Description of the Poor Mountain 1296.24 MHz beacon
WA4LPR
10/2020

Figure 1 is the block diagram of the beacon. Those of you who have worked with transverters will recognize the layout. The beacon is essentially the transmit side of a transverter. It is built around a DigiLO phase locked (PLL) source and a PTS (programmable test source) synthesizer. Figure 2 is the front view of the beacon transmitter.

The DigiLO was obtained from Down East Microwave. It is a very flexible programmable source. It is set up to output 1002 MHz as the "local oscillator "signal. The PTS is a commercial source that can be programmed in 1 Hz steps. The source used for the beacon is a PTS310 which can go to 310 MHz. It was fixed programmed to output 294.24 MHz. The PTS is used as the "IF" signal.

An Isotemp 134 10 MHz OCXO is used as the reference for both the DigiLO and the PTS. While not GPS locked, it should keep the transmitter within a few 10's of Hz of the specified frequency. Good OCXO's take a while to settle down and they don't like to be disturbed. It will take 90 days or so for it to reach its final drift rate. After that time, it will be recalibrated. Linear voltage regulators were used for the OCXO and DigiLO to reduce the effect of noise from the switching power supply. As it turned out, extra filtering was need for the OCXO to reduce the +/-600 kHz sidebands caused by the power supply.

The DigiLO and PTS signals are applied to a MiniCircuits ZFM 4212 diode ring mixer. See Figure 3 for the placement of the components. A 3 element interdigitated bandpass filter selects the sum product (1296.24 MHz) and rejects everything else. This filter was designed and built by WA4LPR. A computer mixer spur analysis was done to insure that there were no close in band spurs generated by these mixing frequencies. The resulting signal is amplified by a 1-2 GHz Avantek APG2003 amplifier. This amplifier has approximately 30 dB of gain. Its output is about 25 dBm but it is capable of as much as 1 watt output. It was obtained for a very reasonable price off eBay.

The output of the APG2003 drives a Toshiba RA18H1213G amplifier. This is a FET power amplifier (PA) that is often used in 1296 MHz transverters. This amplifier was obtained from RF Parts. It can be pushed to as much as 30 watts output but it is rated for a minimum of 18 watts. While the best of the amateur tradition would push for the maximum power output, continuous unattended operation suggests that it be run more conservatively. At the 18 watt level, the PA dissipates 50-60 watts of heat. The APG2003 dissipates another 10-12 watts. Since 24/7/365 operation is anticipated, the heat sink had to be large enough so as to avoid the need for a fan. Fans get dirty and break. The heat sink weighs about 9 lbs and it was obtained off eBay. It definitely qualifies as a "boat anchor" but the transmitter runs only warm to the touch even after 24 hours. The output filter and isolator represent 0.6-0.7 dB of loss so 18 watts from the RA18H1213G results in approximately 14 watts at the output connector.

Up to this point everything is pretty straight forward but the beacon is to operate in an environment with high power transmitters. In fact, there are three high power FM broadcast transmitters in the same building with the beacon and several more FM and TV transmitters nearby not to mention the dozens of two-way radio and cellular systems in the immediate area. In this environment, it important that the beacon transmitter be exceptionally clean and be protected from outside signals.

We may be “amateurs” but, in order to be good neighbors in this environment, it is important we operate to commercial standards.   Because of the harsh RF environment, commercial radio equipment often has an 80 dB spurious rejection spec. Ferrite isolators are often employed. The isolator prevents power from flowing down the antenna into the transmitter. The transmitter output stage is highly non-linear and, without protection, the signals flowing down the antenna can mix in the output stage and then be re-radiated to create a very unpleasant combination of spurious signals.

For the beacon, a 3 element interdigitated mixer filter suppresses the mixing products and a single resonator evanescent mode bandpass filter in the output suppresses transmitter harmonics and rejects the out of band signals coming down from the antenna. The evanescent mode filter has an especially strong stopband out to about 7 GHz. Quarter wave coaxial cavity filters have the disadvantage of spurious passbands at 3, 5, 7, etc times the transmitter frequency. Right where the harmonics are! A ferrite isolator allows transmitter power to flow out to the antenna but any in band signals coming in the antenna are shunted to the termination.   The isolator also protects the transmitter in the event that the antenna is damaged or iced. The reflected power is absorbed by the termination.

