40m Moxon 2018 Update

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Version 1.0

This note looks at the 40 meter Moxon antenna developed by Dave Leeson, W6NL, back around 2007. The initial design was modified twice for greater resistance to wind damage. The most recent update was in 2012.

Leeson created the following note describing the modifications:

100 mi/h W6NL/Moxon for W2SC

The winds aloft at K3LR proved to be greater than anticipated, and the original 2007 W6NL/Moxon 40m Yagis suffered wind damage. A new design was developed in 2010, using a new stronger center section of 1.66" OD pipe along with the original parts of the 2007 design. Element guying is not required for the new configuration. At the suggestion of W2SC, a related 2012 design uses standard tubing diameter for the center sections.

These new center sections are 1.5" tubing, reinforced to triple wall thickness for the first 24", then double wall thickness. This will permit use standard clamps from DX Engineering to fit the 1.5” OD of the inner tube. It is believed that these clamps will fit into the original Cushcraft XM240 aluminum channel that was used to mount the elements to the boom.

The tee loading sections are unchanged in the new design. Here are the dimensions (in inches) of the 2007 and 2010 element sections:

2007 K3LR			2012 W2SC		
Driven Element					
Diameter	Section	Total	Section	Total	
1.5			48	48	New
1.375	42	42	39	87	
1.25	45	87	45	132	
1.125	44	131	44	176	
1	29	160	29	205	
0.875	44.5	204.5	2	207	New
0.75	3	207.5	3	210	
0.625	3	210.5	3	213	
0.5	39	249.5	39	252	
0.375	32.5	282	32.5	284.5	
Reflector					
Diameter	Section	Total	Section	Total	
1.5			48	48	New
1.375	42	42	39	87	
1.25	45	87	45	132	
1.125	44	131	44	176	

1	29	160	29	205	
0.875	44.5	204.5	25	230	New
0.75	27	231.5	3	233	New
0.625	3	234.5	3	236	
0.5	39	273.5	39	275	
0.375	13.25	286.75	13.25	288.25	

All of the original element tubing can be used (except for the bent sections, which should be replaced). The 0.875" OD sections are cut shorter, as are the 0.75" OD sections of the reflector. This design has the same electrical performance as the 2010 design for K3LR, but has sufficiently reduced element deflection that element guying is not necessary.

D. B. Leeson, W6NL/HC8L 4-4-12

I put together a model of the 2007 design a number of years ago, but long after two were installed (120', 185') at K3LR as the 40m mult radio stack. The purpose of the model at that time was to highlight an antenna design where the results obtained from the NEC-2 engine should differ significantly from the NEC-4 engine. The Moxon has that property because the *tee loading sections* turn off the *stepped diameter correction* algorithm used in programs based upon NEC-2 (such as some version of EZNEC and 4nec2). Without the use of the stepped diameter correction algorithm (when stepped diameters are part of the model), the results obtained from NEC-2 are known to be inaccurate. For antennas like the Moxon, that cannot use the stepped diameter correction algorithm, NEC-4 (or MININEC) should be used as the modeling engine.

At this point in 2018, the goal is to revisit the original 2007 model and then compare it to the model results obtained from the 2012 updated design.

The spacing between the driven element and reflector is 258", which is 21.5'. The same spacing is used in both the 2007 and 2012 designs.

For modeling I will be using EZNEC Pro/4 with NEC-4 as well as the AutoEZ front end from Dan, AC6LA.

2007 Design

The 2007 design was modeled at a height of 185', the top Moxon on the K3LR stack.

The modeled 2007 Moxon SWR response is:

