A PROJECT TO BUILD AN 8.4GHz RADIO TELESCOPE Volume IV

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Contents *(continued from volume III)*

Note: page numbers herein are not referenced to previous volumes

7.0 AZ/EL ENCODER INSTALLATION

The azimuth and elevation encoders that will be used for the AZ/EL mount are US Digital Absolute Encoders model numbers: A2T-S-S-D and A2-S-B-D-M-D, respectively. Both are 12-bit digital encoders.

The azimuth encoder is a shaft encoder whereas the elevation encoder is an absolute inclinometer. Both utilize the US Digital SEI bus (https://www.usdigital.com/support/resources/reference/user-guides/sei-serial-encoder-interface-bus) to communicate with a host Windows computer via an SEI-USB bus adapter (https://cdn.usdigital.com/assets/datasheets/sei-usb_datasheet.pdf) to a general purpose USB port on the computer. The encoder output signals are read by a custom dish tracking program that will be described at a later time.

The AZ/EL encoder components are shown in the photo below.

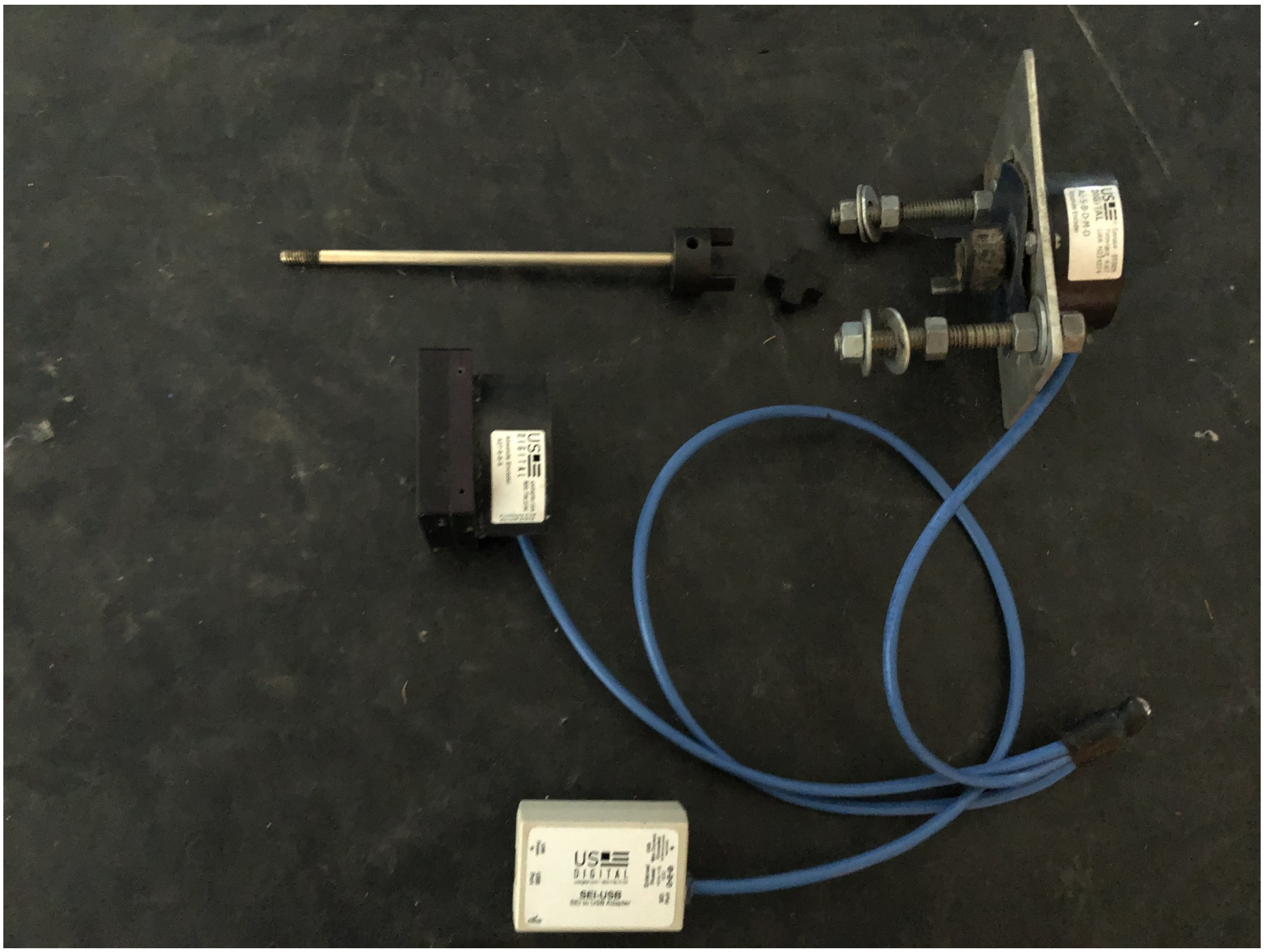

Figure IV-1. Components of the AZ/EL encoder hardware.

In the photo above, the azimuth encoder with its 3-piece flexible coupling assembly and ¼" diameter brass connecting shaft is shown at the top, the elevation absolute inclinometer is shown in the middle, and the US Digital SEI-USB bus adapter module is shown at the bottom. The shaft encoder and inclinometer mount onto the AZ/EL mount whereas the bus adapter will be located in the control room.

The photo below shows that the distance between the rotating plate of the AZ slewing bearing and the stationary bottom plate of the bearing is approximately 5". This distance needs to be included in the coupling shaft length of the AZ encoder.

Figure IV-2. Measurement of the distance between the rotating and stationary plates of the AZ slewing bearing.

The photo below shows the AZ encoder coupling shaft screwed into the rotating plate of the AZ slewing bearing.

