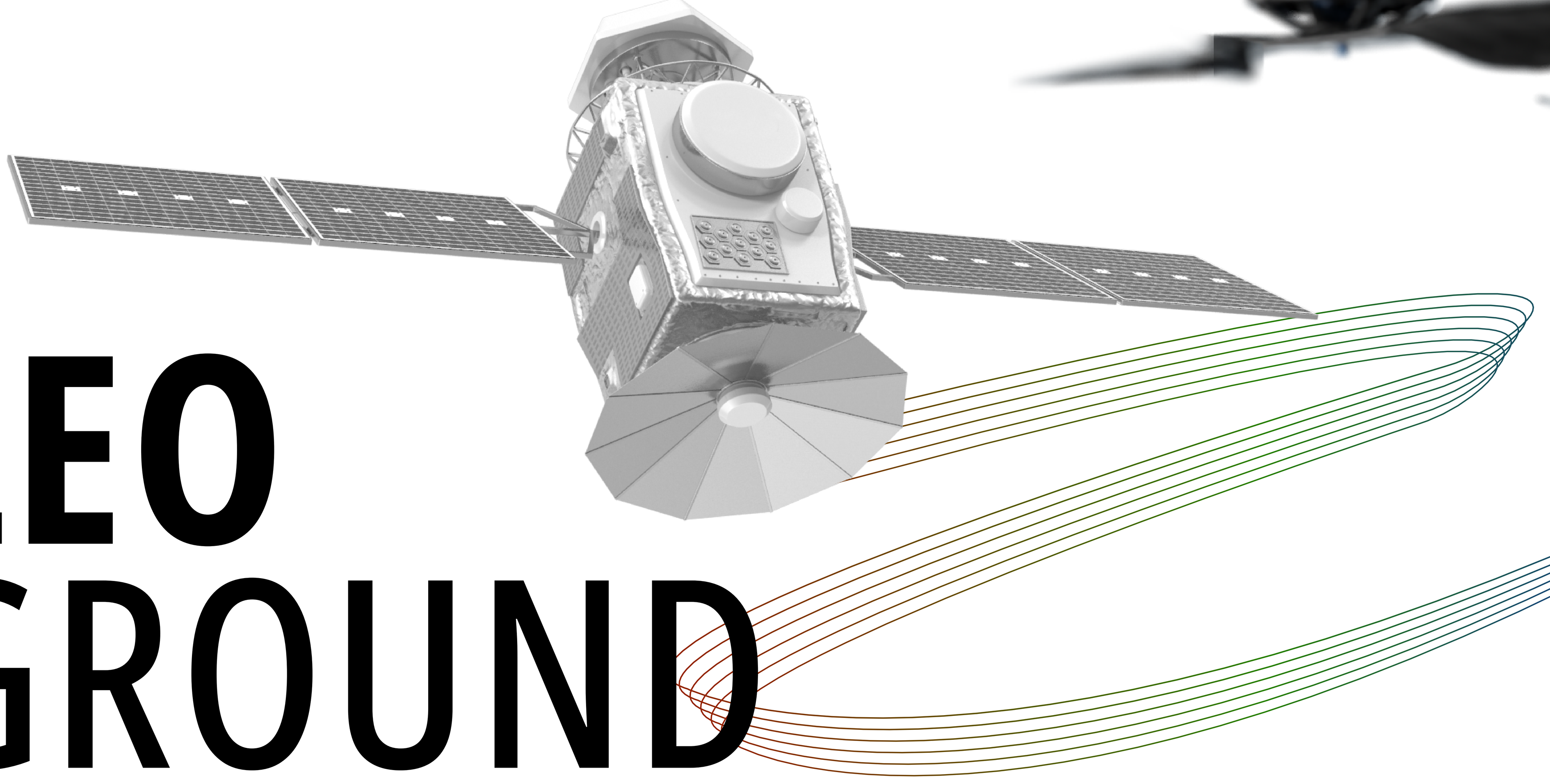

LEO GROUND SEGMENT TESTING

ADDRESSING THE CHALLENGE

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INTRODUCTION

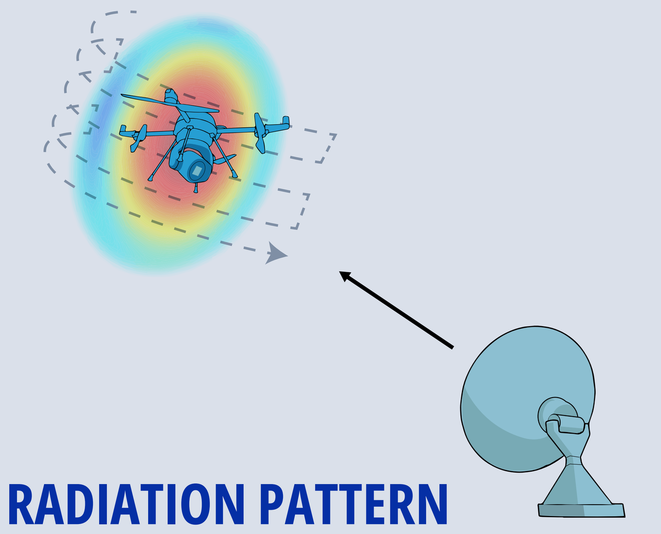
The rise of new Non-Geostationary Orbit (NGSO) satellite constellations requires dynamic tracking and seamless handover from one satellite to another without causing interruptions or signal degradations. This trend is increasing the complexity of the ground segment that is now adapting first with the reutilization of existing on-the-move tracking technology and moving into new developments of commercially viable electronically steered antennas (ESA).

The issue investigated is the lack of clear guidelines on testing the performance of such antennas, which are not currently standardized.

The testing procedure is a qualification methodology for muti orbit tracking antennas based on an Unmanned Aerial Vehicles (UAV) technology with capabilities of measuring antenna characteristics (patterns, gain, polarization purity), and emulating discrete satellite passes where both motion and signal properties are manipulated