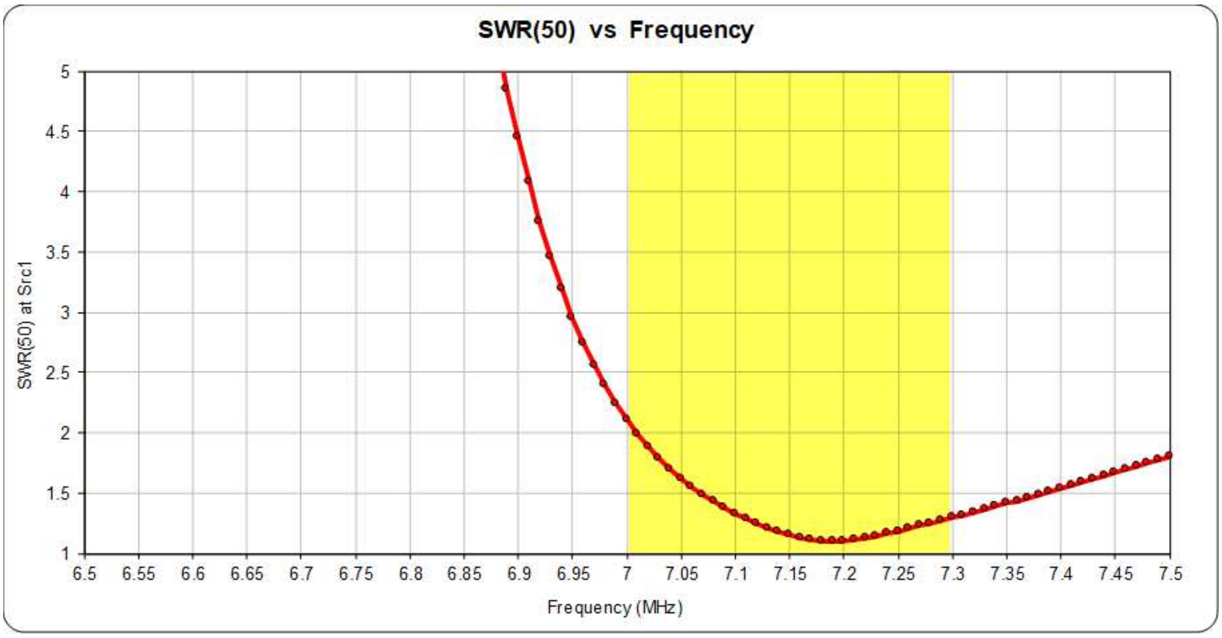

Figure 1 - 2007 Moxon SWR (modeled)

The sweep covers 6.5 to 7.5 MHz. The band is highlighted in yellow.

The modeled 2007 Moxon Gain and F/B response is:

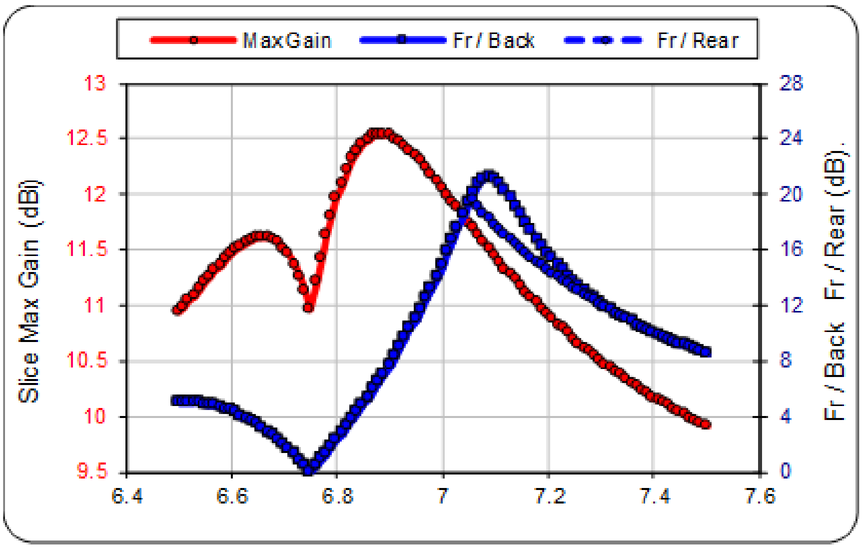

Figure 2 - 2007 Moxon Gain and F/B (modeled)

Although the F/B peak is within the band (7.090 MHz), the maximum gain is down around 6.9 MHz, and drops with increasing frequency. This is a general characteristic of the Moxon. In particular, the gain is maximum at the bottom of the operating SWR range and it drops with increasing frequency. This is the opposite of the typical Yagi, where the gain slowly increases across the frequency range.

