VLF-LF Loop Antenna Installation at Cohoe Radio Observatory

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1. Introduction

In early June 2018 I temporarily installed a loop antenna and a software defined radio (SDR) receiver at Cohoe Radio Observatory in Alaska to determine the site's viability for a VLF-LF receiving station. The tests were successful and are described in {Reeve18-1}. Within a few days of those initial tests I started to permanently install the loop antenna, and by 29 June had completed the installation. Details of the permanent installation are given here.

Note: Internet links and references in braces { } and parentheses ( ) are listed in **section 6**.

2. Antenna Configuration

The antenna is an untuned square loop, which I built in late 2009 for use in my Anchorage observatory (figure 1). Antenna construction details may be found at {Reeve18-2}. However, I could not use this antenna at Anchorage because of strong low frequency radio interference, so I stored the antenna for nine years and then moved it to Cohoe. I added a mast made from PVC conduit and updated the electrical measurements before making the permanent installation at Cohoe. The complete installation consists of the antenna, rotator and associated controller, junction and interface boxes and a treated wood post with galvanized steel post anchor (figure 2). The wood post elevates the antenna above the antlers of rampaging moose that frequent the site.

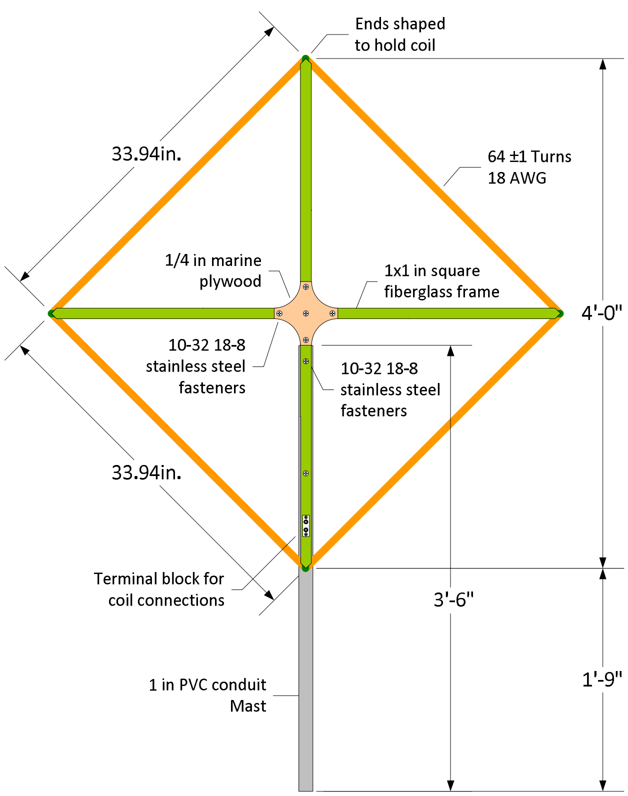

Figure 1 ~ Loop dimensions and basic measurements; see {Reeve18-2} for additional details. Length and area units are non-metric followed by metric in parentheses ( ).

Loop diagonal: 4 ft (1.2 m)
Loop area: 7.9 ft^2 (0.733 m^2)
Loop perimeter: 11.31 ft (3.45 m)
Loop side length: 2.8 ft (0.853 m)
Windings: 64 ±1 turns of 18 AWG coated magnet wire
Estimated wire length: 720 ft (218 m)
Measured inductance: 12.3 mH
Self-resonant frequency: 46 kHz
Tuning: None
Measured dc resistance: 4.535 ohms at 20.6 °C