The worst case beacon spurious is the second harmonic at 85 dB below the carrier. Everything else is undetectable. There are also spurious at +/- 600 kHz of the carrier. They are approximately 75 dB below the carrier. They are a result of the switching noise from the power supply. Since they are in band, they were not considered problematic.

A dual directional coupler in the output and a simple LED bar graph indicator monitors the forward and reflected power. While the indicators are more qualitative than quantitative, they are helpful in monitoring beacon operation at a glance.

The beacon is identified by CW generated by an Arduino computer. Gene, WA4PGI, wrote the software for the computer. The Arduino is a much more elegant solution than the ROM’s and PIC processors of old. He also included a Bessel low pass filter in the keying line. The Arduino has a 5V digital output and the PTS has a very handy port where +5V turns it on and 0V turns it off. The Bessel filter insures a smooth on/off transition with no key clicks. Key clicks would have been especially annoying for those in the local area. With the 10 MHz OCXO and the Bessel filter, the CW sounds as clean (or better!) as anything you will hear on 20 meters.

The beacon can be remotely shut down through a FET switch which removes the DC power from the driver and power amp. The OCXO, DigiLO and PTS continue to operate. A switch on the front panel turns the transmitter on/off or allows for remote control.

The last (but by no means least!) component of the system is the antenna. The antenna is a slotted cylinder antenna often referred to as an Alford Slot. It is a cylinder with an approximately 2 wavelength long slot cut into it. (http://www.w1ghz.org/antbook/Long_Slot_Antennas_Alford.pdf) It is an omni directional horizontally polarized radiator with approximately 6 dB of gain. After about 1 dB of transmission line loss, there should be about 10 watts on the antenna for a 40 W effective isotropic radiated power (EIRP). Our antenna was made and tested by WA4PGI. Figure 4 shows the antenna under construction.

Since the beacon must operate continuously, care was exercised to ensure nothing was run close to or exceeding its limits. The RA18H1213G was mounted so as to minimize hot spots. The heat sink requires no fan and you can't have too much heat sink. The mains power comes in through a filtered power entry module (to keep RF out and switching noise in). There is a 130V transorb line to line and on each line to ground to reduce the effect of line transients.

This has been a fun project that has been a real team effort. Stan, K4RCA, conceived the idea and obtained several of the major components for the transmitter. Thanks to Dave Meier, N4MW, for his contribution of the PTS synthesizer. Stan also recruited Gene, WA4PGI, Josh, KF4YLM, and Dennis, WA4LPR. KF4YLM arranged for a location on Poor Mtn and installed the beacon with the help of John, AE4JA and did some coverage area maps. WA4PGI made the antenna and the keying computer and WA4LPR built the transmitter. Congratulations to the team.

We hope you will enjoy the beacon and it will contribute to increased activity on 1296. For those of you who have that new Icom 9700 but haven't done anything with the 1296, here is your chance. Go to the "Files" on the BRMS group site and find the "23 cm antenna" folder. Gene, WA4PGI, has some instructions for making a respectable 1296 antenna with nothing but hardware cloth and a coax connector that requires little tuning.

Pse QSL!

