Automated Performance Testing to Maximize the Reliability of Ground Stations

Kerry Clapham, Chris Bull *University of Canterbury* • Robin McNeill *SpaceOps NZ* • Assoc Prof Chris Hann *University of Canterbury*

SSC24-WP2-10

Satellite ground station link failures are disruptive to space operations and are to be avoided. Critically, it may not be obvious if a link failure is caused by the spacecraft, or by the ground station, especially during LEOP. We present a scheduler to automate periodic calibration passes on known spacecraft and conduct Y-Factor G/T measurements when the ground station would otherwise be idle. Automatically scheduling, logging and comparing pass metrics against nominal values alerts us to any system performance deterioration. Such automated testing has been successfully used to identify antenna faults and temporary obstructions. We also discuss the usefulness of automatically monitoring radio noise to identify possible source of radio frequency interference and deal with any out of band transmissions. In the future we intend to use our doppler shift to identify noise causing issues.

Automatic pass scheduler

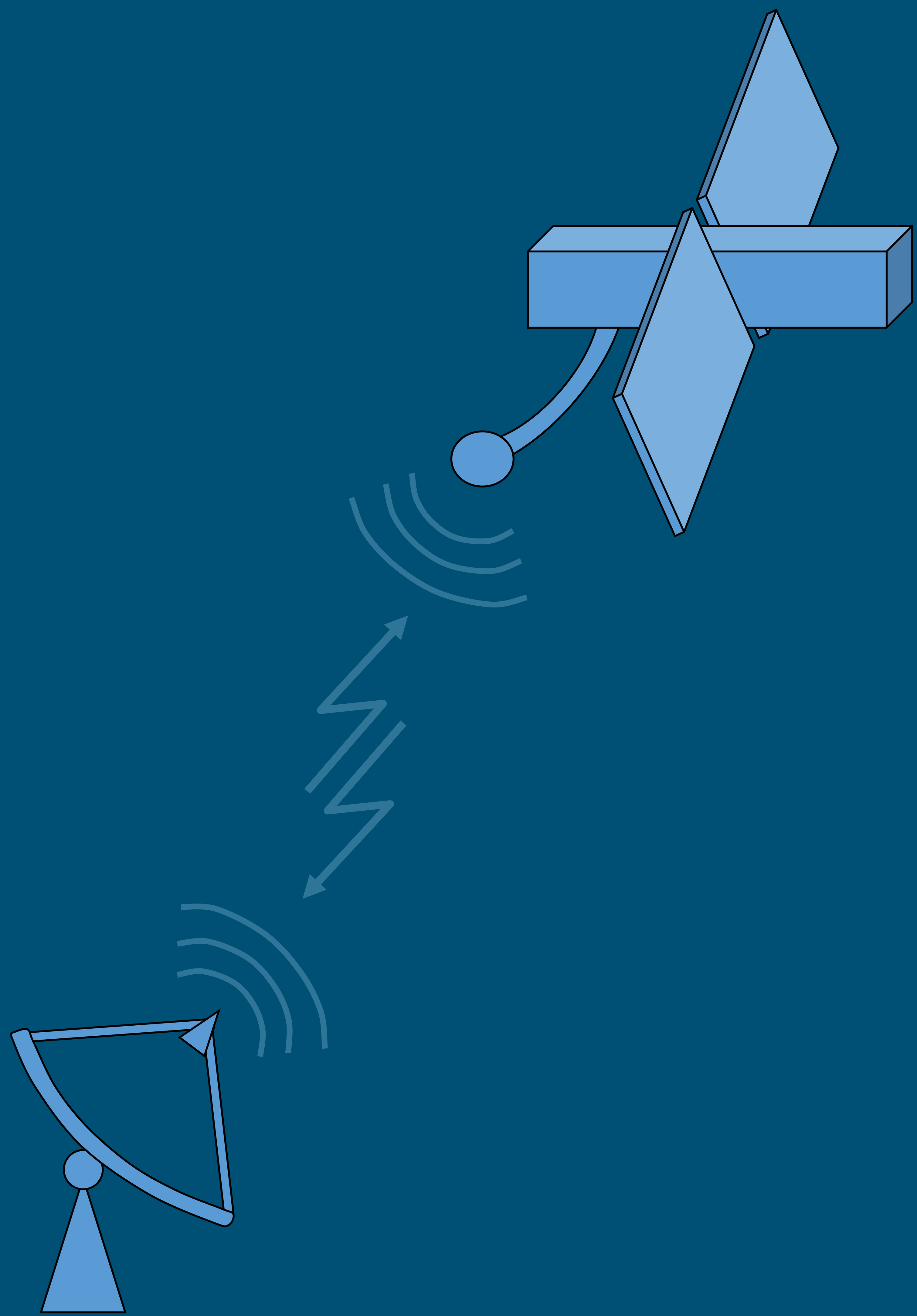
While antennas are not being used for normal operations, they can be re-tasked to perform test passes. Test passes are best performed on spacecraft which transmit continuously. Over time, the spacecraft will traverse the entire sky, giving a complete map of horizon obstructions, time delays and keyholing [1].

