AER/AGS Open File Report 2017-06

Installation Guide and Developed Learnings for Satellite Telemetered Stations in the Regional Alberta Observatory for Earthquake Studies Network (RAVEN)

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Abstract

In the fall of 2013 the Alberta Geological Survey (AGS) began installing a network of satellite telemetered seismic stations that compose the Regional Alberta Observatory for Earthquake Studies Network (RAVEN), to better understand and catalogue earthquakes throughout Alberta.

This report documents the installation procedure's three steps: 1) scouting of suitable locations, 2) preparation of infrastructure, and 3) setup of electronics. Throughout this report, we detail our thought process for each of these steps as a guideline and document our ongoing learnings and improvements to the station designs.

1 Overview

A seismic station records ground vibrations from various sources: wind, ocean-crust coupling, pressure fluctuations, cultural noise from human activities, quarry blasts, or earthquakes. The Alberta Geological Survey (AGS) installs and maintains a provincial seismic network known as the Regional Alberta Observatory for Earthquake Studies Network (RAVEN) (AGS, 2013; Schultz and Stern, 2015). This guide includes a procedural explanation and reference material for the installation and maintenance of new RAVEN sites. The installation of a new seismic station occurs in three phases: 1) scouting and site selection, 2) installation of infrastructure, and 3) setup of electronics. In general, satellite telemetry of seismic ground motion data requires a seismometer to record motions, a digitizer to capture digital signal, a transceiver for satellite communications. Specific to this report, the AGS uses Nanometrics VSAT Libra II products including Trillium Compact seismometers, Trident digitizers, and Cygnus transceivers.

Figure 1. Completed installation of a RAVEN station.

2 Scouting and Site Selection

There are numerous factors to consider when scouting a site for seismic station installation (e.g., Stern et al., 2011). Seismometers are sensitive, and, given adequate site conditions, can record subtle ground vibrations on the order of nanometres per second. When scouting for a site, the main considerations are

- proximity to sources of noise;
- potential for vandalism/damaged equipment;
- potential for vault flooding/heaving;
- clear view of the sky when facing south;
- cellular reception; and
- ease of access.

The first consideration is proximity to noise sources. The most obvious and largest concern regarding regional and local seismicity is the minimization of cultural noise. This noise occurs in the same frequency bandwidth as the regional and local earthquake spectrums (McNamara and Buland, 2004), and thus has the most detrimental effect on the accuracy and completeness of our seismic catalogue (Stern et al., 2013; Schultz et al., 2015). This problem may be unavoidable in situations where the required station density is geographically constrained. However, with the installation of a regional network, station locations may easily be moved tens of kilometres to avoid sources of noise such as cities or towns, frequently travelled roads, railways, or industrial activities. Ideally, stations should be placed tens of kilometres away from these noise sources. Secondary concerns for local earthquake bandwidth noise include constant sources of flowing water, large bodies of standing water, wind, and oscillation of trees. Where possible, sites should be selected in areas that are metres away from tall trees and kilometres away from rivers or creeks.

Potential for vandalism is often mitigated by addressing the first consideration. Remote site locations have little human traffic, and the potential for vandalism decreases by the principle ‘out of sight, out of mind’. Installing in remote locations on private land or controlled areas can have the added benefit of additional security from the local resident or custodian.

One of the most common problems affecting seismic stations in Alberta is flooding of the seismometer vault. To mitigate this issue we recommend placing stations on topographic highs or in areas with proper watershed drainage. While the flooding of the vaults themselves can be partially mitigated even under flooding conditions, it can lead to the more serious issue of vault heave. In winter months, areas saturated by water will forcibly eject the digitizer and battery vault due to the pressure of freezing water expanding and the buoyancy of the vault. This can shut down or potentially damage the station.

In Alberta, a clear view of the sky facing south is important because the satellite telemetry requires a clear view of the satellite (precise azimuth and inclination depends on the site location). In areas where it is uncertain if tree cover will conceal the satellite, we recommend taking a photo which is horizontally levelled and at the height of the satellite dish, facing exactly south (record if it’s true south or magnetic south). Using this photo, look-angle mask, and satellite look-angles, we can ensure an unobstructed view of the sky (Figure 2). Cellular reception at the site is mandatory as the satellite provider needs to be called during setup of the equipment.

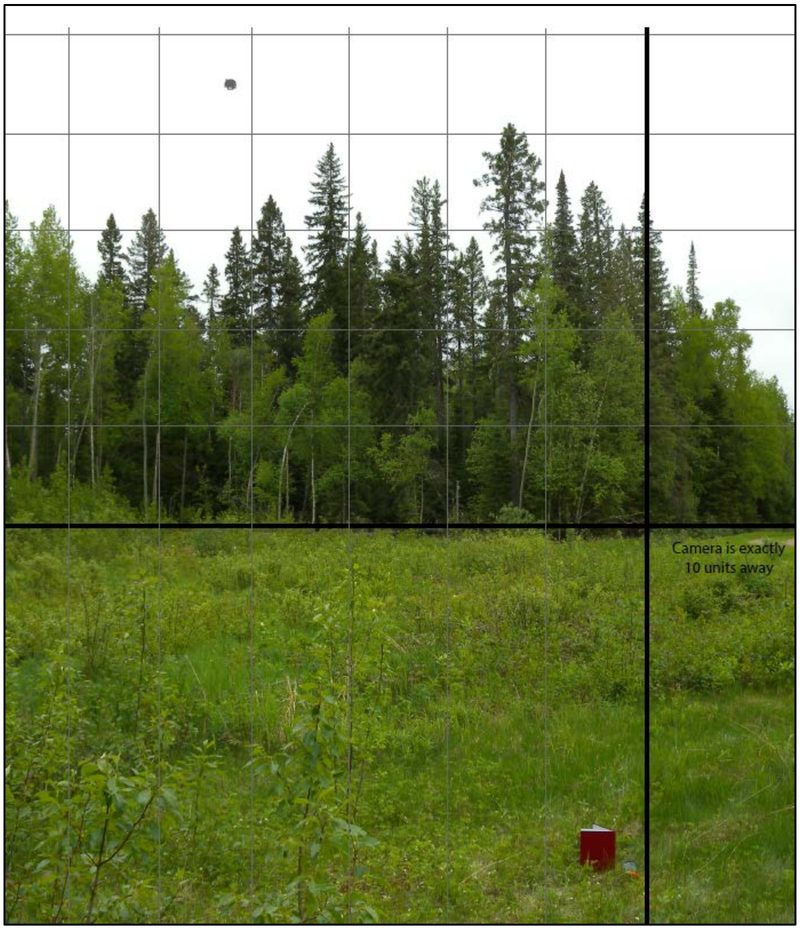

Figure 2. Look-angle mask for a station. The grey grid is the mask, where each square represents ~5º. The horizontal black line represents the height of the satellite dish, and the vertical black line marks the direction of true south. The orange tape, visible next to the red notebook on the ground, was used as the south reference for taking the photo. The grey dot in the sky is the approximate look angle for the satellite. In this case, the grey dot is well above the tops of the trees so a clear view of the south sky is confirmed.

The last point to consider is ease of access. Stations often require maintenance or upgrades; whenever possible, select sites that will be accessible in all seasons.

