40m OWA Yagi Update (2019)

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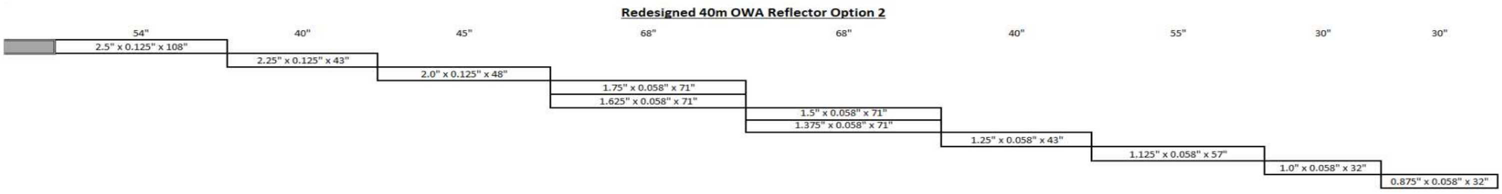
In the summer of 2019, the popular and high performance 4 element 40m OWA that has been in use for many years at stations including K3LR was updated with a new element taper schedule.

The taper schedule was developed by Scott MacDonald and looks like:



Since this small diagram is a bit hard to read, here is the same data in table format. The data is for half of an element (as shown above).

New 40m Half Element Taper Schedule			
Tube Diameter	**Tube Length**	**Exposed Length**	**Outboard Extent**
2.50”	54”	54”	54”
2.25”	43”	40”	94”
2.00”	48”	45”	139”
1.75”/1.625”	71”	68”	207”
1.50”/1.375”	71”	68”	275”
1.25”	43”	40”	315”
1.125”	57”	55”	370”
1.00”	32”	30”	400”
0.875”	32”	30”	430”

The schedule goes out to 430” which represents the reflector extent which is the longest element. The remaining three elements will be shorter, in some cases completely eliminating the outside tube section.

The first three tubes have a 0.125” wall thickness. The remaining tubes have a 0.058” wall thickness. In the 1.75” and 1.5” tube cases the next smaller diameter is telescoped into the whole length of the tube. This creates a tube with a 0.116” wall thickness.

Please see Scott’s documentation for complete details.

Existing Yagi Performance

The existing Yagi has the following element offsets and tip lengths.

Existing Yagi Dimensions		
Element	Offset From Reflector	Tip Length
REF	0.0”	438.75”
DE	261.5”	436.00”
D1	320.5”	403.375”
D2	570.0”	378.375”

The 570” REF to D2 distance is 47.5’, implying a 48’ boom.

The existing Yagi has the following performance. The model was placed at 190’ over rich soil using the real/high accuracy ground model.

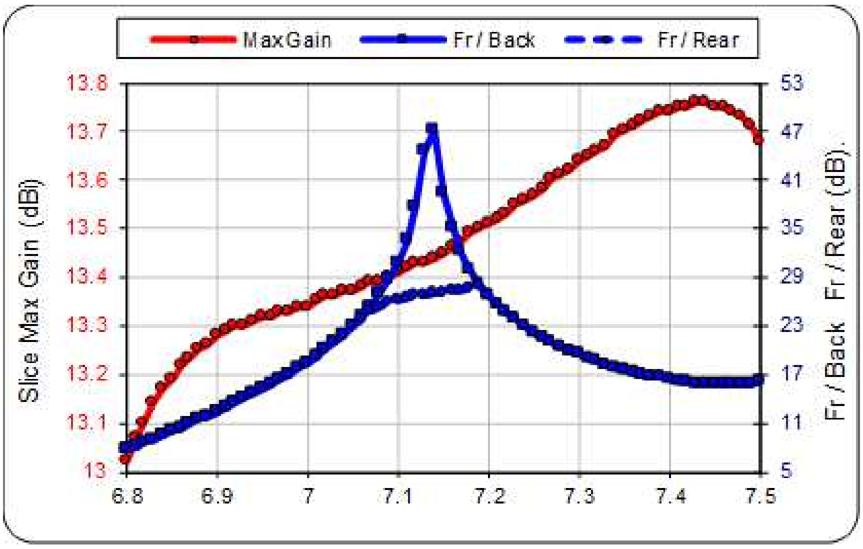


Figure 1 - Existing Gain and F/B Ratio

Gain and F/B are measured at an 11 degree take off angle, which is the angle of maximum gain at that height.