so that a full validation could be completed anywhere in the world. The procedure is valid for both user terminals and gateways operating on all orbit types, and it covers all antenna design types, such as mechanical parabolic and electronic steerable antennas.

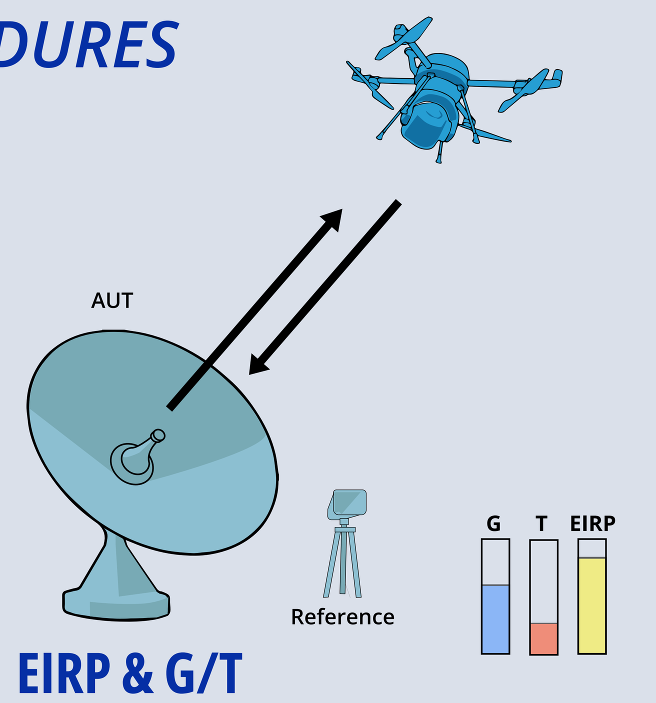
The UAV is equipped with RF transceivers and directional antennas operating over a wide frequency range. The proposed test, measurement and calibration scenarios are possible by positioning these payloads precisely around an antenna under test (AUT) and programming the SDR based transceiver to emulate the same signal signatures as a satellite would do.

MEASUREMENT PROCEDURES



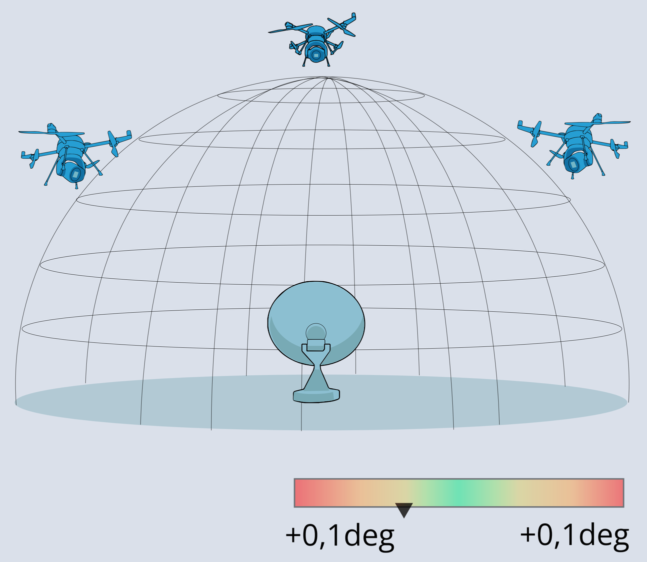
RADIATION PATTERN

The radiation patterns are measured and presented as raster scans (area measurement) or line cuts (single plane). The result of a raster scan is a heatmap, which is made by interpolating all the collected points, and gives an overall picture of the antenna's electromagnetic characteristic. A raster scan can be used to find potential sidelobe imbalance antenna focal issues.