3 Installation of Infrastructure

This phase of installation is the most labor-intensive part, but can usually be completed in a day with a team of three or four people. Here is a checklist of equipment needed for this phase:

- 55 gallon (× 2) polyethylene rain barrels (one with bottom cut off and both lids caulked)
- tarp (and rocks to hold it down if none are found on-site)
- wooden fence posts (× 7), staples, and barbed wire
- station description sign and wood screws
- fast setting concrete, e.g., Post Haste® (× 2 bags), and quick dry cement (× 1 bag)
- cement trowel, water to mix cement, and cement mixing barrel

- satellite dish and solar panel mounting posts
- heavy floor tile with smooth surface
- grounding plate and site-marking stake
- digging tools, such as shovels, augers, pry bars
- miscellaneous tools, including drill set and bits, fencing pliers, hammers, x-acto knife, duct tape, etc.
- safety equipment and personal protective equipment

Two people begin by digging the vault holes, spaced approximately 2 ft. apart, while the third and fourth start to auger holes for the satellite dish and solar panel mounts. Solar and satellite mounts are typically placed a few feet north of the vaults' burial location (Figure 3).

Important note: cabling from the solar panel and satellite dish is a fixed length (16 ft. for AGS). Satellite cables have to go from the low-noise block converter (LNB), to the dish, down the post, underground, and into the vault. If the mounts are placed too far away from the vaults, the installation will be impossible, therefore the satellite dish needs to be located near the digitizer and battery vault. Also, ensure that the posts will not obstruct the satellite lookangle, or solar view of the sun (south). For both mounts, the pointed and angle-ironed ends are buried in the ground.

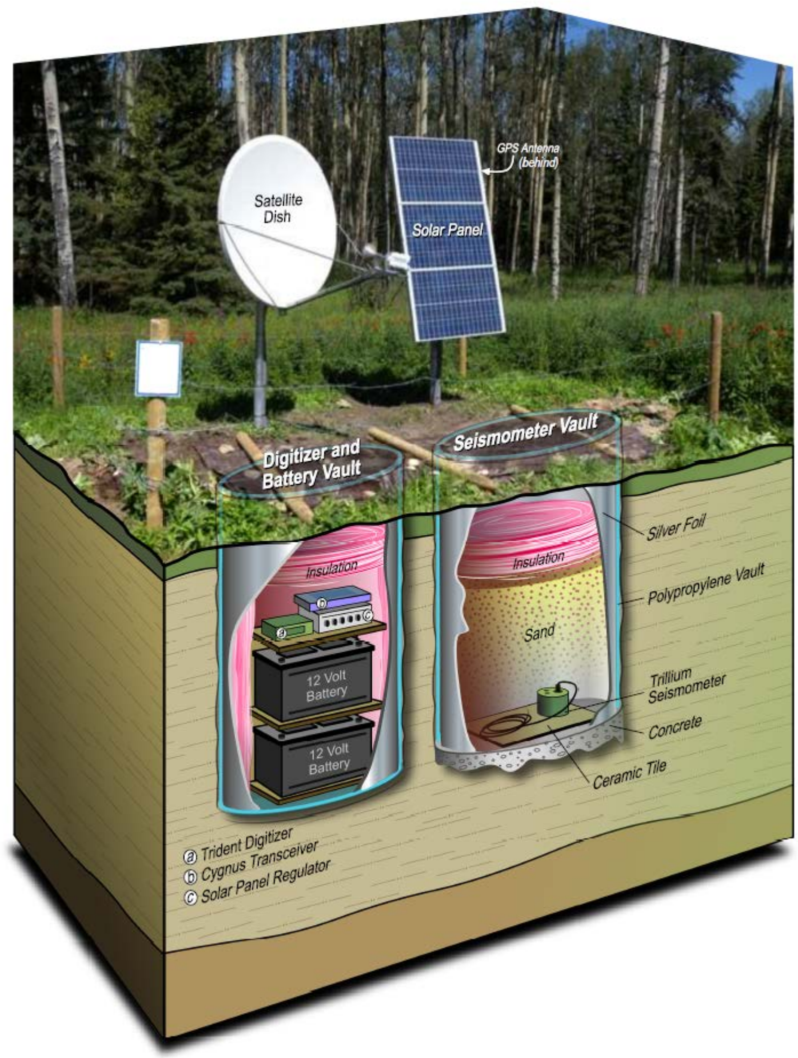

Figure 3. Schematic of a typical RAVEN station.

After the holes are completed, bury the digitizer and battery vault, and cement the mount for the satellite dish in place with the fast-setting concrete. Make sure to tamp extremely well after the cement dries, as loose or vibrating posts can cause noise or a loss of telemetry. Pour cement into the bottom of the seismometer hole, and, as it dries, place the tile so that it adheres to the cement and makes a pier for the seismometer to rest on. It is important that the pier is level and square with N–S after the drying process for ease of seismometer installation. Make sure the lid is locked on the barrel to avoid unnecessary deformation of the barrel while tamping. After the cement has dried, the seismometer vault (i.e., the barrel with the bottom cut off) is lowered into the seismometer hole and back-filled.

Fence off the enclosure while leaving room for the satellite dish and solar panels. In particular, the satellite feed assembly needs to be enclosed within a margin from the fence edge to avoid animals from chewing on the cabling. This is especially important if the satellite and solar mounts are placed south of the vaults, in which case they will be closer to the edge of the fencing. Use pry bars and a small amount of water to secure the fence posts in the ground. If the auger is used instead, ensure proper tamping during back-filling; loose posts will fall over in a few months, allowing animals to get into the enclosure. Bury the grounding plate north of and equidistant to the solar panel and satellite dish mounts with a stake to mark its location. Finally, place the station description sign on the fence posts, cover the vaults with a tarp, and secure the tarp with rocks or additional posts.

Figure 4. Installation of infrastructure. Left to right, top to bottom: digging vault holes, burial of vaults, cementing the seismometer pier, and fenced off enclosure. Not shown: solar and satellite mounts.

4 Setup of Electronics

Electronics setup is the final phase of installation. This task can usually be completed in a day with a team of three to four people who are familiar with the station design, assuming all the recommended preparations were completed ahead of time. This phase can be divided into eight basic steps, certain components of which can be done in parallel:

1) Preparatory work.
2) Power setup.
3) Solar array mounting.
4) Satellite dish mounting.
5) Cygnus transceiver configuration.

6) Seismometer alignment.
7) Telemetry alignment.
8) Finalize and clean-up.

A list of required materials follows:

- solar panels (× 3),
- solar panel mounting assembly,
- satellite dish,
- satellite dish mounting assembly,
- feed horn assembly,
- feed horn, block upconverter (BUC), and low-noise block converter (LNB),
- satellite wire install kit: GPS, Tx/Rx cables,
- spectrum analyzer and cabling,
- cell phone,
- 110 Ah, deep cycle batteries (× 4),
- Multimeter,
- battery shelves,
- battery wiring and wire cutters with clamps attached,
- regulator,
- solar power (6 gauge red and black) and ground (~10 gauge green) wires,
- Cygnus power cable and Cygnus,
- Trident and NMX bus cable (blue),
- seismometer and cable,
- laptop with Cygnus cable,
- compass, angle indicator (check magnetic declination), and look angles,
- vacuum tubing and wire snake,
- housing insulation, silver bubble wrap insulation, and duct tape,
- approximately 15 gallons of fine grained sand (usually 3 bags),
- drill and bore hole set, caulking,
- tools as required.