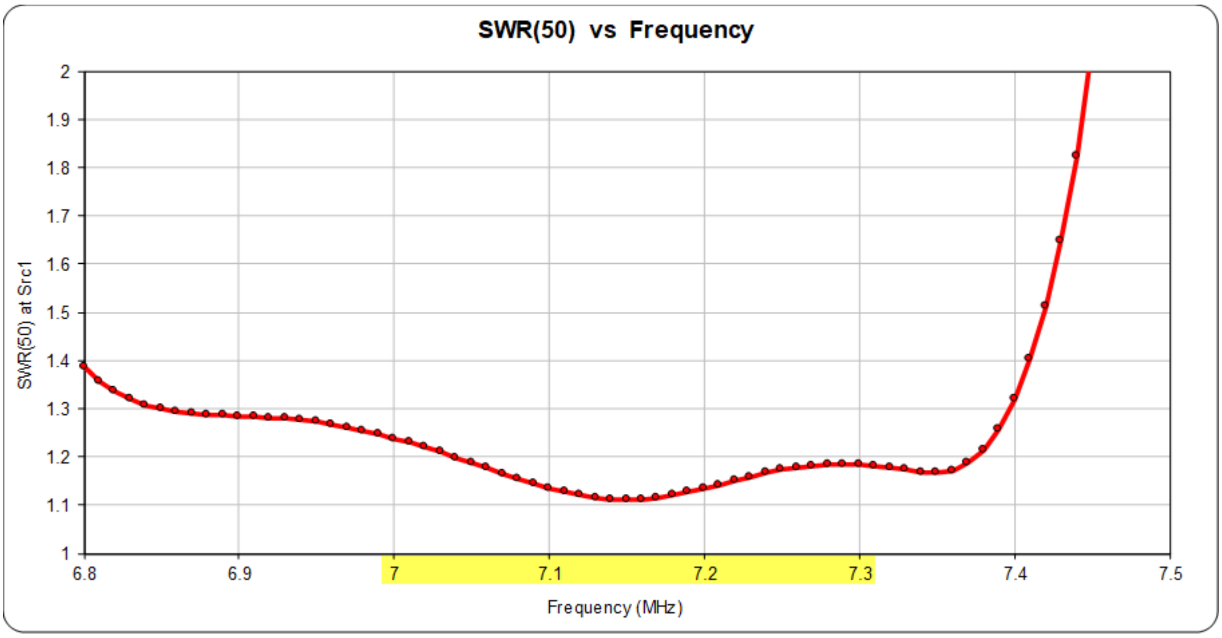


Figure 2 - Existing Yagi SWR Sweep

Note that the sweep is beyond the limits of the band, 6.8 to 7.5 MHz. The 40m band, 7.0 to 7.3 MHz, is highlighted in yellow.

Finally, here is the azimuth pattern at the 11 degree take off angle at 7.140 MHz, the frequency of highest F/B ratio:

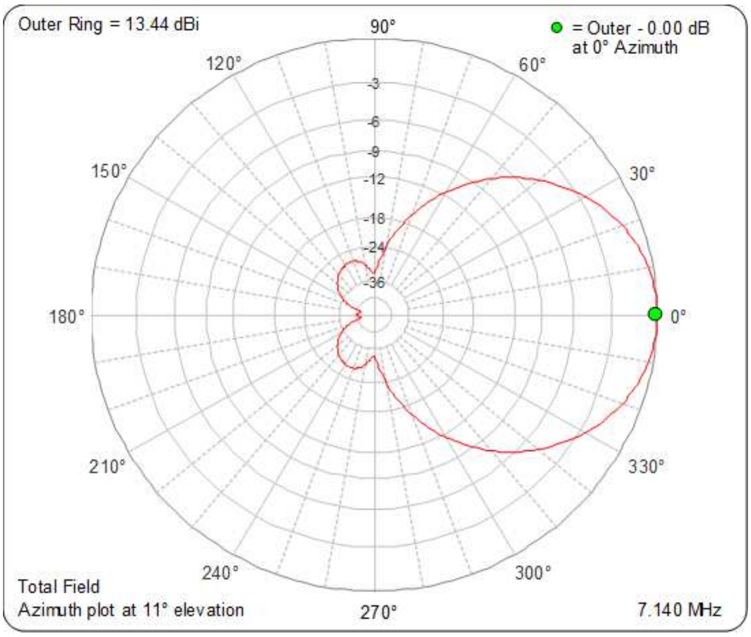


Figure 3 - Existing Azimuth Pattern

Fixed Element Spacing

The taper schedule was updated to the new schedule, and as a starting point for optimization the tip lengths were set to the lengths of the original antenna. The element spacing down the boom was fixed to the spacing of the existing Yagi. All that was optimized was the tip lengths.

After a number of runs, the design process ended with file **2019Taper06.weq**. The optimization targets used are:

Freq (MHz)
6.980
7.050
7.100
7.150
7.200
7.250

Optimization Objective(s)

Target	Weight	Good Enough
|R - 50|	0	0.5
|X|	0	0.5
SWR	50	1.05
Gain	1	99
Fr / Back	1	40
Fr / Rear	0	40

Defaults

Figure 4 - 2019Taper06.weq Optimization Targets

The next graphs compare the performance of 2019Taper06.weq to the original Yagi performance.

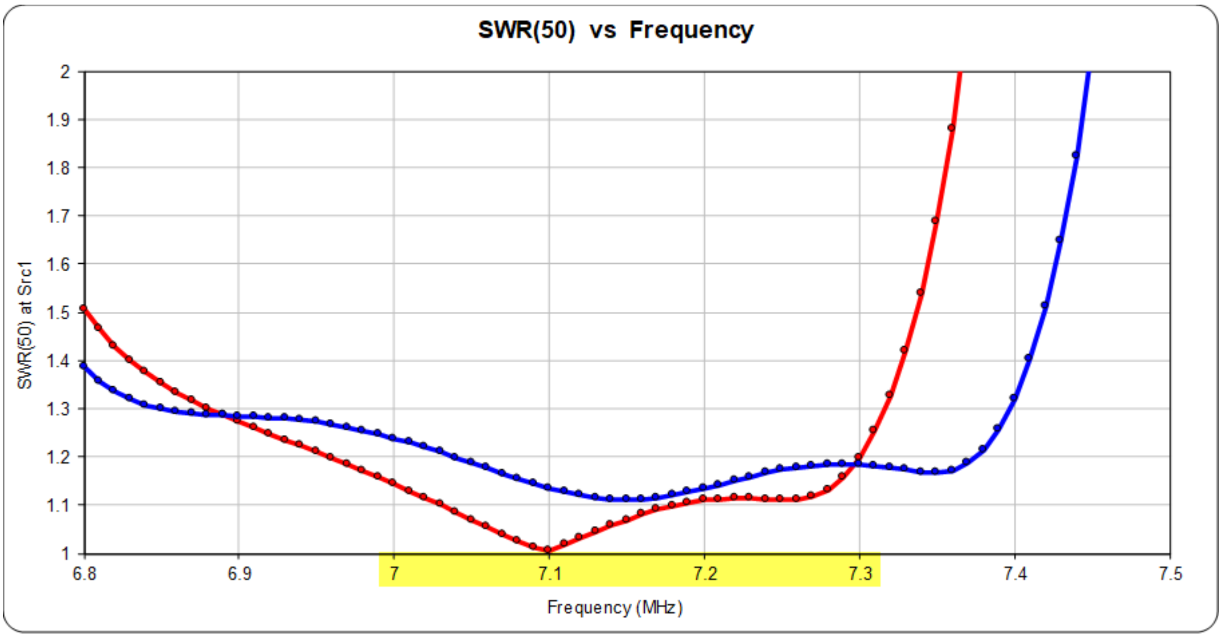


Figure 5 - SWR Comparison

The new design is drawn in red; the current design is in blue.