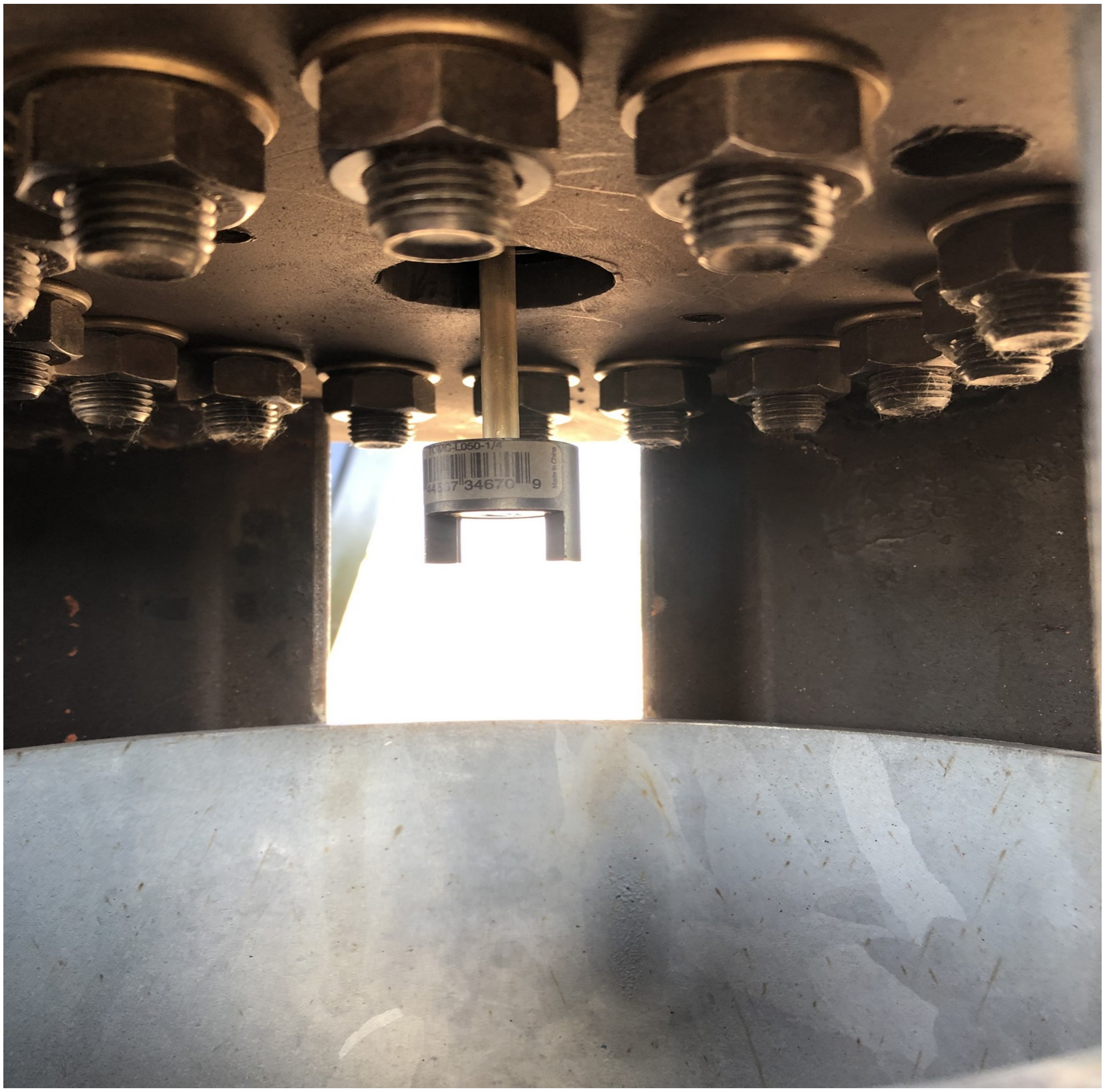

Figure IV-3. Test fitting of the upper half of the AZ encoder coupling shaft screwed into the rotating plate of the AZ slewing bearing.

The photo below shows that the initial length of the AZ encoder coupling shaft is about 1-1/2” too long to allow the lower portion of the coupling and encoder plate to be mounted onto the supporting studs.

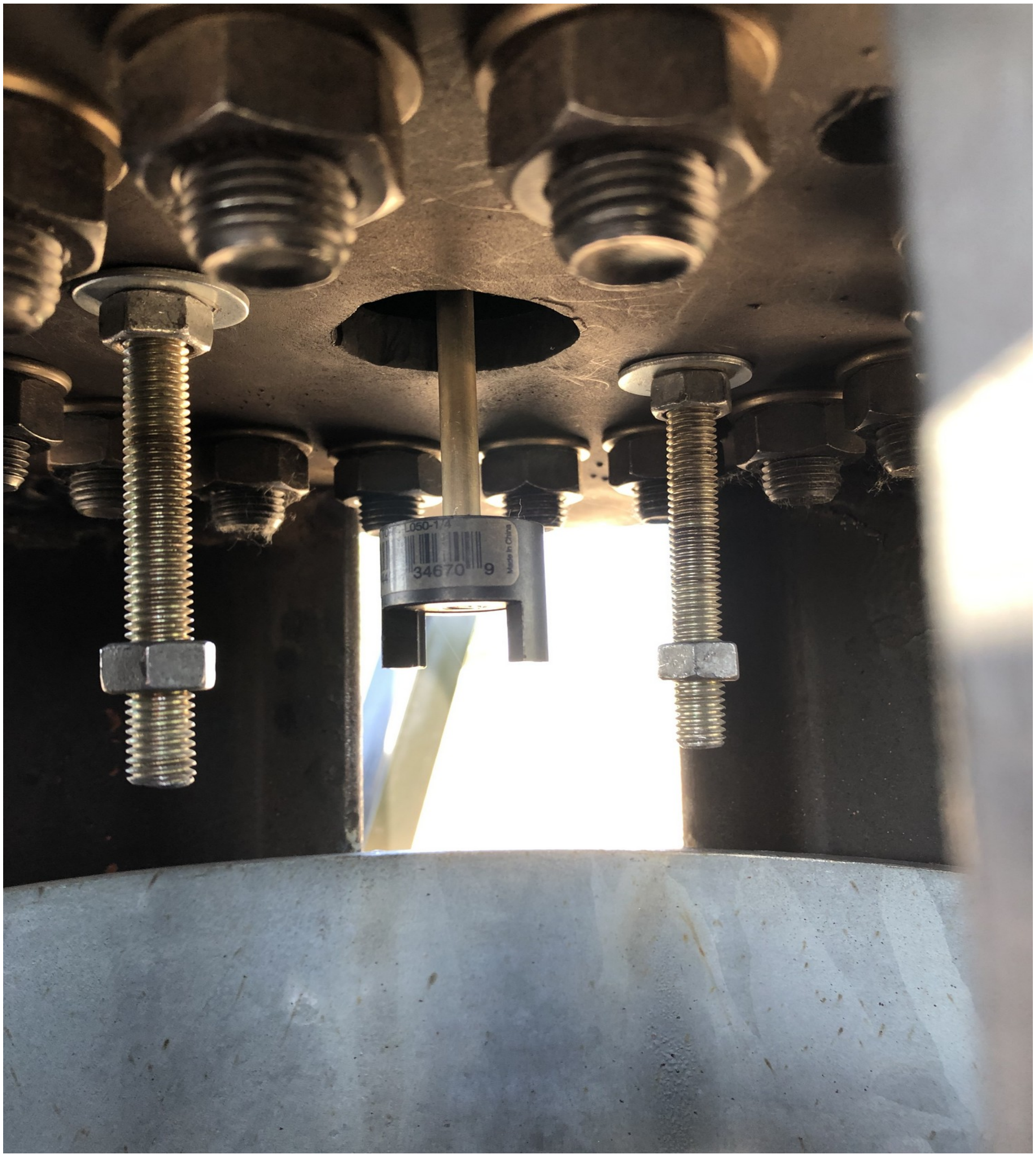

Figure IV-4. After installing the AZ encoder plate mounting studs into the stationary bearing plate it is seen that the coupling shaft should be trimmed about 1-1/2” shorter to allow room for the lower AZ encoder coupling, encoder body, and the encoder mounting plate.