4.1 Step 1 – Preparatory Work

A significant portion of work can and should be done ahead of time at a warehouse to ensure that parts are working, equipment is operational, and to save time in the field.

Solar arrays (three panels) should be pre-made and ready to mount. This may include drilling additional bolt holes into the solar array mounting frame to accommodate assembly alignment. A team of two should review the mounting assembly instructions in advance and review how mounting will take place in the field. Here is a list of points to consider:

- Which end of the solar array will point upwards? The solar array’s centre of gravity should be below the mounting bracket.

- How will cabling to the regulator be managed? It is best to preinstall cabling and zip-strip it to the solar array.
- Does the panel output proper voltage both as an array and individually? Everything should output 12 V.
- Are the panels installed in series or parallel? Panels should be installed in a parallel circuit.
- Is the polarity of cable ends connecting to the regulator being alternated between sites? Sides should alternate for efficient use of spooled wire.

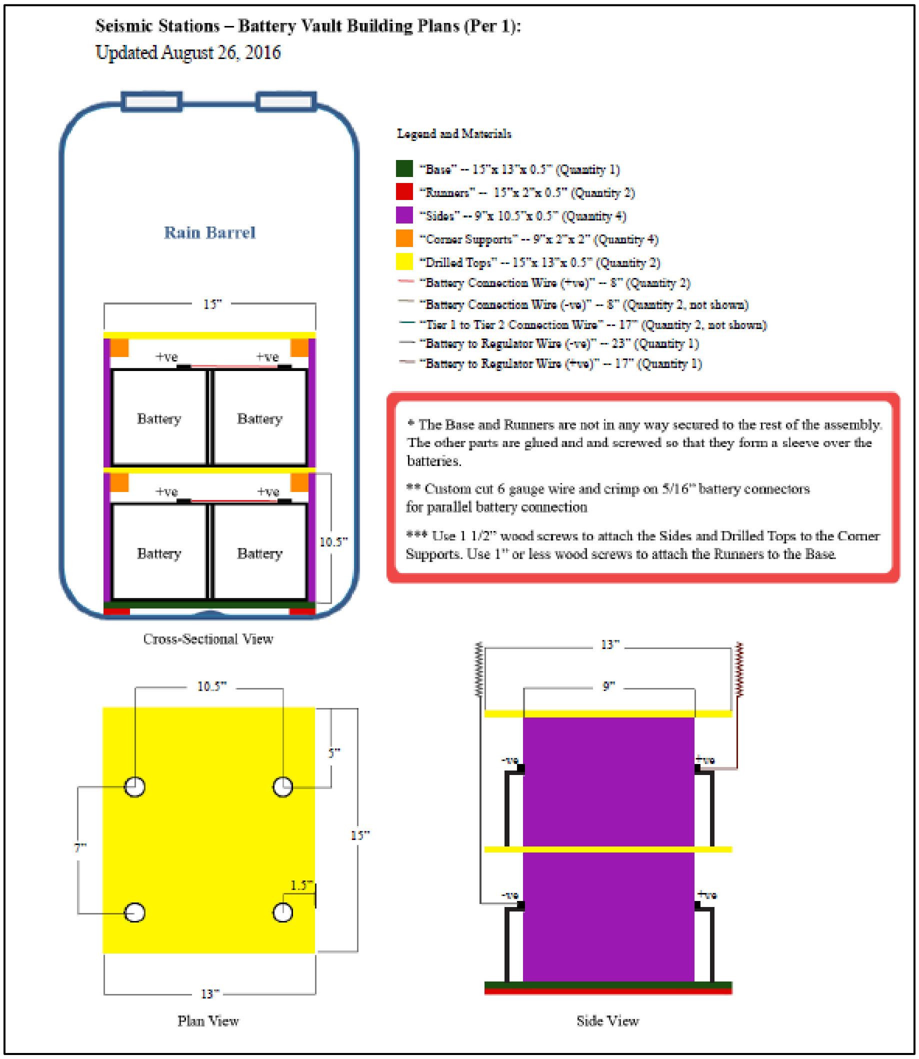

Figure 5. Mounting shelves and battery wiring guide.

Mounting shelves for the battery bank should be preassembled (Figure 5), and wires should be precut with ends crimped as needed. The wiring should be done so that the parallel circuit has equal access to each battery. It is highly recommended that a designated team member completes a trial installation at the warehouse in a test vault because this step is often problematic in the field. Common issues include improper wire sizes or spacing, incorrect number of wires, and the logistics of completing the installation (especially seismometer alignment) in the confined space of the vault. Before heading out to the field, ensure that all batteries are in working order, and that spare wires and parts are available.

A hydrophobic coating should be applied to the satellite dish to better weatherproof the telemetry. If vehicle space permits; the feed assembly, LNB, feed horn, and BUC can be preassembled. Depending on team size, these are the lowest priority elements of the preparation, as completing this in the field typically takes the same amount of time as a two-person team mounting the preassembled solar array.

4.2 Step 2 – Power Setup

This step is performed by one person, while a team of two works on steps 3 and 4. The battery bank is installed in the digitizer and battery vault. Wire the first two batteries on a small wooden shelf to raise them off the vault base, and then place a second shelf on top of it with two more batteries. Wire all four batteries together in parallel (Figures 5 and 6). Place the final shelf on top with the regulator wired into the battery bank. Finally, wire a ground cable from the regulator to the grounding plate, via the bored hole in the digitizer and battery vault, and bury it underground. At this point, the team of two mounting the solar panel array (step 3) should have their power cabling in place, which can then be connected to the regulator. The power cable for the Cygnus can then be installed into the regulator, allowing for the start of step 5.

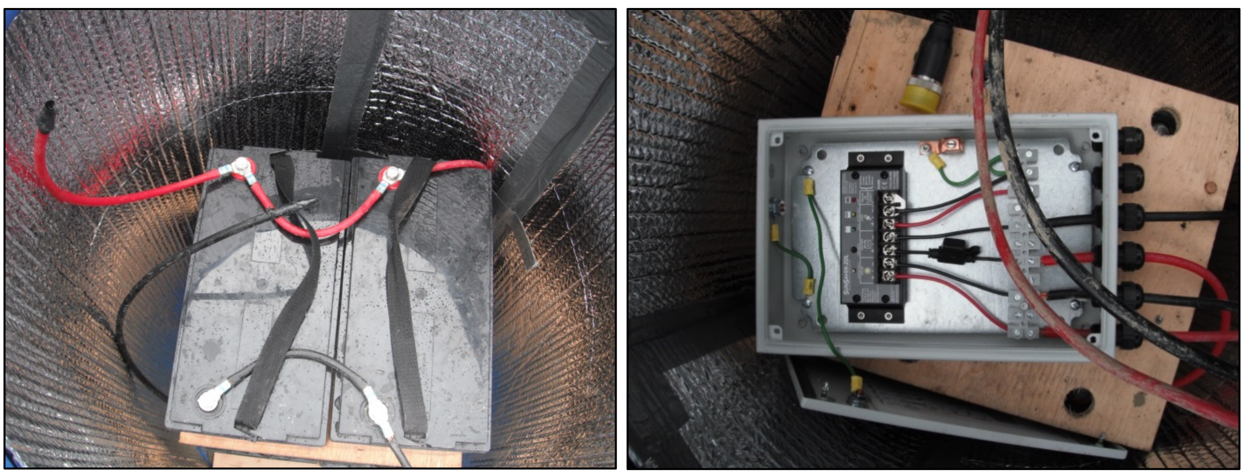

Figure 6. Pictures of battery bank wiring. Left: four batteries in place, wired in parallel. Right: regulator wired for the battery bank and solar panel. Ground cable and Cygnus power cable are not shown.