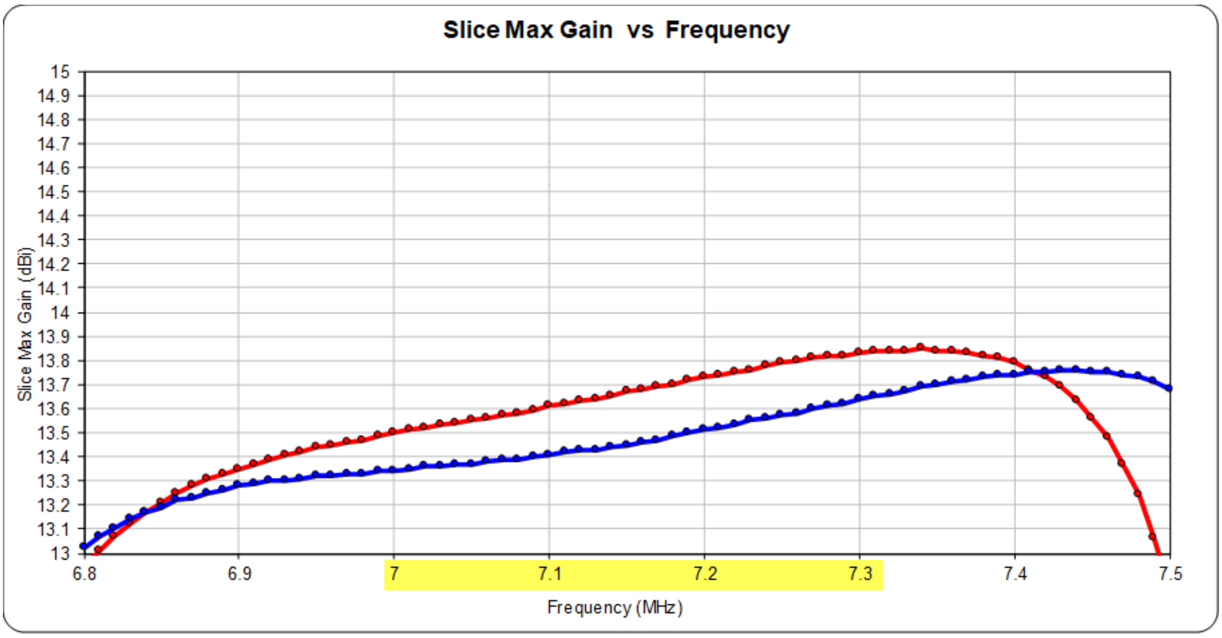


Figure 6 - Maximum Forward Gain Comparison (11 degree take off angle)

The new design is in red. It has about 0.2 dB of added forward gain.