The photo below shows the AZ encoder coupling shaft has been trimmed and the AZ encoder mounted.

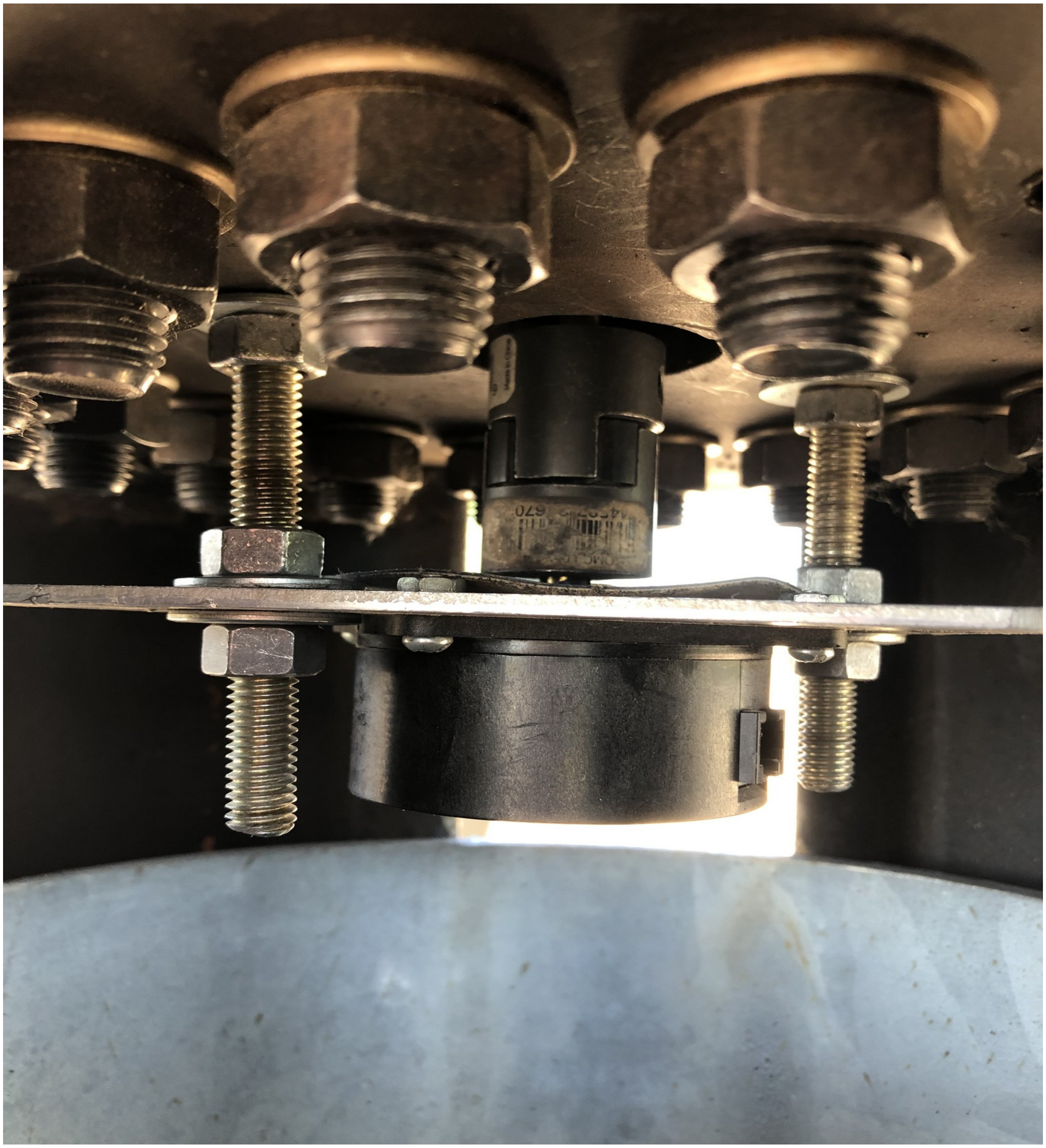

Figure IV-5. AZ encoder is installed, ready to be connected to the SEI bus cable.

The photo below shows the AZ encoder mounted and connected, ready for operation.

Figure IV-6. AZ encoder is installed.

The elevation encoder will be temporarily clamped onto the EL mount for testing, to be relocated onto the dish back structure once the dish is mounted onto the AZ/EL mount. The photo below shows the EL encoder temporarily clamped into a convenient position on the transition box of the EL mount.

Figure IV-7. EL encoder temporarily clamped onto the EL mount for testing.

The photo below shows the tracking program displays indicating that the AZ and EL encoders are functioning properly into the control room.

Figure IV-8. Tracking program testing of the AZ/EL encoders in the control room showing that both encoders are functioning properly.

Next the servo-motor drive units will be installed and tested for proper motion and control of the AZ/EL mount from the control room.

8.0 AZ/EL SERVO-MOTOR DRIVE UNITS INSTALLATION AND CHECKS

The two servo-motor driver modules that are used to drive the servo-motors in this project are Parker OEM670T servo drive modules. The operator manual for these modules can be viewed/downloaded at https://www.parkermotion.com/manuals/OEM670/OEM670_UG.pdf.

The photo below shows the two servo-driver modules that are used in this project.

Figure IV-9. Parker OEM670T servo-motor drive modules that are being used to drive the AZ and EL servo motors in this project.

The photo below shows the rear panel connections of the servo-driver modules.

