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Vivaldi Feed Positioning: Tests, Implementation, and Results

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ABSTRACT

Precision positioning of the Vivaldi feeds as referenced to the dish hub is important in order to realize the proposition that each HERA antenna (dish/feed combination) have similar responses and are properly positioned for redundant calibration. In this work we present potential approaches to assuring that the feeds are accurately positioned in a dish with respect to the hub. We present results of a detailed field test of one approach as well as the implementation of this approach at the HERA site. We show that the achievable precision is within +/- 2 cm in the x-y coordinate, and well under a cm in the z coordinate for the initial positioning. We provide autocorrelation data from antennas with positioned feeds as well as from feeds that have heights that differ from the design height. These data indicate that the amplitude and frequencies of the peaks and valleys in the antenna autocorrelation functions can be manipulated to some extent by varying the feed height.

1. INTRODUCTION

One take-away from the 10-14 June 2019 trip by Eloy de Lera Acedo, Alec Josaitis and Scott Dynes to the HERA site in the Karoo was that the feeds were not being positioned in a repeatable, measurable manner. With 350 feeds to be raised and positioned a clear priority was to develop a workable positioning process so rework on hundreds of feeds would not be required.

Over a series of HERA Commissioning weeklies and Slack messages it was determined that:

- The design positioning accuracy was 2 cm in x, y, and z
- There was a desire not only for an initial positioning process, but for a few dish/feeds to collect x-y-z positioning data over time

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- A way of measuring and adjusting tilt was needed
- A way of reducing the sway of the feed due to wind was needed

Through a series of conversations multiple approaches for positioning the feed were developed: **The Tube** This approach uses a PVC pipe that is placed in a fixture

on the hub and whose top engages with the bottom of the feed. This tube would determine the height of the feed, and also would dampen the wobbles of the feed in a breeze. This approach would still require a solution for positioning the feed in the x and y directions.

Details and ideas discussed:

- The tube will need slots cut into it to engage the bottom of the feed. An alternative is to integrate the tube with the split conduit that is currently used to surround the cables and placed in the slot between the blades on current feeds. Doing this would ensure solid engagement with the feed.
- Some way will be needed to enclose the cables in the tube and allow them to exit at the hub. It could be that the cables pass completely within the tube if there's a hole cut into the hub fixture and if the optical fibers are led outside the hub cable bundle.
- The process for assuring that the tube would be engaged to the feed, the feed lifted, and the bottom end of the tube engaged in the hub fixture needs to be developed.
- One proposed idea: Make the tube is in two or more pieces. We should be able to source joiners for the tubes - larger short tubes that would fit snugly over the outside of the primary tube. The cable would be threaded thru the tube pieces, the upper tube would be engaged with the feed, and the lower tube would be slipped into place, and the joiner slipped into place. The bottom section would be lifted into the depression in the hub fixture.

The cables would emerge from the bottom of the fitting; the fitting would have a cut-out so this would not damage the cables.

The cables would emerge from the bottom of the fitting; the fitting would have a cut-out so this would not damage the cables. The HERA Commissioning weekly group thought that while this would steady the feed from swaying, it did not by itself solve the x-y positioning problem. There was concern about the placement of the central cables, and the stability of the central tube. **Laser Plumb-bobs** An x-y

positioning jig (e.g. a piece of plywood) is fashioned so that it sits firmly in and is aligned with the central hub opening. On this piece of plywood are placed three

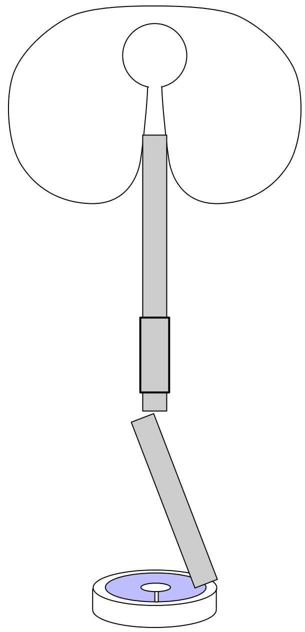

Figure 1. The cables have been threaded thru the tubes, and the top portion of the tube has been engaged with the feed.

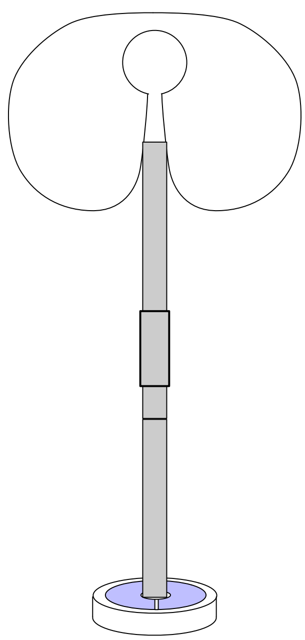

Figure 2. The bottom section of the tube has been aligned with the top section, and placed in the depression of the hub fixture (which has a slot for the cables)

laser plumb-bobs arranged so that the dots will fall in the centers of the PVC 'circles' below the FRP triangle when the feed is centered. Paper discs with bull-eye printing (and maybe reflective dots) are taped/glued to the circles to aid with knowing when the x-y positioning is correct. The space on the plywood under the fourth circle has a laser rangefinder for measuring the z dimension.

This can be used with the tube scheme described above.

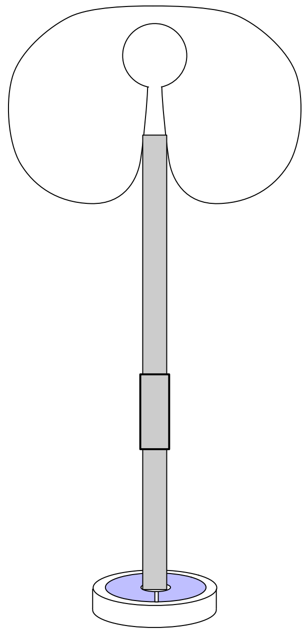

Figure 3. the 'slip coupling' (a plumbing term for this joining tube) is slipped over the joint, which gives the tube its structural rigidity.