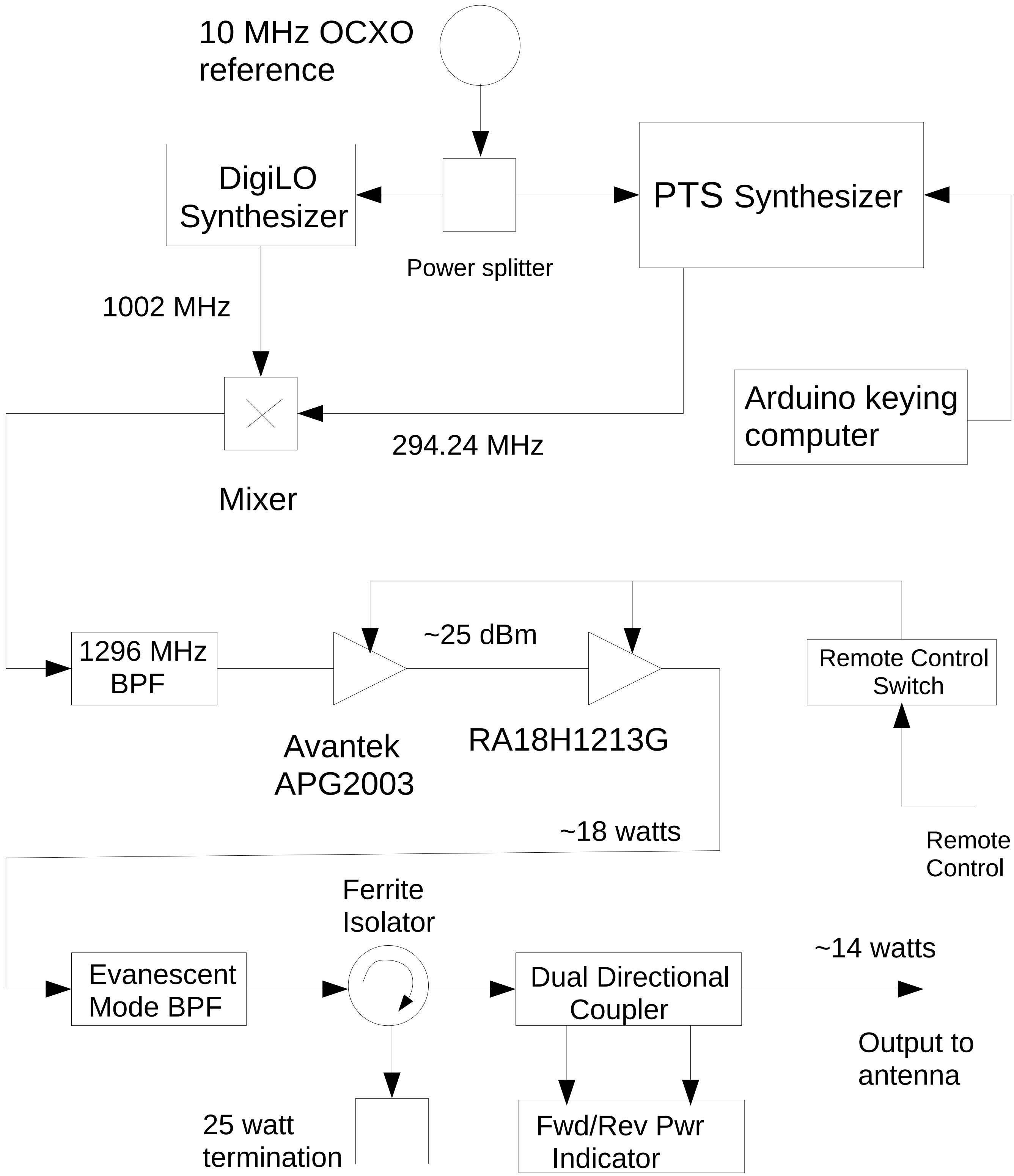

Figure 1: Beacon block diagram.

