10-Meter MoxBeam

Build this Moxon antenna using some unique materials & be ready for Solar Cycle 24

I was excited to read on the Amateur Radio News[1] that "the recent appearance on the sun of two so-called "backward sunspots" may mean solar Cycle 23 is drawing to a close and Cycle 24 now is under way or soon will be." During the peak years of solar cycle 23 I consistently made worldwide contacts on 10-meter PSK31 using 5 watts to an attic mounted Moxon rectangle.

The Moxon rectangle was developed by Les Moxon, G6XN, as a derivative of the VK2ABQ square, with further refinements to natural beam dimensions by L. B. Cebik, W4RNL[2]. The antenna is similar to a 2-element Yagi with the element ends folded toward each other. It has about the same gain, larger F/B ratio, 50Ω feed, and is approximately 30% smaller than the Yagi. For this "Moxon Beam" or MoxBeam project I describe a portable version of my attic antenna that is built from composite lumber, fiberglass tubing, and Home Depot wire for about $75. Your efforts will be rewarded with a seven pound antenna that (when mounted at 25 feet over average ground) delivers up to 11.3 dBi gain, 40 dB F/B ratio, 19° take-off-angle, and has a turning radius of 6.5 feet. For amateurs interested in other bands, I have included a table for constructing this antenna for 6m through 20m using the same technique.

Construction

Hub (Figure 7)

You may have seen the new composite lumber that is used to build outdoor decks. At least one company[3] offers this material in dimensional sizes such as 2x4s and it is an ideal material for building the antenna hub. It saws and drills like wood but is impervious to weather extremes, has low thermal expansion/contraction, and is U.V. protected. The smallest piece available is 12 feet long, and according to my local lumber yard, it is expensive at $26 each. However, you may be lucky (I was) to find a free scrap from a construction site because you only need an 8 inch piece, and the same hub can be used for all bands.

Print a full size template of the hub and temporarily fasten it to the composite material using a glue stick. Mark a centerline down the length of the material and use it to line up the template. Using a table or miter saw, cut two 20° angles on each end to form a "V" along the centerline. The total length should be 7½ inches from end to end. Extend the spreader hole centerlines down the ends and mark the centers. The angles on the ends make drilling the spreader holes easy. By clamping the piece on its end you automatically get the required 20° spreader angle. I find it helpful to drill a $^1/_8$ inch pilot hole first and then enlarge it to the final diameter. Using a drill press with a ¾ inch Forstner bit, drill a two inch deep hole at each location. Trial fit a piece of ¾ inch OD tubing to ensure that the insertion depth is two inches. Next, drill a one inch diameter hole in the hub center for the mast. A tapped hole on the side allows the hub to be secured to the mast with a ¼-20 x 1½ inch thumb screw. And last, drill four ¼ inch holes on the top of the hub for the spreader quick release buttons. If desired, remove sharp corners using a file or router with a round over bit. The hub material can be painted but the manufacturer recommends that you let it weather for 8-12 weeks, and then use any paint or stain that adheres well to wood.

Spreaders (Figures 6, 8, & 9)

The 83 inch long spreaders are made from ¾ inch and ½ inch OD fiberglass tubing ($^1/_8$ inch wall). Cut four 61 inch long pieces of ¾ inch OD tubing (Figure 9, dimension **S2**), and four 28 inch long pieces of ½ inch OD tubing (Figure 9, dimension **S3**). On one end of the ¾ inch OD tubing, drill a $^{17}/_{64}$ inch hole through one wall, one inch from the end. Deburr the inside of the hole with a round file and insert a quick release button. Insert the ½ inch tubing into the other end of the ¾ inch tubing with a 6 inch overlap. Fasten the tubes with a #6 x ½ inch thread-cutting screw in the center of the overlap.

Corner Clamps (Figures 6 & 8)

The four corners clamps are made from ¾ inch OD ($^1/_8$ inch wall) fiberglass tubing. Cut four pieces, 2½ inches long. Using scraps from the spreaders cut 4 one inch long pieces of ½ inch OD fiberglass tubing. Roughen the inside of the ¾ inch tubing with a tubing brush. Then, glue the ½ inch OD tubing inside the ¾ inch OD tubing, flush with one end, using fiberglass epoxy. Allow 24 hours for the glue to set and then remove any excess dried glue inside the ¾ inch tubing with a ½ inch Forstner bit. Then, tap the inside of the ½ inch tubing using a 5/16NC-18 tap. The last step is to drill a $^1/_8$ inch diameter hole all the way through both tubes, ½ inch from the flush end. Use a countersinking bit to smooth the edges and prevent chafing the wire insulation. A 5/16NC-18 x ½ inch long nylon hex head screw is then screwed into the threads. When a wire element is threaded though the $^1/_8$ inch hole the nylon screw is tightened enough to hold the wire, and the corner clamps become part of the element assembly.

Elements (Figures 6, 8, & 9)

The elements are cut from regular Home Depot #14 THHN insulated wire that was left over from dipole construction. This “Machine Tool Wire” (MTW) has 0.015 inches of PVC insulation plus 0.005 inch of outer nylon jacket. Initially, I initially suspected that the nylon jacket affected the insulation’s dielectric constant because the first set of elements I made had a resonance that was considerably lower than the model indicated (EZNEC[4] 4.0 includes the effects of wire insulation). However, closer inspection revealed that the ½ inch metal screws used to attach the elements to the insulators were to blame. The metal screws were replaced with nylon and the element resonance was on target.

