Cylindrical Waveguide Monopole versus Right Hand Circularly Polarized Helix: A Parabolic Antenna Feed Comparison

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ABSTRACT
Two feed antenna types, the cylindrical waveguide monopole and the axial mode helix, are common in astronomical observation programs in typical amateur SETI stations. Such stations often use a single, small parabolic dish as the primary reflector that focuses received radio energy to a point above the dish surface. During a series of solar observations, a cylindrical waveguide monopole provided 33 percent more gain than the helix. This result is particularly relevant to Project Argus Stations.

INTRODUCTION
There has been discussion within the amateur SETI community on the topic of parabolic dish antenna feeds (particularly whether the cylindrical waveguide monopole (CWM) (1) feed, or the right hand circularly polarized (RHCP) helix (2), has the better performance). This technical note compares the two and arrives at a recommendation for the typical, amateur SETI researcher.

Radio Telescope System Overview
The comparison was carried out at the author's station at FN31ng. The station was set up as follows: a 2.44 meter diameter solid aluminum parabolic dish antenna (3) with either CWM, or RHCP feed, a low noise amplifier (LNA) (4) directly connected to the feed antenna, approximately 7.5 meters of Times Microwave LMR-400 low loss coaxial cable follows the LNA into the control room and connects to a 1420 to 144 MHz down-converter (4), a short length of RG 58/U with BNC connectors provides input from the down-converter to an Icom R-7000 communications receiver in which the AGC has been disabled (5). The record output jack on the front of the R-7000 was used for a constant level audio signal input to a RF-2040 detector unit (6).

(Note: the short length of RG-58/U was known to be a weak link in the system. However, as the measurements on the CWM were originally made using this high loss coax, the coax was kept the same for measurements on the RHCP feed to eliminate it as a variable. The RG-58/U has since been replaced with a low loss alternative.)

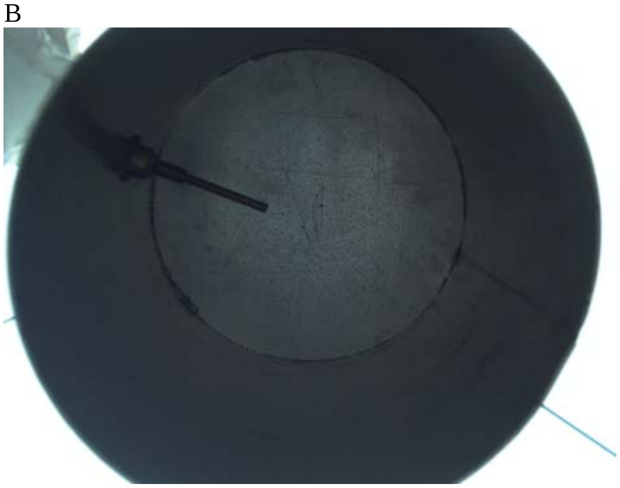
The RF-2040 has audio inputs for two separate channels. The audio inputs pass audio from the receiver to a diode detector, a DC amplifier, and an analog to digital converter for input to the computer's parallel port. Separate controls for each audio channel include a five-position switch with integration values from 0.05 to 2.0 seconds, and a gain control for zeroing from background. In addition, the RF-2040 has DC inputs for up to six other devices such as a temperature probe. The RF-2040 unit was connected to the parallel port of a PC, which was dedicated to the telescope. It was possible to observe simultaneously continuum traces for 1420 MHz and 28 MHz on the audio inputs, and a temperature probe on one of the DC channels.

Radio Skypipe Pro (RSP) (6) software was used to obtain the continuum traces used in this study. RSP is a software package that produces continuum traces for up to eight different channels simultaneously. It allows the user to select input devices and assign them to channels. User specified equations could be applied to each channel, allowing the real-time conversion of data (initially in mV) to degrees Kelvin, or decibels if desired. Reintegration was also possible post collection. RSP is also available as a freeware program without all the functions described and allowing only single-channel observations. Although not useful for SETI applications, where measurement of narrowband weak signals is usually done by FFT and examination of the resulting spectra, RSP has nevertheless been an important tool at FN31ng for determining overall system performance and health, as well as tracking atmospheric conditions over the course of an observation run.