4.3 Step 3 – Solar Array Mounting

This step is performed (preferably) by a team of two. The preassembled solar array is mounted to the post, as per the included instructions. **Important note:** keep the array covered during the installation, as solar panels will produce live electric current under any light source.

After the array is mounted, zip-strip the vacuum hose to the post and feed the power cabling through it to prevent animals from chewing through the power cables (Figure 7). Bury the end of the vacuum hose into the ground, where the power cables run to the digitizer and battery vault. Before burying the wires, insulate them with silver bubble wrap. The insulation should cover the wire from the hose to the barrel, but be careful to not cover the end of the hose or the hole of the barrel to prevent water from entering the vaults. Drill a hole into the vault just large enough to run all cabling required for the digitizer and battery vault (i.e., GPS, Tx/Rx, solar power, grounding, and seismometer cables). Keep the drilled-out plastic from the vault for step 8. The solar array power setup assembled in step 2 can now be installed.

Figure 7. Pictures of mounted solar array (left) and satellite dish (right).

4.4 Step 4 – Satellite Dish Mounting

This step is performed by one person simultaneously with steps 2 and 3. If not done in advance, install the satellite dish on to the mounting bracket. Next, attach the feed horn assembly and the feed horn, as per the instructions, and mount the GPS to the satellite bracket on the east side. Zip-strip all cables (GPS, Tx/Rx) to the mounting assembly, and feed the wires into a vacuum hose in the same manner as the solar power cables (step 3). The cables should run through the hose along the post, and into the ground, where they are installed into the Cygnus in the digitizer and battery vault. With a Cygnus powered and configured (step 5) and these steps completed, the installers would be in a position in which step 7 could proceed.

4.5 Step 5 – Cygnus Configuration

The Cygnus (Nanometrics Inc.) is a transceiver that handles the telemetry of digitized waveform data via a very small aperture terminal (VSAT) system. The seismometer waveform data is first digitized by a Trident and passed over to the Cygnus. This step covers the details of Cygnus configuration through a series of screenshots (Figure 8). Configuration is done through a local Ethernet connection to the remote Cygnus, via a static IP. This allows for the Cygnus to be accessed via any web browser on a laptop. This subsection concerns setup specific to AGS RAVEN stations, and inputs will vary for other networks.

First, login to the Cygnus at the login prompt in the top right corner. For changes to be applied to the current session, the ‘apply’ button needs to be pressed; to make them permanent for the next power cycle press ‘commit.’ After the configuration process, the systems are up and running and the telemetry can now be calibrated to communicate with the central hub.

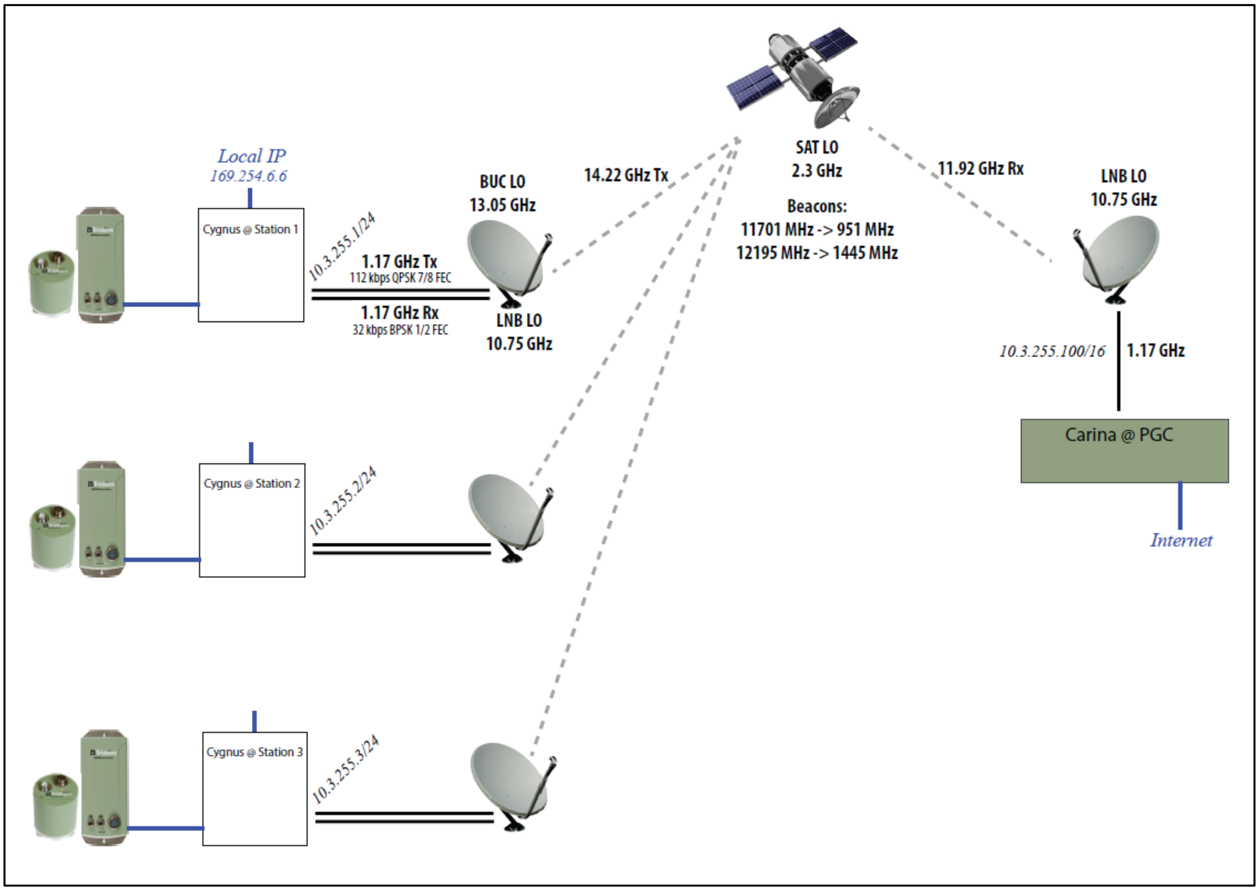

Figure 8. Schematic diagram of communication setup between the hub and remote sites on AGS's first Carina.