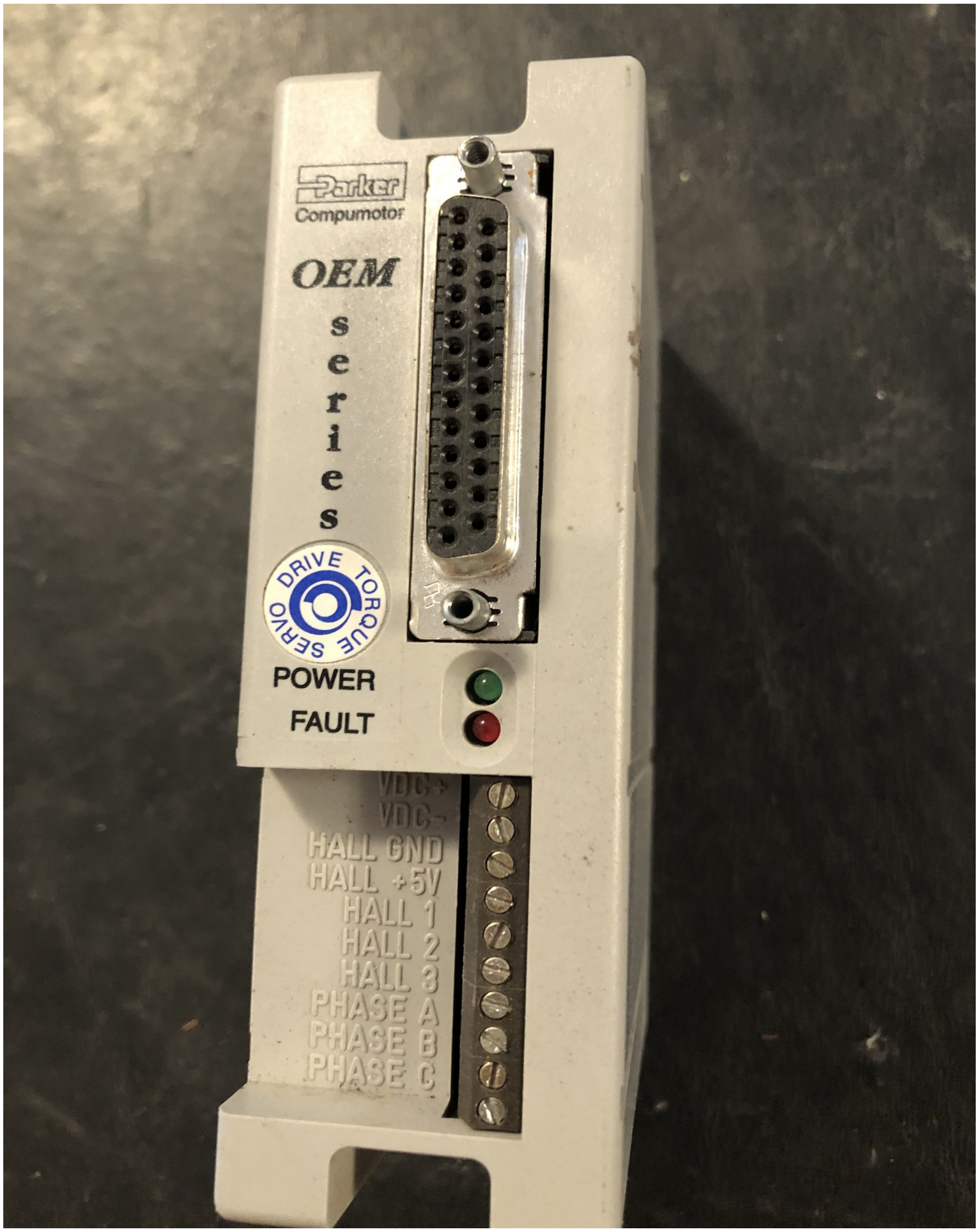

Figure IV-10. Input/output connectors of the Parker OEM670T servo-drive modules.

The photo below shows one of the servo-drive modules strapped to the bottom of the AZ servo motor and temporarily wired to AZ motion control lines from the telescope control room.

Figure IV-11. The AZ servo-motor driver module is strapped onto the AZ servo motor and temporarily wired to the AZ control lines from the telescope control room for testing and initial operations.

The photo below shows the EL servo-motor driver module strapped onto and below the EL servo motor and wired temporarily to the EL motion control lines from the telescope control room.

Figure IV-12. The EL servo-motor driver module is strapped onto and below the EL servo motor and temporarily wired to the EL motion control lines from the telescope control room.

The photo below shows the front view of the dish control panel in the telescope control room to which the servo-motor driver modules are connected.

Figure IV-13. Front view of the dish motion control panel. The panel controls include manual motion control switches, an AZ motion speed control, LEDs that indicate when motion is in progress, and a panel power switch.

The photo below shows the rear view of the dish motion control panel.