- This could be quick to implement, and would be portable between antennas/feeds.
- This assumes that the top of the hubs are pretty level; the laser plumb bobs will assure that the beams are vertical.
- This assumes the geometry of the circles on every feed is the same

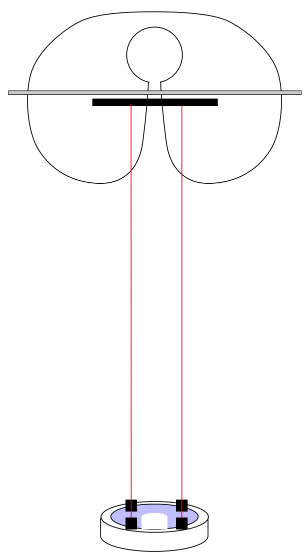

Figure 4. Lasers for three plumb-bobs and a laser rangefinder fastened to a hub fixture point to the PVC circles on the feed.

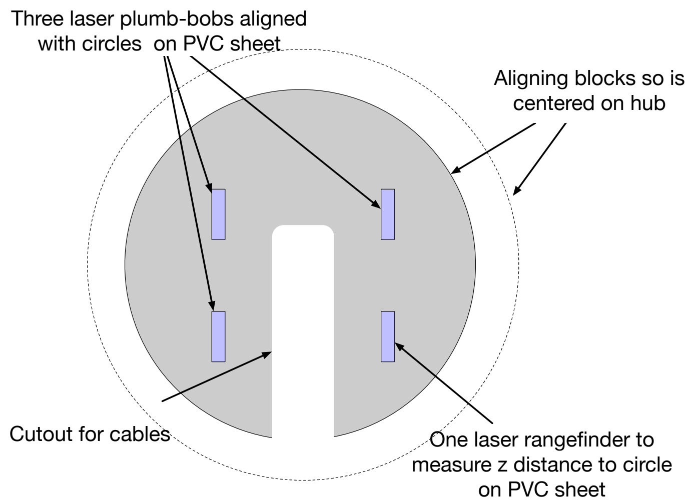

Figure 5. Details of the hub fixture for the plumb-bob scheme.

The HERA Commissioning weekly group thought that this approach was practical. The group thought this should be prototyped at Lords Bridge.

Triangulation

Fiducial points are identified or created on feed structures (e.g. the corners of the FRP triangle). The distance to these point is measured from a set of reference points that are defined by the hub and shape of the antenna. These reference points should be vertically underneath line from the pulleys at the top of the poles to the center of the hub. The setting of the x-y-z feed would entail changing the length of the lines until each feed fiducial point is at the proper distance from the appropriate reference point.

- One assumption of the above is that the corners of the feeds will be very close to the lines from the pulleys at the top of the poles to the center of the hub. Relaxing this assumption would require measuring from two reference points to each fiducial point.
- Choosing the reference points would likely require measurements from the hub to the reference.
- The reference point would have to be some distance off the ground; repeating this for every hub/antenna would be work.
- One could (would) want to use these points to measure the antenna shape with respect to the hub.

The HERA Commissioning weekly group thought that this approach would yield the best information, and would also be very time-consuming to implement.

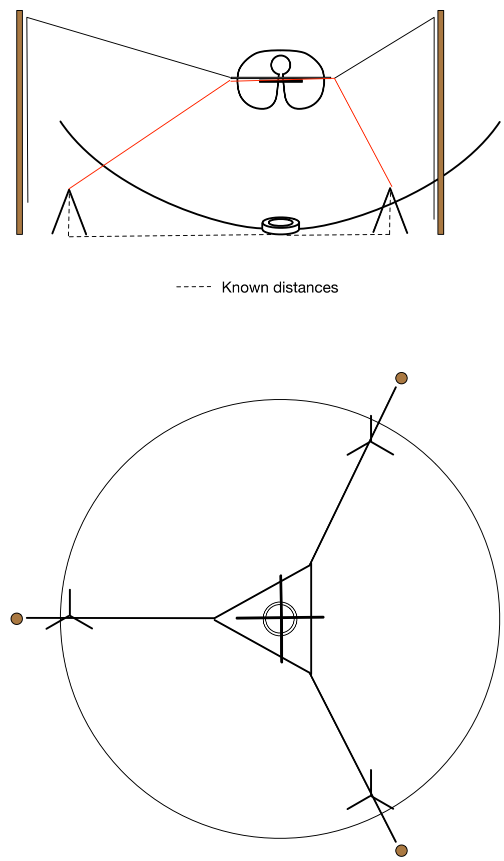

Figure 6. Feed triangulation. Knowing the locations of the three laser rangefinders it is possible to calculate what the distances should be to some point (here, the corners of the GRP triangle) on the feed. Once those distances are obtained, the feed is positioned. The bottom figure shows the tripods for the rangefinders located under the lines. Note that the laser beam would have to transverse the chicken wire.

Photogrammetry

During the 'triangulation' approach discussion photogrammetry was brought up. In this approach pictures of the feed are taken from multiple locations; specific points of the feed would be marked using reflective tape. Using a 3D modeling program such as agisoft photoscan to build a 3D model. Photoscan detects overlap between images and inverts the dataset to solve jointly for a 3D point cloud and camera position and orientation.

This approach was considered primarily for the longitudinal monitoring of the feed position, as the positioning of the cameras and data collection would resemble that of the triangulation approach above.