4.6 Step 6 – Seismometer Alignment

This step involves placing the seismometer on the tile in the seismometer vault and can be done by one person simultaneously to Cygnus setup (step 5) and telemetry alignment (step 7). First, attach the cable to the seismometer and zip-strip the cable to the centre of the compact cylinder; loose enough that the cable is not pulled tight, but not so slack that the cable can move freely. **Important note:** while zip-striping the wires, make sure the level gauge is visible to simplify seismometer alignment later in the process.

The seismometer will have markings for proper orientation with respect to north; ensure that this is toward true north (i.e., that the local magnetic declination has been accounted for). Using a compass with a straight edge, draw a north–south line in permanent marker on the tile, and align the seismometer with this reference. Water in seismometer vaults often washes away these lines, so this step may need to be repeated when visiting sites for maintenance. The seismometers have adjustable legs and a level gauge. It is important that the seismometer is as level as possible, as off-level seismometers draw additional electrical current. Ensure that the adjustable legs and lock nuts are tight as rattling of these components can cause noise in the data. It is worthwhile to practice this procedure in the office and over a vault at the warehouse, as site conditions will make the process much more challenging.

Once the seismometer is aligned and levelled,

1) place a small amount of caulking under the three levelling legs to adhere the equipment to the cement pier to enhance the seismometer-ground coupling;
2) coil excess cabling around the seismometer and tape it to the side of the vault near the bored hole;
3) run the seismometer cabling into the digitizer and battery vault via the bored hole and plug it into the Trident; and
4) bury any exposed seismometer cabling in the soil.

Once this is completed, check the seismometer signal using the Cygnus waveform viewer under the Trident 'Sensor Dashboard'. Ensure that the signal is not erratic (spikey) or periodic, and check that stomping on the nearby soil registers a signal (Figure 9). After operation of the systems has been confirmed, backfill the vault with sand and housing insulation, and place silver bubble wrap on the top. This sand backfill step is important for maximizing the signal to noise ratio of the data (Aderhold et al., 2015).

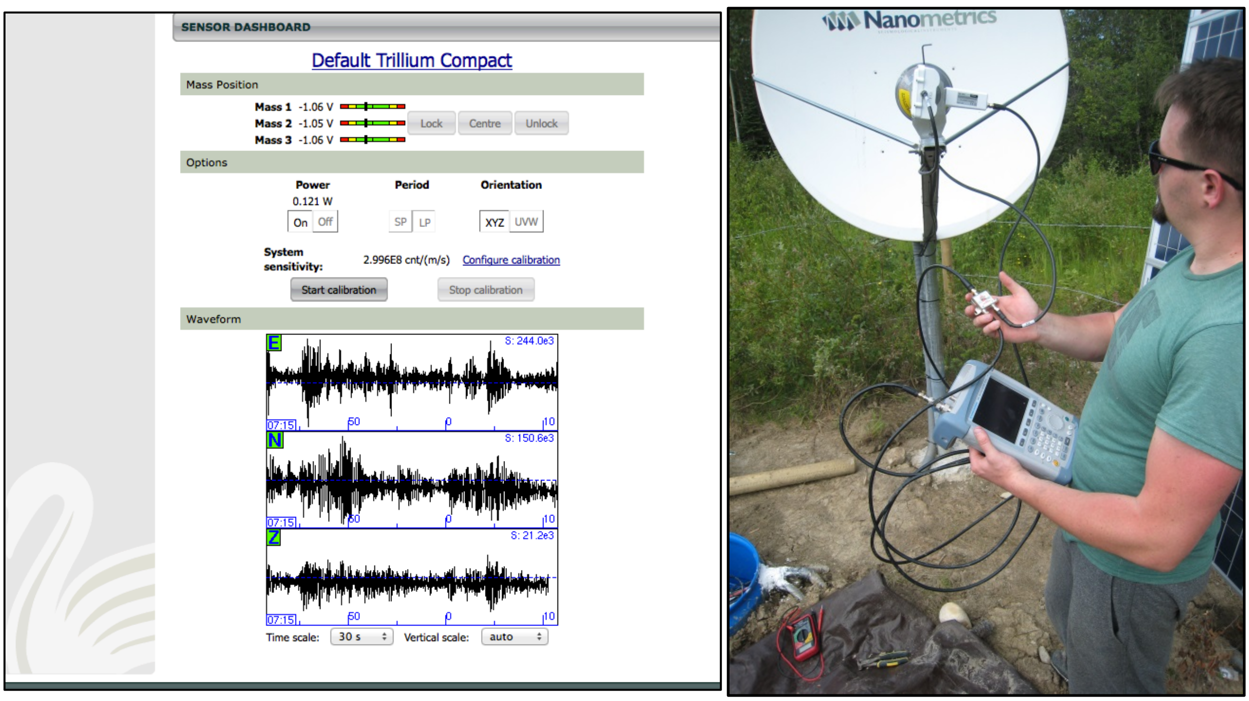

Figure 9. Left: Waveforms recorded from a normally operating Trillium compact which has been adequately levelled. Right: Setup of the spectrum analyzer to the feed horn assembly during telemetry alignment.

4.7 Step 7 – Telemetry Alignment

Telemetry alignment begins with the orientation of the satellite dish in terms of look angle and azimuth. Given a particular satellite, the orientation of the dish can be determined through website calculators (e.g., http://www.dishpointer.com/). Note that all orientations are given with respect to true north. For example, the WTMTA site has coordinates of 55.69422ºN 119.23975ºW, resulting in look angles of 155.95º and 23.99º for true north azimuth and elevation, respectively. The Libra II satellite dish is parabolic and thus has an offset of 17.3º. The offset requires that the dish is oriented at an elevation angle of 6.69º (23.99º − 17.3º = 6.69º). Use an angle indicator to adjust the elevation angle.

Azimuth is best determined with two people. One person stands ~15 m in front of the dish with a compass adjusted so that the line between them and the satellite dish is parallel with the look azimuth. The second adjusts the dish azimuth, such that the dish is looking ‘head on’ at the first person. It is important to be as precise as possible in setting up the initial orientation of the satellite dish; searching for the correct satellite can lead to wasted hours in station setup. With precise initial orientation, the dish will usually be closely aligned with the correct or neighbouring satellite at the first search.

Once the satellite dish is set up, attach the spectrum analyzer to the feed horn assembly. A coaxial cable goes from the LNB to the signal splitter; from the splitter, the cable with DC power goes to the Cygnus Rx, and the other goes to the spectrum analyzer. At this point, the Cygnus can have the LNB turned on in ‘test mode’ to see the received satellite signal. Screenshots of the spectrum analyzer output for the correct satellite and its neighbours have been included to expedite the search (Figures 10–16). If none of these satellites are found, check the orientation of the satellite dish as described above.