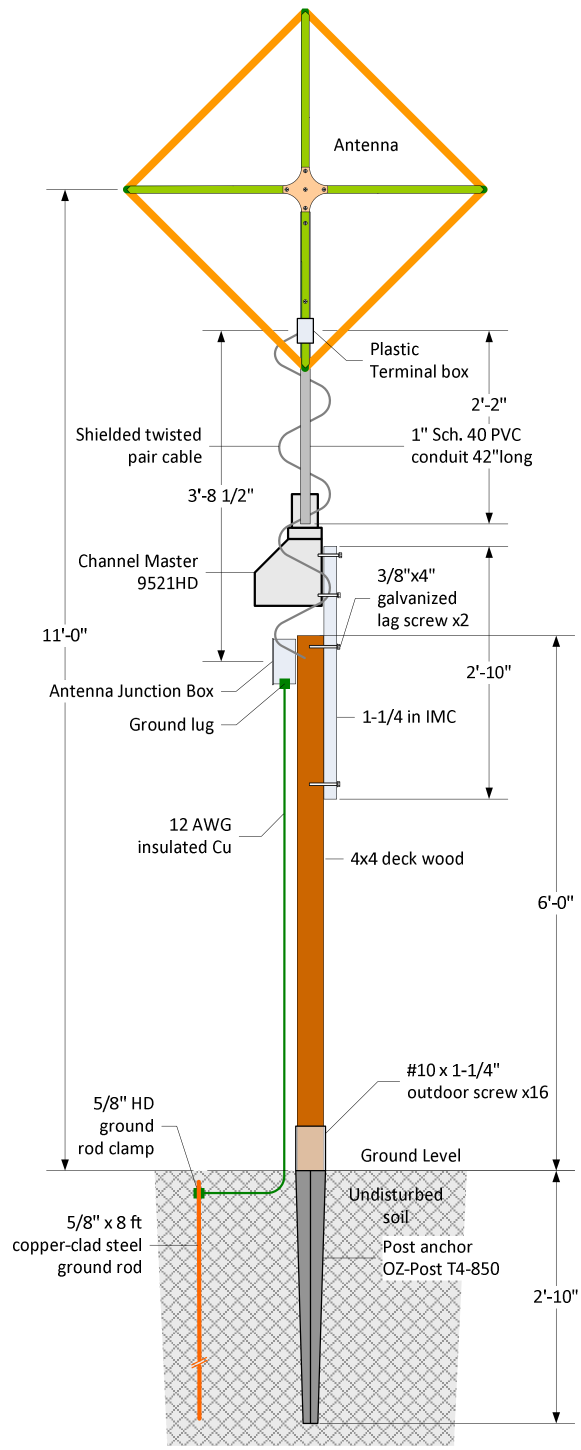

Figure 2 ~ Construction drawing showing dimensions and components used in the loop antenna installation. The dimensions are non-metric and trade sizes are shown where applicable. The intermediate metal conduit (IMC) fixed rotator mast is galvanized and all fasteners are galvanized steel or stainless steel.

The rotator and plane of the loop are calibrated at north-south orientation. The shielded twisted pair from the junction box to the antenna terminals is wrapped 2 turns around the mast and its shield is bonded to ground at the junction box end only. The grounding system is primarily for electrostatic discharge and to minimize potential differences. The antenna is shielded from the extremely rare lightning in the area by nearby trees.

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3. Antenna and Rotator Interfaces

A CAT5e shielded twisted pair (STP) cable is used for both RF and rotator control, one pair for the RF and 3 pairs for control. To allow easy connections, I built junction and interface boxes to break out the individual conductors at the antenna and receiver. The antenna junction box (figure 3) is waterproof and includes only terminal blocks and grounding provisions. The antenna and rotator cables enter the junction box through individual waterproof cable glands, while the STP cable enters through a waterproof 8-contact modular panel-mounted connector assembly (RJ-45). The receiver interface (figure 4) includes a terminal strip, grounding provisions, a bypass switch and connectors for all cables. Circular plastic connectors (CPC) are used for the rotator controller and receiver connections, and the STP cable from the antenna is connected through a panel-mounted 8-contact modular connector. Both the antenna junction box and receiver interface are bonded to the earth electrode system.