The insulator ends are terminated with ring terminals by crimping and soldering. The feedpoint ends are soldered to a Budwig HQ-1 center insulator. When marking the wire corners use a permanent marking pen and place marks $^3/_8$ inch on either side of the corner mark. This will allow you to center the corner clamps on the corners. The wire lengths listed in Figure 9 assume that ¼ inch of wire insulation is stripped for connecting the ring terminals. This gives $^7/_{16}$ inch of additional length from the end of the wire to the tip of an Ace Hardware #34540 (16-14 Gage) ring terminal. Check the ring terminals that you intend to use and adjust the wire lengths as needed to meet the dimensions listed in Figure 9.

First, trim ¾ inch off both sides of the Budwig wires for a total end-to-end length of five inches. For the driven element, solder a ring terminal on the end of the wire. Place the ring terminal on a metal measuring tape (cloth tapes can stretch) with the terminal tip on zero and clamp the measuring tape and terminal in a vise. While keeping constant tension on the wire and tape, measure out 1 ft-10$^3/_{16}$ inches (Figure 9, dimension **B**) and mark the wire. Continue measuring to 7 ft-10$^5/_{16}$ inches (Figure 9, dimension **W1A**) and mark the wire, recheck the measurement and cut. Slip on a corner clamp and then a 2 inch length of ¼ inch OD heat shrink. Trim one inch of insulation from the wire and wrap the stripped wire around the Budwig wire. Adjust until the element wire insulation just touches the Budwig wire and solder. Slide the heat shrink tubing over the solder joint and shrink. Center the corner clamp between the marks and tighten the nylon screw finger tight, then tighten ½ turn with a wrench. Don't over tighten as it doesn't take much torque to secure the wire. Repeat this procedure for the other half of the driven element.

The reflector is longer than the driver and has no Budwig connector. Solder a ring terminal on the end of the wire. Using the clamping method mentioned above, measure out 2 ft-3$^7/_{16}$ inches (Figure 9, dimension **D**) and mark the wire. Continue measuring to 16 ft-9$^{11}/_{16}$ inches (Figure 9, dimension **W2A**) and mark the wire, recheck the measurement and cut. Slip on two corner clamps, strip ¼ inch of insulation, and solder a ring terminal on the end. Measure 2 ft-3$^7/_{16}$ inches (Figure 9, dimension **D**) from the tip of the second ring terminal and mark the location of the second clamp. Center the corner clamps between the marks and snug the nylon screws.

Insulators (Figures 6, 8, & 9)

The insulators provide the required spacing between the driver and reflector elements. Cut two strips, ½ inch wide x 4¾ inch long (Figure 9, dimension **C1**), from plastic screen base material (used for screened-in porches). This material is stable, flexible, and light weight. The element ring terminals are fastened to the insulators using 6-32NC x ½ inch nylon screws and nuts. It is important not to use metal screws here as it extends the element lengths and detunes the antenna. Mount the element terminal rings so that the tip-to-tip measurement is 4$^1/_{16}$ inch (Figure 9, dimension **C**).

Assembly

Assembly of the MoxBeam requires no tools and can be completed in less than five minutes. Place the hub on the ground and plug each spreader into the hub. Rotate the spreaders until the quick release buttons snap into the hub holes. Lay the wire elements out and slip the corner clamps over the spreaders, flexing the spreaders up as you progress. There is sufficient tension created by the elements to hold the corner clamps on the spreaders and the feedpoint taught. Flip the antenna over, place it on the mast and tighten the thumbscrew to lock it in place. The 6m-10m versions can also be installed with the spreaders flexed upward. However, due to higher lateral forces on the spreaders, the 12m-20m versions must be installed with the elements flexed downward. Connect the coax feed line to the Budwig center connector and secure the coax to the mast. Adjust the coax for minimum pull or sag on the driven element. I often include a 1:1 choke balun (to prevent common-mode current on the coax shield) by strapping it to the mast. Disassembly requires a small diameter rod to depress the spreader quick release buttons in order to remove the spreaders from the hub.

For Field Day or portable use the antenna can be hung from a convenient tree limb. A one inch OD wooden dowel inserted in the hub with an eye hook screwed into the top serves as a convenient tie point. The bottom of the dowel is used to suspend the weight of the coax before it is connected to the feed point (see Figure 9, dimension **H)**. Strings tied to opposite ends of two spreaders allow the beam to be rotated from the ground. Another method I find useful is to mount the smaller antennas with the spreaders flexed upward on a painter pole. With the acme threads extending past the top of the hub, a short length of wooden extension pole is screwed into the threads using a plastic coupling. The feedline is then secured to the pole, providing support for the antenna feedpoint. This setup works well when camping by securing the painter pole mast to the camper using plastic conduit clamps.