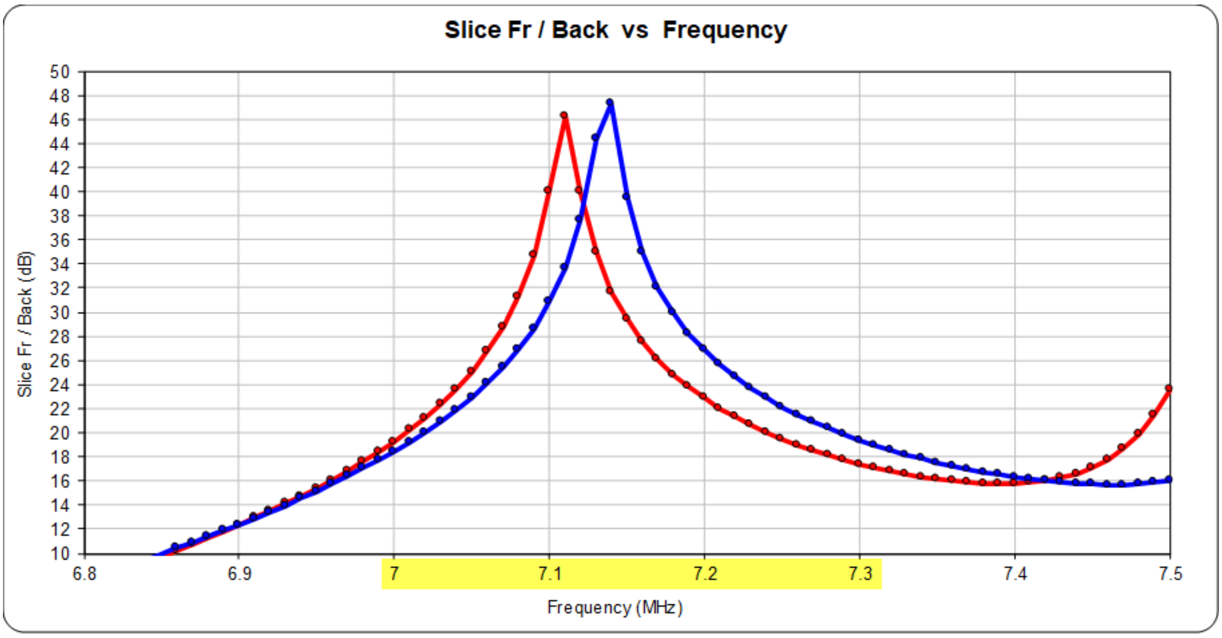


Figure 7 - F/B Comparison

The element tip lengths for **2019Taper06.weq** are:

2019Taper06.weq Yagi Dimensions		
Element	**Offset From Reflector**	**Tip Length**
REF	0.0"	428.250"
DE	261.5"	429.000"
D1	320.5"	400.750"
D2	570.0"	378.250"

These tip lengths would require compensation for the boom and clamps.

Variable Element Spacing

Although there is a strong inclination to reuse the element positions on the boom because of how (nicely) the Yagi mounts to the tower, I thought I would see what happens if the DE and D1 elements were allowed to move 6" in each direction.

After a number of optimizer tweaks and runs I ended up with **2019Taper17.weq**. The dimensions are:

2019Yagi17.weq Yagi Dimensions			
Element	**Original Offset From Reflector**	**New Offset From Reflector**	**Tip Length**
REF	0.0”	0.0”	427.250”
DE	261.5”	**257.5”**	429.750”
D1	320.5”	**314.5”**	401.875”
D2	570.0”	570.0”	379.000”

The important changes are highlighted in red. DE and D1 both move closer to REF by a few inches, and the gap between DE and D1 drops by about 3”.

The performance comparison to **2019Taper06.weq** shows:

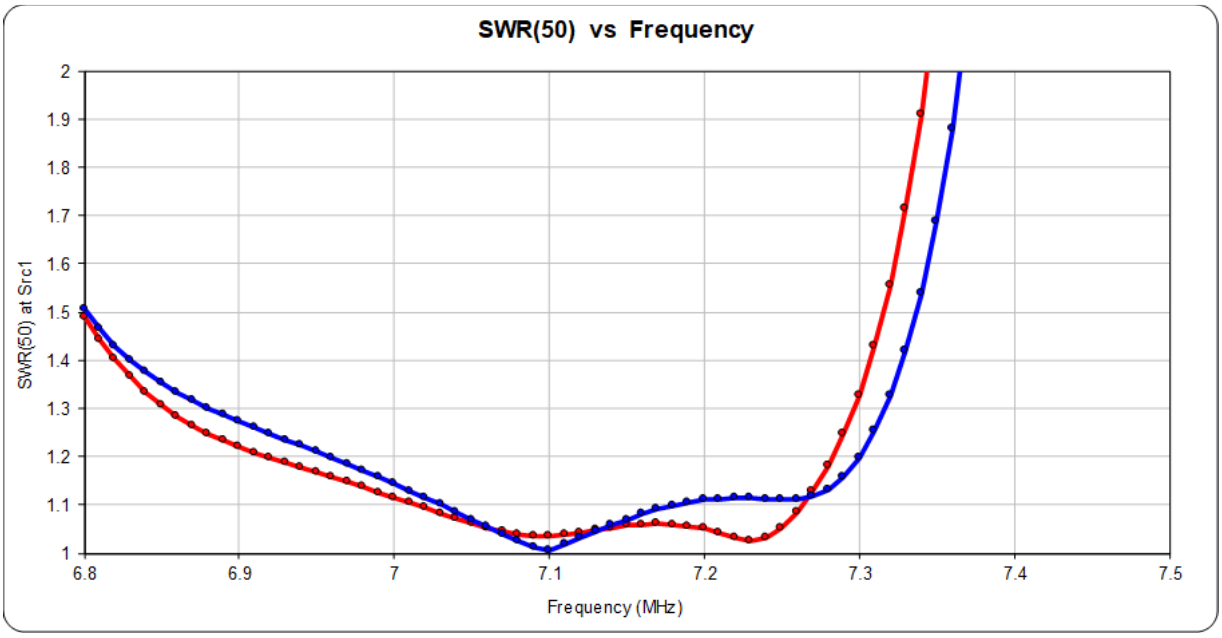


Figure 8 - SWR Comparison

Red is the **2019Taper17** design, blue is the **2019Taper06** design.

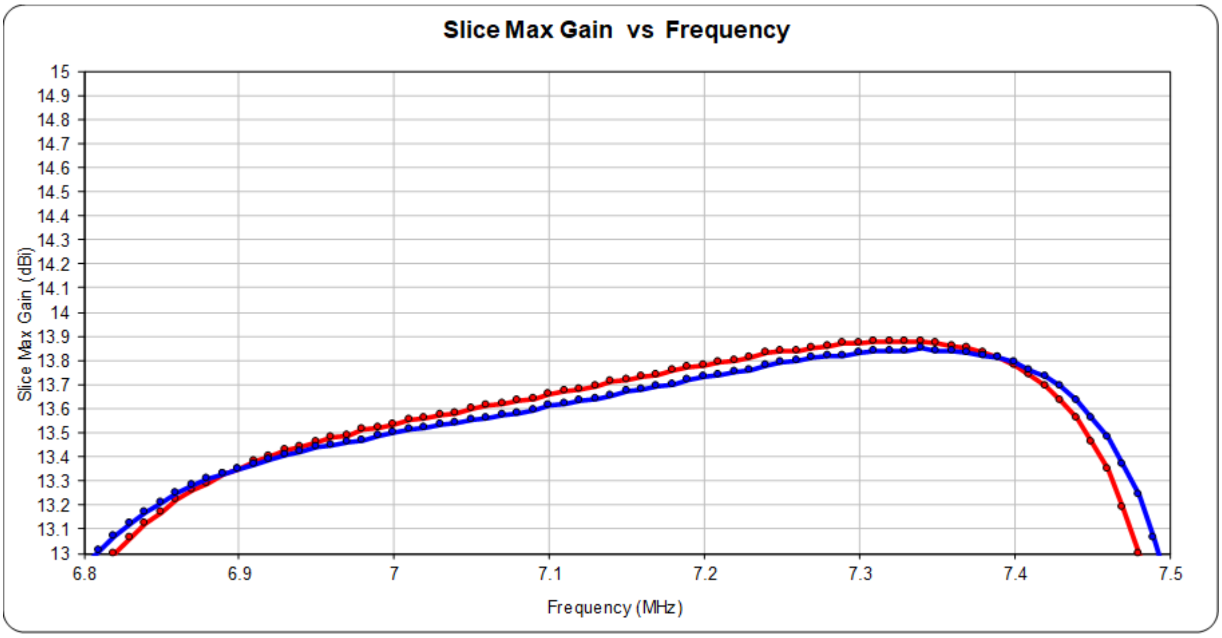


Figure 9 - Gain Comparison

Red is the **2019Taper17** design. It has almost 0.1 dB of added gain over **2019Taper06**.

