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When Should You Test Ground-Station Antennas?

It's not too late to develop a standardized framework for testing ground-station satellite-communications antennas that will serve to prolong the antennas' operational life and minimize network downtime.

Both space and the ground segment for satellites have become considerably more complex over recent years. This significantly increases the risk of errors on the ground, which can have a ripple effect on the whole satellite ecosystem. While most of the industry agrees that it's necessary to test before deployment, there's less clarity on when further testing should occur within an antenna's operational life. This lack of a standardized framework for testing antennas is a growing challenge for the industry.

To ensure that antennas are operating efficiently and effectively for the duration of their operational life, it's essential that they're tested beyond the standard factory and site acceptance tests. Though testing on a continuous basis every few months throughout an antenna's entire life may not always be feasible from a financial or practical perspective, testing at critical points throughout an antenna's lifecycle is manageable and will bring significant benefits.

As any cost-benefit analysis will indicate, the benefits that operators stand to gain from adopting this testing approach clearly outweigh the costs. What exactly does a practical and cost-effective antenna testing framework look like?

Why Test After Deployment?

Antenna testing is integral to ensuring satellite networks perform as expected, but it's often limited to initial test or as a reactionary response to performance issues or RF interference. Factory acceptance tests are thorough and typically carried out once manufacturing is complete and prior to shipment. However, they can't mirror an antenna's operational environment.

Factors such as nearby buildings, trees, or interference from equipment in proximity can significantly affect performance, but they may go undetected until the antenna is in place. Site acceptance testing, while important, often lacks the depth and rigor of factory-level assessments, making it less likely to catch some issues that can impair functionality.

Even when antennas are installed and comprehensive tests don't indicate any issues resulting from environmental factors, the surrounding environment doesn't remain static. Over time, vegetation growth, construction, and new nearby electronic installations can introduce unforeseen interference or line-of-sight problems. Such changes can alter gain and radiation patterns, ultimately degrading performance. Without additional testing, these issues may not be identified until they start to impact service.

Degradation of RF equipment is another factor. As antennas age, performance can deteriorate, which would impact quality of service and result in harmful interference. Most operators have processes in place to troubleshoot when interference becomes apparent. However, this kind of reactive approach means that performance issues are only discovered when they're already impacting service levels. By that time, it's already too late.

Testing at critical points throughout an antenna's life can help prevent many of these types of degradation problems before they escalate.

Also important to note is the difference between testing processes for small and large antennas. Large antennas are typically built on location as opposed to being factory manufactured and finished, so testing is carried out on-site. However, for smaller antennas, these are type-approved and often never tested again after initial factory acceptance test. This can be hugely problematic.

Consider a disaster scenario, in which antennas are shipped out from the manufacturer's depot, deployed, and then returned when the event ends. These antennas may have been damaged in the process without anyone realizing it and when they're next deployed, they may not work as they should.

Let's say the same antennas are later shipped out again for use in another disaster recovery scenario. Imagine the consequences if these antennas aren't functioning correctly after deployment — the impact could well be catastrophic.

Satellites networks today are also incredibly dynamic, both in terms of how the space and ground segment operate and because networks evolve and expand as new ground terminals and satellites are added. Changes to the network can introduce variables that weren't initially considered. As a result, while antennas may have performed optimally when installed, they may not continue to do so as the network evolves.

Satellite Antenna Testing Challenges

Even when operators do recognize the value of ongoing testing throughout an antenna's operational life, in practice, it often falls by the wayside. The primary barrier has historically been the nature of the testing process itself.

In-field testing has traditionally posed logistical and technical challenges, often requiring custom-built infrastructure to house test equipment. Even with this investment, the testing environment could rarely replicate the controlled conditions of a dedicated facility, limiting the accuracy and consistency of results. Thus, comprehensive testing has largely been confined to specialized testing centers.

Yet relying on external facilities brings its own complications. Transporting antennas for off-site testing is not only expensive and logistically complex, but it may also be operationally problematic. Antennas will obviously be offline during transportation and testing, which can lead to operational downtime and an additional financial hit.

Given that relying on off-site testing in such a way can lead to added cost, complexity, and potential loss of service, it's understandable that many operators have leaned toward a reactive model, addressing issues only when they begin to affect performance.

This reactive approach may have been sufficient in an era of simpler network configurations and fewer satellites in orbit, but that's no longer the case. With today's increasing system complexity, both in space and on the ground, the stakes are far higher. Detecting and addressing potential performance issues before they turn into service-affecting faults has become a necessity.

Fortunately, innovations over the last few years in in-field testing capabilities have removed many of the testing barriers historically faced by operators. It's now much easier to test at critical points of an antenna's operational life.

With the continued surge in satellite launches expected over coming years, the pressure on ground systems will only increase. Establishing a standardized framework for antenna testing and clearly defining when these tests should be conducted is essential to ensure ongoing reliability and optimal performance in an increasingly complex satcom landscape.

A Framework for Critical Test Points

1. Development of antennas: Testing during the development of an antenna ensures that the expected outcome is reached and allows for tweaking early design choices so that the desired performance is met. This is particularly important for flat-panel antennas, as manufacturers should aim to produce radiation performance as close as possible to their simulations from software, and this must be at all possible steering angles. While this also applies to a parabolic dish antenna, fewer possible outcomes simplify testing.

2. Registration of antenna with a satellite operator: Several satellite operators have a robust approval program in place to allow antennas on their satellites. When approaching a satellite operator, it's therefore necessary to be able to share detailed information about the antenna performance with them. For a satellite operator, the job of registering a new antenna becomes significantly easier if most of this information is already in place and often leads to a smoother timeline on getting the acceptance to uplink.