Modeling, Measuring, and Testing

Modeled SWR and azimuth plots for free space and 25 foot elevations are shown in Figures 1 and 2, respectively. Figure 4 illustrates an overall picture of the antenna's modeled characteristics when mounted at 25 feet over average ground. Maximum in-band gain is 11.28 dBi at 28.0 MHz and drops to 10.05 dBi at 29.0 MHz. The peak F/B of 39.66 dB is achieved at 28.125 MHz, and the 50Ω SWR minimum occurs at 28.25 MHz. The antenna's response favors the lower end of the band to cover the CW, digital, and SSB modes up to 28.7 MHz with a 1.5:1 SWR bandwidth. If you wish to alter the response or use different wire I suggest validating any changes with an antenna modeling program.

Builders who want to check the outline dimensions of their finished antenna against those of Figure 9 should understand that the corner clamps alter these dimensions slightly. By securing a ¾ inch section of the elements at an angle, the clamps shorten the antenna length "**A**" by approximately ¾ inch and increase the width "**E**" by $^{11}/_{16}$ inch on the 10-meter version. EZNEC modeling shows that this dimensional change does not significantly affect overall performance.

With the 10-meter MoxBeam installed at an elevation of 25 feet, an MFJ-259B analyzer was used to compare the actual and modeled 50Ω SWR. The antenna SWR curve compared very favorably with the modeled data. I tuned across the band and heard several stations on CW and a few PSK signals. K5SP was coming in loud and clear at S8 and we had a nice chat on PSK. Afterwards, I rotated the antenna 180° and his signal dropped to S2. Using the traditional 6 dB/S-unit approximation, this works out to 36 dB, which is very close to the modeled F/B of 39 dB at this height and frequency. Subsequent testing a few weeks later yielded several solid PSK contacts during the New England QSO Party.

All MoxBeams use a dielectric constant of 6 for the wire insulation in the EZNEC models with the exception of the 6-meter version. This version repeatedly came up with a much lower (1 MHz) measured resonant frequency than the models indicated. A quick search on the internet revealed that the dielectric constant can even change with wire insulation color. An email to L. B. Cebik, W4RNL, provided some much needed assistance into this mystery, for which I am grateful. "The most likely answer is that the insulation of the Home Depot wire is changing its dielectric properties in the upper HF range. PVC and other insulating plastics in the same general range often have additives to improve their durability or some other property (fire retardation, etc.) and these materials can alter the dielectric properties, especially in frequency regions that go untested, since they fall outside the wire's use." Although increasing the dielectric constant helped somewhat, I still couldn't get enough change to match the actual antenna. I ended up by leaving the dielectric constant at 6 and increasing the insulation thickness from 0.020 to 0.031 inches. The antenna (made with red insulation wire) was trimmed to the new dimensions and the resulting SWR curve was finally on target.

Final Notes

The Moxon rectangle is a proven performer with decent gain and a great F/B ratio, and the 10-Meter MoxBeam makes a terrific directional beam. However, if you are anxious and don't want to wait for the next solar cycle peak, you can get on the air now with any band from 6m through 20m using the techniques and information supplied in this article.

10-meters is a fascinating band to work. At solar cycle peaks the band comes alive with extremely long-distance signals that refract from the F2 layer. Even in times of solar minimum when F2 is rarely available, 10-meters still has some long-distance capabilities due to sporadic E propagation[5]. This small antenna will provide hours of fun, and because it's portable you can use it just about anywhere. By making use of the latest rugged and weatherproof materials the 10-Meter MoxBeam will soon become one of your favorites, so start building and be ready for solar cycle 24!

Allen Baker, KG4JJH
kg4jjh@arrl.net
www.kg4jjh.com

Notes

[1] Amateur Radio News, "Backward sunspots may herald start of Solar Cycle 24", Aug. 30, 2006; http://www.arrl.org/?artid=6730

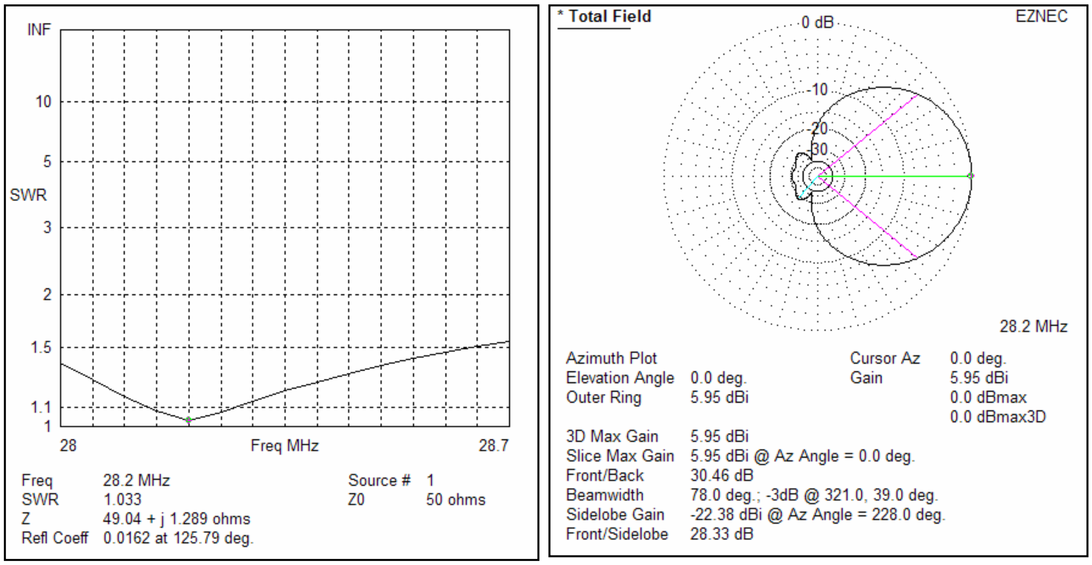
[2] L.B. Cebik, W4RNL, "Moxon Rectangles"; http://www.cebik.com/moxon/moxpage.html

