1):

PC

- mathematical algorithm (PC software) for satellite tracking
- low quality/old satellite orbit parameters (TLE)
- low quality of PC time reference
- time resolution of satellite position prediction
- position resolution of satellite prediction
- time delay between the calculation of the satellite position and rotor reaction (moving of the antenna to the calculated satellite position)

Link 1

- delays in transmission between the PC and rotator controller

Rotator controller

- algorithm for rotator controlling
- precision/resolution of rotation measurement of the rotator
- delay connected with the starting and stopping of the engines for rotation (accelerating the rotation)
- resonance vibrating of rotators

Link 2

- delays in transmission between rotator controller and rotator

Rotator

- calibration of the zero position
- calibration of the rotation angle measurements

Antenna

- wind vibration
- rotation vibration
- inertia of the antenna systems

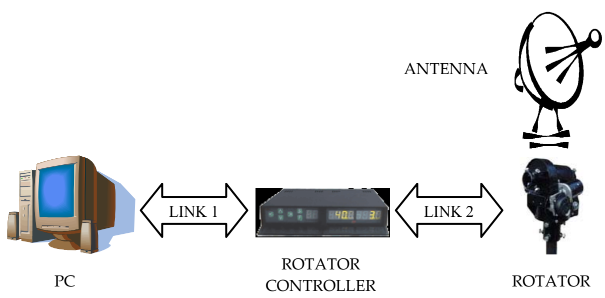

Figure 1. GS tracking system configuration diagram.

As stated above, there are many sources of potential problems with the precision of the satellite tracking of the antenna system.

The BRITE-PL team for communication with BRITE satellites uses the ground station GSCAMK located in Warsaw at the Nicolaus Copernicus Astronomical Center. GS uses a complex antenna system for the up-link to the UHF band and down-link to the S-band. For the UHF system a 4 crossed YAGI system is used where the beam has a width of about 10 deg whilst for the S-band it uses a parabolic dish antenna where the beam has a width of about 4 deg (Fig. 2, Fig. 3).

Figure 2. GSCAMK antenna system.

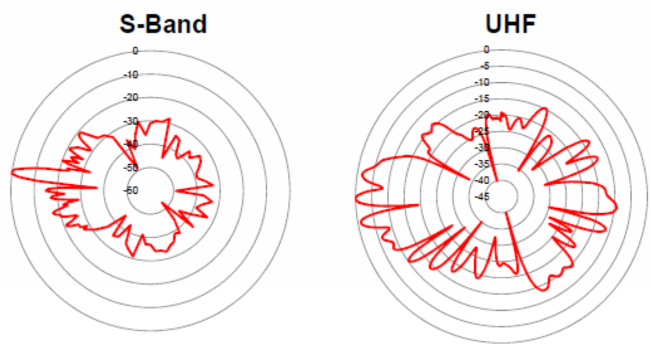

Figure 3. GSCAMK antenna beam characteristic.

For the tracking of the LEO satellites system a special upgraded version of the SPID Elektronik rotator named BIG RAS was used with an expected precision of 0.2 deg [4]. During communication sessions with the BRITE-PL-1-Lem satellite, the team observed an unstable down-link signal. They therefore decided to precisely measure the quality of the tracking system.

II. Preparation of the Tracking Quality Measurement.

The MSL team organized an experiment to compare the antenna tracking system with the real position of the LEO satellite by optical observation. In the experiment the group used an ISS satellite because this satellite is the brightest LEO object. Visual observation of ISS has a few requirements:

- correlated satellite orbit position above GS (about 1-2 hours after the sun has set or 1-2 hour before the sun rises, the sky above GS must be dark and the satellite must be in sunlight. This configuration happens every 1 week over a 1-2 months period)
- calibrated antenna system
- good weather (no clouds)

The correlated orbit was predicted for one month ahead. On the appropriate dates (good for ISS observation) the weather was observed and if optimal weather was expected at night, during the day, precise rotor calibration was carried out. The calibration of the rotator system was based on setting the antenna directly towards the sun (the position of the sun is calculated by the tracking software) and setting the antenna system at the position when the antenna feed generates the sun-light shadow precisely in the center of the antenna dish. The team waited about 1 month for good weather to be correlated to a good ISS position. On the 11.04.2014 at 20:30 UTC, the experiment was carried out. The prediction of the position of ISS is presented in Fig. 4. The maximum expected elevation for the satellite was 59 deg.

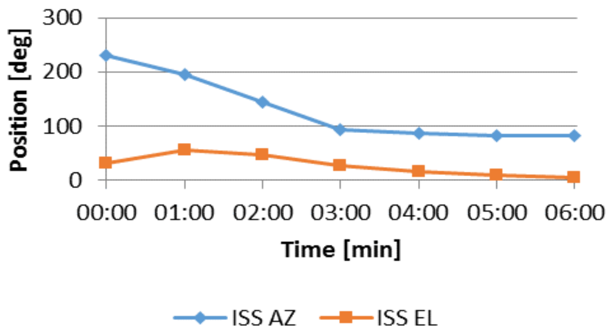

Figure 4. Position of ISS during experiment

Figure 5. Calibration of the camera mounting.

Before the experiment on the antenna system, a video camera was mounted (Fig. 2). In the experiment a Sony HDR-PJ650VE camera was used [3]. It is important to switch off any anti-vibration systems in the mounted camera. The next step was to calibrate the camera using the moon for observation. The antenna system was set at the moon's position and then the camera was set to the moon's position too. After this, the, antenna system was moved 2 deg up, vertically and horizontally (it is the size of an S-band antenna beam) in order to set the camera to the correct value of the optical zoom and record on film the angulation reference of the S-band antenna beam (+/- 2 deg, absolute 4 deg). At the post processing operation stage this reference was marked with a red cross (Fig. 5). This cross is rotated a little to the right because the camera was not mounted parallel to the horizon.

