Installing the LWA Antenna at Cohoe Radio Observatory

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1. Introduction

The Long Wavelength Array (LWA) antenna is a sloping crossed-dipole originally designed to be used in large arrays of 256 antennas. However, the antenna also has proven to be quite useful in single installations and small arrays of two to eight antennas. This paper describes through a chronological series of pictures the construction of a single LWA antenna at Cohoe Radio Observatory in southcentral Alaska (figure 1). This information may be useful to future users as a supplement to the *Guide to Antenna Assembly* supplied with the LWA antenna.

Figure 1 ~ LWA antenna installed at Cohoe Radio Observatory during May and June 2017. This single antenna is used for studying solar radio emissions and HF and low VHF propagation. The antenna is built on a gravel pad and protected from marauding moose by a simple wood barrier. Image © 2017 W. Reeve

2. Antenna Description

The LWA antenna is an active inverted-V design whose dipole elements consist of triangular wings or blades. Two dipoles form a crossed-dipole assembly that has a frequency range from below 5 to approximately 90 MHz. The dipole elements are made from welded 3/4 in (19 mm) square aluminum tubes. The element frames are factory welded and supplied as four subassemblies along with a 1.5 m long mast, four pre-assembled fiberglass rod support frames, enclosure for the front-end electronics and all hardware. The total weight of one antenna is approximately 44 lb (20 kg) about half of which is the heavy-duty steel mast. Only a few ordinary tools are required for assembly.

A dual active balun, or front-end electronics (FEE), is located at the vertex of the dipoles. The balun converts the balanced dipole to unbalanced 50 ohms impedance for connection to a coaxial cable transmission line and also provides 35 dB gain (figure 2). The FEE is powered through the coaxial cables by bias-tees in an LWA power coupler located at the equipment enclosure. The FEE noise figure is 2.7 dB and, because of its relatively high gain, determines the system noise figure in most systems. Additional technical details for the antenna including radiation patterns are given in {Reeve14-2}.

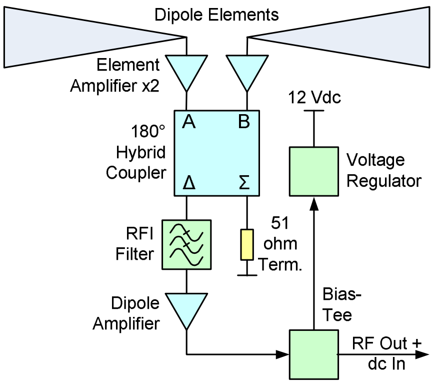

Figure 2.a ~ Front-End Electronics (FEE) block diagram. The currents produced in each dipole element are coupled directly to an amplifier with about 25 dB gain. The amplified outputs from the two elements are connected to a 180° hybrid coupler that combines them in phase. The output from the hybrid coupler is filtered and then amplified by about 12 dB. The total gain from the elements to output is about 35 dB. The noise temperature is 250 K (2.7 dB noise figure). The active balun itself has a usable frequency range of 500 kHz to 115 MHz. Image © 2014 W. Reeve

Figure 2.b ~ FEE printed circuit board dual assembly. This image shows one of two printed circuit boards (PCB), which are fastened together such that they face opposite directions. The two PCBs are identical in all respects with two exceptions: 1) Only one PCB has a power indicating LED; and 2) The directions of the SMA-F connectors are different (one is mounted on the front, or component, side of one PCB and one is mounted on the back of the other PCB). The assembly is mounted in an enclosure hub with the connectors facing down into the hub where they connect to the coaxial cable transmission lines. The dipole elements connect to the gold mounting rings near each edge of the PCBs. The 180° hybrid coupler is the white rectangular block in the middle of the PCB. One corner of the assembly is cut off for alignment in the FEE enclosure. Image © 2019 W. Reeve