[3] Portico Composite Decking and Railing, Trex Company, (available at Home Depot); http://www.trex.com/

[4] EZNEC, Roy Lewallen; http://www.eznec.com/

[5] "10 meters", Wikipedia Article; http://en.wikipedia.org/wiki/10_meters

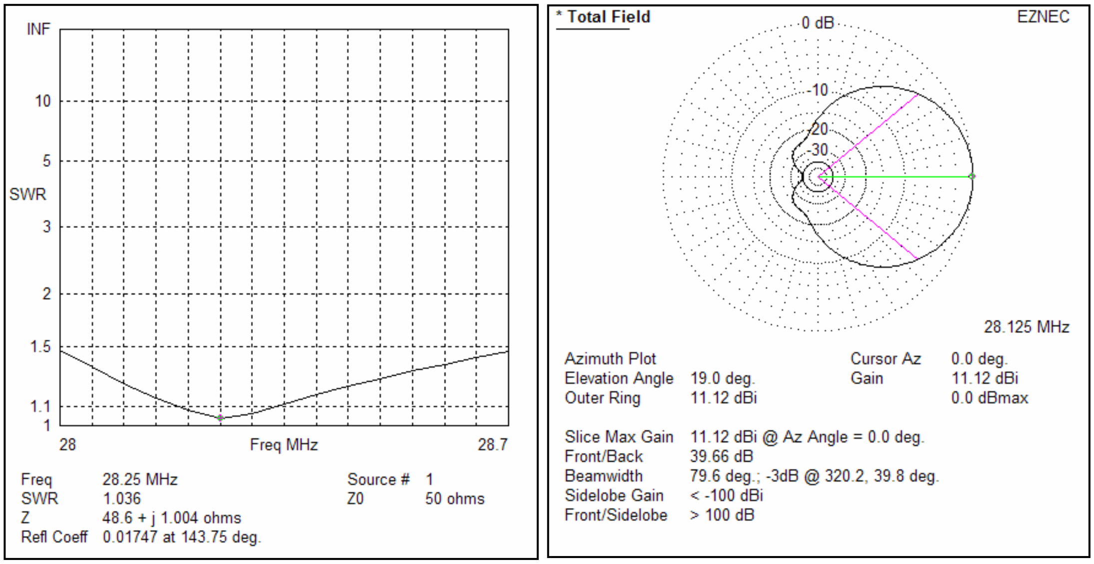
EZNEC 4.0.37 Plots



```
Freq        28.2 MHz                    Source #   1
SWR         1.033                       Z0         50 ohms
Z           49.04 + j 1.289 ohms
Refl Coeff  0.0162 at 125.79 deg.
```

```
Azimuth Plot                        Cursor Az   0.0 deg.
Elevation Angle   0.0 deg.          Gain        5.95 dBi
Outer Ring        5.95 dBi                      0.0 dBmax
                                                0.0 dBmax3D
3D Max Gain       5.95 dBi
Slice Max Gain    5.95 dBi @ Az Angle = 0.0 deg.
Front/Back        30.46 dB
Beamwidth         78.0 deg.; -3dB @ 321.0, 39.0 deg.
Sidelobe Gain     -22.38 dBi @ Az Angle = 228.0 deg.
Front/Sidelobe    28.33 dB
```

Figure 1
10-Meter MoxBeam SWR and Azimuth plots in Free Space



```
Freq        28.25 MHz                   Source #   1
SWR         1.036                       Z0         50 ohms
Z           48.6 + j 1.004 ohms
Refl Coeff  0.01747 at 143.75 deg.
```

```
Azimuth Plot                        Cursor Az   0.0 deg.
Elevation Angle   19.0 deg.         Gain        11.12 dBi
Outer Ring        11.12 dBi                     0.0 dBmax

Slice Max Gain    11.12 dBi @ Az Angle = 0.0 deg.
Front/Back        39.66 dB
Beamwidth         79.6 deg.; -3dB @ 320.2, 39.8 deg.
Sidelobe Gain     < -100 dBi
Front/Sidelobe    > 100 dB
```