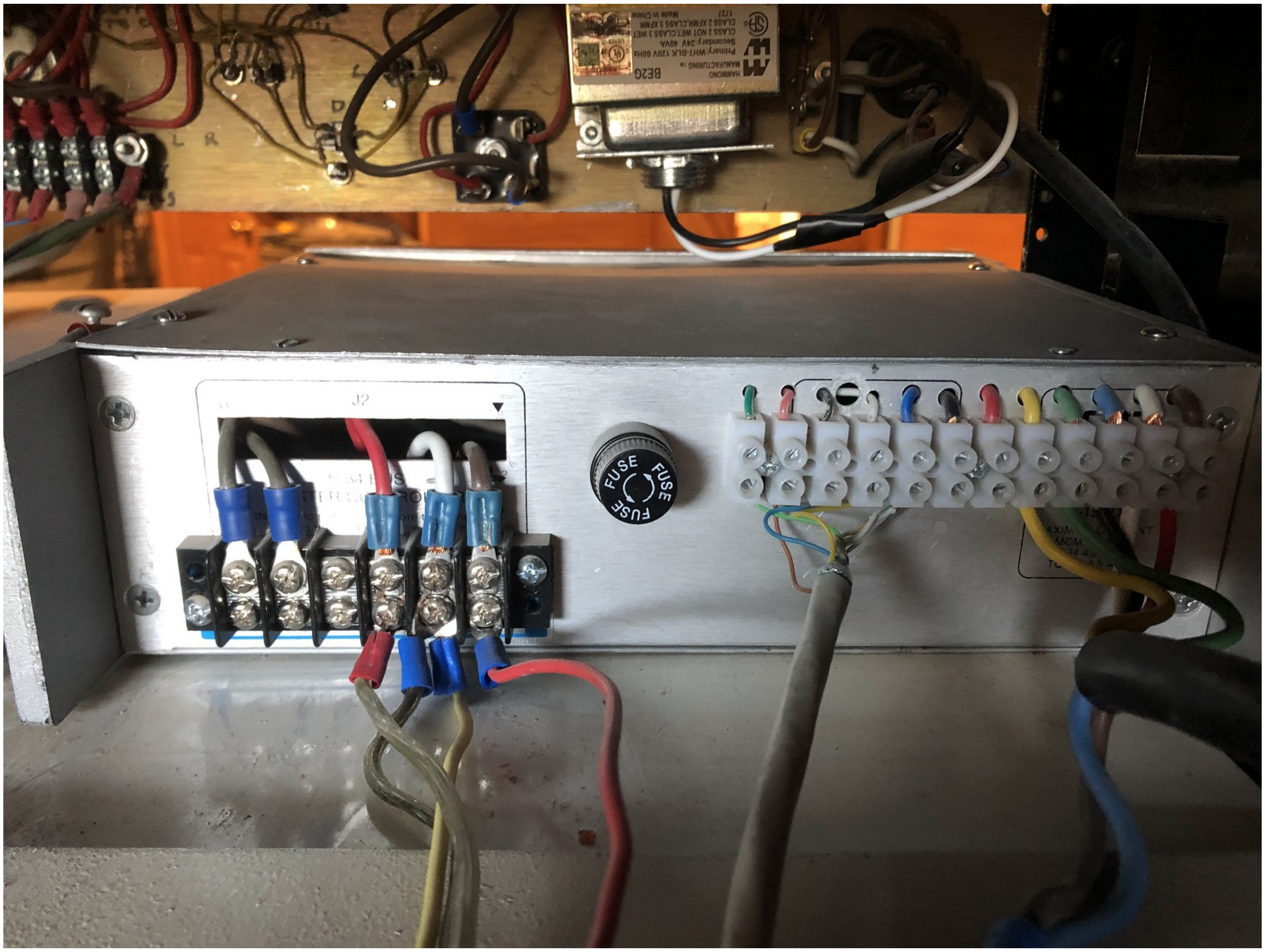

Figure IV-14. Rear view of the dish motion control panel.

The large gauge wires on the right side of the white terminal strip are connected to the servo-motor driver modules on the AZ/EL mount. The small gauge wires on the left side of the white terminal strip are input lines from a Weeder Technologies digital output module that interfaces with a tracking computer USB I/O port. The lines connected to the black terminal strip are inputs from external power supplies that are needed by the servo-motor driver modules.

The photo below shows an inside view of the dish motion control panel chassis which contains motion control relays and support circuitry.

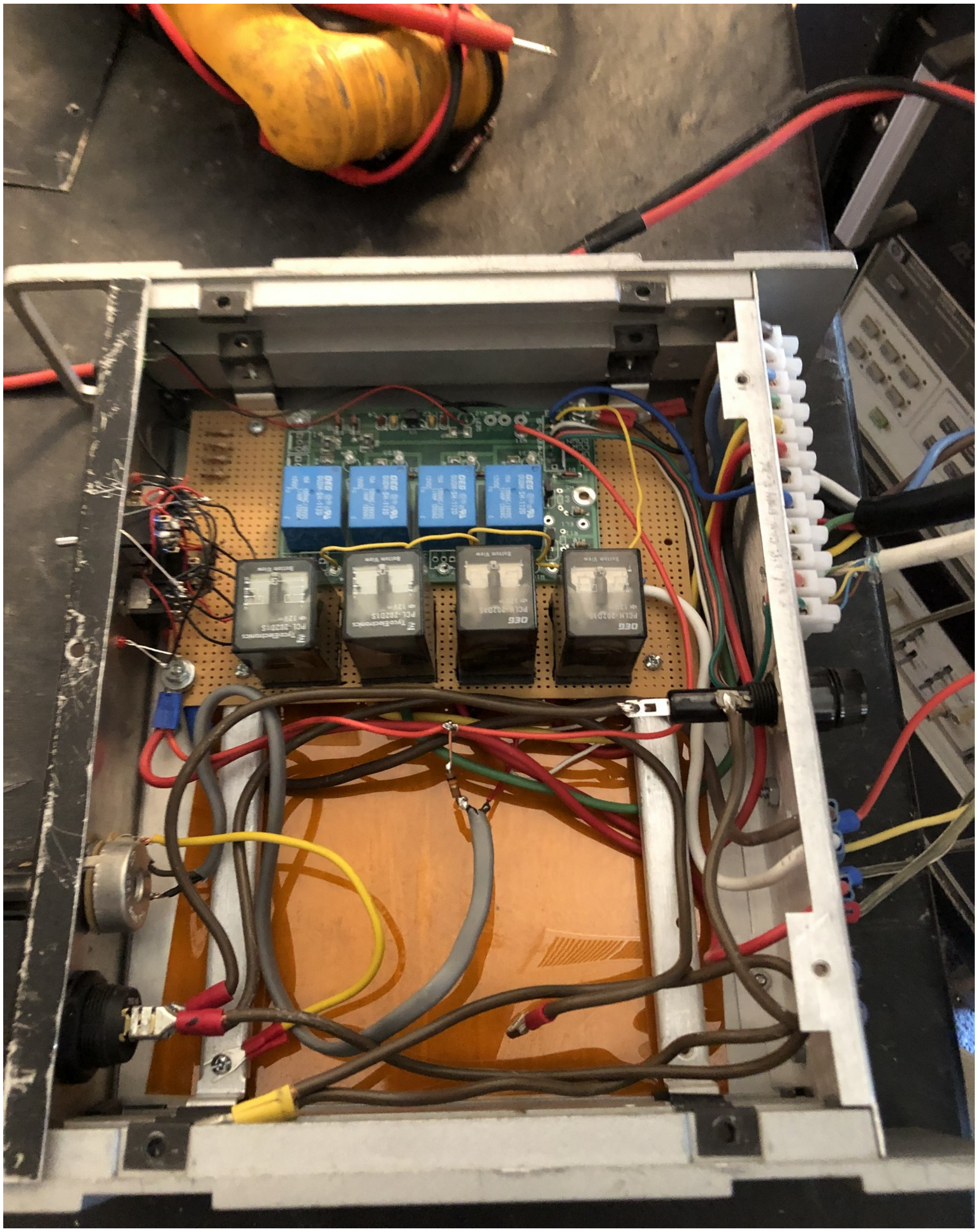

Figure IV-15. Inside view of the dish motion control panel chassis showing motion control relays and supporting circuitry.

The photo below shows the Weeder Technologies WTDOT-M digital output module that is used to interface the motion control panel to the dish tracking computer.

Figure IV-16. The Weeder Technologies WTDOT-M digital output module used to interface the dish motion control panel with a general purpose USB port of the dish tracking computer.

The user's manual for the Weeder Technologies WTDOT-M digital output module may be viewed/downloaded at

https://weedtech.com/wtdot-m.pdf.

The photo below shows a portion of the equipment rack containing the external power supplies that supply operating voltages to the servo-motor driver modules via the dish control panel.

Figure IV-17. View showing the two external power supplies that supply operating voltages to the servo-motor driver modules of the AZ/EL mount.

The 30 VDC power supply provides main board voltage for the servo-motor driver modules and the 10 VDC power supply provides motion command voltage for input to the servo-motor driver modules via the dish motion control panel connections/relays.

The photo below shows the operational AZ/EL mount ready to accept the 4.6m dish structure.

Figure IV-18. AZ/EL mount completed, including manual and computer-driven AZ/EL motion control from the telescope control room.