A version of this approach for long-term feed position monitoring is currently being developed by Alec Josaitis.

2. DEVELOPMENT OF FEED XYZ POSITIONING

Of the above approaches, the laser plumb-bob approach was developed for the initial positioning, and the photogrammetry approach chosen for the monitoring of feed position over time.

The design of a prototype for the plumb-bob approach was completed. Based on the design equipment was purchased and the approach was tested at Lords Bridge during early July 2019 as described below.

2.1. *Feed XYZ positioning - practical details from experience at Lords Bridge and the HERA site*

The design of the plumb-bob approach was detailed. Based on that design, equipment was purchased and the approach was tested at Lords Bridge in early July 2019. The construction of the jig was straightforward. The length of the $\frac{1}{4}$-20 bolts used to attach the laser plumb-bobs did not have any interference issues with the PVC pipes that took the place of the rebar rod across the diameter of the hub with the two dishes used in Lords Bridge.

The use of the round plywood cutouts as positioning stops on the bottom of the plywood worked well at Lords Bridge. At the HERA site the round plywood was replaced with a round PVC fitting. This fitting did interfere with the rebar until its thickness was halved by a hacksaw. One feature of the round positioning stops was to allow the rotation of the center of the jig around the center of the hub; this worked as long as care was taken to press the jig against the 'back' of the hub. The dotted line on the jig plan made visual checking of the alignment easy.

Positioning of the laser plumb-bob dot on the jig target was made a little complicated by the left-hand threading of the locking knobs on the base of the plumb-bobs. The relative rotation of the body and base required to center the laser dot in the target was a little fiddly.

2.2. *Overview of feed positioning*

- Using 3 laser plumb-bobs positioned atop the hub, and paper targets on the on the feed PVC circles, x-y positioning to an accuracy of less than 2 cm was achieved in a straightforward manner. This was done on two separate occasions with two different dishes and feeds at Lords Bridge, and with all Node 0 antennas on site.

- Using a laser distance measure, the height of the feed could be placed within the precision of the laser measure (3 mm).

- On-site experience suggests the order of positioning is an x-y positioning, followed by a height (z) positioning where the z height is set to what is desired by changing the length of the central line.

- Ongoing feed location measurements are actively being developed by Alec Josaitis, using photogrammetry techniques that utilize a camera at the hub and a checkerboard target on the feed. This will be detailed in a separate memo in the near future.

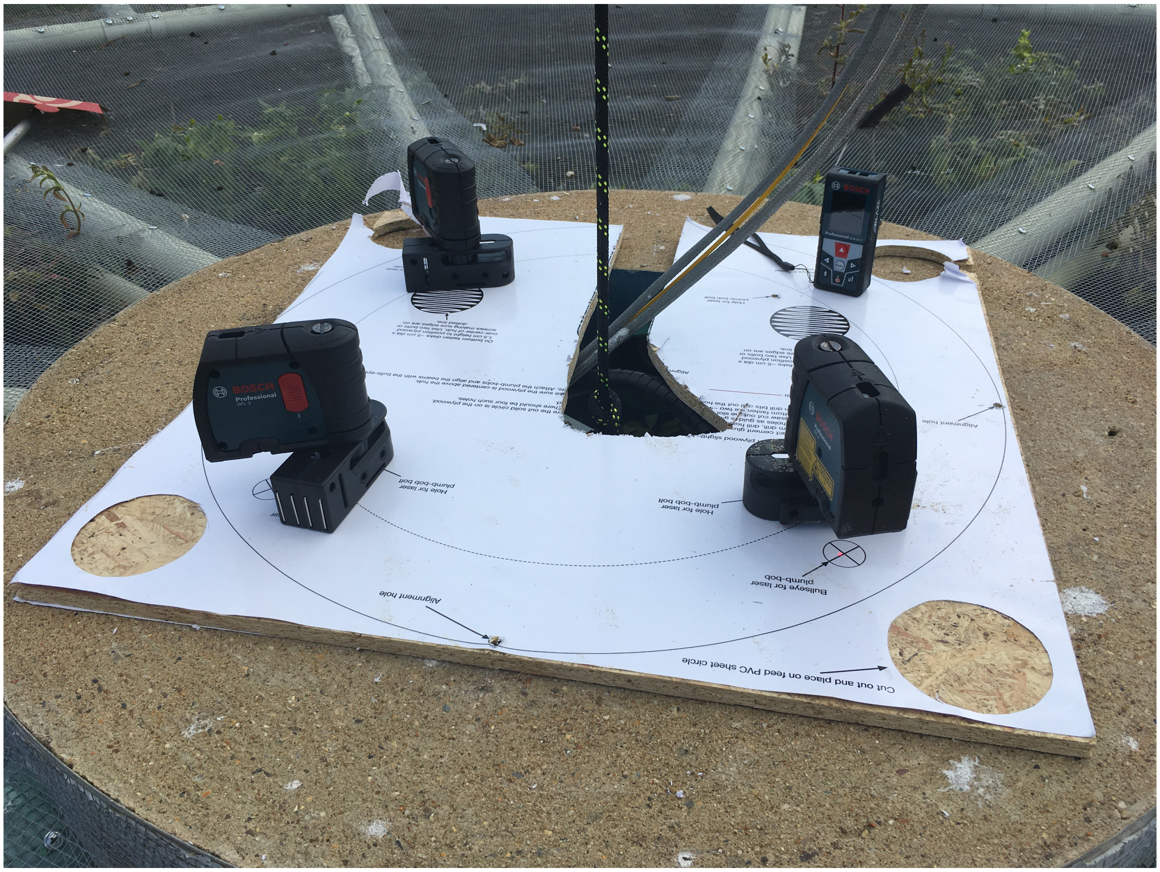

Figure 7. A picture of the diagram glued to the top of a sheet of plywood and placed in position over the hub. Two round plywood cutouts were fastened to the bottom of the plywood to register the center of the diagram with the center of the hub. This image is from the testing at Lords Bridge.