Figure 2
10-Meter MoxBeam SWR and Azimuth plots @ 25 feet

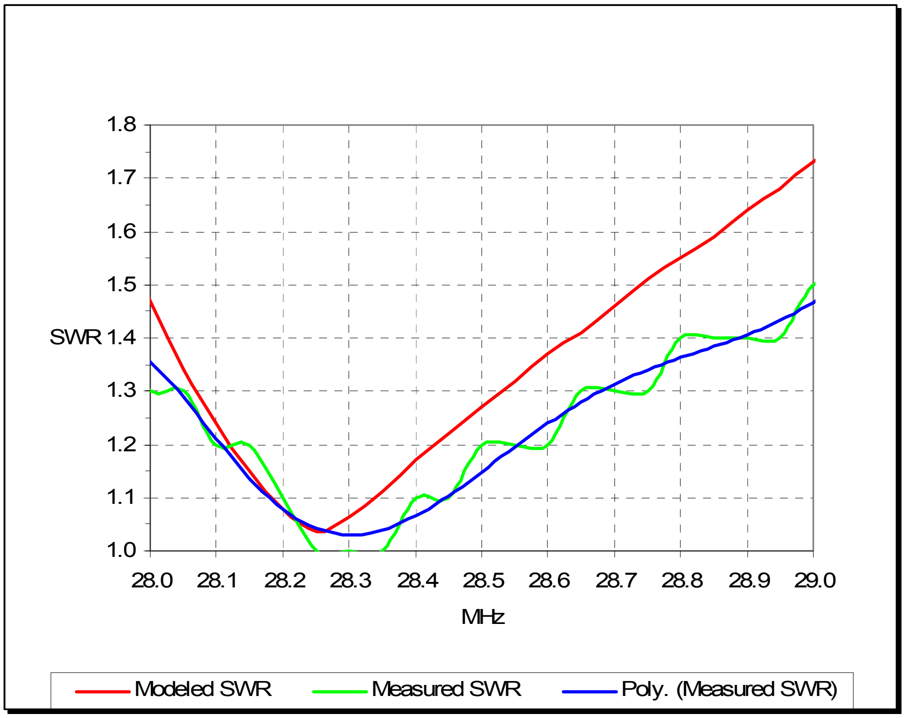


Figure 3
10-Meter MoxBeam modeled & measured SWR @ 25 feet

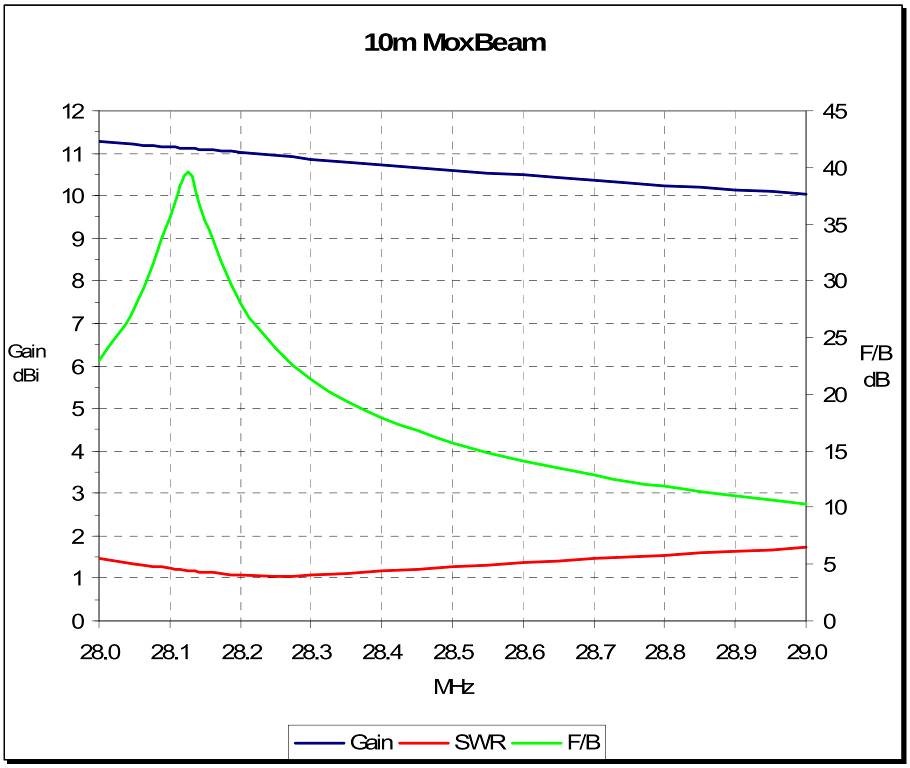
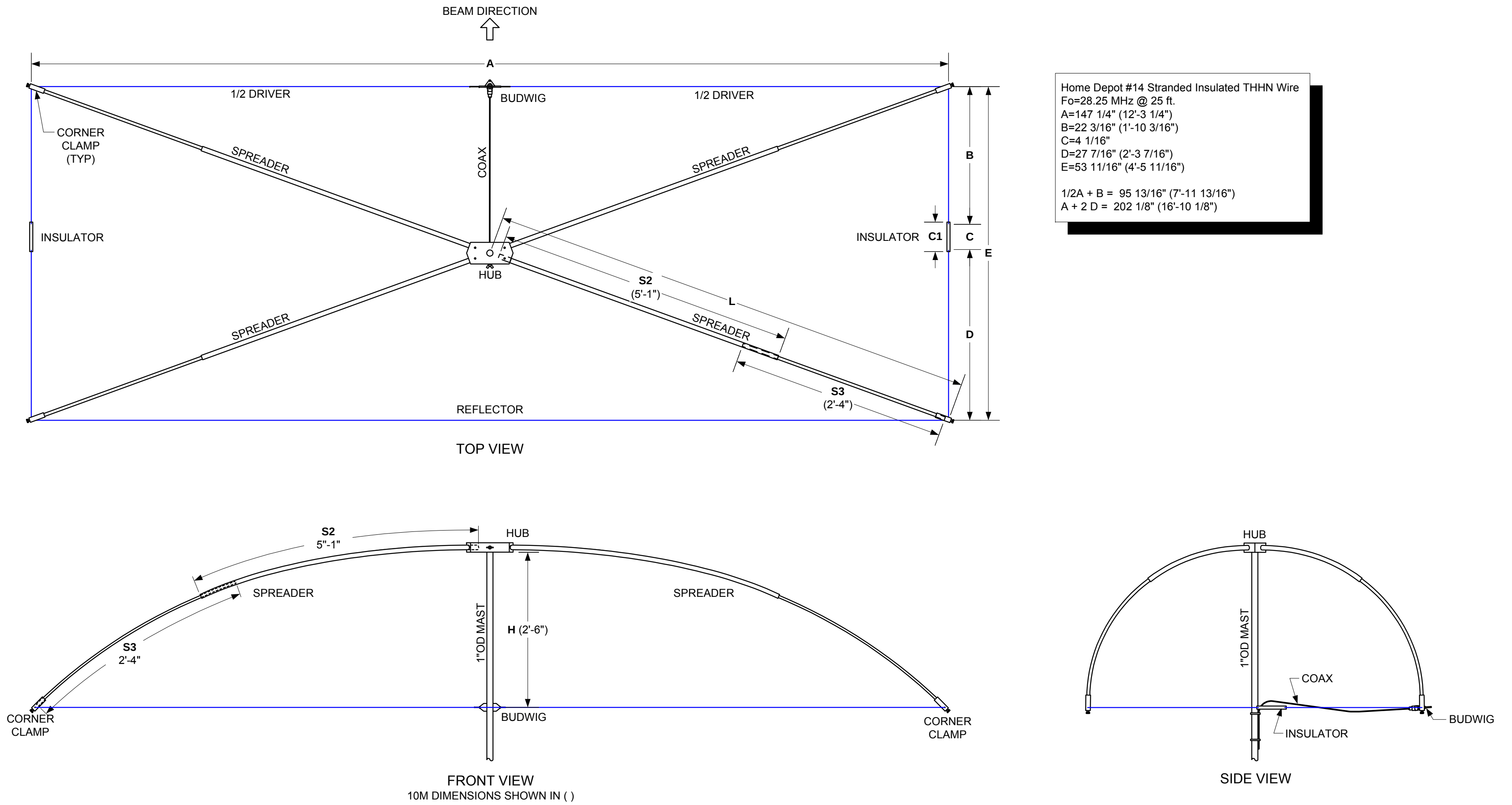