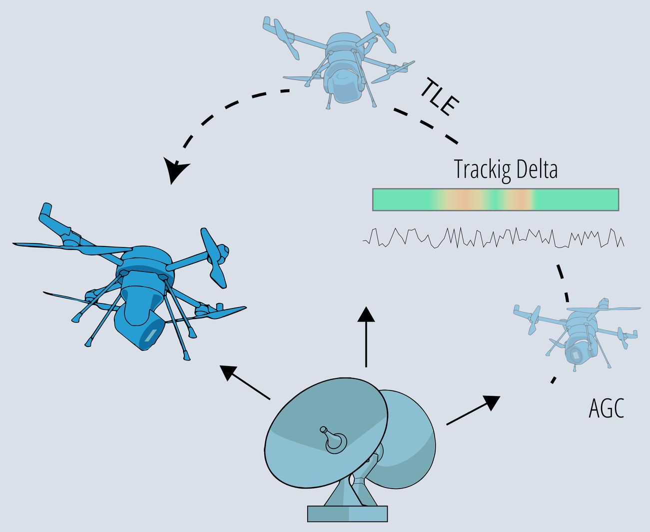
EIRP & G/T

The system EIRP & G/T can be measured by using a reference antenna and applying the principles of the substitution method. In the case of electronically steered antennas, these values should be measured for each beam state.



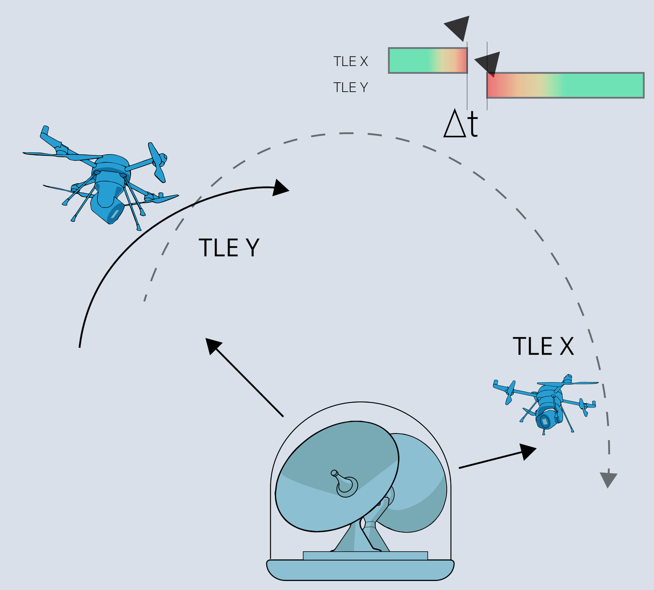
POINTING ASSESSMENT

To verify pointing the UAS system will hover at fixed position generating a signal for the antenna to lock itself onto. The angles from both systems then compared with each other to calculate the resulting angle offset. This test is done in multiple directions providing a holistic pointing assessment of the AUT.