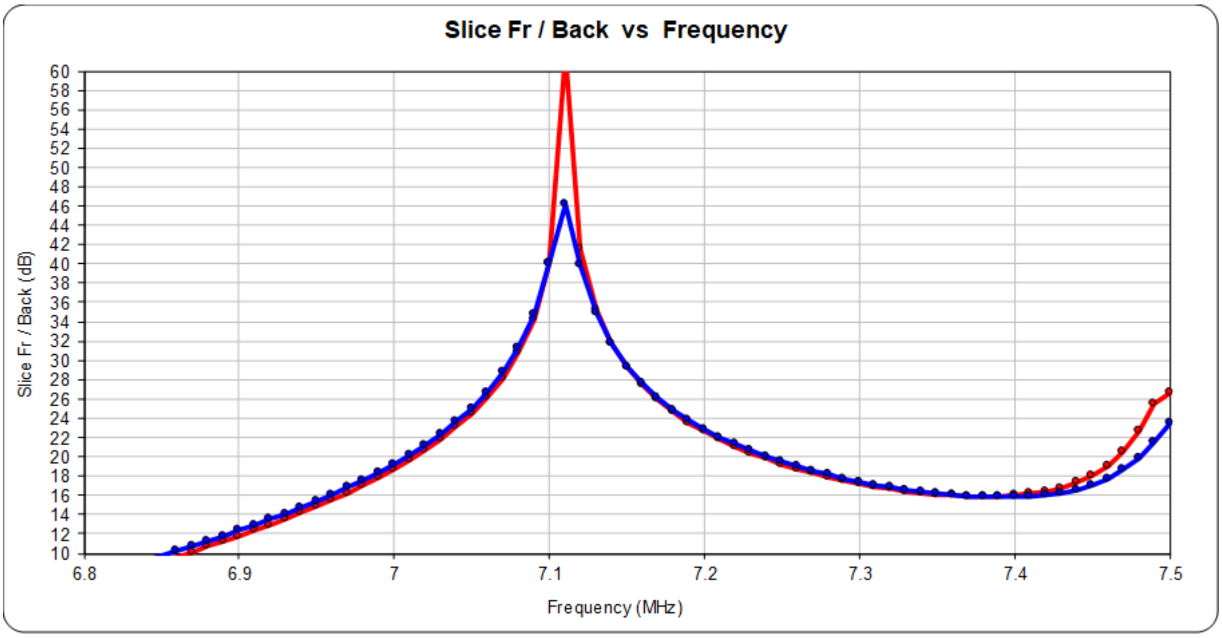


Figure 10 - F/B Comparison

Red is the **2019Tape17** design. The F/B curve has not shifted.

Element Tip Boom Compensation

After some discussion with K3LR, the last design, **2019Taper17**, was selected for construction.

The next step is to apply the 0.5% *boom/clamp compensation*. This is where the elements are made 0.5% longer to account for the effect of the boom and clamps that can't be represented in the model. The added length is put exclusively into the tips, even though it is computed for the entire ½ element. The following table shows the new lengths and the final tip diameter. Dimensions are rounded to the nearest 1/8".

2019Taper17.weq Compensated Dimensions (for Construction)					
Element	**Original Offset From Reflector**	**New Offset From Reflector**	**Tip Length**	**Compensated Tip Length**	**Tip Diameter**
REF	0.0"	0.0"	427.250"	**429.375"**	0.875"
DE	261.5"	**257.5"**	429.750"	**431.875"**	0.875"
D1	320.5"	**314.5"**	401.875"	**403.875"**	1.000"
D2	570.0"	570.0"	379.000"	**381.000"**	1.125"

Since the elements get shorter as you move to the front of the antenna, the diameter where the element stops increases (the outer tip sections aren't used).