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3. Site Preparation

Figure 3 ~ A 25 x 25 ft (8 x 8 m) gravel pad was built for the LWA antenna. It has a light dusting of snow soon after being finished in mid-October 2016. The pad location and corners were staked and an excavator was used to remove the peat and clay overburden and tree roots from the pad area to a depth of about 4 ft (1.2 m) – down to the underlying glacial moraine gravel from the last Ice Age. Next, the area to the right of the image was excavated to mine the gravel for the pad. Finally, the pit excavated during the mining was backfilled with the debris and leveled. The pad was left to settle over the winter until May 2017. Image © 2016 W. Reeve

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4. Antenna Mast and Ground Grid Installation

Figure 4 ~ The first order of business in May 2017 was to locate the center of the pad and drive the galvanized steel OZ-Post ground stake that supports the antenna mast. The stake was hand-driven with a weighted driver – the red tubular structure with handles on top of the mast. The stake penetrates the ground about 28 in (0.9 m) and provides a very stiff foundation. The mast was held vertical during the driving operation with the aid of a post level strapped to the mast just below the driver. A collar clamps the mast in position on the stake collet. The collar can be seated with a heavy hammer and a wood block but I used the yellow purpose-built tool on the ground in the left foreground of the image. Image © 2017 W. Reeve

Figure 5 ~ After the stake and mast were installed, the 10 x 10 ft (3 x 3 m) ground grid was placed on the pad and centered on the mast. The mesh is oriented north-south and east-west, the same as the dipoles. It is held down in several places with yellow plastic tent stakes. Note the milled slot (black line) in the lower part of the mast. A modified type E PVC conduit fitting is attached later over the slot and the coaxial cables are then fed up through the conduit fitting into the mast and up to the FEE located at the top. Image © 2017 W. Reeve

Figure 6 ~ Ground grid details. The grid is made from 4 ft (1.2 m) wide rolls of 14 AWG (2 mm) galvanized welded steel garden fence mesh. To obtain the required overall dimensions, three overlapping sections were joined with swaged Nicopress splicing sleeves. The wires were cut in the center of the grid to accommodate the mast. Two yellow tent stakes, which hold the grid down, are visible in the left and right foreground. The grid does not need to be bonded to the mast. Image © 2017 W. Reeve

Figure 7 ~ Pad, mast (center of image) and ground grid ready for installation of transmission lines and remaining antenna components. This image was taken on 7 May 2017 before the ground cover and deciduous trees turned green. The antenna is 40 ft (12 m) from the observatory building. Image © 2017 W. Reeve

5. Transmission Line Conduit and Moose Fence

Figure 8 ~ Liquid-tight, flexible, non-metallic conduit was installed below the ground grid and in a shallow trench to the observatory building seen in the background. The conduit is 1 in trade size and 50 ft (15 m) long. It ends under the left side of the building. Before backfilling the trench, two LMR-240 coaxial cables (6 mm diameter) were pulled through the conduit; excess lengths of cable are barely visible hanging over the top of the mast. SMA-M connectors at the FEE end were installed before the cables were pulled through the conduit. The observatory ends were connectorized later. Image © 2017 W. Reeve

Figure 9 ~ Conduit installation detail. As mentioned above, the mast is milled to accept the modified conduit fitting supplied with the antenna. The fitting is fastened to the mast with two screws. In most installations the conduit is simply slipped up into the conduit fitting without a conduit connector, but I later installed a connector to reduce movement of the conduit during the freeze-thaw cycles at this sub-arctic location. In many installations, only a short piece of conduit is used to protect the coaxial cables from rodents and the cables are direct-buried. Image © 2017 W. Reeve

Figure 10 ~ View of the pad and back of the observatory; the 1.5 m high antenna mast is visible in the center of the image. From the beginning of this project I knew a fence would be needed to protect the antenna from rampaging moose that frequent the area. Rather than wait until the antenna was in place, I decided to build the fence before assembling the antenna. Treated deck wood material provides longevity for the fence and has been delivered and stacked in the left corner of the pad. Image © 2017 W. Reeve