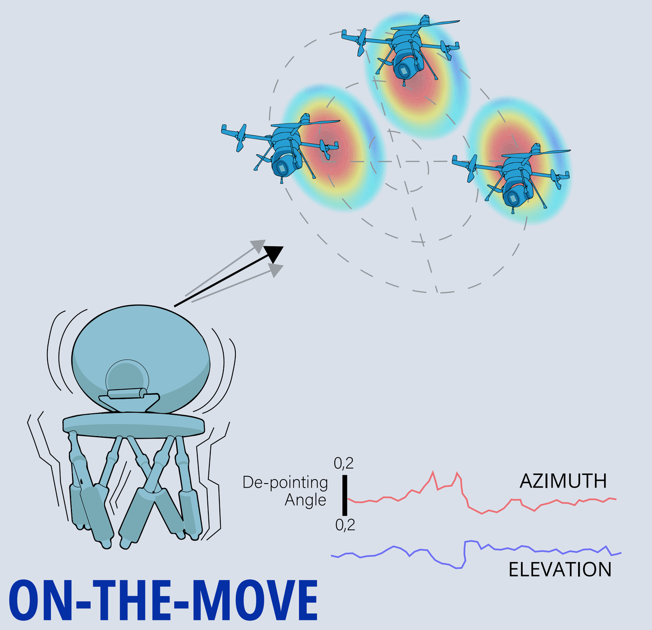
TRACKING EVALUATION

To verify tracking, the UAV will assume the trajectory of a satellite, which is generated on demand based on the desired angular characteristics, e.g. high elevation passes. The payload is programmed to transmit specific modulations, as well as to receive, demodulate and store the signals from the AUT. The desired trajectory versus actual trajectory is compared to evaluate the antenna tracking deltas.



HAND OVER & MULTIBEAN

For handover, two UAVs are used to emulate a handover scenario. The measured parameter is the time of handover for a single beam system, or the assessment of uninterrupted operation (make-before-break) for multiple beams systems. The multi constellation operation is tested in the same way.



ON-THE-MOVE

The on-the-move operation addresses an extra complexity where the antenna operation should be evaluated whilst on vehicle in motion (car, train, ship, or airplane). For that a motion table can be employed to simulate the movement, whilst a dynamic depointing assessment is measured by evaluating the quality of the received signal during the test.

SUPPORTING ALL STAGES OF SATELLITE CONSTELLATION DEPLOYMENT

PRE-LAUNCH

Preparation of the grounds segment for LEOP: the test procedure will ensure that the prototype gateways and user terminals are well calibrated and prepared for the initial launch of the first constellation satellites. Worst case test scenarios can be emulated so that both the antenna and the ops teams are well prepared.

Assessment of antenna vendors: every satellite constellation is different and the choice of ground segment technology, and architecture is essential for the overall success. The proposed test structure allows an operator to quickly evaluate between different antenna models, and to communicate identified problems and further design requirements to vendors, which could then quickly iterate on their designs.

Validation of the waveforms: new constellations might engage in novel approaches for forming their signal infrastructure. With a flexible SDR payload, one can test different waveforms and ensure that the full link will be operational prior to launch.

DEPLOYMENT

Calibration for optimal performance: gateway antennas are usually shipped to location in pieces and then assembled on location. A calibration procedure will ensure maximum efficiency such that maximum gain and uptime is achieved. For electronically steerable antenna such calibration routines might be necessary month by month and an autonomous routine with UAV proves to be a cost-effective option

Site Acceptance Testing: after installation of gateways or larger antennas a comprehensive validation procedure will ensure compliance and validate the performance. Each antenna can then be equipped with a test certificate providing reliability and catching any potential manufacturing/installation issues as early as possible. Such data can then be stored in a virtualized environment so that it can be used for scheduling or link budgeting purposes.

Type approval/qualification of User Terminals: different user terminals are fit for different purposes, and cost is usually a major factor when determining user adoption. The test procedure proposed above allows the operators to evaluate same parameters in an apple-to-apple comparison way and be able to make the necessary tradeoffs between technology and costs.

LIFE TIME SUPPORT

Troubleshooting: after the antenna has been in operation QuadSAT technology is used to regularly monitor the performance of the antenna during scheduled maintenance as well as to troubleshoot antennas that are underperforming.

Upgrades: in cases where antennas are to be upgraded QuadSAT technology is used to understand the current state of the antenna's performance to first know if an upgrade would be sensible, then to validate the performance post upgrade.

Solving interference incidents: whether the interference is affecting other satellite constellation or users of other spectrum services (such as telecom, radar, etc.) the UAV can be used to geolocate the source or evaluate the environment and provide data to ensure effective interference mitigation.

CONCLUSION

The test procedure is designed to assess multiple aspects relevant to the operation of the NGSO satellite ground segment such as reliable transmission, tracking accuracy, modes of operation, system resilience, system efficiency, and redundancy. Using one UAV, the test procedure can evaluate the antenna's pointing alignment, tracking verification, and search functionality. With two UAVs it will be possible to emulate test scenarios to evaluate the make-before-break and multibeam functionality.
This should give both the equipment manufacturer and the satellite operators good grounds to communicate needs and desires and facilitate an easy approval process and therefore easier business transaction.
Our research and method validations have demonstrated that the flexibility, positioning, and repeatability of UAS testing can provide satellite operators with an efficient and cost-effective method for verifying the readiness of their ground segment.

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