TLE propagation

Our system automatically fetches a data file containing all active satellites from CelesTrak. Fetching all the active spacecraft at once minimises transaction overheads on the CelesTrak website. The TLEs for all spacecraft with beacons transmitting in our frequency band of interest are propagated to find available passes. Spacecraft are then ranked to determine which spacecraft which are most reliable. All customer pass opportunities are reserved/blocked out, then an attempt is made to schedule each test pass opportunity in priority order.

Storing the results

A new database has been created to store key metrics of each antenna system every 2 seconds. Choosing to use a database is important as it allows rapid review of system performance. Graphs such as signal strength vs elevation and pointing error vs elevation/azimuth are possible. In 2019, we presented an analysis of keyholing on a custom built S-/X-Band antenna and the methodology to address the keyholing. In 2024 we continue to use this methodology. Figure 1 shows the keyholing occurring on a commercial-off-the-shelf (COTS) UHF positioner. The positioner slows to a stop between commands, causing it to lag behind the spacecraft. Figure 2 shows our PointSource antenna control unit continually tracking the same spacecraft.



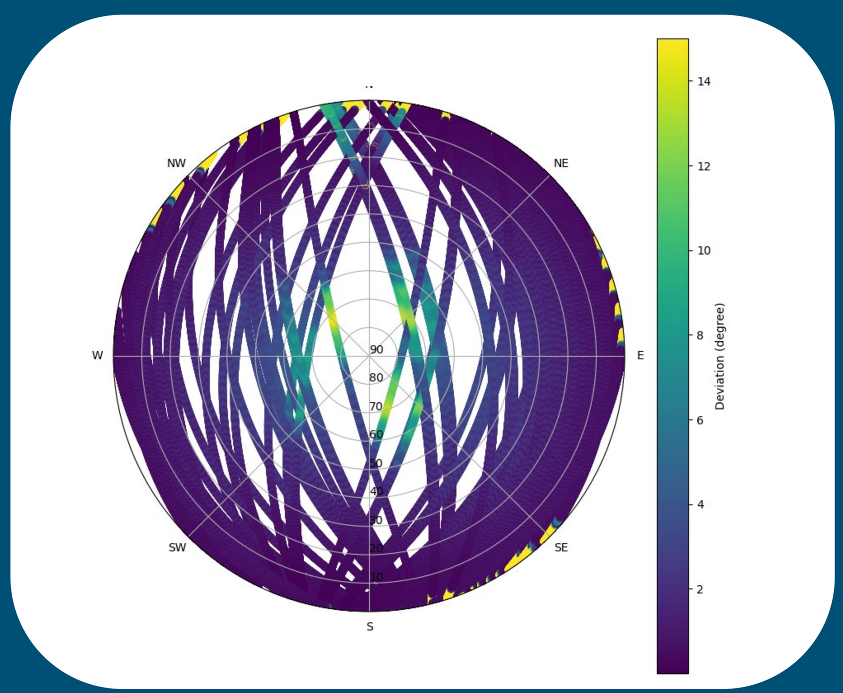


Figure 1: Pointing error of an COTS UHF Positioner. Notice the large deviations near the center of the plot (keyholing).