Figure 11 ~ The moose fence was built in four sections, three of which are placed close to final position on the pad in this image. The fourth section at left is ready to be moved onto the pad. I originally planned to use ground stakes for the fence posts but later decided to make the fence sections easily movable by fastening them to cross-braces. The fence uses only enough material to prevent moose from getting close to the antenna and hopefully not significantly disturbing the antenna pattern. The only metal used in the fence is in the screws used to hold the pieces together. These screws are compatible with the chemicals used in the wood treatment. Image © 2017 W. Reeve

6. Antenna Assembly

Figure 12 ~ A sawhorse holds the four triangular tie and link frames, which have been fastened to the cast steel flange fitting at center. The assembly supports the four dipole elements – two for each dipole of the crossed-dipole assembly. The triangular supports are made from solid fiberglass rods fastened to trapezoidal blocks at the vertices of each triangle assembly. The four individual frames are supplied preassembled. Note the ground grid. Image © 2017 W. Reeve

Figure 13 ~ The completed flange and fiberglass frame assembly has been slipped over the mast and is resting on the conduit fitting. By this time the excess coaxial cable has been pulled back to top of mast. Image © 2017 W. Reeve

Figure 14 ~ FEE hub baseplate installed on the mast. The clamp at the base of the hub has not been tightened. Note the two coaxial cables have been taped to keep moisture out. Prior to being pulled through the conduit, the cables were marked at both ends with green and red colored tape for identification. Image © 2017 W. Reeve

Figure 15 ~View looking north shows the first pair of dipole elements that have been placed and oriented. Before the clamp on the top hub and the fasteners on the support frame flange and elements are tightened, the elements are rotated to the desired direction and the fiberglass triangular frames are leveled. In the LWA, all antennas are referenced to true north (dipole elements are oriented north-south and east-west). In single antenna applications specific orientation is not necessary; however, at CRO, the antenna is referenced to true north in case I decide to install additional antennas for a future array. Image © 2017 W. Reeve

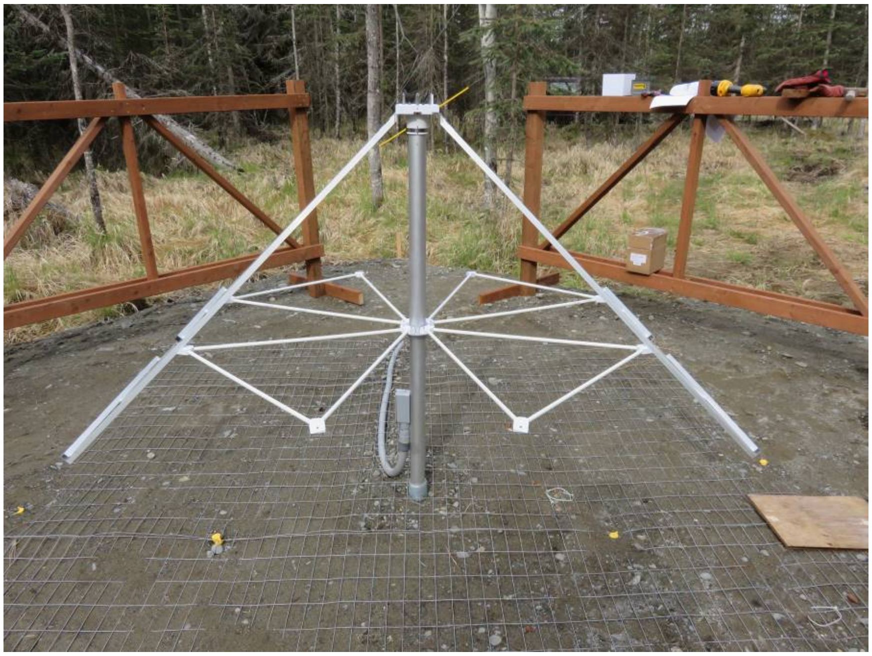

Figure 16 ~ Another view of the north-south dipole. This view is looking west. The elements of each dipole form a right angle at their vertex. During assembly the fasteners are not fully tightened until all the components have been placed and aligned. Image © 2017 W. Reeve