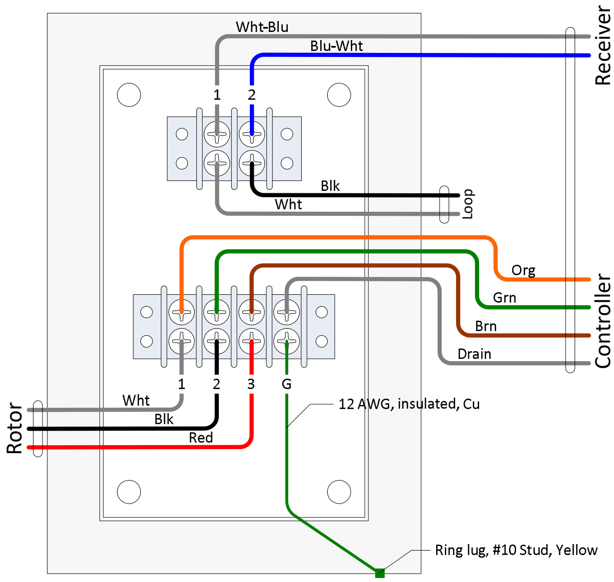

Figure 3 ~ Antenna junction box. The NEMA 3R steel enclosure houses two terminal blocks, one for the RF cable pair and another for the rotator control cable pairs. Enclosure dimensions are 4 W x 6 H x 3 D in. Pair 1 (blue) is used for RF. The individual conductors in the other three cable pairs (orange, green and brown) are individually paralleled to reduce voltage drop. Not shown is the feed-through connector for the 8-contact modular STP connector (RJ-45).

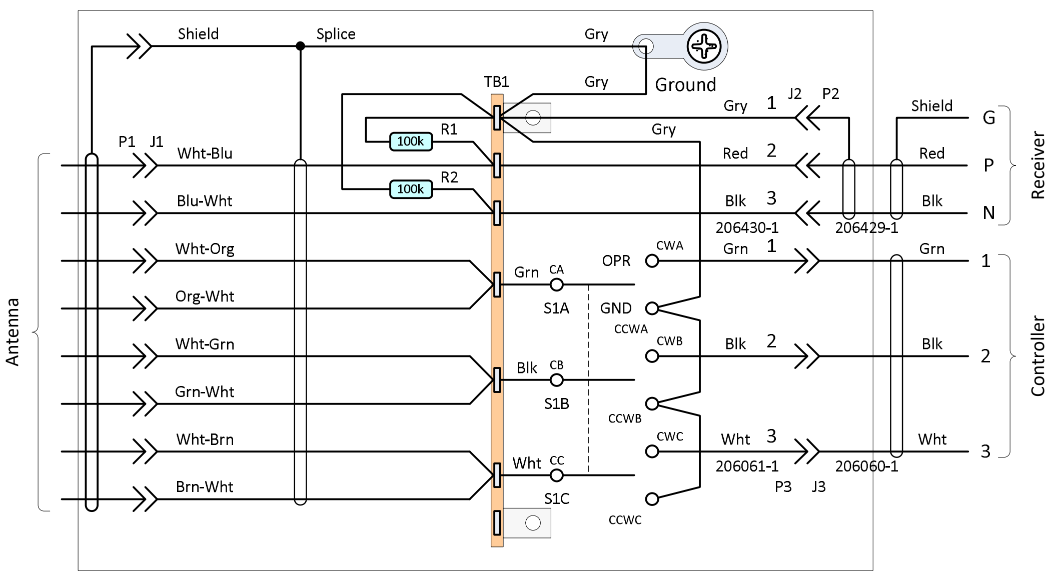

Figure 4 ~ Receiver interface. The 3PDT bypass switch (S1) allows the rotator control pairs to be grounded when not needed for turning the antenna so as to act as additional shield conductors for the RF cable pair.

The rotator itself, a Channel Master 9521HD (figure 5), is designed for television and FM broadcast antennas but is well-suited for the loop antenna. It uses spring-loaded, clamp-type connections for the 3-wire control cable (a picture of the wiring compartment is shown later). The rotator controller is designed for manual operation and has no provisions for remote operation. Pushbuttons on the front panel close internal relays, which apply phase-shifted ac voltages to the rotator motor.

The rotator does not provide position feedback to the rotator controller. Instead, position is indicated by timing the rotation duration. The rotator rotates through its full 360° range in 60 s, giving a rotation speed of 1° s^{-1}. The system is synchronized when the controller drives the rotator counter-clockwise for 60 s to its mechanical stop and then resetting the rotator controller indicator to 000°. I plan to modify the rotator controller by bringing out the relay control leads for connection to an Ethernet enabled external control. With this setup I can remotely control the rotator by accessing the CRO local area network with, say, TeamViewer. The external control will operate the rotator controller relay for a preset time and also will allow synchronization. These modifications will be reported in a future paper.