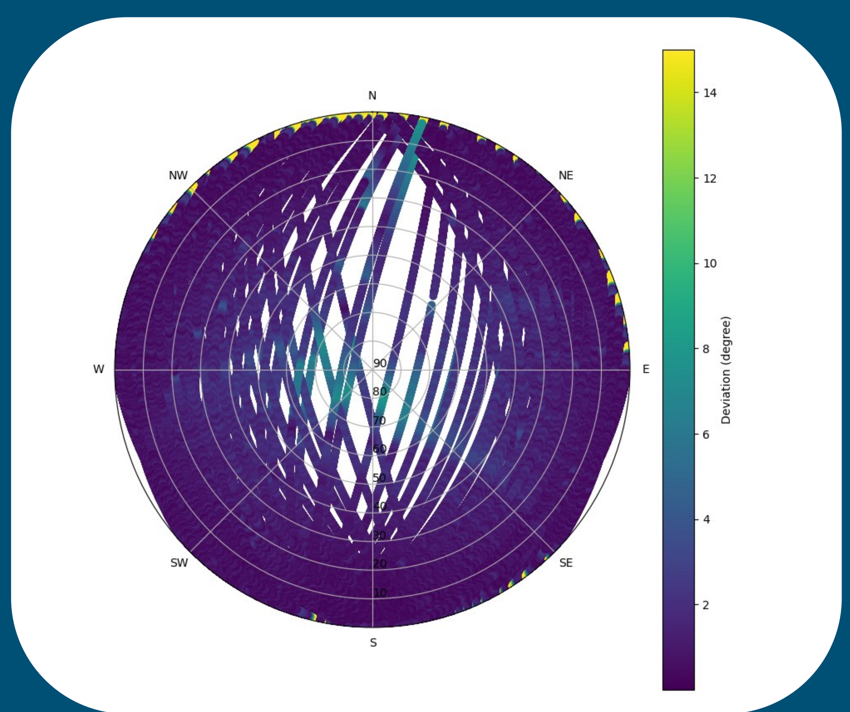


Figure 2: Pointing error of the SpaceOps NZ PointSource UHF Positioner. Notice the smaller deviations near the center of the plot showing reduced keyholing.

Figure 5 & 6: Measurements provided in this poster were taken on the pictured 400MHz Yagi antenna (AWA-2) and 3.7m S-/X-Band parabolic antenna (AWA-4).

Finding interference-causing spacecraft

As part of our routine test passes and system operations, we occasionally come across spacecraft transmitting in the same frequency channel. We have also found spacecraft transmitting over a wider frequency band, causing complex interference, as shown in Figure 3. SpaceOps NZ is currently developing an algorithm which determines the orbit of spacecraft based purely off observed doppler shift. By identifying the orbit of spacecraft causing interference, it will be possible to identify the interfering spacecraft and predict which future customer passes may be affected by the spurious transmissions. Currently, based on three consecutive passes, the orbit of any circular orbiting spacecraft can be calculated, with no initial information about the spacecraft's orbit. SpaceOps NZ intends to complete automated doppler shift orbit determination by next year.