Figure 4
10-Meter MoxBeam modeled Gain, F/B, & SWR vs. Frequency @ 25 Feet

10-Meter MoxBeam Materials List					
Qty	**Description**	**Source**	**URL**	**Each**	**Total**
1 Ea	Hub, Trex Composite Lumber	Home Depot	homedepot.com	$0.00	$0.00
2 Ea	½ inch OD x 8 ft Fiberglass tubing*	Max-Gain	mgs4u.com/fiberglass-tube-rod.htm	$6.50	$13.00
4 Ea	¾ inch OD x 8 ft Fiberglass tubing*	Max-Gain	mgs4u.com/fiberglass-tube-rod.htm	$9.00	$36.00
33 Ft	#14 PVC Insulated Stranded Wire	Home Depot	homedepot.com	$0.08	$2.64
4 Ea	Nylon screw, 5/16-18x1/2 inch	Ace Hardware	acehardware.com	$0.25	$1.00
1 Ea	Budwig HQ-1	RF Connection	therfc.com/anttacc.htm	$8.00	$8.00
1 Ea	Thumb Screw, Stainless, ¼-20 x 1½ inch, #91745A546	McMaster-Carr	mcmaster.com	$1.80	$1.80
1 Box	Ring Terminal, #34540, 16-14 gauge	Ace Hardware	acehardware.com	$2.79	$2.79
4 Ea	Nylon screw & nut, 6-32 x ½ inch	Ace Hardware	acehardware.com	$0.50	$2.00
1 Pk	Quick Release Button, Stainless, #92988A530	McMaster-Carr	mcmaster.com	$10.63	$10.63
					$77.92

* Max-Gain Systems will cut tubing to specification, which can significantly reduce shipping charges.

Figure 5



Home Depot #14 Stranded Insulated THHN Wire
Fo=28.25 MHz @ 25 ft.
A=147 1/4" (12'-3 1/4")
B=22 3/16" (1'-10 3/16")
C=4 1/16"
D=27 7/16" (2'-3 7/16")
E=53 11/16" (4'-5 11/16")

1/2A + B = 95 13/16" (7'-11 13/16")
A + 2 D = 202 1/8" (16'-10 1/8")