The two antenna feeds appear very different. The CWM (Fig. 1) is a cylinder made of 0.3 cm rolled aluminum on the sides and a round aluminum plate at one end. The end of the cylinder facing the dish remains open. The seams where the sides and the top meet are welded. The internal diameter of the cylinder is 15 cm and the depth is 27.4 cm. The probe is brass 0.4 cm tubing, 4.8 cm in length, and is mounted on a female type N connector and inserted into a hole of the appropriate size in the wall of the cylinder approximately 9.25 cm from the closed (shorted) end of the waveguide. The depth of the waveguide is calculated such that when mounted at the optimum focal length for the dish on which it is to be used, about 50 % illumination is achieved. Such illumination serves to reduce side lobe spillover, limiting the noise received from the sides of the installation. The total bandwidth covered by this feed is 100 MHz, from 1350 to 1450 MHz.

A

B



C

Figure 1 a. Side view close up of CWM. b. inside view of CWM with monopole just visible to the rear. c. CWM shown mounted at focus of 2.44-meter dish.

In contrast, the RHCP (Fig. 2) is a piece of 0.45 cm copper tubing, wound about a form in a clockwise direction for three turns (a left hand circular polarized helix would be wound in an anti-clockwise direction). The resulting spring-shaped antenna is 5.5 cm in the internal diameter and 11.0 cm in length. The spacing between turns is 3.4 cm. This assembly is then soldered on one end to a female N connector, which has been mounted through a ground plane plate made of 0.3 cm aluminum. The ground plane is circular in shape and 18.4 cm in diameter. This entire assembly is then encased inside a piece of schedule 40 PVC pipe of the same outer diameter as the ground plane plate and sealed to prevent entry of water. The open end of this PVC radome was also capped and sealed.

Figure 2. RHCP Helix removed from its radome housing (15)

Approximate calculations (7) show this RHCP design should display a bandwidth of almost 500 MHz. Gain could not be determined simply using the empirical formula:

$$\text{Gmax (dB)}=10.25+1.22L-0.0726L^2 \qquad \text{eq. 1}$$

where L is equal to the length of the helix in wavelengths because the calculation does not hold for helices less than two wavelengths at the operating frequency (8). A 42 cm or longer helix is impractical as a feed for a small parabolic reflector. The total length, as well as the spacing between turns of the helix, determines its beam width. The beamwidth, in turn, determines how much of the dish surface is illuminated. A three-turn helix illuminates approximately 75.6 percent of the parabolic dish surface used here (7).

The CWM has linear polarization. It can be mounted so that the monopole probe is vertical or horizontal in reference to the horizon. Polarization is therefore characterized as vertical or horizontal.

The RHCP is circularly polarized in a right-handed (or clockwise) fashion. It is more complex than the CWM in that when mounted and aimed at a reflective surface, as is the case when used with a parabolic dish, it actually receives left circular polarized waves that reverse upon reflection off the dish surface. This reversal can be very effective at nulling right circular polarized signals that are characteristic of many man-made satellites in orbit over the Earth.

Solar transits of the antenna beam, with the receiver detecting in upper sideband mode, were used for purposes of optimizing feed placement, as well as taking the needed measurements for comparison. In addition, the primary dish was originally manufactured for a 10 GHz microwave relay system, therefore the manufacturer's feed and wave guide were removed and replaced with a feed suspension system more suitable to the present use. All measurements are carried out at a frequency of 1420.4058 MHz. The calculated focal length for this dish was found to be 0.94 meter (7). Each feed, in turn, was placed at this distance from the bottom of the dish and fine-tuned empirically by moving the feed closer or farther away to find the best signal with the Sun in the center of the beam. For the CWM, this best placement was found to be approximately 120 cm from the apex of the dish to the probe inside the feed. For the RHCP, best position was found to be 93 cm from dish apex to first winding of the helix (9). Figures 3 and 4 are actual traces from each feed type (note: the traces selected for these figures were chosen aesthetically and may not be the best in terms of baseline deflection).