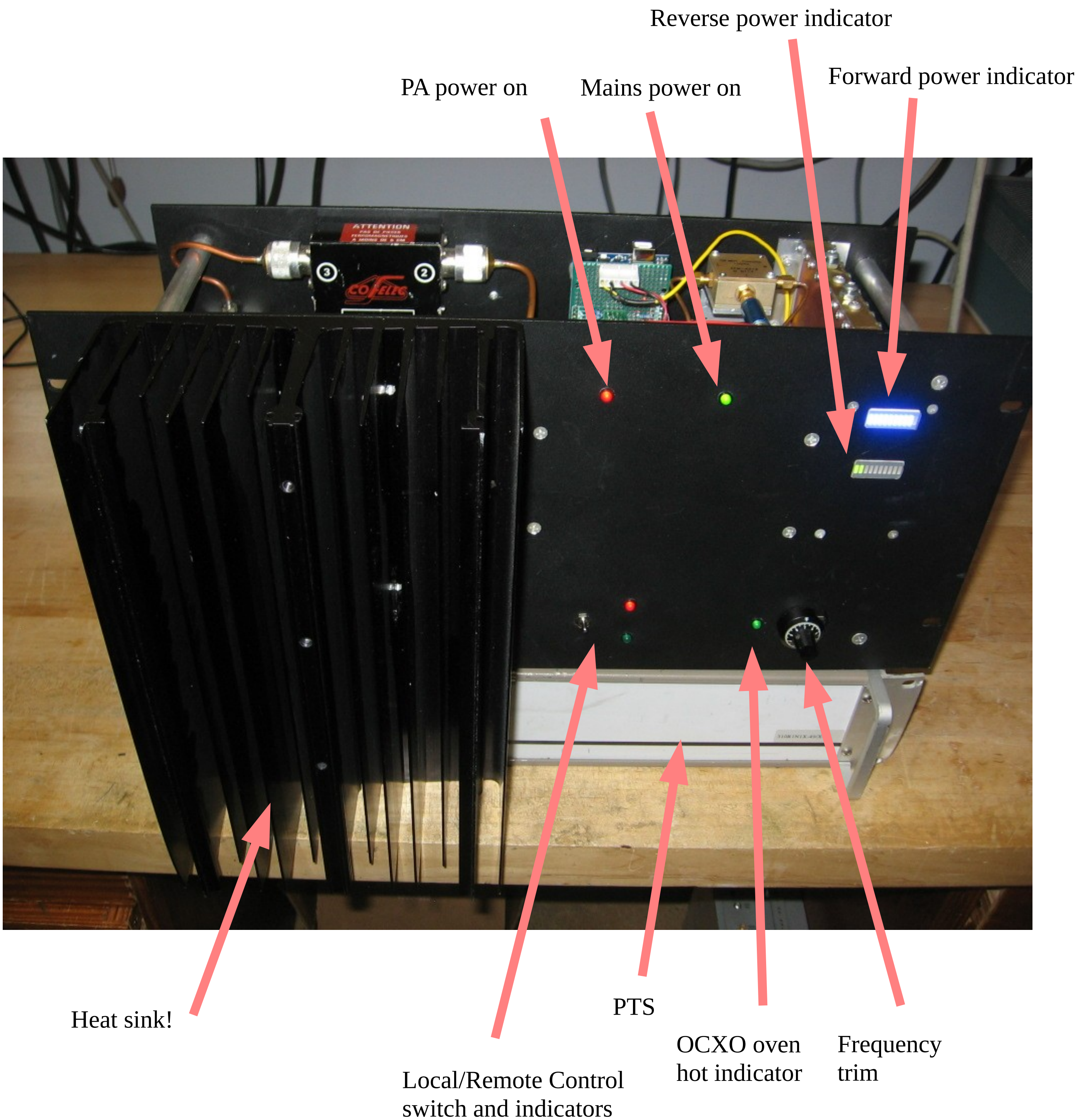

Figure 2: Beacon front panel.