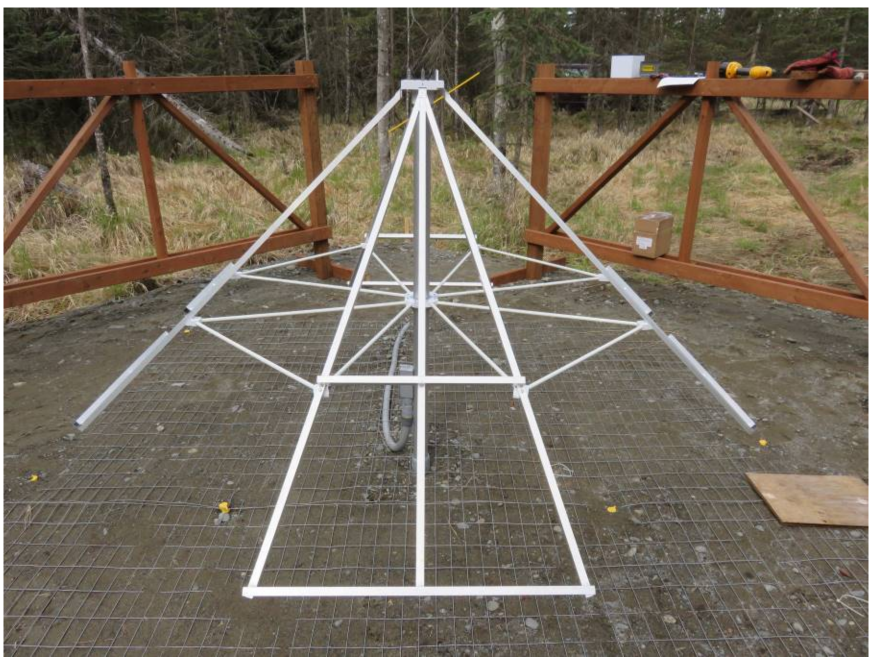

Figure 17 ~ Second dipole (facing east-west) has been placed. View is looking west. At this point, the mechanical assembly is finished, all fasteners are tight and only the FEE needs to be installed. Image © 2017 W. Reeve

Figure 18 ~ Another view of the crossed-dipole assembly after mechanical assembly has been finished. Image © 2017 W. Reeve

Figure 19 ~ View of the support flange and fiberglass frames. The bottom of the flange (not visible) has set screws for securing it to the mast after the link and tie rod frame assemblies are set at the proper height and are level; when all parts are properly assembled the tie and link rods are perfectly horizontal. Image © 2017 W. Reeve

Figure 20 ~ Closeup view of the fiberglass frame support flange. All fasteners are stainless-steel; the ones shown here that hold the trapezoidal blocks to the flange are 10-32 hex head machine screws. Also visible here are the small holes in the blocks for pins that secure the fiberglass rods to the blocks. Image © 2017 W. Reeve