KG4JJH		
MOXBEAM ASSEMBLY		
SCALE: NONE	SHEET 1 OF 4	REV. 0
DESIGN: A. BAKER	DATE: 4/27/07	

Figure 6

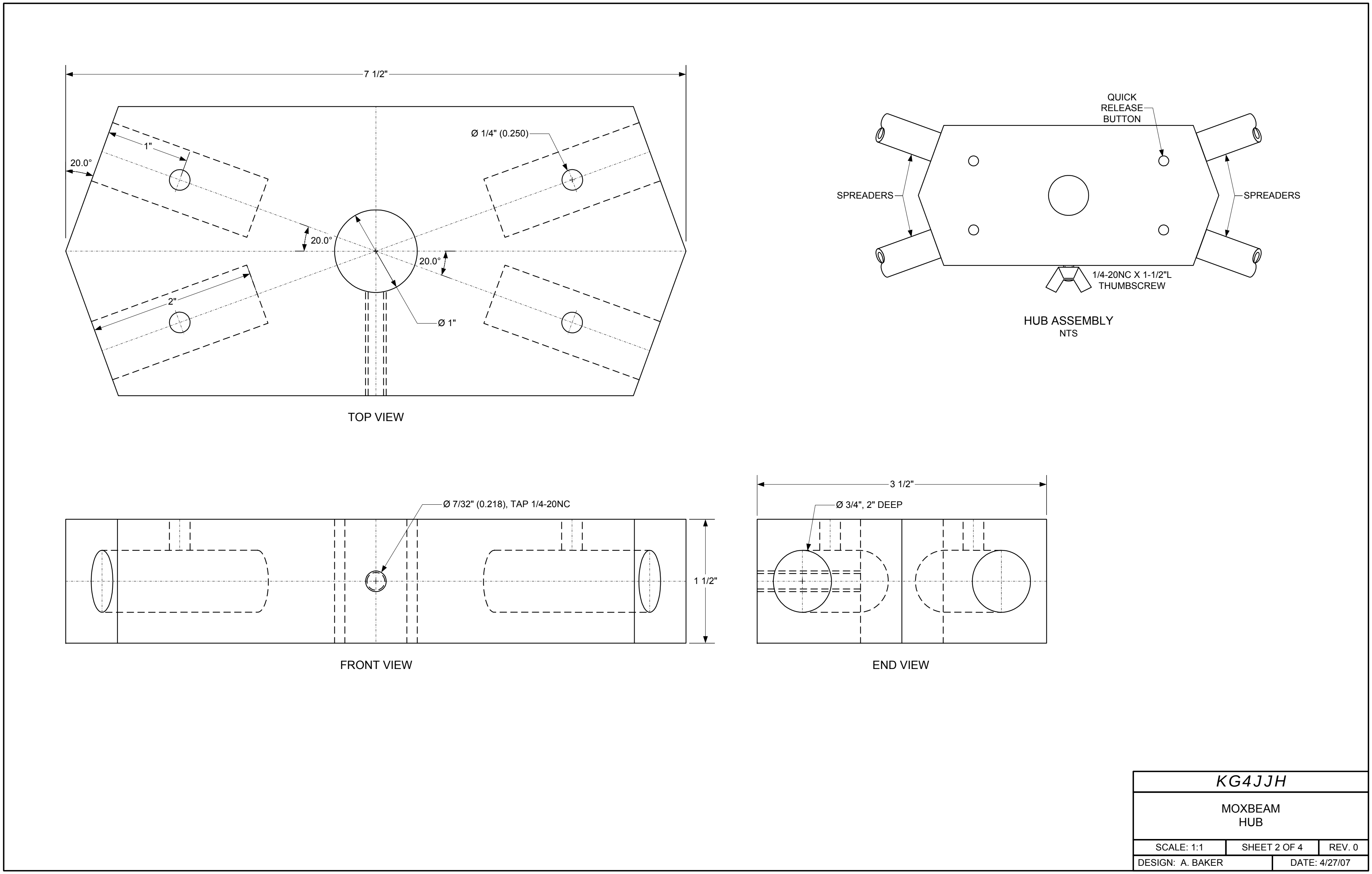
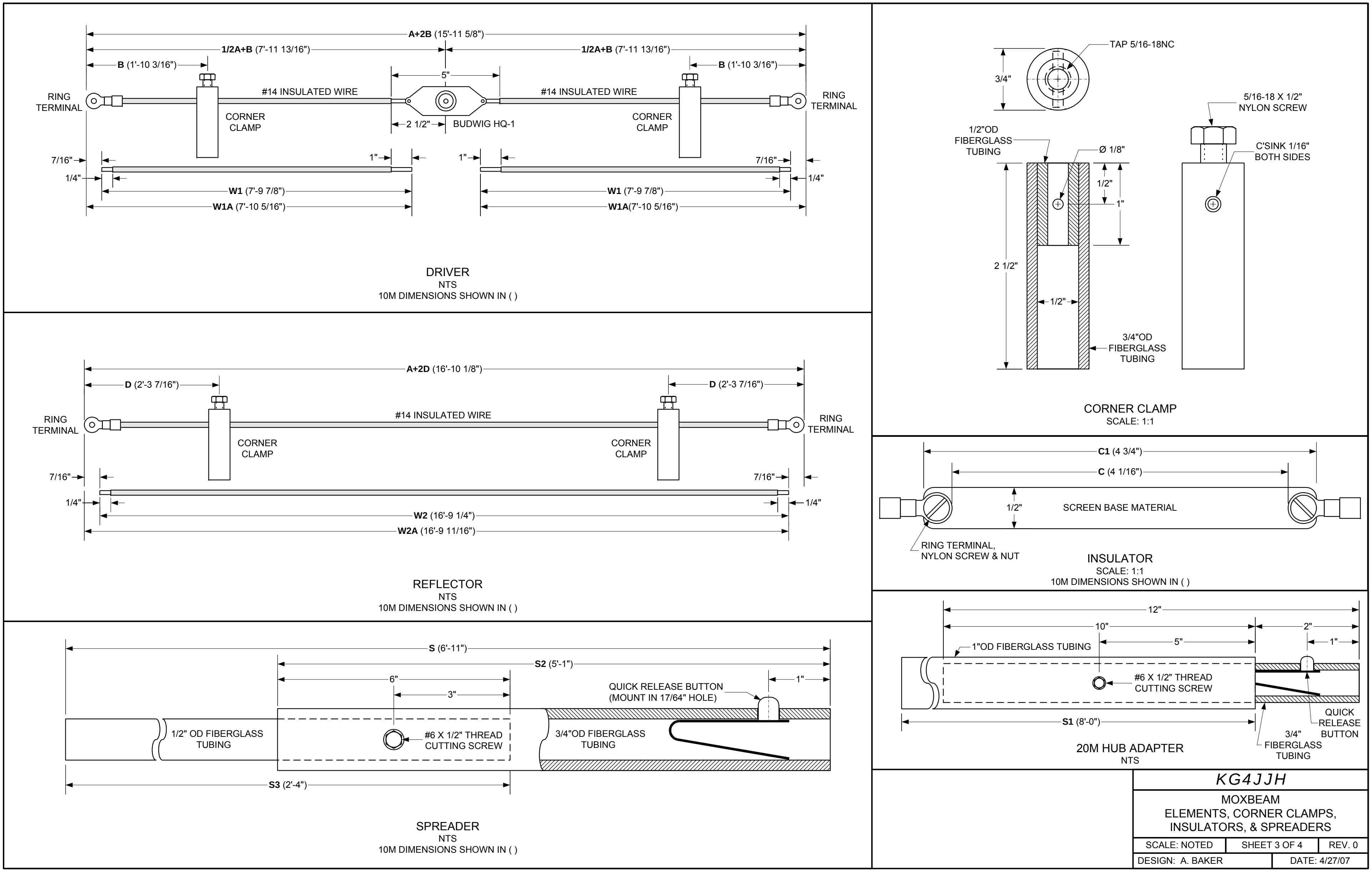