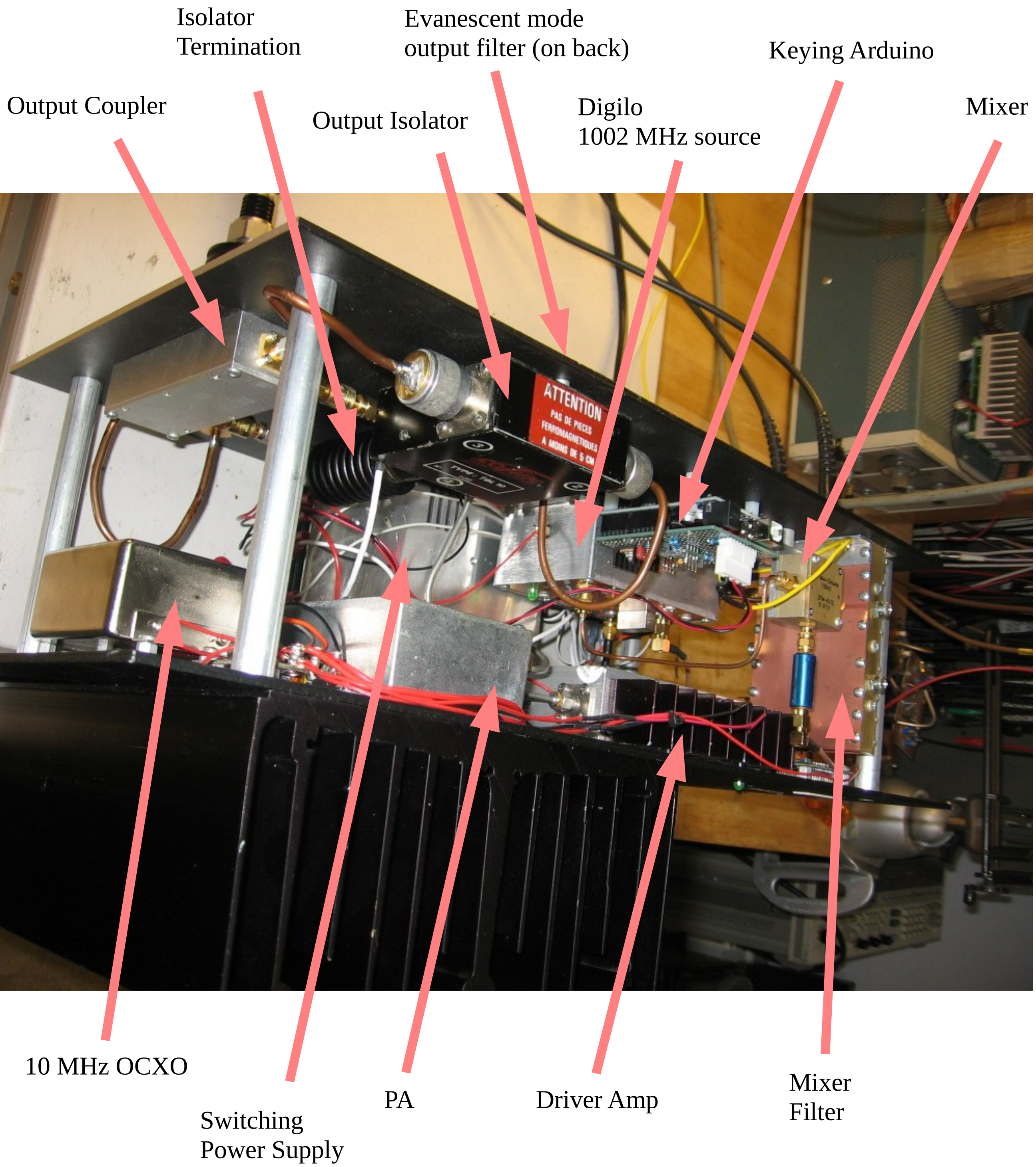

Figure 3: Beacon internal view.

Antenna feed point with coax balun. Notice the tuning tab.

Cylinder with slot.

Figure 4. Alford Slot antenna under construction.

One of the more unique aspects of this project has been the output filter. It employs a waveguide evanescent mode or waveguide beyond cutoff filter. Waveguide beyond cutoff does not propagate energy but it does store it so a section of waveguide looks like a pi network of inductors. The filter uses a length of WR137 waveguide with a cutoff of 4.3 GHz. The screw in the center into a hollow sleeve from the other side forms a capacitor to make the tuned circuit.   The result is a low loss resonator with a strong stopband out to approximately 7 GHz. It was implemented using the analysis from Paul Wade, W1GHZ, *Waveguide Filters You Can Build – and Tune. Part 3 Evanescent Mode Waveguide Filters*, QEX, ARRL, March 2010, pp. 23-29. Because the filter looks like a network of lumped inductors and capacitors, it was modeled in a LTspice simulation. This modeling appears to be unique and the accuracy of the simulation is encouraging. It needs to be explored in building more complex filters.