There were two primary challenges during use. The first was how to initially position the feed such that any of the laser dots was visible. This was accomplished at Lords Bridge by taping a piece of cardboard to the end of a pole, and using that to trace the dot from near the hub to a spot on the feed. Once the spots were visualized on the feed targets the x-y positioning was straightforward. This 'spotter pole' approach was not needed at the HERA site. Given that there were 3-4 people raising the feed, someone walking around the dish could call out the initial centering accurately enough so that at least one laser dot was visible on the feed. From that point the centering was straightforward. One notable thing about the feed raising at the site was that the crew only winches to increase tension- backing off the winch to reduce tension is not a natural thing for them. This would explain why eyebolts get bent without springs in the lifting line system, and springs get overstretched when they are.

Rotation of the plywood around the z-axis was done to better align the plumb-bob dots with the center of the PVC circle targets. While there was an initial concern that

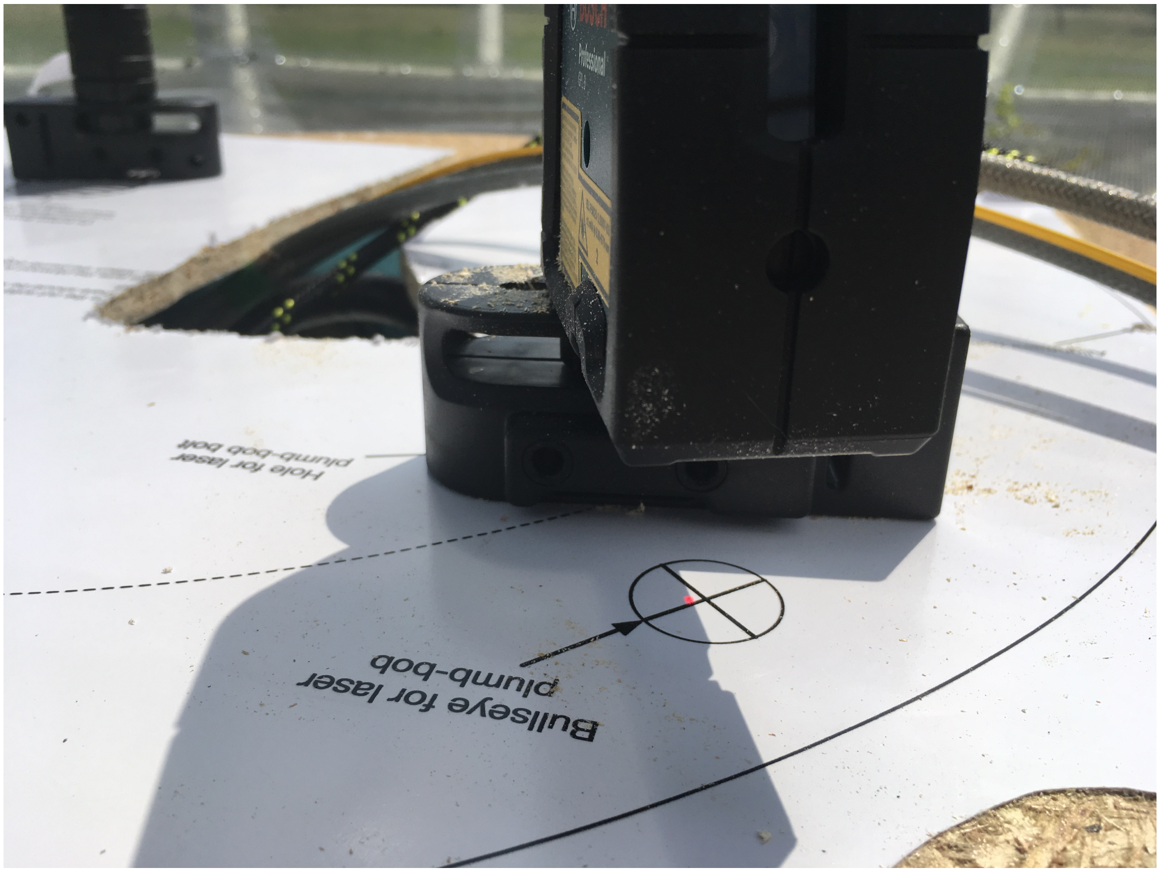

Figure 8. A detailed image of the downward projected laser beam (red dot) on the bullseye. This is slightly misaligned. The centers of the PVC circles should be exactly over these bullseyes when the feed is properly positioned (and assembled, level, etc.)

this would be overly fiddly, practice showed this to not be the case. An alignment line was added to the production plan design.

The second challenge was the Z measurement. Unlike the plumb-bobs the dot from the laser measure was not guaranteed to be vertical. In the end the method used at Lords Bridge was for one of us to sit on the hub and point the laser measure and point itat the PVC circle target until the beam was spotted. The laser measure beam for the GLM20 units is substantially bigger and perceptually brighter than those of the plumb-bobs, so this was not hard. The hard part was to then lower the base of the laser measure onto the hub fixture, and to read the Z measurement. The GLM20 units have the feature that clicking on the red button freezes the readout, allowing the operator to visually see the laser dot on the PVC circle target while clicking the button, and then reading off the measure.

At the HERA site the ‘sitting on the hub’ approach is not a possibility, as the center screens are screwed in to the PVC tubes. Fortunately, the crew has experience with measuring the height and were able to do so easily.