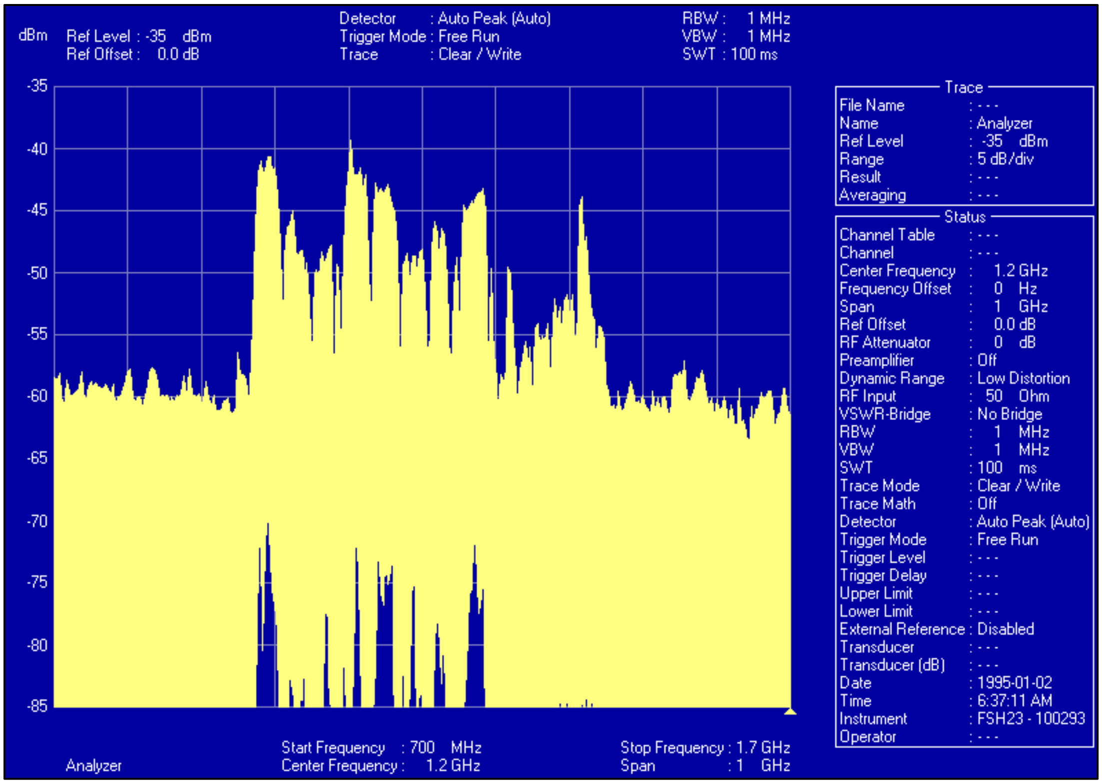

Figure 10. The target satellite, co-polar to the lease (2014). Note the specified variables.

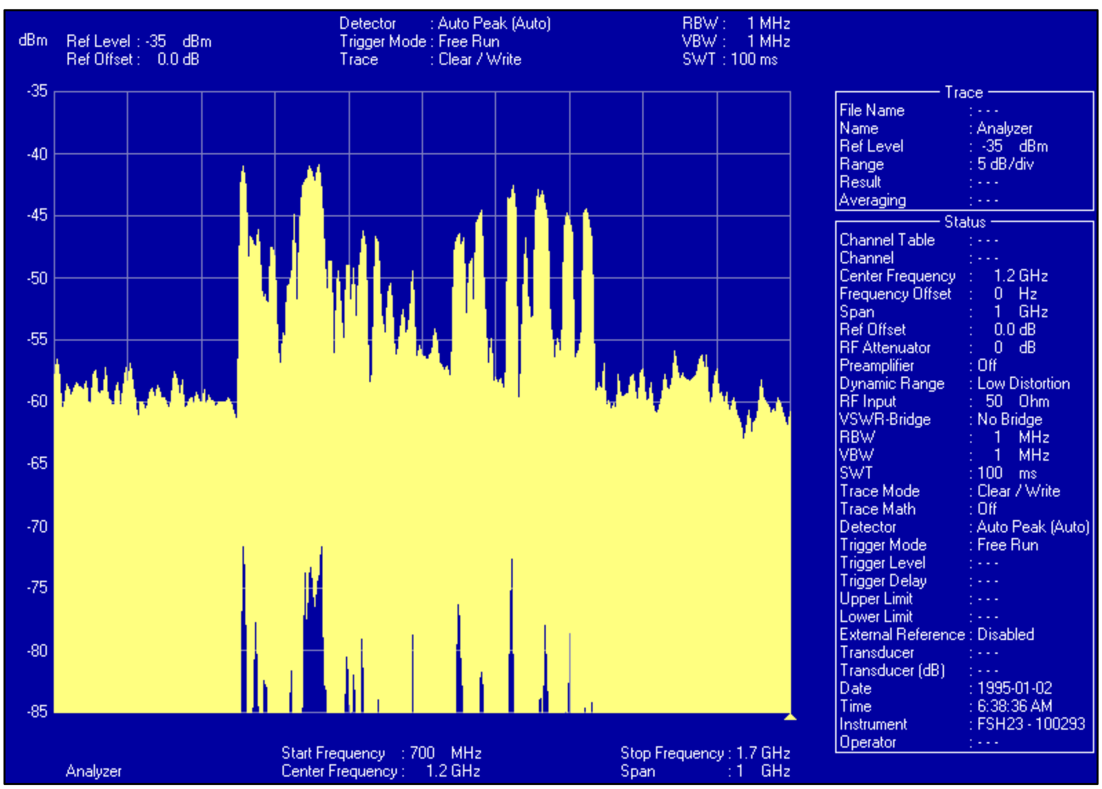

Figure 11. The target satellite, cross-polar to the lease (2014).

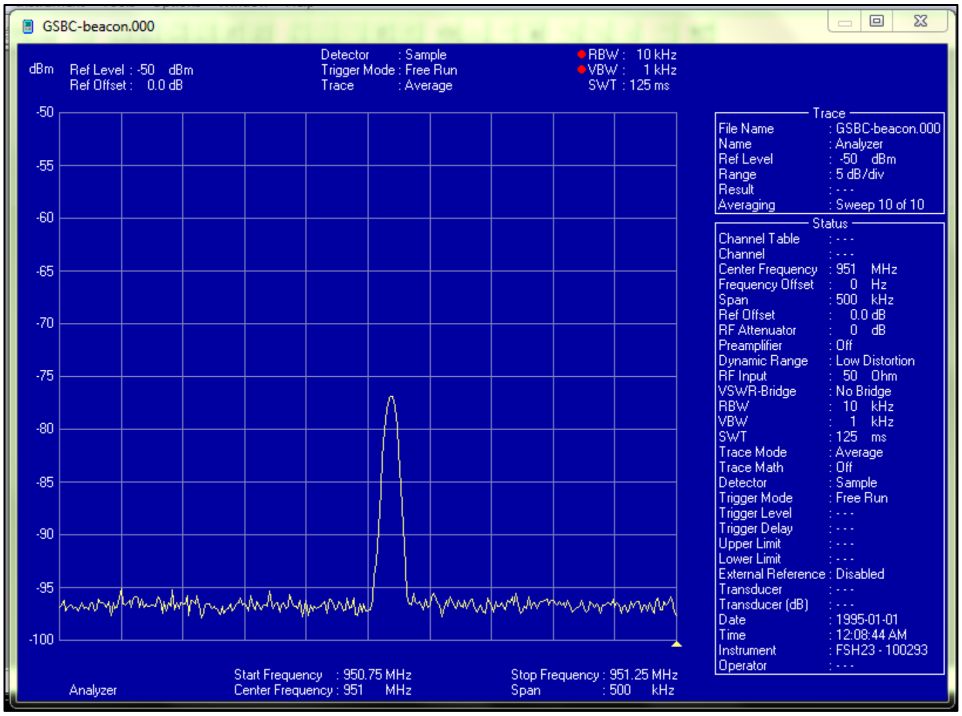

Figure 12. Beacon used to maximize gain in the fine-tuning of satellite orientations. Note the variables: centre *f* 951 MHz, 500 kHz span, 10 kHz RBW, 125 ms SWT, and 10 sweep passes.