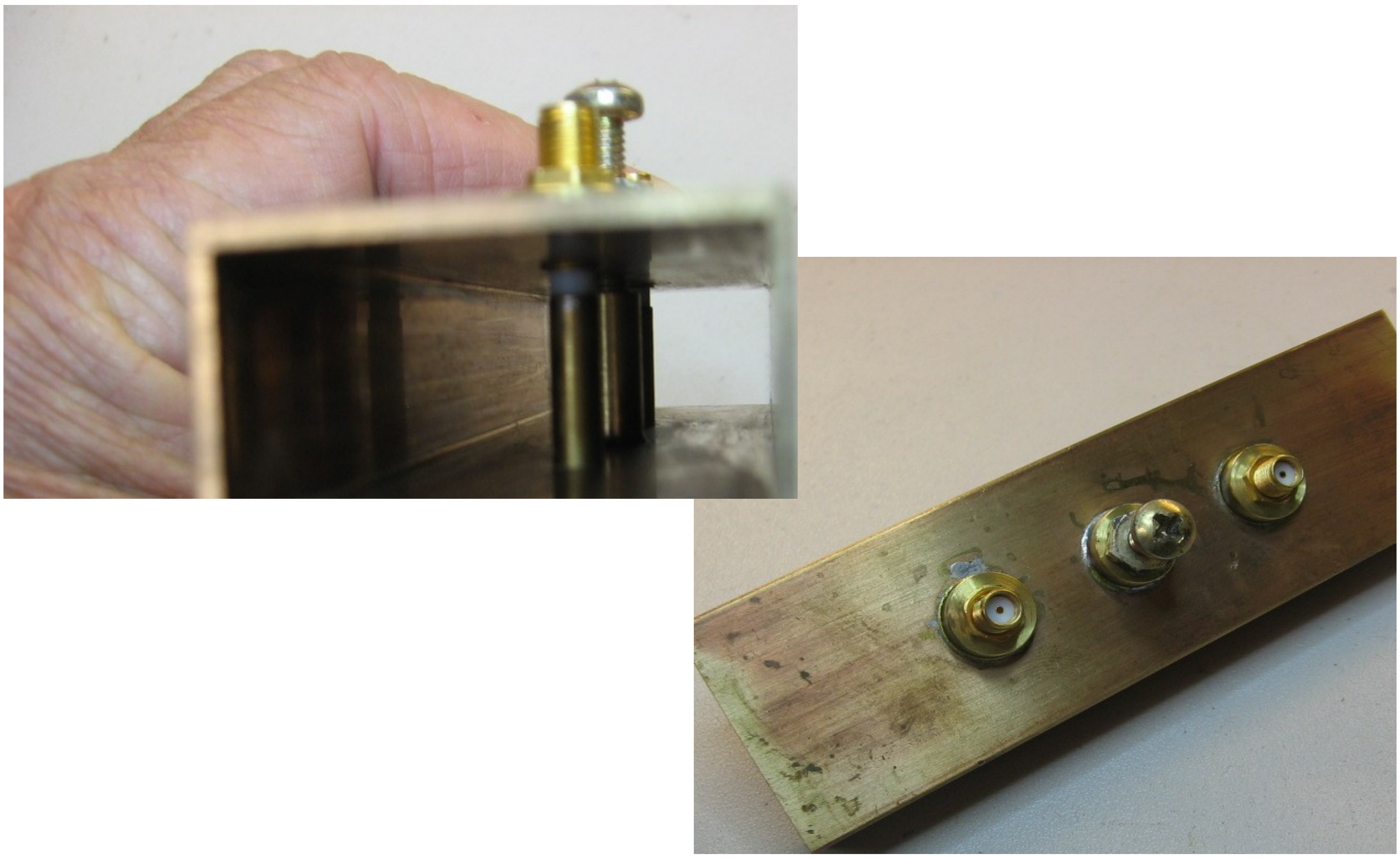

Figure 5: Evanescent mode output filter.