An important feature of the height measure is the central line that is used at the HERA site to set the height to which the feed can be raised. While this was present at

Figure 9. A picture showing the upward laser beams from the plumb-bobs and the distance measure shown in the first picture. The right-most circle shows the laser measure beam, which is used only for the z measure. The other circles show the (fainter) beams of the plumb-bobs, all very near the centers of the concentric circles. The diameters of the innermost circles differ by 2cm, so the distance between each line radially is 1 cm. Note that the beams indicate that a better match to the centers would be had by rotating the plywood clockwise about the z axis. For this positioning the x-y positions are all well within a cm of their desired location, and the z measure is exact to the precision of the laser measure: 4.427 meters. This measure takes into account the 11mm thickness of the plywood.

Lords Bridge, it was untied from the central PVC pipe initially as we were interested in determining the precision to which the feed could be positioned. The thinking was that once the feed was at a particular height, this line could be tied off and the lifting lines tensioned to stabilize the feed in the wind.

At the HERA site the revers of this was tested - the feed was raised to a height several cm above the desired height, and the central line was pulled until the feed was at the desired height. This would put tension on the central line.

One question that arose from the height positioning at the HERA was whether to set a height and then pull down and fasten the central line using a knot, or to set the length using a splice and lift until the central line is tight. As many of the central lines were the wrong length, the Node 0 feeds were raised, and the length of the central line adjusted by changing the splice until the height was as desired.

Following the testing at Lords Bridge a few changes were made to the initial design:

- The drill hole sizes were changed from 6 to 8 mm to better accommodate the $\frac{1}{4}$-20 bolts
- The cable cut-out on the plan was extended across the center of the hub
- A 'North Pole Line' was added to the plan to allow the operator to better orient the plywood on the hub.

The laser plumb-bob method was implemented on-site during late-July to early August 2019 visit by several HERA personnel. The 'plans' were printed out by the SARAO project manager onto foamcore board, which was glued to 60cmx60cm plywood boards. The instructions were followed (i.e. cable cut-out was done, laser plumb-bobs mounted). Two boards were fabricated.

The x-y positioning was initially complicated by people having to learn which way to rotate the jig around the dish z axis to better bring the plumb-bob laser dots in alignment with the on-feed targets.

The biggest departure from Lords Bridge was the fact that on the first feed raised, two dots fell right in the middle of the target, but the third dot was almost 2 cm from the target. Investigation showed that a laser plumb-bob on one board was not projecting dots vertically; this plumb-bob will be replaced.

Using the xyz jig all the feeds in Node 0 were raised and positioned to within 2 cm in the x-y direction, and to within a few mm in the z direction.

3. SPRING PLACEMENT

The original placement of the springs between the feed and the lifting lines resulted in a resonance of the dish-feed-spring system. To remove this sharp feature from the bandpass the springs were removed from the lifting lines, which resulted in sufficient force being applied when lifting the feed to distort eye bolts and cause loaded pulleys to slip off eyebolts. We have heard that three feeds fell due to distorted eyebolts. To resolve this problem, it was decided that springs would be used in the lifting line system to act as a buffer for over tensioning the system, and that the 'bent wire' eyebolts would be replaced by larger forged eyebolts.

At Lord's Bridge hree spring placements were tested - (a) two springs in parallel between the bottom pulley and the bottom eyebolt of the telephone pole, (b) using saddle clamps a single spring attached in parallel with the rope between the upper and lower pulleys, and (c) a single spring attached in series with the rope between the upper and lower pulleys.

Two springs in parallel (a) During testing at the Lords Bridge HERA dishes lifting the feed using approach (a) showed that the action of the saddle clamps resulted in excessive tensioning of the springs with no actual shortening of the feed line when the winch was being cranked. In other words, as the winch was cranked the saddle clamp would bind the line so that the springs would lengthen with no decrease in the length of the line to the feed. Additionally, because the springs were between the pulley and the eyebolt, the springs saw a tension twice that of the lifting line. When the feed was positioned the line is clamped together with the saddle clamp and the winch tension removed. This removal of the winch tension resulted in the lifting line being subjected to the full (double) tension of the springs, which resulted in the height of the feed increasing by ∼22 cm.

Spring attached in parallel with the line (b) Procedures for determining where to attach the springs in parallel with the line were developed using measures taken from raised feeds at Lords Bridge. At Lords Bridge springs were then attached in-line with saddle clamps, leaving sufficient slack to allow the spring to stretch to hold the load of a raised feed. Approach (b) was transparent to the user - the system behaved as expected. When tried on site in the Karoo, the saddle clamps did not effectively bind the rope to the springs, and the rope slipped through the saddle clamps so that all the load was borne by the lifting lines. At Lords Bridge tensions in the three lines were measured with a tension meter. The maximum tension for a properly located feed (the distance between the vertex of the dish parabola and the top of the notch of the feed being 5.00 meters; the PVC circles being positioned 4.438 m above the hub) was a maximum of 340 lbs. There was an unexpectedly large range in tensions. The tensions of the lines for the two 'properly' positioned feeds were (330, 250, 270) and (310, 250, 340). The expected tension from the project engineer's calculations is 350 lbs. Repeated measures with the tension meter varied by no more than 5 lbs - the quanta of measure.

This unexpectedly large variation in tensions was observed on-site. The tension of each of the three lifting lines was recorded following the positioning of all feeds in Node 0. Many of the tension values were higher than the 350 lbs mentioned above; the site crew has a preference for only increasing tension to move the feed, and not reducing the tension of the opposed lifting line(s). The mean value for the measured tension is 358.75 lbs,with a maximum of 490 lbs. and a minimum of 210 lbs. The difference between the highest and lowest tension for each feed has a mean value of 84 lbs, with a standard deviation of 57 lbs. The root cause underlying the variation in tension is not understood. If the feed were centered within the equilateral triangle created by the poles, and there were no friction the tensions should be the same. Potential causes for the variation would include:

- The feed not being in the center of the equilateral triangle created by the poles. If the feed were not in the center, the loads on the lines would differ. A quick estimate of this effect would indicate that a one meter offset from the center would result in roughly a 20 percent difference between the high and low values, which is about what is seen (84/359 $\sim$ 23%), even though a discrepancy of a meter between the center defined by the poles and the center of the hub would be unexpectedly large.