7 1/2"
20.0°
1"
Ø 1/4" (0.250)
20.0°
20.0°
2"
Ø 1"
TOP VIEW
QUICK RELEASE BUTTON
SPREADERS
SPREADERS
1/4-20NC X 1-1/2"L THUMBSCREW
HUB ASSEMBLY
NTS
Ø 7/32" (0.218), TAP 1/4-20NC
1 1/2"
FRONT VIEW
3 1/2"
Ø 3/4", 2" DEEP
END VIEW
KG4JJH
MOXBEAM
HUB
SCALE: 1:1
SHEET 2 OF 4
REV. 0
DESIGN: A. BAKER
DATE: 4/27/07

Figure 7



DRIVER
NTS
10M DIMENSIONS SHOWN IN ( )

REFLECTOR
NTS
10M DIMENSIONS SHOWN IN ( )

SPREADER
NTS
10M DIMENSIONS SHOWN IN ( )

CORNER CLAMP
SCALE: 1:1

INSULATOR
SCALE: 1:1
10M DIMENSIONS SHOWN IN ( )

20M HUB ADAPTER
NTS

KG4JJH

MOXBEAM
ELEMENTS, CORNER CLAMPS,
INSULATORS, & SPREADERS

SCALE: NOTED	SHEET 3 OF 4	REV. 0
DESIGN: A. BAKER		DATE: 4/27/07

Figure 8

MoxBeam Statistics														
Band (Meters)	**Elevation: Free Space**				**Elevation: 1WL**					**Elevation: 1/2WL**				
	F_O (MHz)	**Gain (dBi)**	**F/B (dB)**	**1.5:1 BW (MHz)**	**Elev. (Ft.)**	**F_O (MHz)**	**Gain (dBi)**	**F/B (dB)**	**1.5:1 BW (MHz)**	**Elev. (Ft.)**	**F_O (MHz)**	**Gain (dBi)**	**F/B (dB)**	**1.5:1 BW (MHz)**
6	50.300	6.04	22.28	50.0-51.1	19.5	50.300	11.37	19.69	50.0-51.0	9.8	50.250	10.57	17.54	50.0-50.9
10	28.200	5.76	29.77	28.0-28.7	34.9	28.150	11.38	22.69	28.0-28.6	17.5	28.150	10.58	19.58	28.0-28.5
12	24.960	5.92	31.81	Full Band	39.5	24.930	11.34	23.64	Full Band	19.8	24.900	10.02	21.96	Full Band
15	21.150	5.91	33.40	Full Band	46.5	21.150	11.30	24.78	Full Band	23.3	21.100	10.60	19.92	21.0-21.4
17	18.098	5.86	36.05	Full Band	54.4	18.068	11.32	24.80	Full Band	27.2	18.068	10.57	19.58	Full Band
20	14.100	5.82	34.72	Full Band	69.8	14.100	11.24	24.82	14.0-14.3	34.9	14.075	10.58	19.41	14.0-14.25
Gain and F/B listed at resonance					WL in feet: λ = 983.56909 / F(MHz)					WL in meters: λ = 299.792458 / F(MHz)				

Figure 10