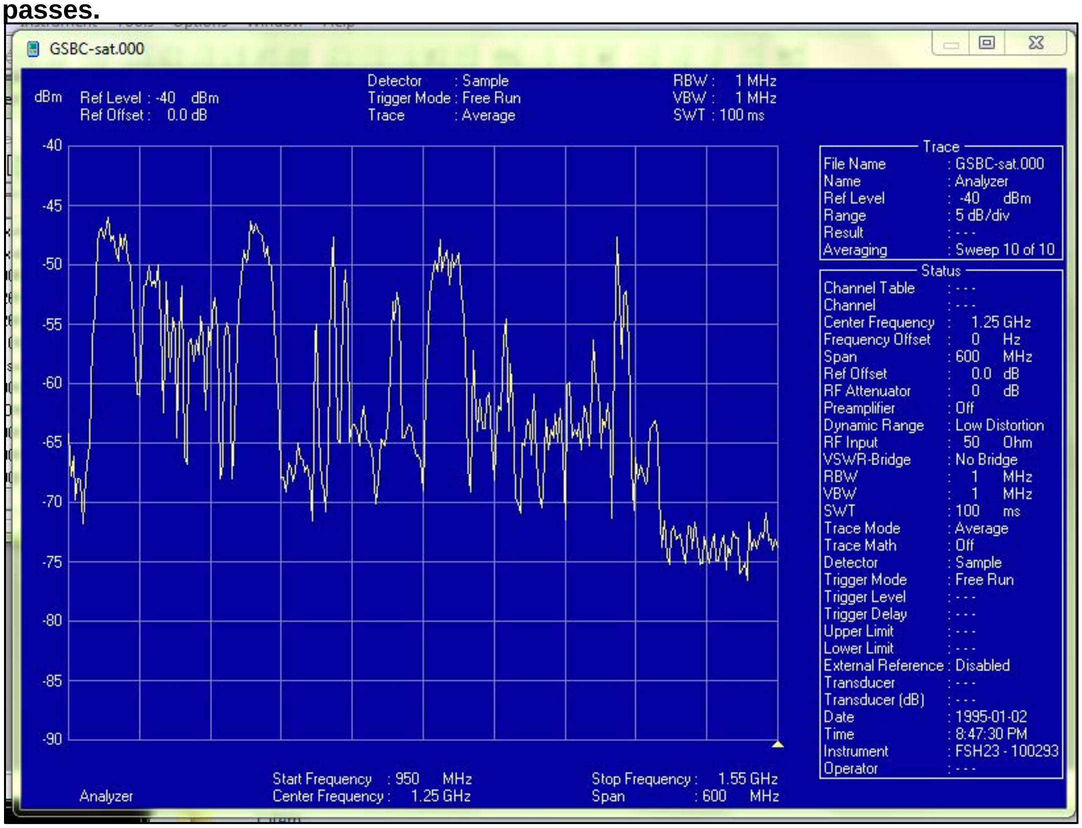

Figure 13. Sample of time-division multiple access (TDMA) schedule in action for NBCX stations (on same satellite as RAVEN).

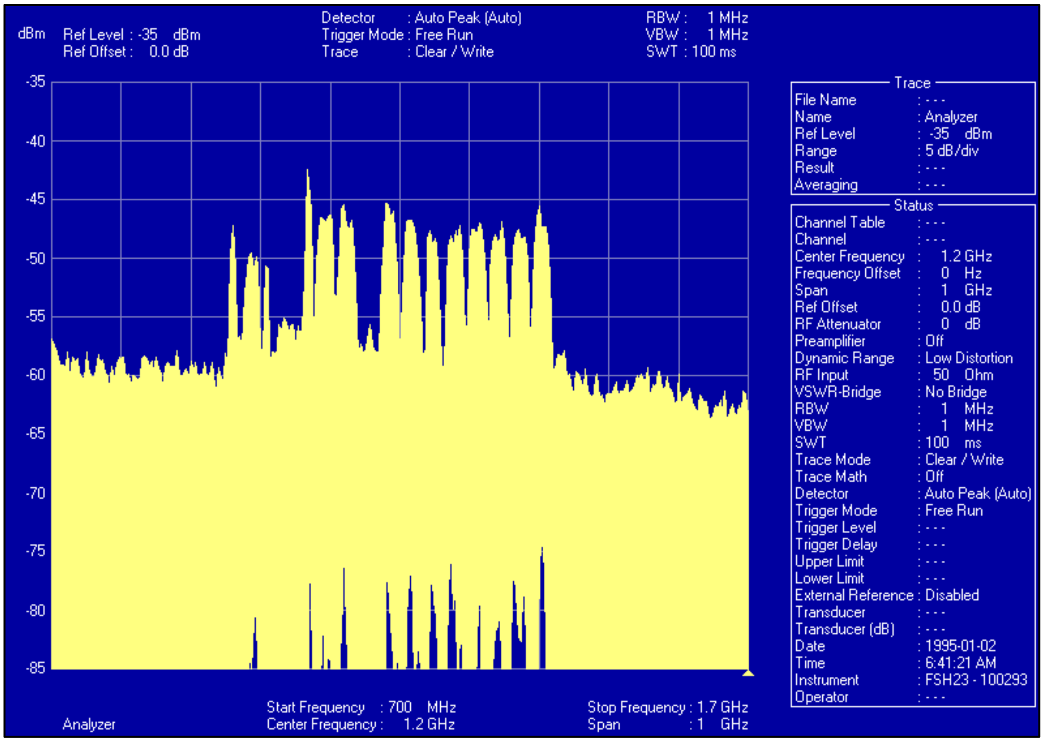

Figure 14. Eastern neighbour, on cross-polarity (2014).