Figure 5 ~ Channel Master 9521HD (left) and controller (right). The rotator uses a geared 2-phase ac motor. Fixed mast mounting clamps are on the left side of this image and the rotating mast mounting clamps are at the top. The motor wiring compartment is at the bottom. The rotator controller front panel (upper) has three control buttons, Sync, CCW and CW rotation. It has an infrared interface to work with a wireless remote control unit (not shown). The rear panel (lower) has connections for the rotator cable and ac power. Images source: Channel Master

4. Antenna Installation

The antenna installation started with a survey and temporary installation as noted in section 1. Once the permanent site was chosen I used mostly left-over material from previous projects including intermediate metal conduit (IMC) for a fixed mast, stainless steel and galvanized steel fasteners, a galvanized post anchor and a treated wood post. The following is a photo-narrative of the overall effort (figures 6 through 13).

Figure 6 ~ Preparation for driving the galvanized steel post anchor.

Upper: A short section of 4x4 treated wood post with a level attached was placed in the anchor for leveling. The horizontal wood piece just above the level is for directional sighting with a compass; the edges of the post are oriented north-south and east-west. The soil layers consist of 6 to 12 in peat at the surface and 18 to 24 in of loam-sandy silt over an extremely hard sandy-gravel glacial moraine.

Lower: The post anchor at upper-left is stuck into the peat layer. The post anchor was manually driven with the post driver shown on the ground next to the anchor. The driver consists of a drive rod, a weighted stabilizing handle and a square alignment spacer for the OZCO T4 series post anchors. The driver weighs about 12 lb. A Garmin 680T GPS receiver is seen on the right side of the image. The receiver has a compass function that I used to align the post so that its sides are pointed N-S and E-W to aid in antenna directional alignment.

Figure 7 ~ Anchor and wood post installation, completed.

Upper: Close-up of post anchor after it has been driven to full depth with the manual driver. Note the holes in the post anchor for stabilizing screws that hold the wood post in place.

Lower: The temporary short wood post section used for alignment was replaced with a 6 ft wood post for the permanent installation. This view shows the south facing side of wood post after mounting the fixed mast for the rotator. Galvanized lag screws fasten the mast to the wood post. The rotator, at the top of the mast, is barely visible against the background.

Figure 8 ~ Flexible conduit installation.

Upper: Two 25 ft lengths of 3/4 in (trade size) flexible liquid-tight non-metallic conduit were coupled together and placed in a shallow trench between the loop antenna and building. After installation about 10 ft was cut from the conduit, leaving a run of about 40 ft. Conduit trench is just deep enough to prevent moose hooves from crushing the conduit in the spring when the ground is soft.

Lower: After backfilling the conduit trench.

Figure 9 ~ Cable preparation for pulling.

<u>Upper</u>: Before the conduit was placed in the trench, a pull-string (survey string) was sucked through it with an ordinary vacuum cleaner. A piece of foam rubber was tied to the string as an air plug that moved easily through the conduit.

<u>Lower</u>: The string was tied and taped to the shielded twisted pair cable. The cable was then fed into the conduit while the string was pulled (the nominal inside diameter of the conduit is 0.83 in.). Very light tension was required to pull the cable through the conduit, and no tension was placed on the connector.