- Friction due to pulleys. There are friction losses in pulleys. These are typically 8 percent for pulleys with plain bearings (i.e. not ball bearings).

Single spring attached in series with the rope (c) On-site the lifting line was cut at the location where the springs were installed in (b) and attached to the springs in the same manner used to attach the ends of the lifting lines to the feed triangle ends (double overhand knot with a saddle clamp and thimble). This was effective - the springs took up the entire load, and there was no slipping. This is the approach that was adopted on-site, and all Node 0 feeds were retrofitted to have springs in series with the lifting line. All feeds on Node 0 were xyz positioned with the springs in this position.

Figure 10. A picture showing the approach of the spring in parallel with the line. Here the length of line between the top and bottom saddle clamps is 48 cm; the photo shows that there is still a little slack in the line when the feed is in position.

Figure 11. A similar picture from the site showing the spring in series with the line approach. Note the length of the tails on the double overhand knots.

3.1. *Springs - practical details from experience at Lords Bridge and the HERA site*

The original placement of the springs between the feed and the lifting lines resulted in undesirable EMI properties of the dish-feed-spring system. The springs were removed from the lifting lines, which resulted in sufficient force to dangerously distort the eye bolts when lifting the feed. There was at least one case where the distorted eye bolt released a loaded pulley; luckily nobody was injured.

As a result it was decided that there should be springs in the lifting system as they would serve to 'buffer' the forces that would be applied via the winches and greatly increase the difference between 'not cranked enough' and 'cranked so much something broke'[. There were two alternatives that were developed and tested at Lords Bridge: putting springs between the bottom pulley and the pole eye bolt, and putting springs in-line with the rope between the upper and lower pulleys. A further alternative was developed on-site at the end of July ?19, where springs were put in series with the lifting lines.

Springs between the bottom pulley and the pole eye bolt This approach was tested at the site very shortly after a pulley under tension unexpectedly came off a deformed eyebolt. The crew drilled a hole at the bottom of a pole and installed a new eyebolt, and attached a spring to the eyebolt and pulley with D-shackles. The crew did not like this arrangement, as the spring would be stretched very close to their bodies.

This approach was tested at Lords Bridge. In this position the springs would be subject to twice the tension as they were located between the lifting line and the feed. To mitigate this, two springs were ganged together. One dish was fitted with springs in this manner, and a feed raised.

Two issues came to the fore. The first involved winching in the line. The saddle clamp had been left in position to clamp off the line (i.e. clamp it to itself) as is the practice on-site. When winching in, the friction between the lifting line and other things such as the winch body or saddle clamp would cause any shortening of the lifting line during winching to result from the stretching of the spring, and not by any actual lifting of the feed.

The second issue was due to the doubled tension on the pulley as a result of both the feed and the winch tensioning the line. When the feed had been raised, the lifting line was clamped to itself, and the tension on the winch removed. This removal of the winch tension resulted in the doubled tension provided by the spring to be transferred to the lifting line, resulting in the feed height being increased. At Lords Bridge the measured feed height increased from 4.416 m (1.1 cm lower than the mark) to 4.631 m (20.4 cm above the mark). No further effort was expended on this approach following this measurement.

Springs in parallel with the lifting line The second approach tested at Lords Bridge was to put the spring in parallel with the lifting line between the upper and lower pulleys. This placement would serve two purposes: when the feed was in the correct position, the spring would be below the edge of the dish, and if the spring were stretched too far the line would take the tension and the spring could not suddenly release from the line, potentially injuring someone.

In early designs two loops would be tied into the lifting line; the spring would be attached to these loops using D-shackles. The knot used would have been the Alpine Butterfly knot. During discussions Dave DeBoer suggested that the springs could be attached to the line using saddle clamps. This was tested at Lords Bridge. It was found that if the line and spring were clamped with the saddle along the line and the U-bolt along the spring sufficiently tight saddle clamps could be effectively used. If the saddle were located on vinyl tape used for marking clamping positions, the adhesive would provide enough lubricative properties so that the line would slip through the saddle clamp when the feed was raised to the proper height.

Figure 12. A picture of the springs between the bottom pulley and pole as tested at Lords Bridge.

Through the 48 cm of line between the saddle clamps was found to be enough line to allow the spring to take all the tension when the feed was at the right height, but to allow the line to take up the tension when ∼500 lbf of tension was on the line.

During testing at Lords Bridge a method was developed where the right attachment points for the spring could be determined by measurement. Two types of measurements were determined: where the attachment points should be for feeds that were already lifted (with and without springs between the lifting line and the feed), and

Figure 13. A spring with 48 cm of slack line attached with saddle clamps. This is a picture from Lords Bridge.

for dishes where the lifting lines were slack. These measurements are overcome by events, as this method was not adopted for production use.

When the lifting lines are slack, the method is to pull the end of the line that will attach to the feed (with the thimble) outside the dish, and pull both the ascending line and descending lines taut (the tension will be on the upper pulley). A measuring tape is used to position the thimble 72 cm off the ground; the point at which the winch side of the line should be cut is also 72 cm above the ground.

Figure 14. A spring and lifting line when the feed has been lifted to the proper height. Note that the spring is below the level of the dish, and that the line is slack between the attachment points. This is a picture from Lords Bridge.