The azimuth pattern at the F/B peak looks like:

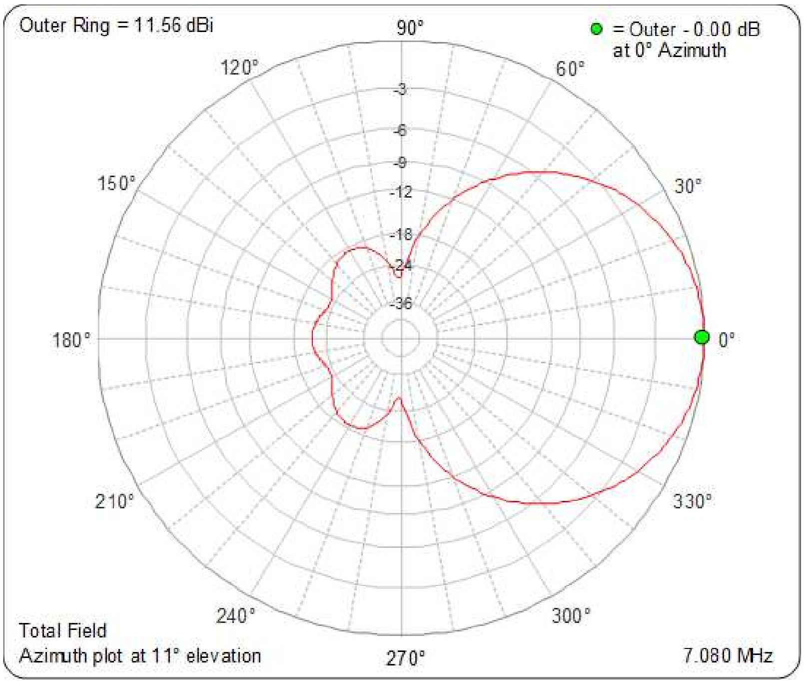

Figure 3 - 2007 Moxon Azimuth Pattern at 11 Degree TOA

A maximum F/B of 21 dB is not that high for a Moxon. Using the Moxgen program from Dan, AC6LA, a 40m Moxon designed for 7.1 MHz has this azimuth pattern with the same conditions as the 2007 Moxon:

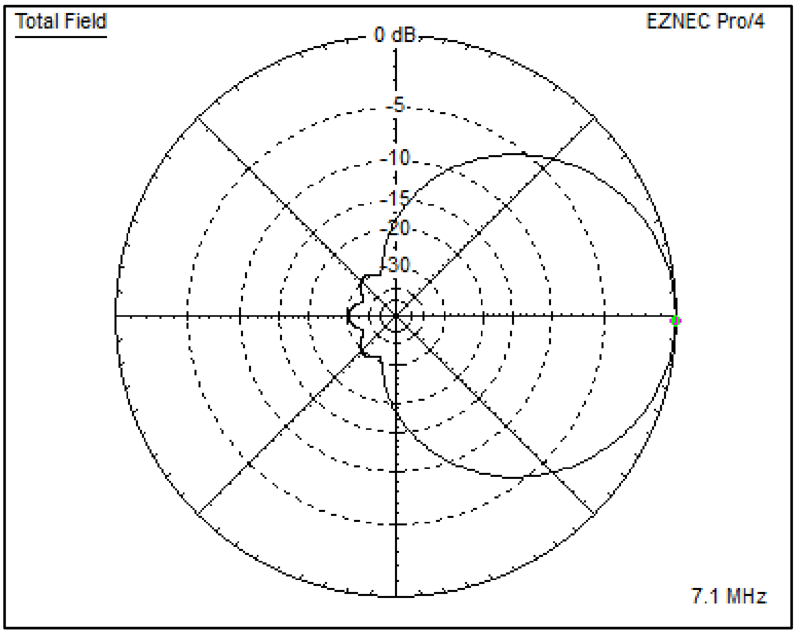

Figure 4 - Moxgen 40m Moxon (30 dB F/B)

The F/B is at 30 dB. Perhaps a side-effect of the W6NL design (that has significant mechanical advantages) is a reduction in the F/B ratio.

I have measured SWR data for the 2007 Moxon at 185’, taken on October 5, 2017. The comparison to the model is:

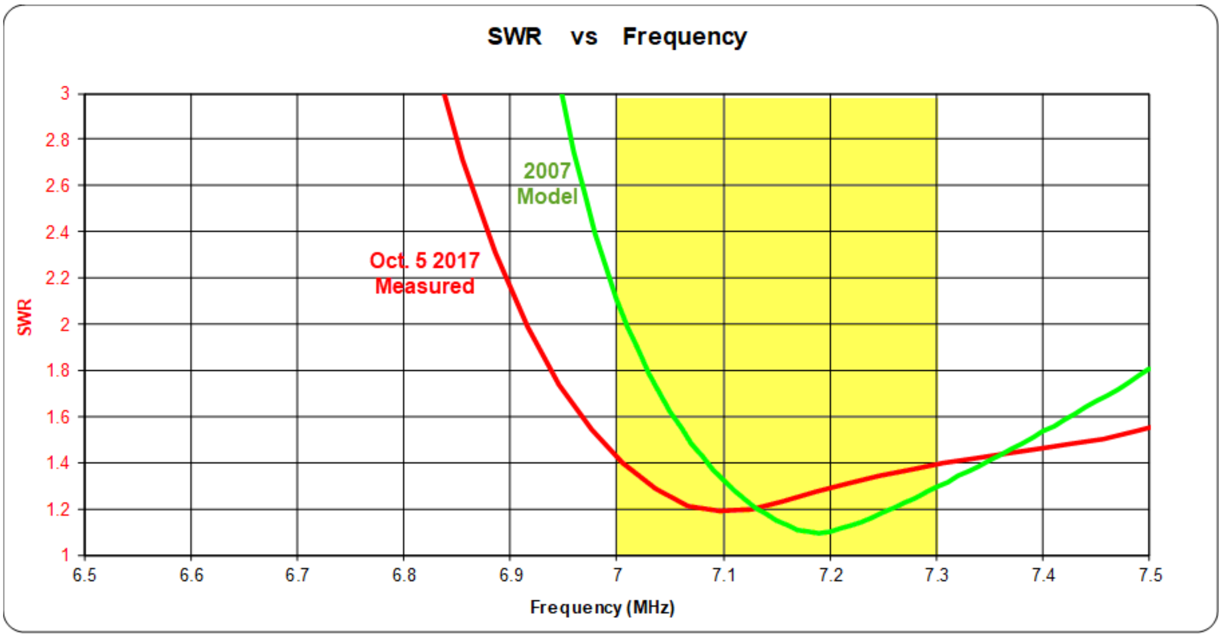

Figure 5 - Measured versus Modeled SWR (red is measured, green is modeled)

The measured SWR curve shows a downward frequency shift of about 100 KHz. That shift improves the SWR in the band. If it also moves down the gain and F/B curve, however, they will be substantially below the band.

2012 Design

The following graphs compare the 2012 performances curves to the 2007 curves.

The SWR comparison is:

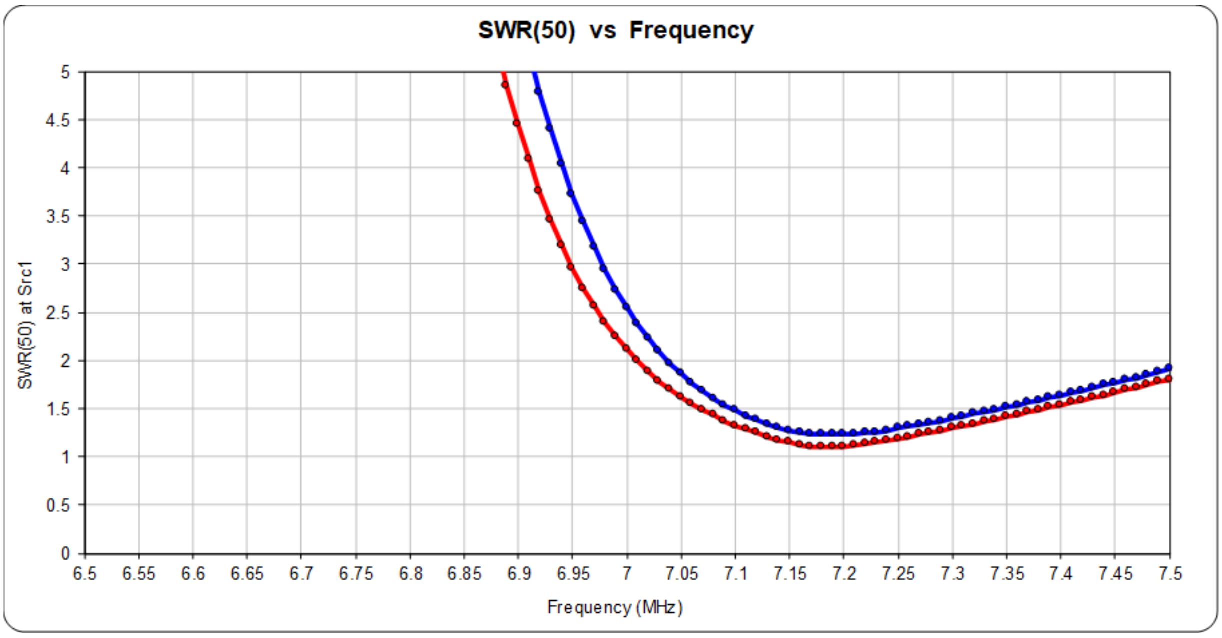

Figure 6 - SWR Comparison, Red is 2007, Blue is 2012

The max gain at an 11 degree take off angle comparison is:

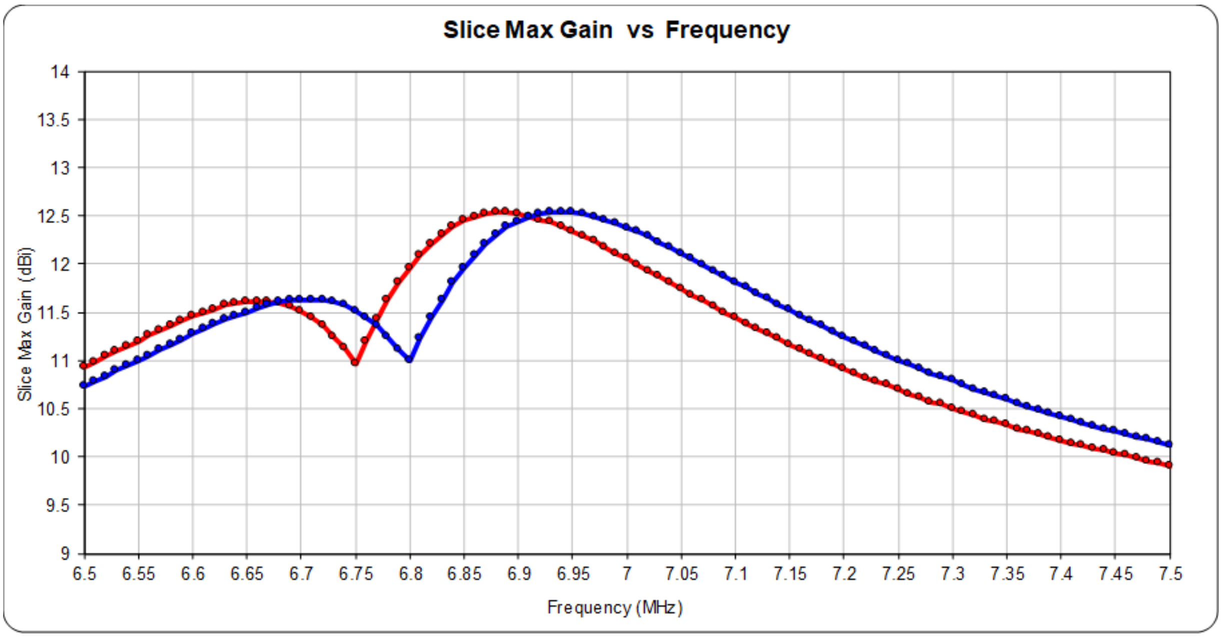

Figure 7 - Max Gain Comparison, Red is 2007, Blue is 2012

The F/B comparison is:

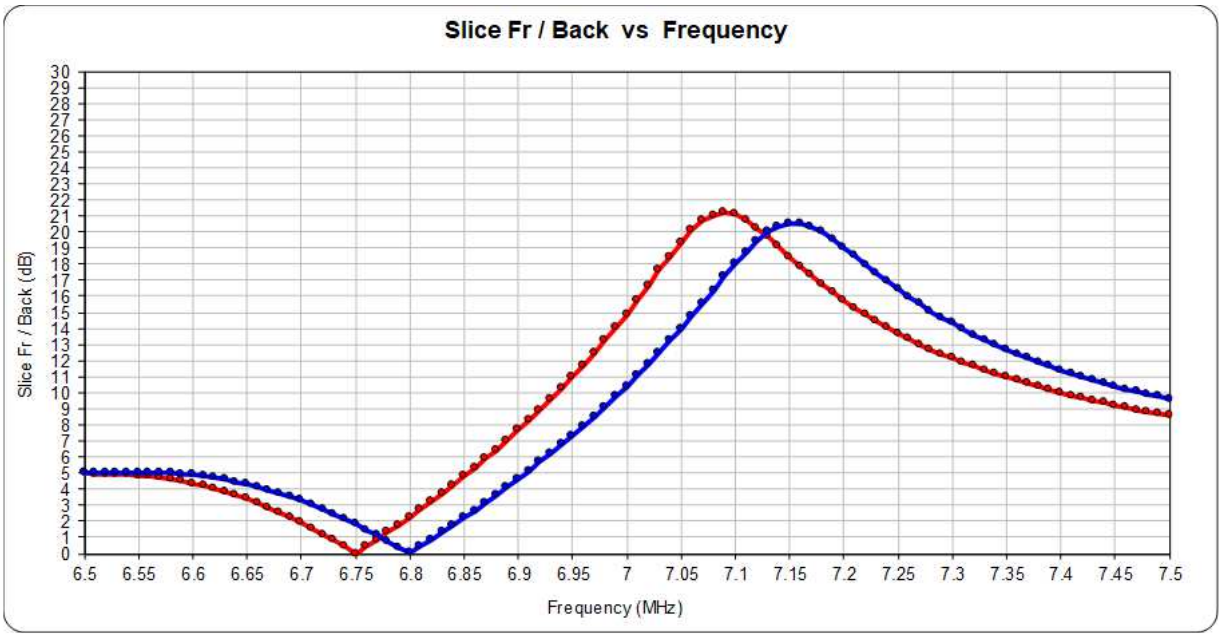

Figure 8 - F/B Comparison, Red is 2007, Blue is 2012

The SWR, gain, and F/B curves are nearly identical, although the 2012 design shows an upward frequency shift of about 50 KHz. I have no idea if this is intentional or not.

The azimuth pattern is very similar to the 2007 pattern. At 7.140 MHz, near the F/B pear, the pattern looks like:

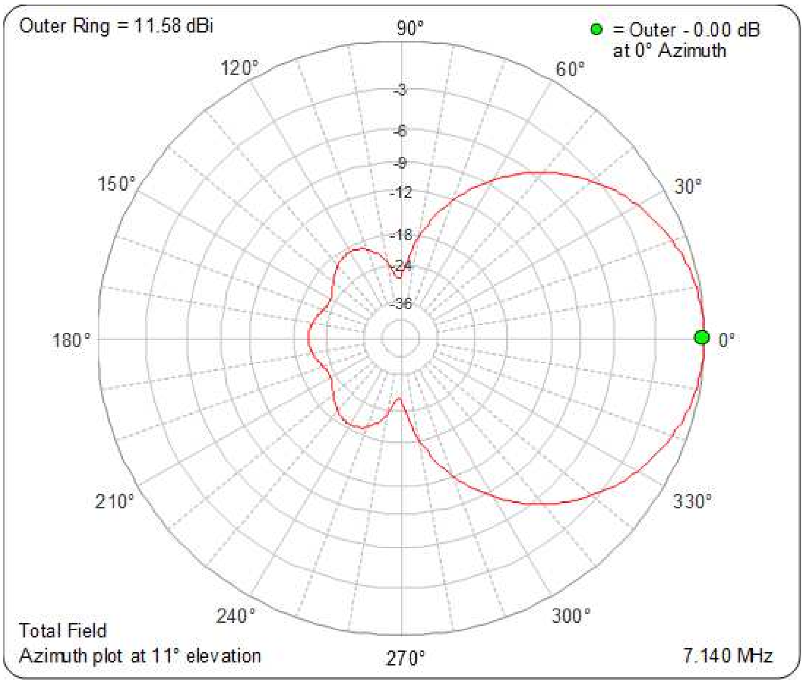

Figure 9 - 2012 Moxon Azimuth Pattern

Optimizing the Design

Since I had the design captured in the AutoEZ format it was easy to add a few variables and optimize the design. I added 4 variables, as shown in the following diagram.