The AZ/EL mount is now operational and ready to accept the 4.6m dish structure.

9.0 FEED HORN SUPPORT STRUCTURE FABRICATION

The goal of this task is to build a feed horn supporting structure onto the 4.6m dish that is generic and versatile so that the dish and AZ/EL mount can be used for a variety of frequency ranges, from L band through 10 GHz, accommodating a variety of different style feed horns.

With this in mind it has been decided to use a hexagon-shaped feed horn mounting "ring" with at least a 12" inside diameter clearance to straightforwardly provide a means of attaching adjustable brackets that can be used to clamp cylindrical waveguide sections onto in such a way as to allow positioning of feeds in not only the "z" direction (i.e., along a line defined by the focal point and vertex point of the dish) but also in an "x, y" plane defined as a plane passing through the focal point of the dish and perpendicular to the vertex-focal-point line mentioned. The hexagon will be fabricated from 1.5" square aluminum tube of 1/8" wall thickness and will be attached to three 82" long 1.5" square aluminum tube support arms of 1/8" wall thickness. At the attachment points steel will be used in the form of transition brackets with bolts passing through the aluminum and steel components. The details of the transition brackets will be shown as they are being fabricated.

The photo below shows the initial cutting of 1.5" square aluminum tube (6061 alloy) at a 30 degree angle to form one side of the hexagon mounting ring.

Figure IV-19. Cutting a 30-degree angle for an end of a side of the hexagon mounting ring.

The photo below shows the hexagon mounting ring sides clamped into position for welding.

Figure IV-20. Hexagon mounting ring components are clamped into position for welding.

The photo below shows the hexagon ring components welded together.

Figure IV-21. The hexagon feed horn mounting ring sides are welded together.

The aluminum welding was done by the author using a spool gun attachment of a MIG welder running at minimum power output with Ar gas flowing. The spool wire was 0.035” diameter ER5356 aluminum alloy.

The photo below shows one of the slots of the three slotted feed horn supports being cut using a manual motion table of a horizontal mill.

Figure IV-22.   Slots being milled into square aluminum tubes that will become adjustable feed horn supports.

The photo below shows how the slotted feed horn supports will be attached to the hexagon ring structure.

Figure IV-23. Photo showing how the slotted feed horn supports will be attached to the hexagon ring.

The photo below shows that the minimum radius circular waveguide/housing that can be used is about 2.5” (5” dia) and can adjust to accommodate a maximum radius of about 5” (10” diameter). The

8.4GHz LO/feedhorn assembly housing that will be used on the telescope has a diameter of 8” which easily fits in the space available of this feed horn mounting scheme.

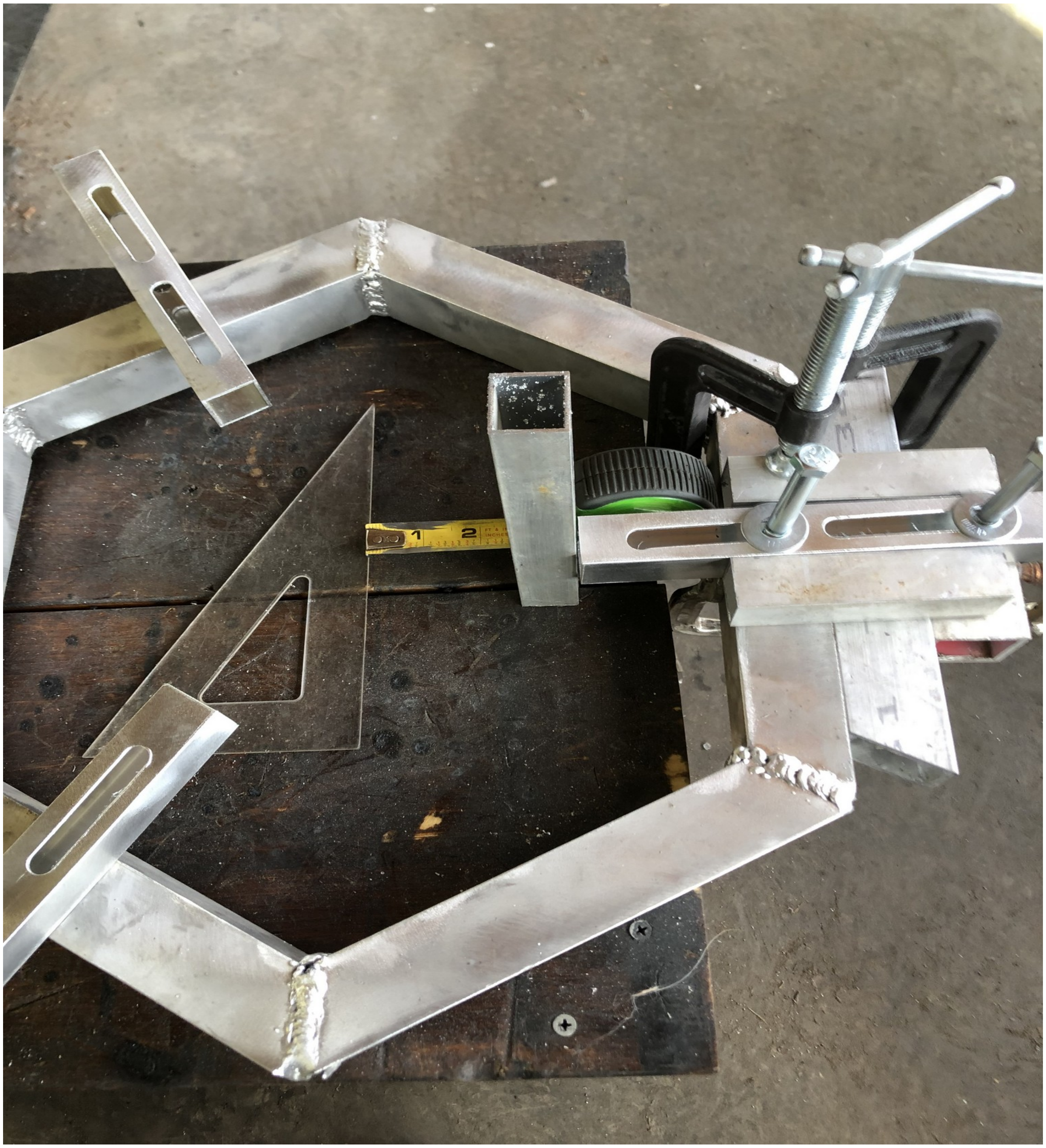

Figure IV-24. An initial measurement of the minimum radius that can be used with this feed horn mounting scheme. A maximum feed diameter of about 10” can be accommodated with adjustment of the supports in the slots.