Springs in series with the lifting line While on-site in Late July implementing the 'spring in parallel' with the lifting line approach it became clear that attaching the spring to the rope with saddle clamps was unsuccessful – more than half of the spring/lifting line attachments failed, with the lifting line sliding through the saddle clamp. In discussion with the crew about going back to the 'knots in the line' approach one of the crew (Rushelle, last name unknown) suggested that we should just cut the lifting line, and attach the springs to the cut line in the same manner that is used to attach the end of the line to the feed (a double overhand knot with a thimble and a saddle clamp). She said that the crew would not be concerned by the proximity of the spring, and that this approach would take less time than the tying two Alpine Butterfly knots in each lifting line, and making sure the correct length of slack line would remain.

This method was put into practice. Many lifting lines on several dishes had already been taped to indicate where the springs should be clamped to the line; these lines were cut halfway between the spring attachment points. Double overhand knots, thimbles, and saddle clamps were used to form the attachment points, and the springs were attached with D-shackles.

Figure 15. Positioning the feed end and winch end of the lifting line to determine where to cut for spring placement. The line goes from the thimble, through the top pulley, and then drops back to the ground. **For the spring in series with the line: If the thimble is positioned 72 cm above the ground, the location to cut is also 72 cm above the ground.** Note that the image shows 60 cm; this was for the saddle clamp approach that is not being pursued. The line should be pulled tight when measuring. Attaching a light line to the thimble prior to taking the thimble out of the dish makes it much easier to reattach the thimble to the feed.

4. RESULTING CHANGES IN THE AUTOCORRELATION FUNCTIONS

Prior to moving the springs and positioning the feeds we collected data for Node 0 antennas so we could calculate and plot the autocorrelation. We collected similar data following the spring movement and the feed xyz positioning.

Figure 16. Left panel: A picture of the lifting line - spring attachment for the ?springs in series? approach. A double overhand knot with a good-sized tail is tied; the thimble is inserted, and the saddle clamp is used to hold the rope together so the thimble does not fall out. Right panel: A picture of the lifting line with a spring attached in series. This was taken during the July-Aug 2019 site visit.

The feed x, y, and z measures are not known for the 'pre' positioning plots shown in Figure 18. These data exhibit peaks and valleys that differ in frequency and relative power. For example, compare the antenna 23 curve (brown in Figure 18) with that of antenna 12 (green). The antenna 23 autocorrelation shows a pronounced valley at ∼110 MHz, while that of antenna 12 shows a relatively smaller peak.

In contrast, the 'post' xyz positioning autocorrelation plots shown in Figure 19 exhibit very similar peak and valley structures in terms of both frequency and power. While other activities that might affect the autocorrelation plots did occur (e.g. fiber cleaning, lowering and raising feeds) these plots are evidence that accurate positioning of the feeds leads to a great similarity in the autocorrelation functions.

The antenna 23 vs antenna 12 autocorrelation curves of Figure 17, and shown more con. While the curves shown in Figure 18 represent an accurate positioning with respect to the design height (the top of the notch of the feed 5.00 m above the vertex of the parabola), there seems to be more amplitude of the peaks in the positioned feeds than of the antenna 12 'pre' autocorrelation curve. If the desire is for a spectrally uncomplicated autocorrelation curve it might be that the design height is not the optimal height.

To better estimate if the complexity of the autocorrelation functions could be modified by changing the height of the feed the heights (z dimension) of the feeds in Node 9 were measured. The Node 9 feeds had not been positioned in either x, y, or z; the z dimensions were measured, but neither the x or y offsets from the desired

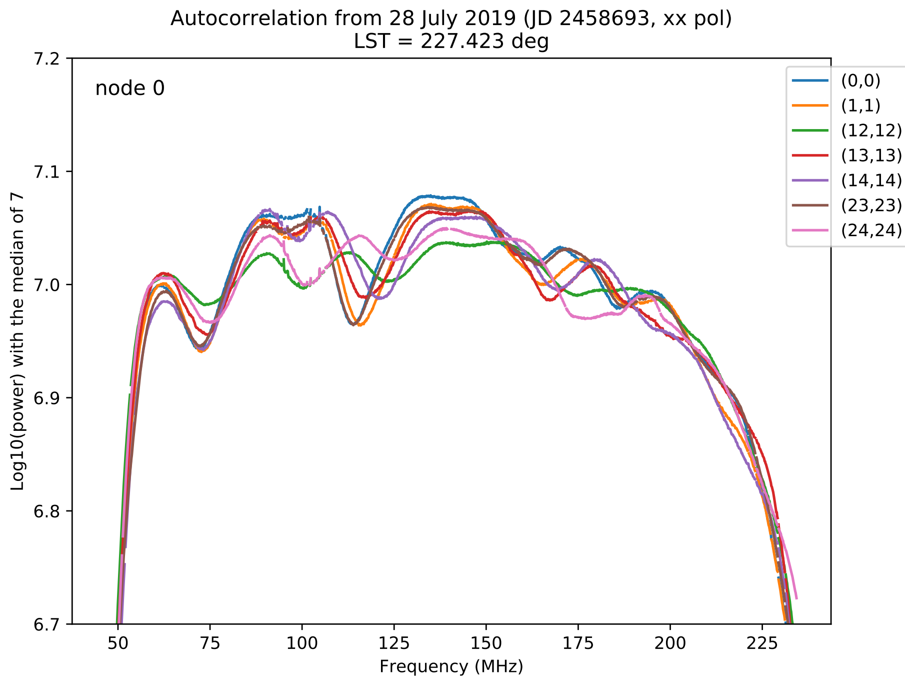

Figure 17. A plot of the autocorrelation functions for the Node 0 antennas prior to the updating of the spring positions and the xyz positioning of the feeds. Each autocorrelation curve has been moved in the y direction its median value is 7.0. Note that only 7 antennas are shown; the other antennas exhibited clearly bad signals (e.g. no input).

locations are known. The autocorrelation functions of the Node 9 antennas (feed and dish) were determined and used to create Figure 19. This figure shows the autocorrelation functions for the Node 9 antennas and a single Node 0 antenna, where the the median value for each curve is set to the difference in feed height relative to the Node 0 feed height. The amplitude and frequency of the peaks and valleys changes relatively smoothly as the feed height changes, particularly at lower frequencies. This suggests that the feed height could be changed to optimize some figure of merit of the antenna system; this would necessarily include features in addition to the shape of the autocorrelation function, including the beam pattern.