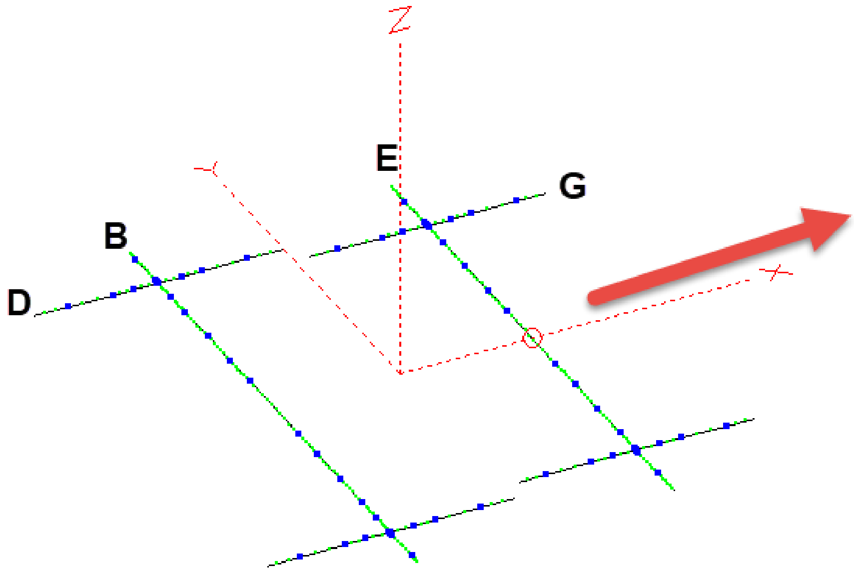

Figure 10 - 2012 Moxon Optimization Variables

The letters are the variable names used in AutoEZ. The definitions are:

B: the tip length of the reflector that extends beyond the junction.

D: the perpendicular tip length of the reflector that extends beyond the junction.

E: the tip length of the driven element that extends beyond the junction.

G: The perpendicular tip length of the driven element that extends beyond the junction.

The reflector has two B tips and four D tips. The driven element has two E tips and four G tips.

The tip junctions are not going to move in the optimization, nor the spacing between elements on the boom.

After a number of runs I came away with the conclusion that the Moxon design places the SWR dip very close to the maximum F/B frequency. In the case of the classic Moxon, that F/B is around 30 dB. In this design it is around 21 dB. The maximum gain is at a lower frequency. The maximum gain drops by about 1 dB by the time you get to the maximum F/B. The maximum gain frequency, maximum F/B frequency, and minimum

SWR frequency are locked together and move together. I was not able to get the maximum gain frequency to also be the maximum F/B frequency.

It is possible to add an impedance matching device to move the SWR dip under the maximum gain. A 25 to 50 Ohm transformer could be used. While this does line up the SWR dip with the maximum gain frequency, the SWR bandwidth is narrowed and the maximum F/B is still at a high frequency. If all you cared about was gain, with little concern for F/B or bandwidth, this would be the way to go.

I ended up with the conclusion that it's not useful to worry too much about gain and that the 2012 design is pretty well-balanced.

If there is a concern about the 2012 design as expressed by the model it is a claimed SWR of 2.5 at 7.0 MHz. To take a whack at that issue I directed to optimizer to reduce the SWR at 7.075 MHz.

I ended up with the 2012OptimAll03.weq design. The SWR comparison to the stock 2012 design is:

