Flyswatter Experiments at 47 and 77 GHz

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Introduction

I have always been intrigued by the flyswatter or periscope antenna ever since a local friend of mine, Craig Young, KA5BOU installed one on his tower for 10 GHz operation. Recently, he upgraded his to a different sized reflector and I became the owner of his original “stop sign” reflector. My goal was to install it on my Rohn 45 rotating tower primarily for 47 GHz and higher operation. It has been used successfully on 47 GHz for the last couple of years and I was anxious to try it on 77 GHz as well.

Concept

The beauty of using a rotating tower for the periscope antenna is that both the periscope reflector and the equipment rack located near the base of the tower are rotating in sync. This assures that the polarity of the ground mounted antenna is not rotated with respect to the reflector. Otherwise the polarity of the ground mounted antenna would have to be rotated to maintain the desired polarity. The periscope reflector that Craig built uses a legally obtained stop sign hinged for elevation or tilt control. A small actuator is used for adjustment on elevation. Craig used a small digital elevation indicator that he found at an RV shop. It only reads to the nearest degree which was probably ok for 10 GHz. A revised elevation scheme is on my list of things to do.

A big advantage of the flyswatter arrangement is that all delicate and pricey microwave equipment is ground mounted. Although, I normally do not leave the equipment at the base of the tower when it is not in use. This new taller tower seems to be a lightning magnet anyway.

Things to consider

Paul Wade’s On-Line antenna book[1] has a downloadable excel spread sheet that allows one to easily optimize the major parameters in a periscope antenna system. On my tower I had already determined that the maximum separation between the reflector and the ground antenna would be 55ft or 16.8m. I chose this height based on the fact it was just below my second guy ring and I wanted all the larger microwave antennas to be between the second and third guy ring. I was also stuck with using the same reflector aperture of about 30 inches or .76m on all frequencies. My only real variable to optimize for a given band was the aperture of the ground mounted antenna. A summary of my predicted system performance is shown in Figure 1.

					Actual system
Frequency	10.3 GHz	24 GHz	47 GHz	76 GHz	76 GHz
Optimum Dish Diameter	.85m (33.6")	.5m (19.7")	.23m (9")	.15m (6")	.34m (13.5")
Flyswatter Aperture	.76m (30")	.76m (30")	.76m (30")	.76m (30")	.76m (30")
Reflector Spacing	16.8m (55ft)	16.8m (55ft)	16.8m (55ft)	16.8m (55ft)	16.8m (55ft)
Suggested Flyswatter Aperture	1m (39.4")	0.6m (23.6")	0.5m (19.7")	0.4m (15.7")	0.4m (15.7")
Final Results					
Dish Gain	36.6 dBi	39.4 dBi	38.5 dBi	38.9 dBi	46.1 dBi
System Gain	34.7 dBi	39.8 dBi	34.7 dBi	34.3 dBi	34.2 dBi
Effective Gain of Periscope over Dish	-2.0 dB	.4 dB	-3.8 dB	-4.6 dB	-11.8 dB
Figure 1 Summary of data from Paul Wade's on-line antenna book					

For my fixed reflector height of 16.8m (55 ft), the .76m (30”) flyswatter aperture is probably optimum for 24 GHz with only slightly reduced performance at 10 GHz. At some point, I may actually try the flyswatter at 24 GHz and see how it compares to my Macom 2 ft dish at about 60 ft. However, my main goal was to experiment at 47 GHz and 76 GHz. It is interesting to note that with the optimum choice of spacing and aperture size, one can actually get some system gain from the flyswatter.

Results at 47 GHz.

To date, I have only run tests over a nearly unobstructed path of 23km (14 miles) from my home to an open spot on the other side of Lake Lavon in Farmersville in EM13td. This is based on an antenna height of 55 ft at my station. I have worked AA5C, AA5AM, and K8ZR during the 10 GHz and up contest through 47 GHz.

I attempted to document received signal strength from AA5AM during one of our earlier tests. Scott is running a DB6NT transverter at about -7dBm into a homebrew horn with a theoretical gain of 24 dBi assuming 50% efficiency. His EIRP is 17dBmi. The path loss is calculated from 20 log (4πd/λ) and turns out to be 153dB. This does not account for any additional atmospheric loss from moisture, etc. The received signal at W5LUA should be -136 dBm. With my assumed system gain of a little more than 34 dB, the signal level at my receiver should be -102 dBm. Based on a 30 Hz effective bandwidth of the panadapter on my Flex-1500 I believe my noise floor to be -174 dBm + 5 dB NF + 10 log (30Hzbw) = -154 dBm. Scott’s signal should have been 52 dB over the noise under perfect conditions. I measured his signal at 43 dB S/N ratio. The 9 dB difference is either in dish efficiency and or propagation anomalies. This test was run on Nov 29, 2017 when the temperature was 55F and the dew point was 45F.