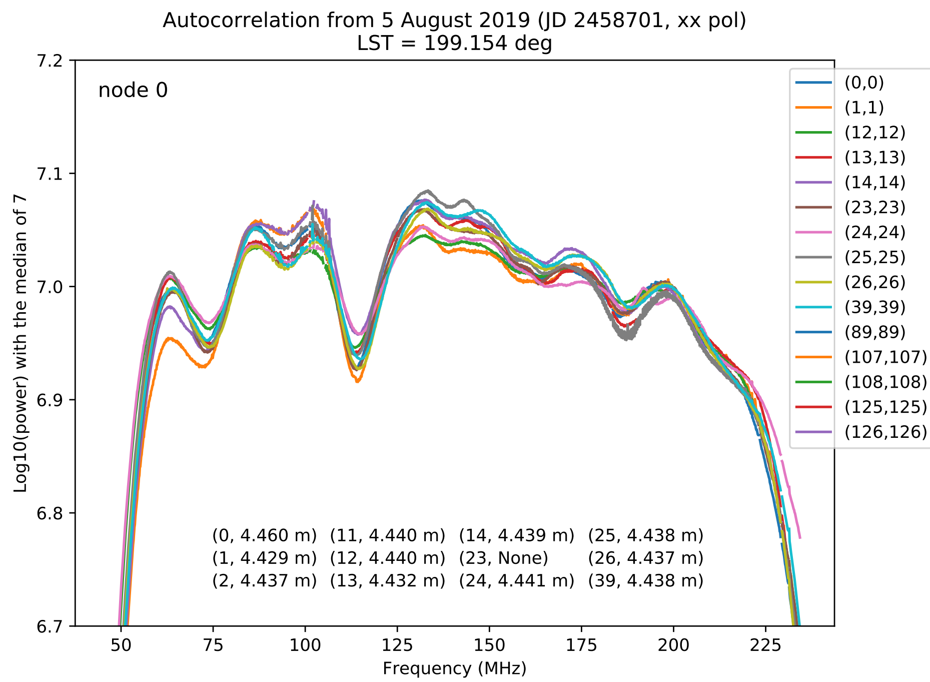

Figure 18. A set of autocorrelation plots for Node 0 antennas from data taken after the springs were placed in series with the lifting lines and the feeds were xyz positioned. An offset was added to each autocorrelation curve so the median value was 7.0. Note that only 8 of the 12 Node 0 antennas are displayed in the figure; the other antennas exhibited clearly bad signals (e.g. no input).

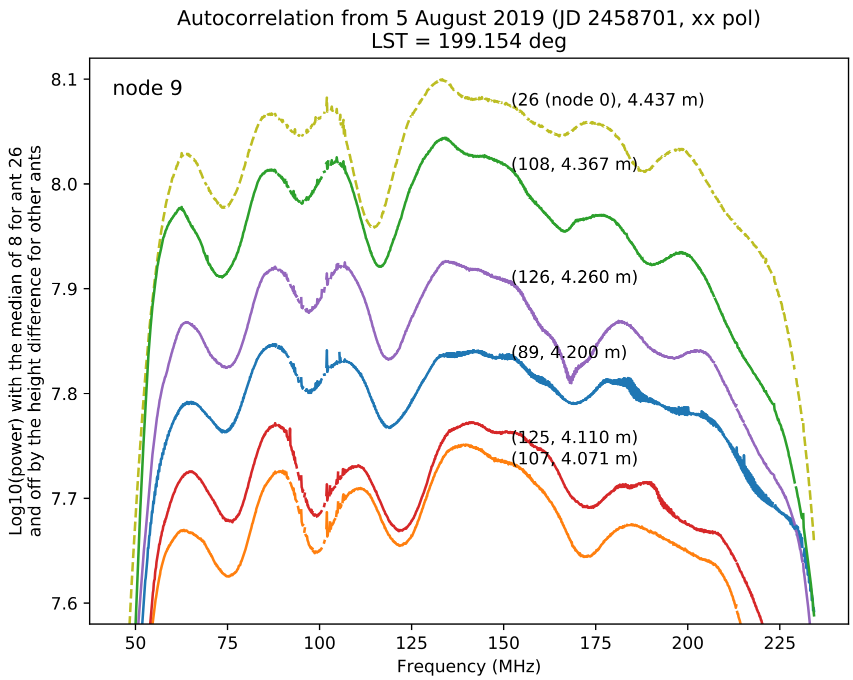

Figure 19. Autocorrelation plots for Node 9 antennas (feed and dish) and a single Node 0 antenna. , An offset was added to the plot of Node 0 antenna 26 so the median value was 8.0. The median values of the remaining curves are offset from 8.0 by the difference in height in centimeters between antenna 26 and the antenna plotted. The dish number and the feed height to the PVC circles in meters are shown. Note that the depths and frequencies of the peaks and valleys changes relatively smoothly for frequencies below 135 MHz.