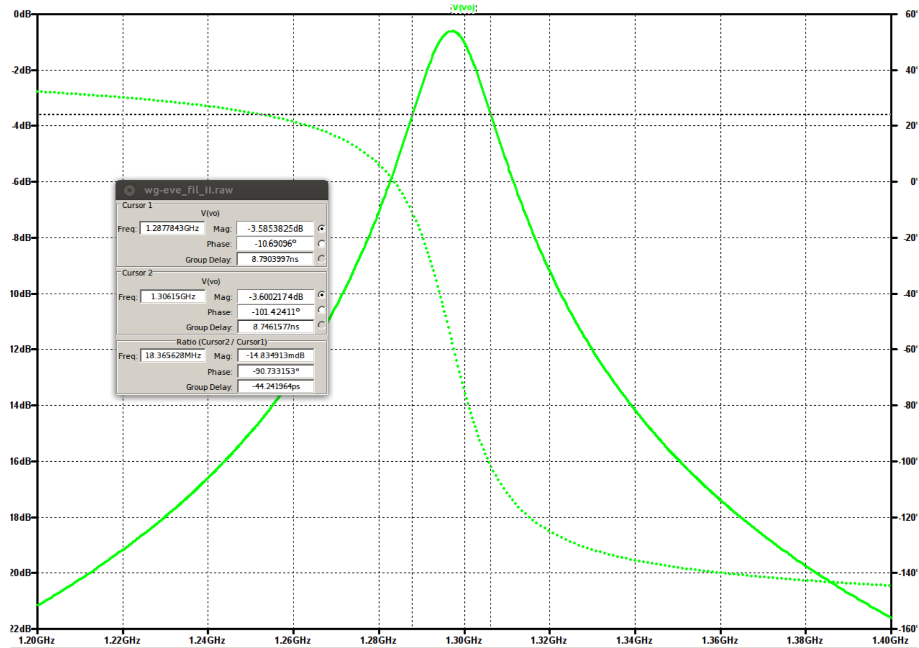

Figure 6: Single resonator evanescent mode filter LTspice simulation, 3dB bandwidth: 18.36 MHz. The loss is approximately 0.58 dB.

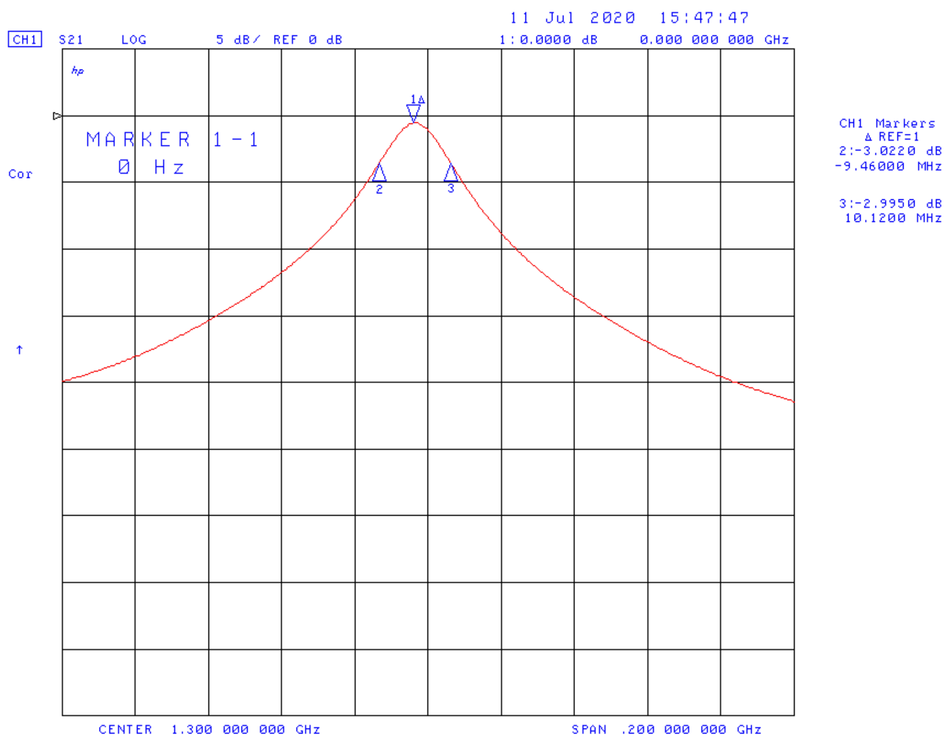

Figure 7: Single resonator evanescent mode filter measured 3 dB bandwidth: 19.58 MHz. Scale is 5 dB/division.