Moving on to 77 GHz

On September 4, 2019, AA5AM and I attempted 77 GHz along with 47 GHz at the same EM13td site in Farmersville. The rig that Scott was using is the same rig that I used to copy RW3BP off the moon on 77184 MHz. Noise figure is sub 5 dB. The rig has since been modified on transmit as the output power is low, about -1 dBm at 77184.1 GHz. The antenna we started with on this rig was a small 1.1” X 1.4” commercial horn with a calculated gain of 26 dBi at 50% efficiency. Scott’s EIRP would be about 25 dBmi. Path loss at 77 GHz is 157 dB plus 18 dB of additional path loss due to a Dewpoint of 68F. The additional path loss due to dewpoint was extrapolated from a curve created by Brian Justin WA1ZMS. The power

level received at my location should be about -150 dBm. With my projected system antenna gain of 34 dB, the power level incident to my receiver should be -150 dBm plus 34 dB = -116 dBm. The sensitivity of my system with KX-3 with PX-3 panadapter should be -174 dBm + 5 dB NF + 10 log (11HzBW) = -158 dBm. I should receive the signal at 42 dB S/N on the PX-3 panadapter in a 5 kHz wide span. The 11 Hz panadapter bandwidth is based on information in the Elecraft PX-3 manual.
We had success on our first attempt. After some peaking on both ends, Scott's signal was about 22 dB over the noise at my home location. See Figure 2.

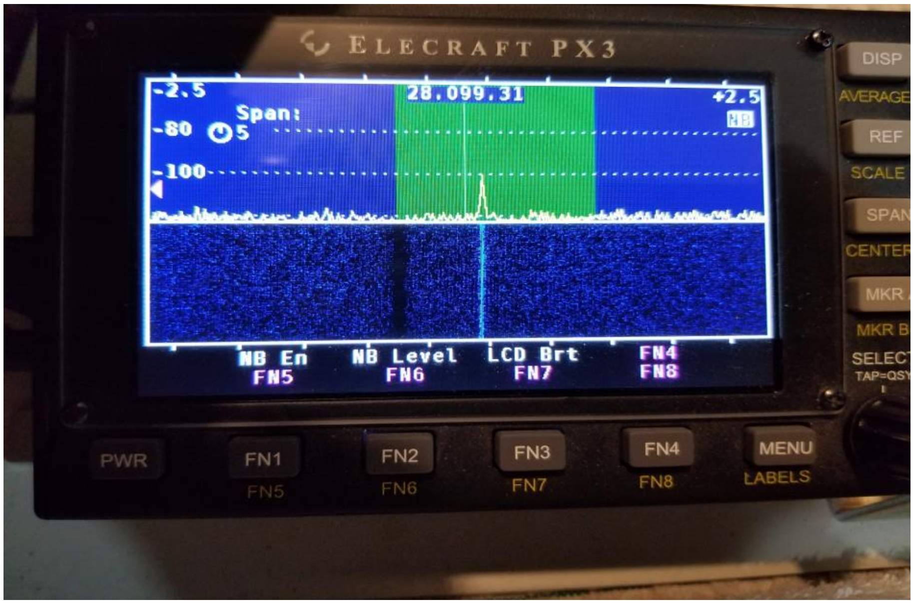

Figure 2. W5LUA reception of AA5AM who was using a small horn

Although the actual test result was 20 dB worse than predicted, I was still happy with the Flyswatter antenna system. I was not able to optimize my elevation due to an indicator malfunction. The Flyswatter was initially set at 45 degrees with respect to earth at this azimuth angle so it is close to being optimum.

The next transmission from Scott on 77 GHz was with a 6 inch diameter lens antenna loaned to the cause by Kent WA5VJB. The lens antenna was manufactured by Flann Microwave with a posted gain of 37.5 dBi but no mention of frequency on the label. It was a WR-15 horn so it may have been designed for 60 GHz. Figure 3 shows the enhanced signal as received by W5LUA.