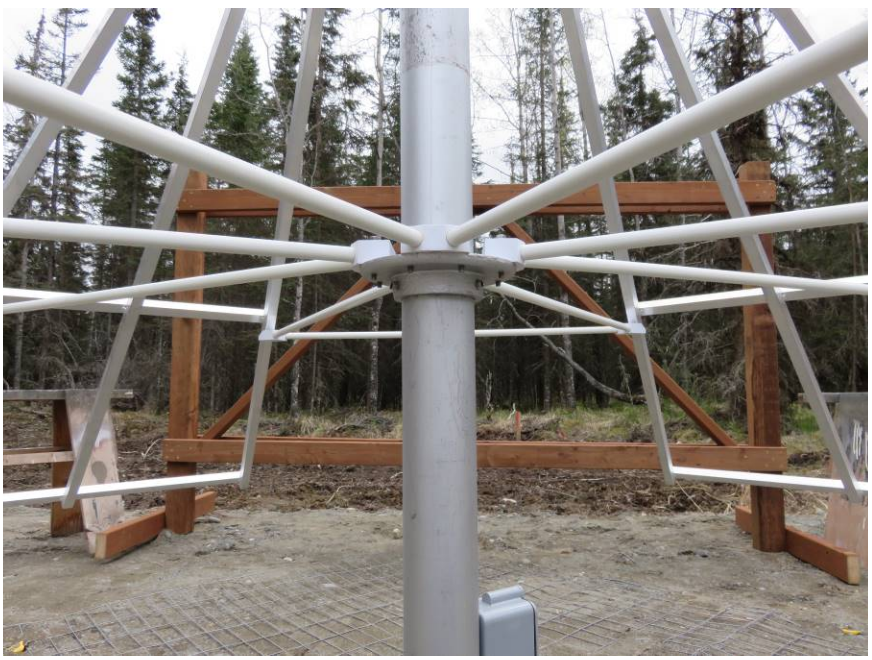

Figure 21 ~ Closeup view of underside of the center flange. Two of the four hex set screws that hold the flange in place on the mast are visible. The antenna assembly is very rigid and will survive 90 mph (145 km h^{-1}) winds. Winds that high never occur at Cohoe but have at other antenna installations around the world. Image © 2017 W. Reeve

Figure 22 ~Closeup view of the FEE enclosure cover and hub baseplate. The bottom of the baseplate has a tube with four slits. The tube is slipped over the mast and a stainless-steel worm-gear clamp is installed that squeezes the tube for a tight fit. The antenna elements are fastened underneath the baseplate to threaded studs using flange nuts. Image © 2017 W. Reeve

Figure 23 ~ Closeup view of fiberglass support block for the aluminum elements. A single 10-32 hex head stainless-steel machine screw on each side of the dipole element frame holds the frame to the block. Image © 2017 W. Reeve

Figure 24 ~ View of the type E conduit fitting, conduit and conduit connector. The conduit connector was installed after the conduit installation. The conduit connector is not necessary in most installations and is not supplied with the antenna. The cover on the conduit fitting has a rubber gasket to keep moisture out. Image © 2017 W. Reeve

7. Front-End Electronics Installation

Figure 25 ~ The cover has been removed from the FEE hub baseplate. Note the FEE alignment pin in the back corner of the baseplate. This view also shows the four 1/4 in coupling nuts and studs that hold the FEE PCB assembly in place and also connect the FEE to the dipole elements. Each element is fastened to a 1/4 in stud underneath the baseplate. The two coaxial cables are visible and the protective tape has been removed to ready them for connection to the FEE. This view also shows some of the aluminum welds in the foreground. Image © 2017 W. Reeve

Figure 26 ~ FEE assembly fastened to the four coupling nuts. Note the alignment pin near the left corner of the hub baseplate, which ensures the PCB is properly oriented. Not seen are the two coaxial cables that have been connected at the bottom of the PCB assembly before it was fastened down. As noted previously, only one PCB has a power indicating LED and it is placed facing up. The thick hub baseplate mechanically decouples the antenna elements from the FEE to prevent damage from wind and thermal cycling. Image © 2017 W. Reeve