As indicated in the photo above, a perpendicular piece of square tube will be welded onto each slotted feed support to form a “tee” such that the top of each tee can be placed along the z-axis of a cylindrical waveguide or waveguide housing and held in place using two large hose clamps, strapping around each end of each tee and enclosing all three tee supports with the feed horn z-axis in the middle of the tees to put the feed horn phase center in the proper position.

Rather than welding the main elements of the feedhorn support onto the hexagon ring the decision is to bolt the elements together and onto the hexagon instead. This will allow for the most versatility and flexibility for the hexagon ring later if a different design for the three support tee structure needs to be implemented. In such a case the present design can be unbolted and removed leaving space for whatever new design might be desired.

The photo below shows the first step in fabricating the feedhorn support structure, bolting two 5” long 1.5” square tube spacers onto a side of the hexagon ring using 3/8”-16 all-thread lengths.

Figure IV-25. Two spacers are bolted to a side of the hexagon mounting ring.

The photo below shows the two top guides for a side clamped into position on the spacers, ready for drilling and bolting into place.

Figure IV-26. The two guides for the slotted support are clamped into position ready to be drilled and bolted onto the spacers and hexagon.

The photo below shows the guides bolted into place on the hexagon ring.

Figure IV-27. Two guides for the slotted support for this hexagon side are bolted into place using through 3” long 3/8”-16 bolts with nuts on the underside.

The photo below shows a completed adjustable feed horn support for one side of the hexagon.

Figure IV-28. One side of an adjustable hexagon feed horn support assembly is now completed and installed, including welding an off-center cross member to the slotted support.

A 10” long piece of 1” square tube was welded as a cross piece onto the slotted support to form a tee structure. The tee may be moved in or out along the slots as necessary and tightened to accommodate different diameter feed horns. The cross piece was welded off-center onto the slotted support to maximize versatility of the mount when using feed horn assemblies of varying lengths and phase center positions. Two similar additional assemblies will now be fabricated and installed onto the hexagon ring to provide a three-sided support system for a feed horn or feed assembly.

It is expected that this feed horn support design will prove to be sturdy, compact, easy-to-build, versatile, adjustable, and even removable should a different scheme be desired later. The remaining three unused sides of the hexagon ring will serve as attachment positions for three long feed system support struts that will attach to the steel back structure of the dish.

The photo below shows all three feed horn supports fabricated and installed on the hexagon ring.

Figure IV-29. All three adjustable feed horn supports are now fabricated and installed on the hexagon ring.

Next will be to fabricate and install the long feed system support struts, including making the steel transition elements for the ends of the three struts.

The plan is to use steel brackets for both the upper and lower end attachments. For the upper brackets 2"x1"x1/8" thick steel channel pieces will be used. The photo below shows six 5" long channel iron pieces cut for the upper end brackets.

Figure IV-30. Channel iron pieces cut for the upper end bracket fabrication.

The photo below shows one of three of the pieces marked for cutting at a 45 degree angle to match the angle that the long feed horn support struts form with respect to the hexagon feed horn mounting ring sides.

Figure IV-31. One of three bracket pieces marked for cutting of the required angle to be welded.

The photo below shows fitting of two of the pieces together prior to welding with marks shown for drilling attachment bolt holes.

Figure IV-32. Fitting of two elements together for an upper end bracket, with drill hole positions marked for the attachment bolts.

The photo below shows an upper end bracket drilled and clamped for welding.

Figure IV-33. An upper end bracket drilled and clamped for welding. Note the use of two welding magnets used to keep the angled piece in place during welding.

The photo below shows the bracket after welding.

Figure IV-34. An upper end bracket after welding.

The upper end steel brackets were welded using a 0.035” diameter wire feed MIG welder with Ar 75% - CO_2 25% flowing gas mixture.

The photo below shows all three upper end brackets after painting and installation onto the hexagon feed horn mounting ring.

Figure IV-35. Upper end feed horn strut brackets are completed and installed on the hexagon feed horn support ring. The upper end of the feed horn support structure is now complete.

The feed horn end of the feed horn support assembly for the dish is now complete and ready for installation of a feed horn assembly. Next task is to cut the three long feed horn support struts and fabricate lower end steel brackets to attach the lower ends of the struts to the dish back structure.

The photo below shows cutting 1.5” square aluminum tube to the appropriate lengths for the feed horn support arms.

Figure IV-36. The three feed support arms being cut to length.

The photo below shows a feed support arm being drilled and bolted onto the hexagon mounting ring bracket.

Figure IV-37. Long feed support arm being drilled and bolted onto the hexagon mount.

The photo below shows the three feed support arms installed onto the hexagon mounting ring.

Figure IV-38. The feed support arms are bolted onto the hexagon mounting ring.

The photo below shows the feed support structure positioned onto the dish surface ready for fabrication and fitting of the lower steel brackets.

Figure IV-39. Feed support structure is fitted onto the upper surface of the dish in preparation for fabrication and installation of the lower attachment brackets.

The photo below shows a close up of the positioning detail for fabrication of the lower end bracket for the support arm, through the dish surface.

Figure IV-40. Lower end support arm positioning detail for fabricating and fitting of a lower end steel mounting bracket.

The photo below shows the under side of the dish at the pass through hole and the dual vertical support posts of the dish back structure to which the lower end of the feed support arms must attach.

Figure IV-40. Under side connection point of the dish back structure to which the feed support arm bracket must attach.

The lower end brackets will be fabricated using parts cut from a 3/8” thick steel plate and 5” long pieces of channel iron. The photo below shows the components that will be used in the fabrication.

Figure IV-41. Parts are shown that will be used in the fabrication of the lower end brackets for the feed support arms. One bracket part (left) is shown cut and drilled for bolts and is shown with a clevis installed at the corner. The clevis will be used when the dish is lifted by a crane. The plate (right) is marked to cut two additional bracket elements. The three channel iron pieces (upper right) will be welded to the plate elements to form the completed brackets.

The photo below shows the plate (left) after drilling the required bolt holes and prior to cutting the two bracket elements from it.

Figure IV-42. Plate (left) drilled and marked prior to cutting the bracket elements. A cut and drilled bracket element is also shown (right).

The figure below shows a completed lower end bracket consisting of the bracket plate element welded to a channel iron element and installed on a feed support arm.

Figure IV-43. A completed lower end feed support arm bracket. Note the top hole that will be used to attach a clevis for assistance in lifting the dish later.

The photo below shows the attachment of the lower end support arm bracket to the dish back structure.

Figure IV-44. A view showing how the lower end support arm bracket bolts onto the steel dish back structure.

The photo below shows a completed lower end support arm bracket installed on a support arm including a clevis for later lifting support when positioning the dish onto the AZ/EL mount.

Figure IV-45. A completed lower end feed support arm bracket installed onto a support arm including a utility clevis for later use in lifting the dish into position.