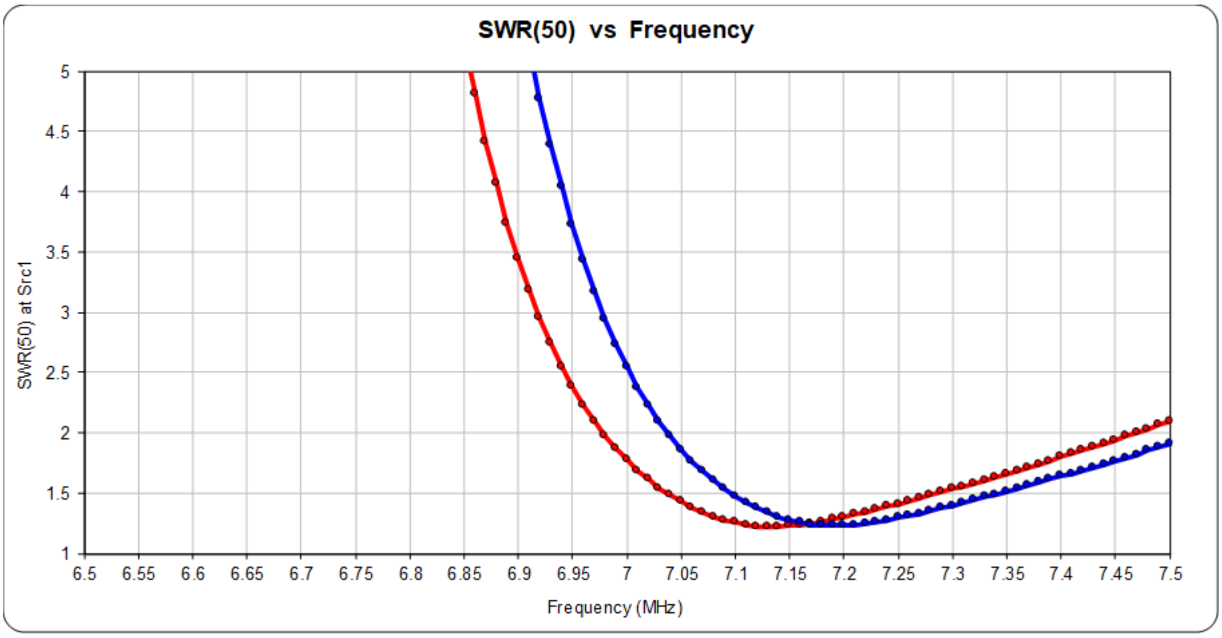

Figure 11 - 2012OptimAll03 SWR Comparison

Red is the optimized SWR curve, blue is the 2012 model curve. Now the optimized curve does not look better as much as shifted downward in frequency. The F/B curve comparison is:

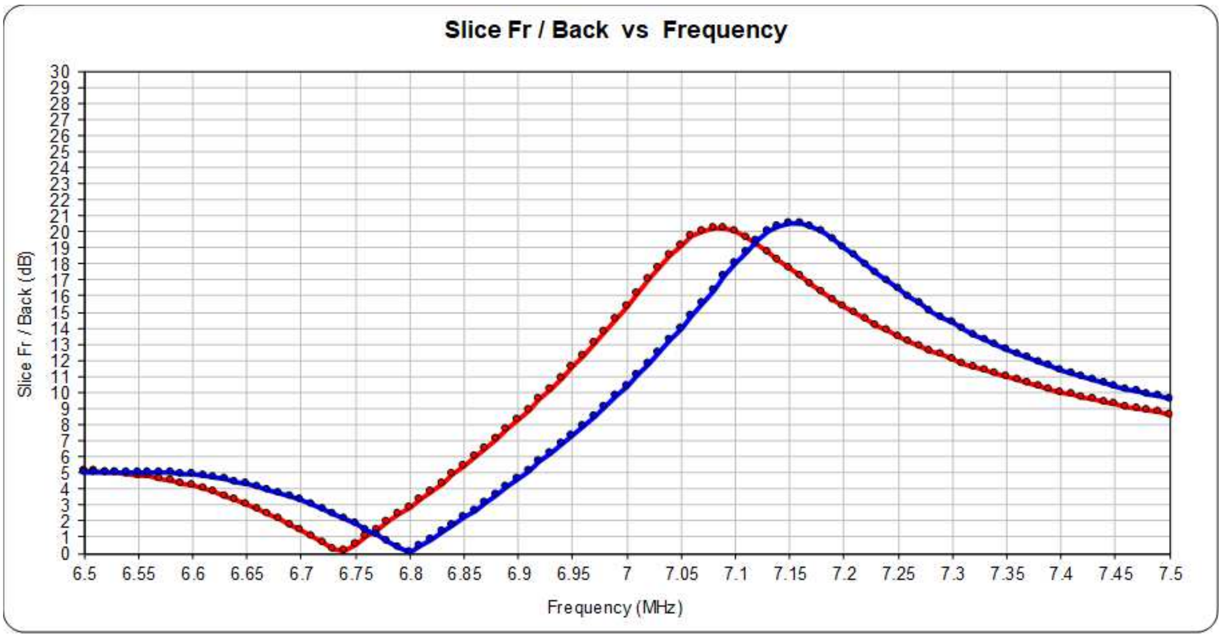

Figure 12 – 2012OptimAll03 F/B Comparison

Red is the optimized design, blue is the stock 2012 design. The optimized design F/B peak is at 7.075 MHz. So, it's not so much that the design was optimized, but rather shifted to a particular frequency.

I end up with the idea that the performance combination in terms of gain, F/B, and SWR, are locked together, and all you can do is shift it up and down in frequency, but not fundamentally change the relationship.