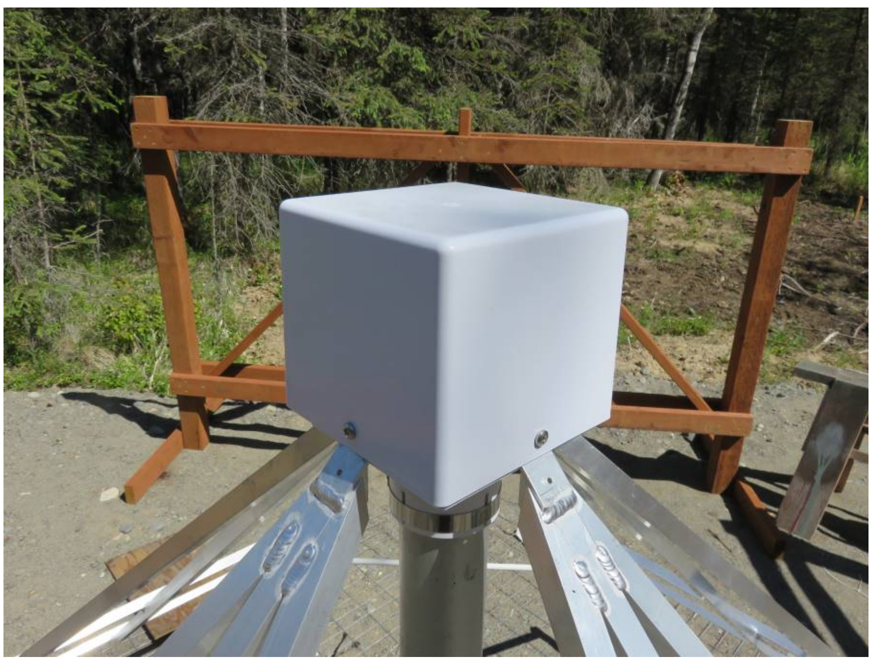

Figure 27 ~ The FEE enclosure cover is held on the hub baseplate by four self-threading stainless-steel screws. The entire assembly is very durable and weather resistant. Image © 2017 W. Reeve

Figure 28 ~ Completed antenna installation and moose fence. The four fence sections are connected with loose 1/2 in polypropylene ropes with clips that attach to threaded eyes on the fence posts. The removable ropes allow easy access for maintenance but prevent moose from entering the space around the antenna. This image was taken on 1 June 2017 as the surrounding foliage was turning green for the summer. Image © 2017 W. Reeve

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8. Applications at Cohoe Radio Observatory

Immediately after finishing the installation described above, I connected the antenna to a power coupler assembly that includes two bias-tees and a 90° hybrid (quadrature) coupler. Because the two linearly polarized dipoles are perpendicular to each other, combining their signals with a quadrature coupler produces left-hand and right-hand circular polarizations on the coupler's other ports (see {Reeve14-1}). The two coupler outputs are connected to RF power splitters for signal distribution to the receivers, and connectorized attenuators are used to control the signal levels at the receiver inputs (figure 29).

I soon setup two Callisto spectrometers for receiving solar radio emissions between 45 and 85 MHz, one Callisto for each polarization. Despite the low flare activity associated with the diminishing sunspot cycle I captured a Type I radio noise storm as well as Type II and III radio bursts before the winter set in (the Type II radio burst is described in {Reeve18-1}. Meanwhile, I expanded the applications to include HF and low VHF propagation studies. In particular, I started using the antenna to monitor transmissions from the High Frequency Active Auroral Research Program (HAARP) facility in interior Alaska using software defined radio (SDR) receivers. My radio observations at CRO of one such HAARP research campaign are described in {Reeve18-2}. Although the LWA antenna design frequency range is stated to be 5 to 90 MHz, I routinely received transmissions at 2.7 MHz during the summer 2018 research campaign at the HAARP facility 400 km away. The upper end of the frequency range is limited by interference from ubiquitous FM broadcast stations.