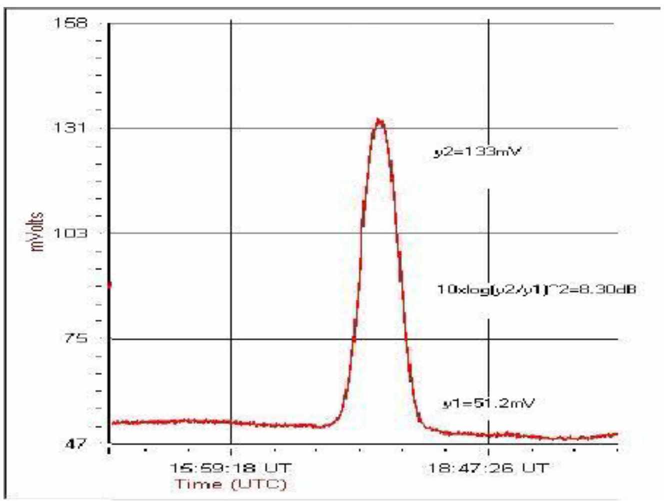


Figure 3. CWM feed; solar transit

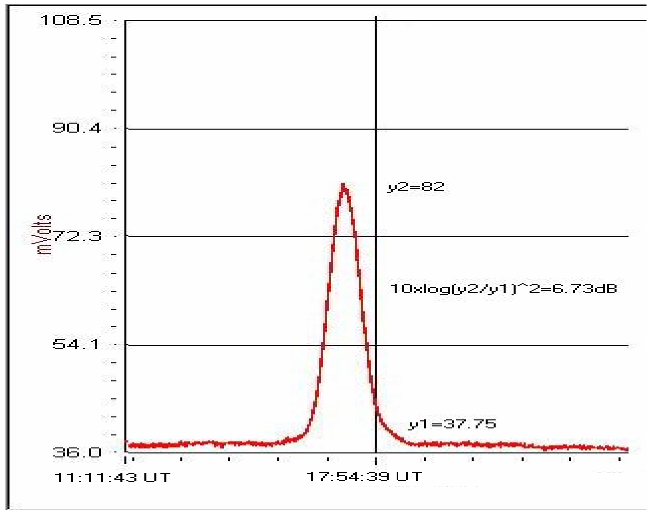


Figure 4. RHCP helical feed; solar transit

RESULTS AND DISCUSSION

The results of the best solar transit for each feed are given in Table 1 below.

Feed	mean dB	sd	solar flux	G/T (power ratio)	G/T (dB)
RHCP	6.29	0.158	71	3.6	5.5
CWM	8.29	0.078	83	5.4	7.3

Table 1. Best solar transit results (n=3).

The variability of the solar output makes direct comparison of baseline deflections of solar transits inadequate. Gain/Temperature (G/T) measurements take solar output variation into account by factoring in the measured solar flux for that observation day at the nearby frequency of 1415 MHz (11, 12). This reference provides an internal standard for canceling out the effects of variations in the solar output between successive solar transits.

The CWM performed 33.3 percent better than the RHCP when G/T power ratios were compared. A three-turn helix has a half power beam width of 87.3 degrees. Most SETI researchers prefer a fifty per cent illumination of the dish surface. A 2.44-meter dish with a F/D of 0.39 has a 132-degree illumination angle. This gives a preferred beam width of 132 x 0.5=66 degrees (7). Comparing to the previously stated beam-width of the RHCP gives (66/87.3) x 100= 75.6 percent dish surface illumination by the RHCP. When larger areas of the dish surface are illuminated by the feed, it is reasonable to assume that noise from side lobes become an increasingly significant factor, thereby reducing the signal to noise ratio of the system (13, 16). This suggests that only much larger parabolic dishes with a similar F/D might take advantage of this type of feed.

CONCLUSIONS

The RHCP helix has the advantages of wider bandwidth and the ability to detect signals from space that are very likely to be circularly polarized. The CWM however, would pay a small penalty for its linear polarization when reception of circularly polarized signals is likely. The CWM also has one-fifth the bandwidth the RHCP has. Nevertheless, it seems clear that the CWM is the better performer in reception of signals from a natural source as the Sun. The results show that the CWM is more capable of achieving the surface illumination necessary for a higher signal to noise ratio. At the same time, the CWM performs better in minimizing side-lobe radiation than does the RHCP. The results suggest that the three-turn helix used in this study is inadequate for use in most amateur radio telescopes of modest size. It would seem that the best feed for small, amateur installations, at present, is the cylindrical waveguide monopole.

Further work with the RHCP might improve this feed for small parabolic reflectors. The addition of a scalar choke, or placement inside a waveguide to limit side lobe illumination, could increase signal to noise and therefore its performance. How this would affect the antenna beam pattern remains to be determined. Using four, or more, turns rather than the three presented here might also be beneficial by bringing dish surface illumination down to fifty percent.

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