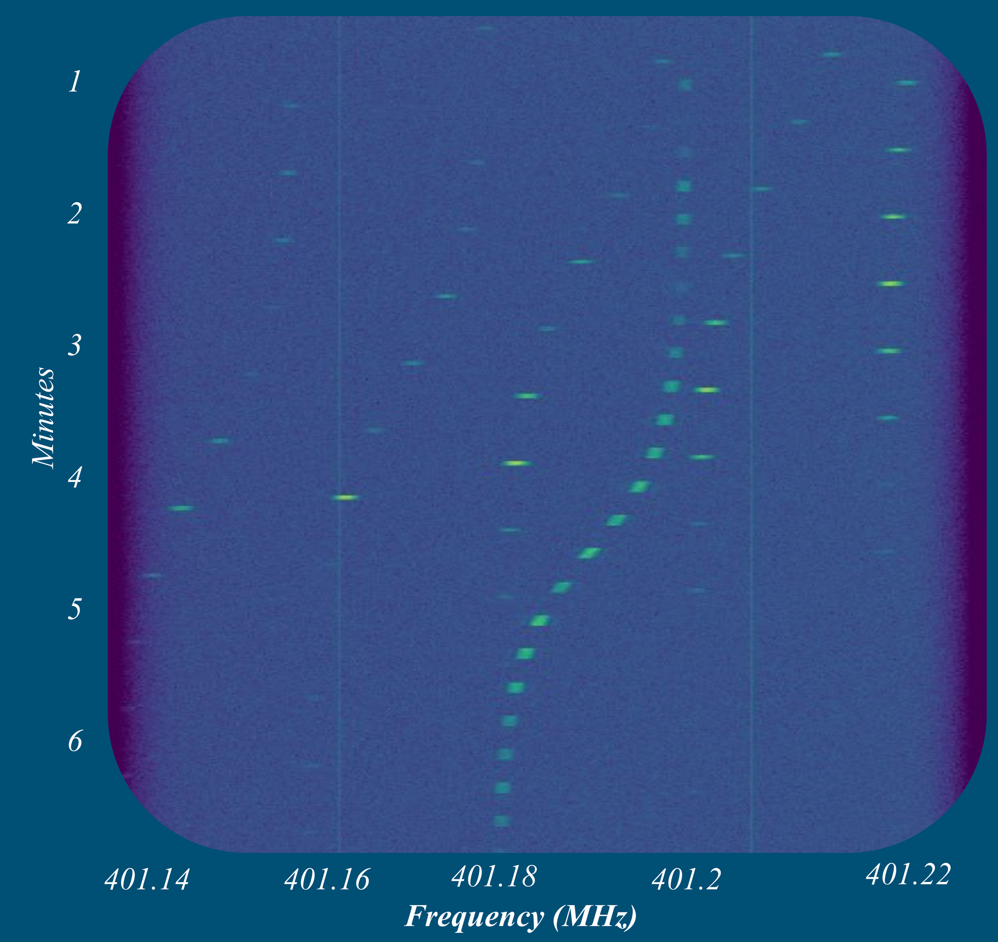


Figure 3: A waterfall plot showing complex interference. The signal from the satellite of interest is in the center of the plot, decreasing in frequency during the pass due to doppler shift. A second unexpected spacecraft causes interference. SpaceOps NZ is developing an algorithm to automatically identify such interfering spacecraft from doppler shift.

Using G/T to track antenna degradation

A Y-factor gain-over-temperature (G/T) measurement is the ultimate measurement of antenna performance. By pointing the antenna at a noise source such as the sun, then pointing the antenna at a cold part of the sky, it is possible to calculate the receiving system's sensitivity.

In the past, a client noted that their antenna was no longer closing the link margin. When we investigated the issue, we discovered the G/T of the antenna system was some 3 dB less than it was when installed. The root cause of the issue was that condensation and water in the feedhorn had created oxide, weakening the antenna performance. Cleaning out the feed of oxide restored normal operation. On our antennas, we routinely measure the G/T of the antenna as part of standard operating procedures. Should the antenna G/T measurement reduce, we can rectify the problem before the performance deteriorates sufficiently to jeopardise spacecraft communications.

Future works - Automatic G/T automation

At present, measuring G/T is a manual and time-consuming process. However, we are working to automate the measurement of G/T. The sun is currently high in the sunspot cycle, meaning that an X-Band antenna's G/T fluctuates by up to 0.5dB per day. Automating the measurement of G/T will capture the general trend of the G/T measurements, giving a more accurate picture of the change in performance over time.

We hypothesis that if we were to obtain sufficient G/T measurements automatically, we could calibrate our existing antennas compared to official solar-flux measuring stations. We could then use our calibrated antennas to make real-time solar-flux measurements, augmenting the typically sparse dataset of official solar-flux measurements.

Further Information

For further information please contact:
kerry.clapham@spaceops.nz

[1] The sum of the parts: Lessons learnt from designing and building a 3.7m S/X-Band antenna. Small Sat 2022. K. Clapham, C Hann & R McNeill

SPACEOPS NEW ZEALAND

UC UNIVERSITY OF CANTERBURY