This is the first time where we have applied boom compensation to a 40m aluminum tubing element. It's not clear if 0.5% is the best correction factor. Since the element is 2.5" in diameter at the boom, the inductance per unit length is already lower than thinner elements such as on 20 or 15 meters. This could change the correction factor since the *upset* due to the boom is no doubt different and probably less.

Modeled SWR Curve at 120' High

Because of the uncertainty in the compensation factor, it is highly desirable to test the antenna and be able to tweak it. This should be possible with the lowest Yagi at K3LR. It's at 120'. Here is the SWR curve for the **2019Taper17** Yagi when it is placed at 120' off of the ground. It can be compared against the measured SWR curve.

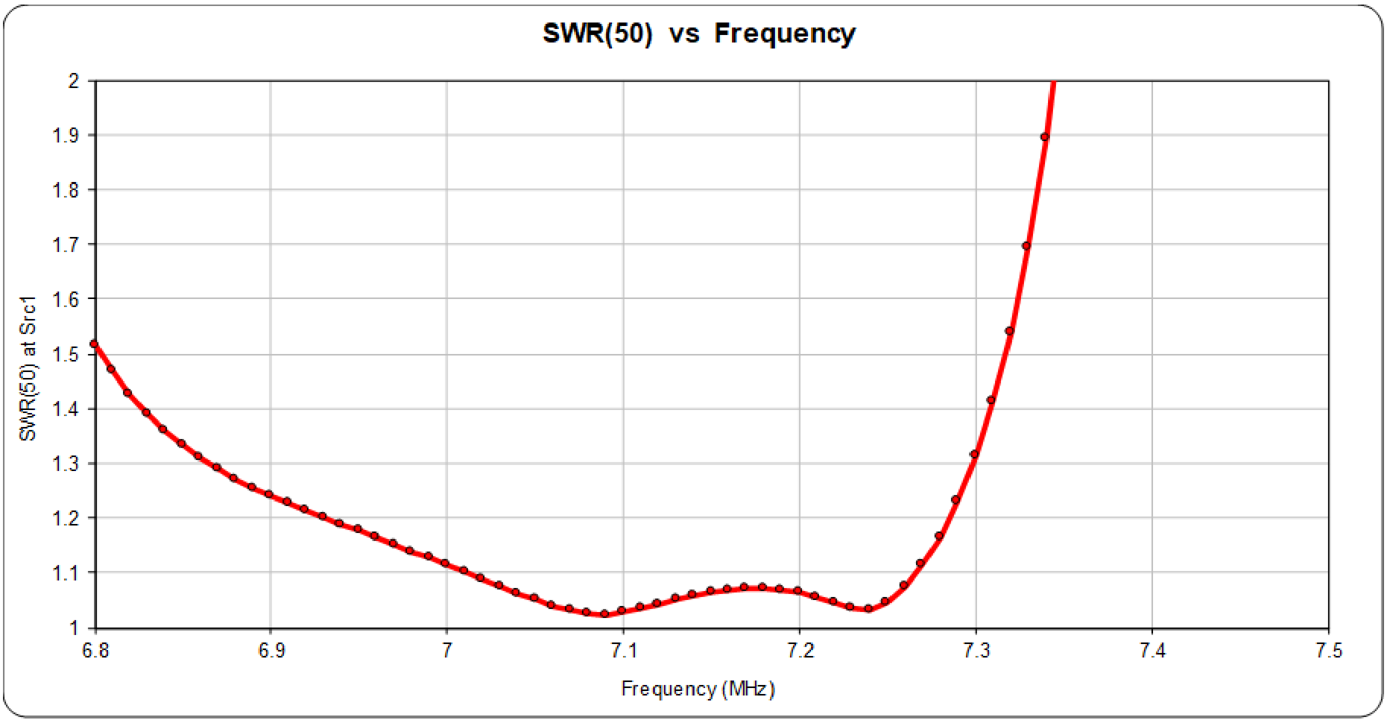


Figure 11 - SWR Curve for 2019Taper17 @ 120'