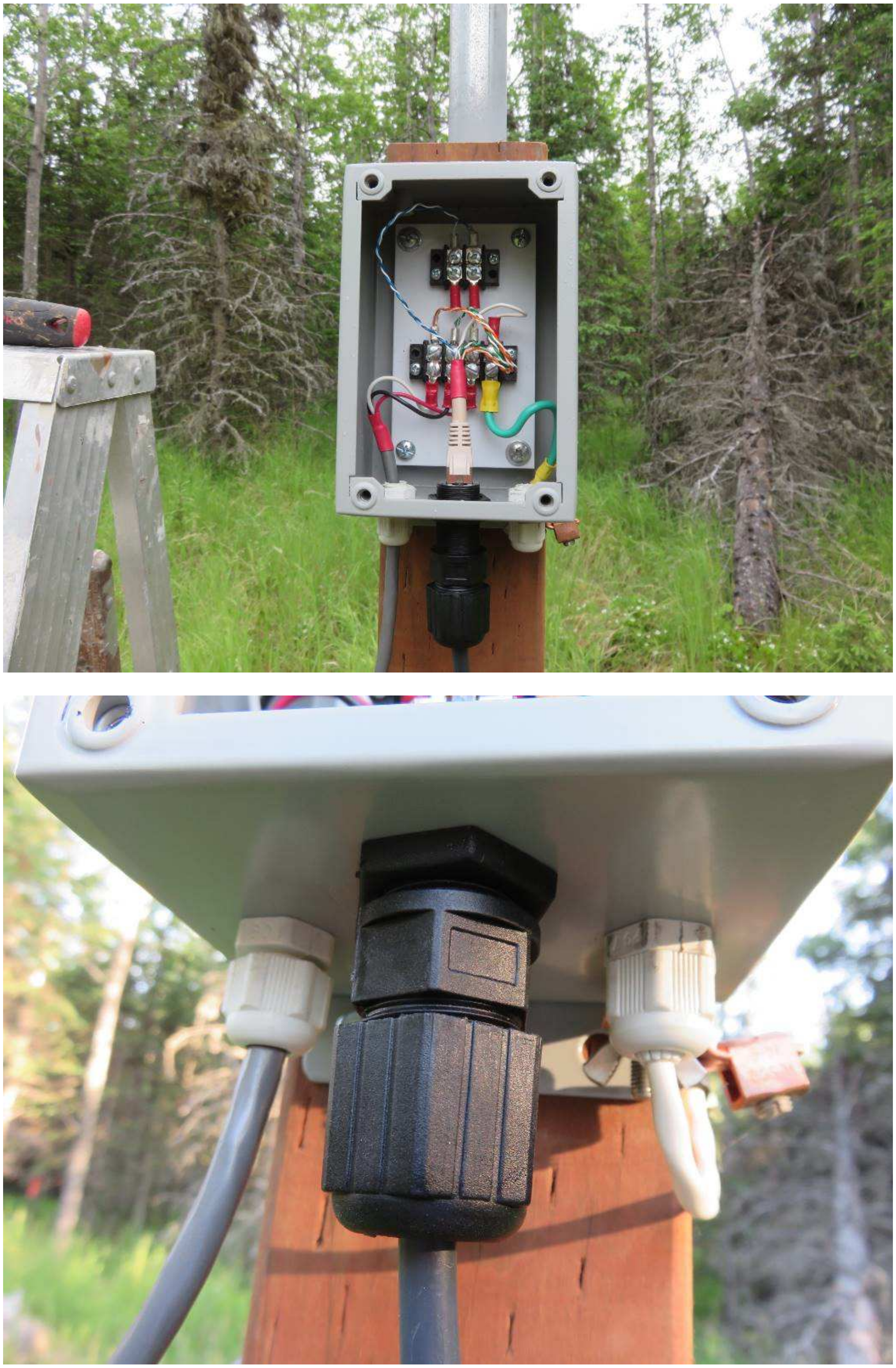

Figure 10 ~ Antenna junction box

Upper: Antenna junction box contains two terminal blocks, one for the twisted pair used for RF transmission and one for the three pairs used for rotator control. The individual conductors in each rotator pair are paralleled to reduce voltage drop. The box is NEMA 3R rated and made from mild steel.

Lower: Cable glands prevent water from entering the junction box. The left connector is for the cable to the rotator and the right connector is for the twisted pair cable to the antenna. The center connector has a built-in 8-contact modular connector feed-through for connection of the external connectorized shielded twisted pair cable to the internal cable.

Figure 11 ~ Rotator and antenna junction box.

Upper: The Channel Master HD9521A rotator is seen near the top of this image and the antenna junction box is below it near the top of the wood post. The yellow and gray lines in the background are guy wires for the tower about 50 ft away.

Lower: Another view of the rotator and antenna junction box showing the rotator control and antenna RF cables.