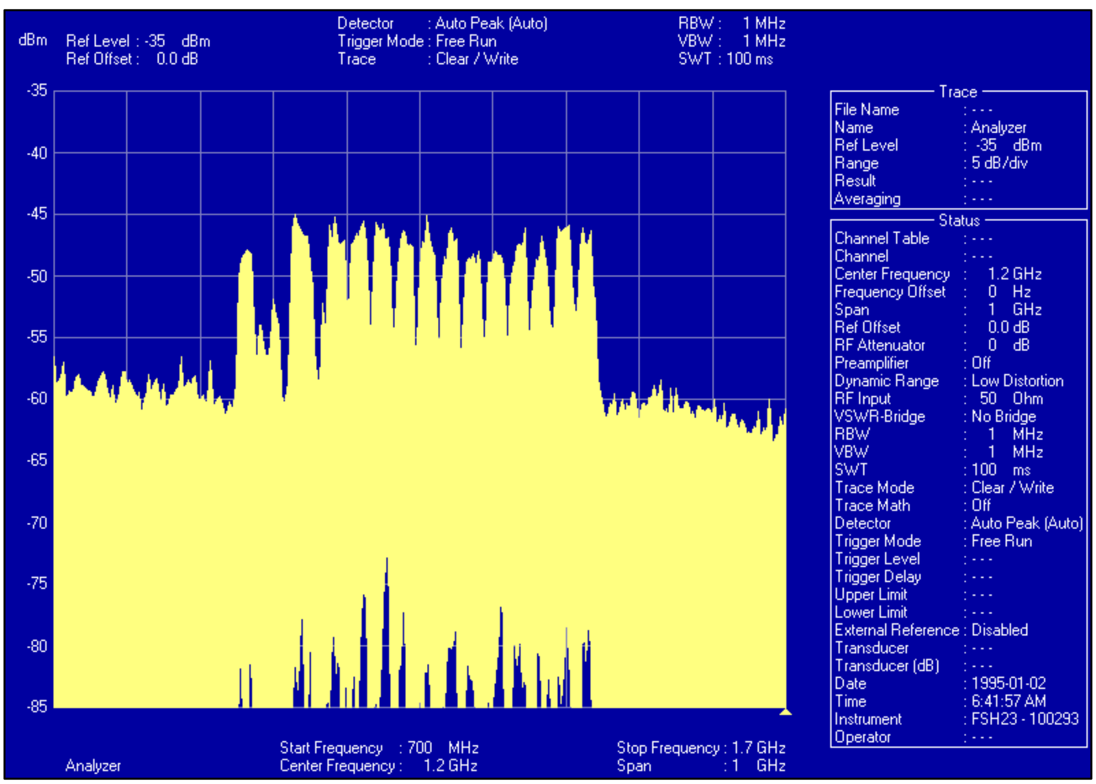

Figure 15. Eastern neighbour, on co-polarity (2014).

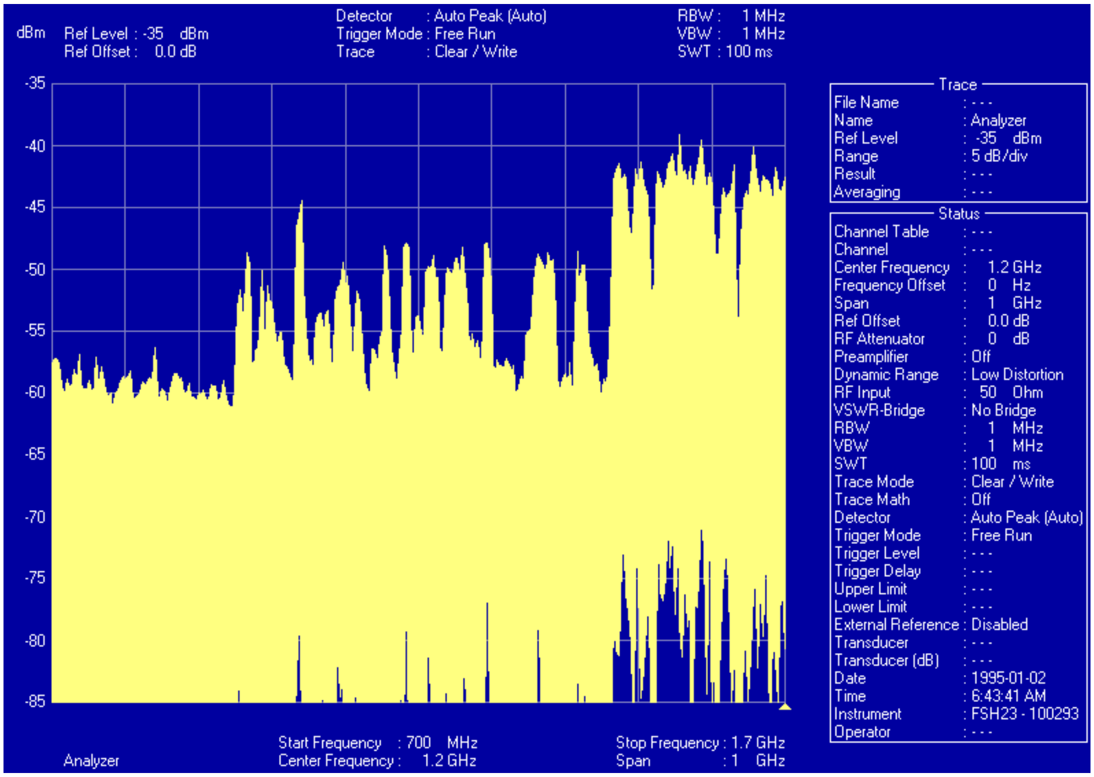

Figure 16. Western neighbour, on co-polarity (2014).

Once the correct satellite has been found, begin fine-tuning the orientation. Find the beacon as seen in Figure 12, adjusting the LNB orientation as needed to be co-polar. With two people, lock the nuts on the adjustable legs for elevation and azimuth; one person slowly turns one of the nuts (90º at a time), while the other watches the time-averaged beacon data. The goal is to maximize to beacon's gain, but with time averaging (to reduce noise) this can take a few seconds to appear on the spectrum analyzer. Sweep past the maximum to ensure it has actually been found, as noise can make it difficult to discern the true peak. Once the elevation, azimuth, and LNB orientation are set to maximize the beacon gain, you are ready to call the satellite company.

Once on the line with the satellite company, request a cross-pole test for a newly setup VSAT system. The service assistant will give you a specified frequency for the test. To send a signal to the satellite, change the Cygnus to 'test mode', input the provided frequency, change the modulation type to 'CW', and turn on all check boxes (BUC power, LNB power, BUC 10 MHz, RF signal). The service assistant will have you adjust the azimuth, elevation, and LNB orientation until the system does not interfere with other leased frequencies or polarizations on the satellite. After this is complete, the Cygnus can be changed back to 'normal mode' and should begin receiving on the TDMA schedule (note this can take up to five minutes). If the spectrum analyzer is configured as per Figure 13, the scheduled bursting can be viewed. Finally, unhook the spectrum analyzer and associated coaxial cabling; the system can now transmit on its own.

4.8 Step 8 – Finalize and Clean-up

The system is now up and running, transmitting data to the hub. It is important to double check all of the settings of the Cygnus and Trident configurations to ensure they are correct; a single typo can result in a lengthy revisit to a station to fix a simple mistake. After everything is confirmed to be operational, and confirmation of signal has been received from the hub, the seismometer vault needs to be backfilled with sand. Carefully pour the fine grained sand in a spiral pattern, starting at the outer edges of the vault and moving in toward the instrument. Take special care when pouring around the seismometer not to shift its position. Enough sand should be poured to cover the seismometer with about 1 in. of sand. Make sure that the silver bubble wrap insulation is fully covered by sand.

Next, the bored holes in the vaults need to be closed by applying caulking around the wiring passing through the holes. If the original plastic from the hole was kept, a small opening at the edge of it can be cut for the wires, and it can be used with caulking to close the hole. This step is important to ensure that water and pests do not enter the vault, both of which can be damaging to the equipment. After the caulking has dried, close the vaults with their supplied lids and cover the vault tops with a tarp. The tarp must be weighed down (e.g., with rocks) so it does not blow away.

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