3. At initial deployment in operational environment: Site-acceptance testing often requires less stringent testing requirements than going through an antenna approval program. At this point, it's about making sure that no installation errors have occurred, or damage caused during transportation that will impact the performance of the antenna.

These tests are particularly important for large antennas, where it's often mandatory to comply with regulatory standards or satellite operators, as well as for mission-critical antennas.

4. Refurbishment or preventative maintenance: After refurbishment or periodic maintenance, antennas need testing to measure the changes in performance with the possibility to predict antenna grace period. Gravity and weather will have an impact on surfaces and the shape of the dish. In many cases, the performance degradation can be recovered through adjustments of the sub-reflector or panels on larger antennas, instead of acquiring a new antenna.

Mission-critical antennas for disaster recovery should also routinely be tested after deployment. They often operate in a highly stressful environment and play a critical role in saving lives. During such events, damages that aren't visible may occur. If not tested, there's a risk that a faulty antenna gets deployed in a future disaster or military operation, which can cause major consequences.

Environmental changes can occur after installation. This may include new buildings or tree/vegetation growth that could cause line-of-sight issues, as well as installation of other equipment in the vicinity that may cause interference. One factor to consider is roll out of 5G and installation of 5G base stations, which may affect an antenna's performance.

5. After software updates: Software updates may unintentionally create a negative impact on an antenna's performance in certain operational scenarios. Therefore, it's necessary to verify an antenna's capabilities post update. Determining whether a specific update will trigger the need to carry out an antenna test will depend largely on the nature of the update and whether it's a major or minor update.

6. After changes to hardware: When network hardware such as antennas, receivers, or other equipment is replaced or repaired (for example in response to malfunction or degradation), it can impact the operation of an antenna.

7. Troubleshooting antennas: This will provide a better understanding what caused performance issues resulting from degradation due to age, malfunction, or human error, so that appropriate action can be taken to resolve the issue.

Nature of the Required Antenna Tests

The type of tests required at each of these critical points will likely depend on the specific scenario. Typically, though, tests will be needed to verify radiation pattern, cross-polar discrimination, effective isotropic radiation power (EIRP), gain, and noise temperature.

Radiation pattern cuts using detailed 2D views of an antenna's radiated energy are essential for analyzing sidelobes, beamwidth, and alignment. They help to identify setup errors, verify calibration, and support 3D pattern visualization.

3D visualizations are more comprehensive and are used to verify an antenna's radiation pattern, enabling detailed analysis of sidelobes, beam symmetry, and overall performance. This is essential for identifying construction or setup errors, verifying sidelobe levels, and ensuring precise alignment.

Measurements to evaluate cross-polar discrimination are an essential factor in determining how well an antenna differentiates between polarization angles. It helps ensure the antenna minimizes unwanted polarization leakage, maintains signal integrity, and preserves polarization purity.

Tests to determine EIRP may be required to measure the power radiated from an antenna's main lobe. This enables emitter comparisons and assists in optimizing power concentration for effective transmission. In addition, evaluating the antenna gain and noise temperature helps to accurately characterize system sensitivity, optimize receive chains, and validate link budgets for satellite communication compliance.

Perfect satellite alignment is critical for high-performance communication, reducing latency, minimizing signal loss, and ensuring uninterrupted data flow. Tracking tests are also required to evaluate antenna tracking performance, ensuring beam alignment and link integrity with non-geostationary orbit (NGSO) and geostationary orbit (GEO) satellites for seamless connectivity and maximum throughput.

Testing tracking capabilities with live satellites is challenging due to limited access and orbital schedule constraints. Yet, such tests are crucial to deliver consistent performance throughout passes and dynamic scenarios. Technology in this field has advanced in recent years and is now available to enable precise emulation of NGSO satellite passes at any time and location.

By replicating realistic conditions such as varying speeds, altitudes, and trajectories, these tests accurately evaluate an antenna's ability to maintain perfect alignment. The data can then be used to optimize tracking algorithms and ensure seamless operation across low-Earth-orbit (LEO) and medium-Earth-orbit (MEO) constellations.

Know When and How to Test Ground-Station Antennas

Performance and reliability are critical in satcom, and testing antennas only at the point of deployment or when a problem arises is no longer sufficient. By implementing a testing framework that determines the critical points when antenna testing is required, operators will be able to detect potential issues earlier, minimize service disruptions, and make sure antennas are always operating optimally.

Satcom is a high-stakes environment and knowing when to carry out additional testing of antennas and what tests to carry out could well give operators a competitive advantage.

Joakim Espeland is the CEO and co-founder of Quadsat, a Danish company that makes high-accuracy antenna test, measurement, and spectrum monitoring solutions. Previously a Telecommunications Technician and subsequently Service Engineer, he started Quadsat in 2017, initially designing the technology and building IP before securing funds to build and grow the company.

He has been approved by the GSOA-MRA satellite-operator members as an Authorized Test Entity, being competent to perform satellite earth station testing and/or evaluation. And he has been instrumental in securing investment for Quadsat, which is backed by industry-leading Venture Capitalists specializing in this sector, alongside investment from the Danish government.

Joakim has also been key to securing testing missions and building relationships with many of the leading players across the satellite industry, including Eutelsat, Govsat, SES, The European Space Agency, and the SOMAP group, amongst others. Together with his co-founder, he has grown the company to scale-up stage over recent years, which now employs more than 40 people. He holds a Bachelor of Electrical and Mechanical Engineering degree.