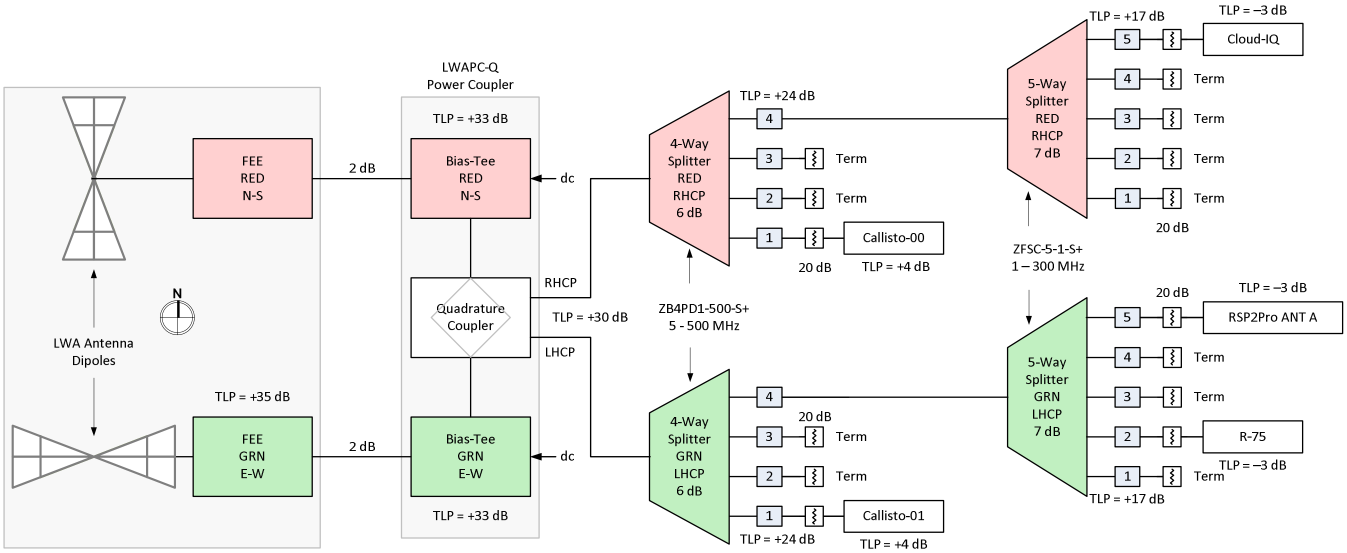

Figure 29 ~ Block diagram of the LWA antenna application at Cohoe Radio Observatory showing (left-to-right) the antenna with FEE, the model LWAPC-Q power coupler and RF splitters. All splitter connections are through RF patch panels for easy signal distribution to receivers, and all components in the signal chains are color coded for easy identification. The nominal Transmission Level Point (TLP) at each interface also is shown in the drawing. Image © 2019 W. Reeve

9. Summary

The LWA antenna is designed for easy field assembly and the success of the design is proven in many installations around the world. I spent a couple hours erecting the antenna at CRO including the ground grid and driving the mast ground stake; two people could assemble the antenna much faster. The individual parts are easy to handle and everything fits very well together. The details provided here may be used to supplement the *Guide to Antenna Assembly* supplied with the LWA antenna. Additional LWA antenna information is available at {ReeveLWA}.

10. References and Weblinks

{Reeve14-1} Reeve, W., Antenna Applications for the Quadrature Coupler, 2014, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_QuadCouplerApp.pdf

{Reeve14-2} Reeve, W., Modeling the Long Wavelength Array Crossed-Dipole Antenna, 2014, available at: http://www.reeve.com/Documents/Long%20Wavelength%20Array/Reeve_LWA-Model.pdf

{Reeve18-1} Reeve, W., Analysis of a Type II Solar Radio Burst Observed on 20 October 2017, 2018, available at: http://www.reeve.com/Documents/CALLISTO/Reeve_TypeII-Burst.pdf

{Reeve18-2} Reeve, W., HAARP: Radio Observations of the HAARP Summer 2018 Research Campaign, 2018, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_HAARP_Obsv_Jul2018.pdf

{ReeveLWA} http://www.reeve.com/RadioScience/Antennas/ActiveCrossed-Dipole/LWA_OrderInfo.htm

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