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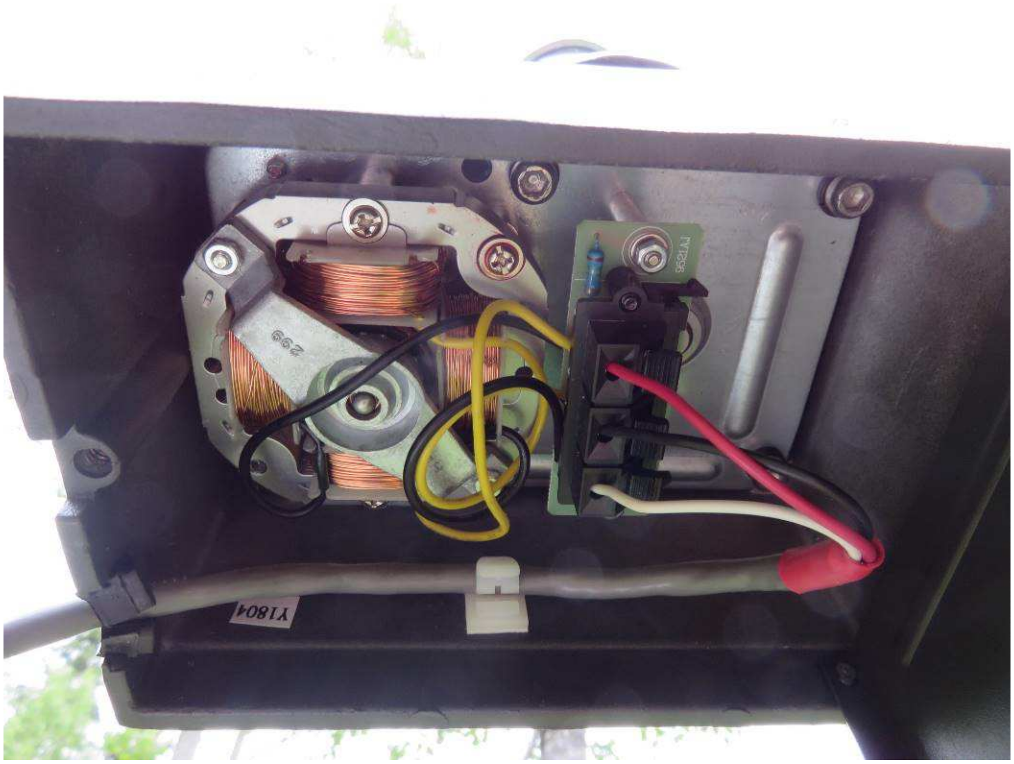

Figure 12 ~ Rotator connections and ground rod.

Upper: Rotator motor and connection compartment. The wire connections to the rotator are through pressure connectors like those used on speakers. The motor and connection compartment cover have been removed for this picture.

Lower: Antenna ground rod. The ground rod was driven 2/3 of its 8 ft length with a manual post driver and the remaining distance with a 10 lb sledge hammer. The top of the rod is a few inches below ground level. The underlying glacial moraine is so hard the installation required about 1 h of pounding. Prior to using the sledge hammer I temporarily installed the heavy duty ground rod clamp to ensure it could be placed if the rod end became mushroomed. I used oxide inhibitor on the connection and then buried the exposed end of the ground rod.

Figure 13 ~ Completed loop antenna installation ready for service.

Upper: Loop antenna against a background of quaking aspen trees. The shielded twisted pair connection to the antenna is wrapped two turns (720°) around the mast and unwinds as the antenna is rotated. The rotator has a maximum rotation of 360° with mechanical stops at each end.

Lower: Long view showing the surrounding landscape with black spruce (at least one dead one killed by spruce bark beetle) and quaking aspen.

5. Discussion

All materials used to build the antenna and associated interfaces are suitable for outdoor installation. The one possible exception is the coated magnet wire used to wind the loop, which may not be outdoor rated. The loop windings are exposed to sunlight and weather. I expect the wire coating to deteriorate over time due to exposure to the Sun, but I have no idea how long it will take or how severe it will be. I also expect some change in the loop electrical characteristics during rain and until the windings dry out. The dielectric constant of water is about 80 times that of dry air so the rain will increase the distributed capacitance of the loop windings and decrease the antenna's self-resonant frequency. However, since the installation was completed I have not noticed any obvious effect of rain on the loop's performance.

6. References and Weblinks

{Reeve18-1} Reeve, W., Initial Results from VLF and LF Observations at Cohoe Radio Observatory, 2018, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_CohoeVLFInitial.pdf

{Reeve18-2} Reeve, W., Square VLF Loop Antenna, 1.2 m Diagonal ~ Mechanical and Electrical Characteristics and Construction Details, 2018, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_SquareLoopAntenna1.2m.pdf

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Document Information

Author: Whitham D. Reeve

Revisions: 0.0 (Original draft started, 21 Aug 2018)
0.1 (Minor edits, 14 Sep 2018)
0.2 (Minor edits, 04 Oct 2018)
0.3 (Minor edits, 13 Oct 2018)
0.4 (Final edits prior to distribution, 26 Oct 2018)

Word count: 2321
File size (bytes): 6161920