Each of the three feed support arm lower end brackets will have a clevis installed to help keep the dish properly oriented when the dish is being lifted into position by a crane using two eye bolts installed onto the center ring of the dish. The eye bolts will take the majority of the weight load during the lift.

This completes the feed support system fabrication and installation. The dish is now ready to be moved to the AZ/EL mount and lifted by crane onto the top of the AZ/EL mount for installation.

10.0 INSTALLATION OF THE DISH ONTO THE AZ/EL MOUNT

The dish will be moved to a location near the AZ/EL mount so that a light crane can lift the dish onto the mount. However, before engaging a crane to come it will be necessary to modify the square mating bracket atop the AZ/EL mount by drilling a new set of "pick point" through holes.

Using the current set of through holes would result in one of the feed support arms of the dish being located at the top of the dish when the dish is pointed at the horizon. It has been decided that a better mounting orientation would instead place a feed support arm at the bottom of the dish when the dish is pointed at the horizon because a bottom orientation would allow a more direct cable routing from the tower to the feed horn mounting ring up the support arm and would more be useful and more accessible as a mechanical marking feature for the dish when initially calibrating azimuth pointing angles.

The modification necessary to achieve a bottom oriented arm requires drilling a new set of "pick point" through holes through the square mating bracket that is rotated 180 degrees relative to the existing set of through holes. To accomplish this task while preserving hole alignments with the dish back structure triangle it will be necessary to fabricate a rigid drilling template based on the existing hole locations. Such a template will be fabricated by first bolting a steel plate at each through hole location then welding connecting re-bar rods between adjacent plates to form a connected-plate template that can be unbolted and rotated 180 degrees on the square mating bracket to permit accurate positioning for drilling the new set of through holes.

Moving the dish to be near the AZ/EL mount and the "template fabrication" are the next tasks to be completed.

Photo below shows the dish being transported to the AZ/EL mount location.

Figure IV-46. 4.6m dish being moved to the AZ/EL mount location.

If the photo above is enlarged one can see that the stiffening beams in the triangle base of the dish back structure are not flexing during transport even though the fork extensions clearly are. This demonstrates that the back structure stiffening beams are functioning as expected under this load.

The photo below shows the dish positioned near the AZ/EL mount ready for a crane to lift it into position atop the AZ/EL mount for installation.

Figure IV-47. 4.6m dish in position near the AZ/EL mount ready for a crane to lift it into position atop the AZ/EL mount for installation.

Next task is to fabricate a rigid drilling template for rotating the through hole bolt pattern currently atop the AZ/EL mount by 180 degrees so that a feed support arm of the dish will be at the bottom of the dish when the dish points to the horizon rather than at the top.

10.1 FABRICATION OF A RIGID DRILLING TEMPLATE

The photo below shows cutting six bolt plates that will be used to form the rigid drilling template.

Figure IV-48. Cutting six 6" square bolt plates that will form the rigid drilling template.

The photo below shows drilling a center hole for one of the template plates.

Figure IV-49. Drilling a center bolt hole in one of the rigid template plates.

The photo below shows the six plates that have center bolt holes drilled.

Figure IV-50. Center bolt holes have been drilled in the six rigid template plates.

The plates are ready to be bolted onto the rectangle mating structure atop the AZ/EL mount prior to connecting the plates with rebar to form the rigid drilling template.

The photo below shows rebar clamped onto one of the template plates prior to welding.

Figure IV-51. Rebar clamped onto a plate of the rigid template being fabricated prior to welding.

The photo below shows the rebar connections between plates being welded to the plates.

Figure IV-52. Rebar connecting rods being welded onto the template plates.

The photo below shows a corner plate with two welded rebar connections.

Figure IV-53. A corner of the rigid template after welding of two rebar connections.

The photo below shows two plates of the rigid template in position after rotating the template 180 degrees on the rectangle mating structure.

Figure IV-54. Two plates of the rigid template in position after rotating the completed template 180 degrees.

The photo below shows the completed rigid drilling template clamped onto the top structure of the AZ/EL mount ready for marking of the hole positions and drilling of the new pick-point holes.

Figure IV-55. Rigid template completed and clamped onto the top member of the AZ/EL mount in preparation for hole marking and drilling.

Fabrication and positioning of the rigid drilling template is completed. Things are now ready for marking and drilling of the new pick-point through holes.

10.2. DRILLING OF NEW PICK POINT HOLES

The rotated pick point hole pattern will be drilled through the rectangle mating structure using the rigid drilling template that is clamped to the top of the AZ/EL mount to specify the new hole locations.

The photo below shows that the new hole positions are marked using white paint to define the hole and a center punch mark to specify the hole center.

IV-56. New hole positions marked with white paint and center punched.

The photo below shows the magnetic drill press in position to drill a new through hole.

Figure IV-57. A magnetic drill press in position to drill new through holes.

The photo below shows a through hole drilled in four steps to 7/8” starting with a 7/32” diameter drill.

IV-58. A 7/8” diameter through hole has been drilled using a magnetic drill press.

The rotated through hole pattern has now been drilled on the rectangle mating structure. The AZ/EL mount is now ready to accept the dish.

10.3 LIFTING OF THE DISH

The photo below shows a test lifting of the dish by the crane, checking balance of the lift rigging and checking whether or not anti-tilt rigging would be necessary.

Figure IV-59. Test lift of the dish by the crane. Rigging and balance look good.

A test lift by the crane shows that simple strap connections to the two center eye bolts is all that is required as the dish is well balanced and does not tend to tilt one way or another during lifting. The crane registered that the dish weighs about 1800 lbs, in excellent agreement with the pre-lift estimate we gave to the crane company when we scheduled the crane initially. No significant stress was experienced by the aluminum hexagon feed mount by the lifting straps passing through the hexagon.

The photo below shows the dish being set onto the AZ/EL mount by the crane.

Figure IV-60. The dish is being set atop the AZ/EL mount by the crane.

The photo below shows bolt tightening after the dish was set atop the AZ/EL mount.

Figure IV-61. Bolt tightening after the dish was set onto the AZ/EL mount just as heavy rain began falling.

Installation of the dish was done in a light rain with heavy rain beginning just as the final bolts were tightened. It had been raining off and on all week and more was forecast so we were lucky to be able to complete the dish installation as we did without having to wait for drier weather.

The photo below shows the safely installed dish just as rain began falling.

Figure IV-62. Dish installation completed as rain began falling. Timing was fortuitous.

Only minor work needs to be done on the dish now, such as removal of the center eye bolts and installation of the center plate which will be done later with the dish pointed at the horizon.

THIS COMPLETES THIS SECTION AND COMPLETES VOLUME IV of the real-time documentation series. Further work will be reported in volume V:

http://www.k5so.com/project_to_build_an_8.4GHz_radio_telescope_volume_V.pdf