A subsequent step is the normal ISS tracking and the recording of the antenna view on film (typical communication window is about 10-15 min but ISS was observed 6 min only). Next, is the movie postproduction (Fig. 6 - it presents one frame of the post produced material). The recorded movie is combined with the red cross from Fig. 5 (expected size of antenna beam) and with the ISS prediction map. This map is generated by Orbitron software [1]. It represents a view of the sky above GS (at the center is sky's zenith and the biggest ring is the sky's horizon). The curved line represents the ISS sky track (not the camera view track) and at the point of this line is the predicted actual ISS position. Close to center of the red cross is one bright point. This is a real photo of the ISS. The size of ISS represents 0.08 deg so is better than a rotator resolution (0.2 deg).

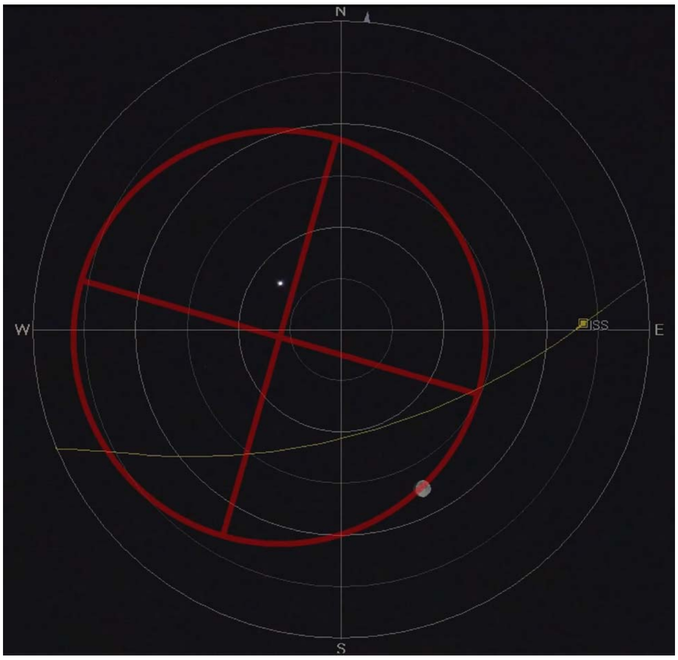

Figure 6. Tracking measurement – one frame form the post produced movie.

III. EXPERIMENT RESULTS

Fig. 7 presents the results of the experiment. Max Error is the maximal differential between the antenna and the ISS position. Min Error is the minimal distance between the antenna and the ISS position. One point represents data recorded over 10 sec. It means that during this 10 seconds the distance between the antenna and the ISS position changes from Min Error to Max Error and in the opposite direction as well (minimal one time but typically it was several times). The experiments show that the maximal error of the tracking system is +/- 4 deg (absolute is 8 deg). It is two times bigger than the antenna beam size; therefore losing the RF signal is expected. A short analysis of the data shows that the measured rotor configuration was insufficient for preparing a good satellite down-link.

First conclusions were that the software correctly calculates the satellite position (Min Error was smaller than 2 deg) but rotor configuration should be more aggressive. The rotator should update the position more often than 1 time per second and the rotator engines should start faster (system start-stop engines should be configured to faster reaction). There is a difference in the Max Error when antenna is moving up and down, so possibly the antenna system needs a weight balance.

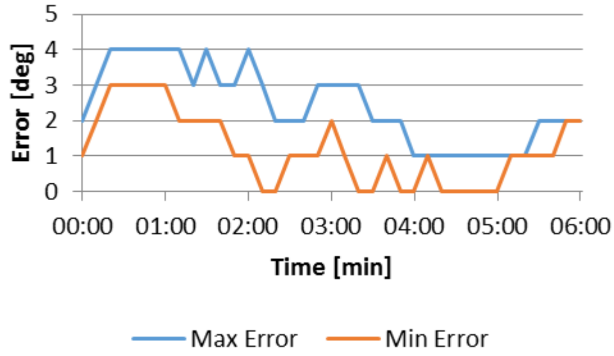

Figure 7. Measured tracking quality.

IV. SUMMARY

In all likelihood there is no better method for qualification of antenna tracking system than to compare it to the real satellite position. The presented optical method is efficient, simple and an inexpensive solution for this measurement. The resolution of presented measurement (0.08 deg) is better than the rotator resolution (0.2 deg) and the antenna beam size (4 deg). If a bigger resolution is necessary it would be possible to mount a camera with a better optical system (e.g. using a small telescope). The weaknesses of the presented method are expected good weather and the correlating of the satellite orbit with sunrise and sunsets. It is possible to use other visible satellites but GSCAMK is located in Warsaw where there is a problem with dark skies. ISS bright is about -3.2 mag so it is the second brightest object in the sky (after the moon). There is no problem with the ISS observation in Warsaw. Other visible satellites have 1.3 to 4 mag and needs a dark sky [2].

The results of the experiment are being used by the BRITE-PL team for calibrating the antenna tracking system and two weeks later the quality of the RF downlink was better, but still the system is calibrated in small steps.

This document was created in cooperation with Marcin Stolarski Laboratory company [5] which prepared the described experiment.

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