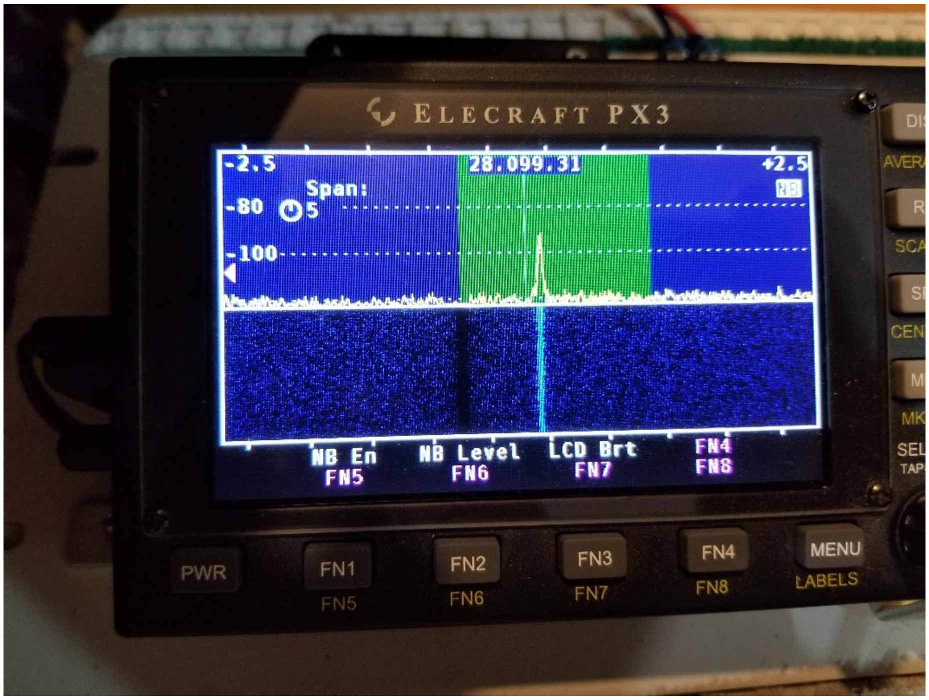

Figure 3. W5LUA reception of AA5AM who switched to a 6 inch Lens Antenna

Theoretically the 6 inch lens antenna should have a gain of about 12 dB over the small horn. Measurements show closer to 10 dB over an actual path. There was considerable fading on signals. Since we were shooting across our small Army Corp of Engineers Lake, there may have been some effects from the lake. As mentioned before the Dew Point was a comfortable 68F.

The next test for comparison was to try 47 GHz over the same path. Scott fired up the DB6NT transverter with a mighty -7dBm into a 24 dBmi horn and I saw similar S/N ratio at 47 GHz. I was able to mount both my 47 GHz transverter and the 77 GHz transverter on the platform at the same time. This made band switching easy.

Equipment Platform

I constructed my equipment platform out of two 6 ft. pieces of .25” thickness 2” aluminum angle anchored with u bolts to the Rohn 45 tower. The spacing between the two pieces of aluminum angle is 10.5”. This works out to be convenient for me as both my 47 GHz and 77 GHz transverters are built on standard 10.5” high standard 19” rack panels. I add the equivalent of wings on each of the transverters to allow them to slide along the aluminum angle pieces. The center of the flyswatter reflector is 34 inches away from the tower. When I was first running tests on 47 GHz, I found the actual position for optimum S/N to be fairly broad. Possibly because I am illuminating a smaller portion of the flyswatter reflector. Although maybe not optimum, I decided to take advantage of this, and mount both rigs on the platform to allow for easy band switching. The final configuration is shown in Figure 4. The 47 GHz transverter is the one closest to the tower. The 77 GHz transverter has a Trimble GPS 10 MHz reference

oscillator built in. Notice the GPS antenna to the left of the 77 GHz transverter. At the moment I am turning the tower with an HDR-300 rotor driven by a Green Heron Engineering rotor control box. Eventually, I will turn the tower with an M2 Orion rotor which will have better pointing accuracy.
The real challenge is to perfectly aimed each antenna at the flyswatter reflector. I use 2 guy wires and turnbuckles for support and aiming. I also use shims to perfect the alignment. A Sears torpedo level with digital readout helps as well.

Figure 4. Equipment platform with both 77 GHz and 47 GHz transverters mounted

A view of the reflector is shown in Figure 5. The reflector is about 30 inches at its widest and is spaced 34 inches out from the tower. The azimuth is fixed to hopefully keep it in perfect alignment with the equipment platform. It is variable in tilt only with a small actuator. When Craig was using this reflector he used a small rotator to rotate the flyswatter reflector as his tower was not a rotating tower.

Figure 5. Flyswatter reflector with elevation/tilt control.

Conclusion

The flyswatter reflector has more than met my expectations. As the results show, I have a few more dB to squeeze out of the system. I am hoping to work some greater DX and a few grids without going to a mountain top. As noted earlier in the analysis, the flyswatter reflector is too big for optimum performance at 47 and 77 GHz. I need to decide if it is worth going to a smaller reflector and forget using it also on 10 and 24 GHz. However, the number 1 item for me to work on is to fix my elevation indicator. The upper bands are a real challenge and a lot of fun!

73 de Al Ward W5LUA September 5, 2019

Reference

1. W1GHZ Online Microwave Antenna Book. http://www.w1ghz.org/antbook/contents.htm