Optimized DO Loop (VE3DO)

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Version 1.0

The DO Loop, created by VE3DO (Ivan Payne), is one of several broadband resistor terminated small receiving antennas intended for bands such as 160 meters (1.8-2.0 MHz).

The term *optimized* is a little misleading in this context. Normally that means using an antenna optimizer program such as the one included in AutoEZ. The optimizer searches for a single design that maximizes some specified antenna characteristics with weighted targets. In this case I will be using AutoEZ, but instead of the optimizer feature I'll be using the ability to automatically iterate through a set of variables to manually explore the design space around the original design. EZNEC Pro/4+ v. 7.0 (NEC-4) was used for modeling.

Here is a diagram of the original design that includes the variables and their values (red).

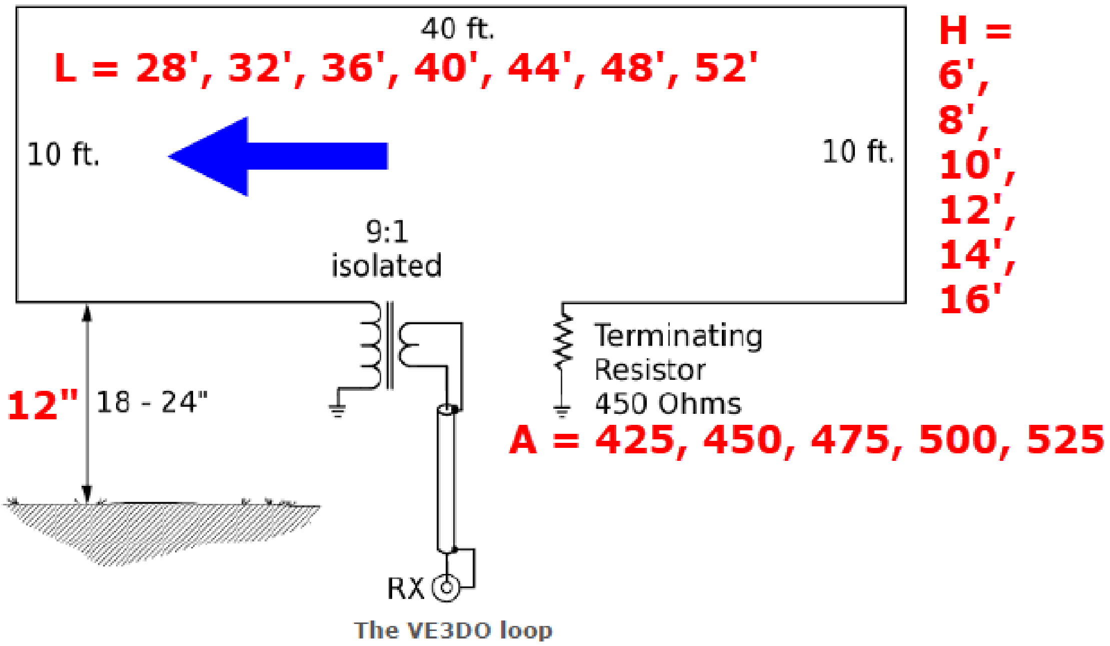


Figure 1 – DO Loop Design Space

The **L** variable is the length of the loop. It moves in 4' steps from 28' to 52'. 40' is the original length. There are 7 different values.

The **H** variable is the height of the top vertical wire. It moves in 2’ steps from 6’ to 16’. 10’ is the original height. There are 6 different values.

The **A** variable is the termination resistance in Ohms. It moves in 25 Ohm steps from 425 to 525 Ohms. 450 is the standard value, although that is often implemented as a 470 Ohm resistor. There are 5 different values. When reporting the SWR the models in this note include a 450 to 50 Ohm transformer at the feed point. It is, therefore, a 50 Ohm system. Changing the transformer windings can create a 75 Ohm feed point.

Although the height off of the ground is shown as 18” to 24”, the modeled loop lower wire is fixed at 12” off the ground. This means that the actual length of the side wires is the top height minus 1’. So, when the top wire is modeled at 11’, the side wires are 10’ long (11’ – 1‘ = 10’).

Ground characteristics can influence the performance of antennas close to the ground. For these EZNEC models the Real/MININEC ground type will be used. The ground description is *Pastoral, rich soil, US Midwest* because that’s where I live.

The total number of model permutations given the three variables, and their ranges is:

7 X 6 X 5 = 210

160m modeling will be done at 1.830 MHz.

The process I’m using will begin with having AutoEZ automatically run all 210 models. That takes a few minutes but is over before you know it. I am doing a full 3D analysis of each configuration. I will then examine the total data set for any variable combinations that stick out due to good performance. If necessary, additional models will be run to investigate possible improved performance at a targeted variable range.

Baseline Expectations

Here are the characteristics of the baseline or original dimension design, presented in the first diagram. The only difference is that the bottom wire is 12” off of the ground, not 18” to 24”. The frequency is 1.830 MHz. The resistor value is 475 Ohms.

The 3D plot of the pattern is:

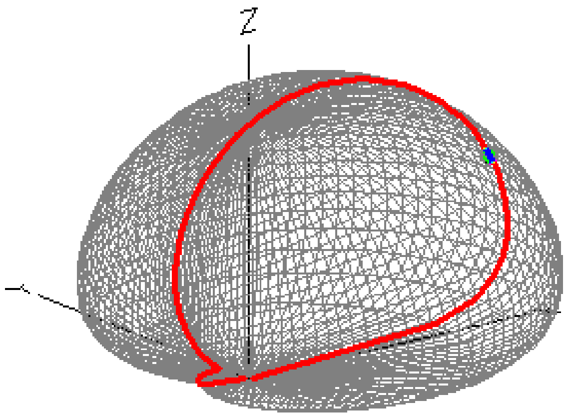
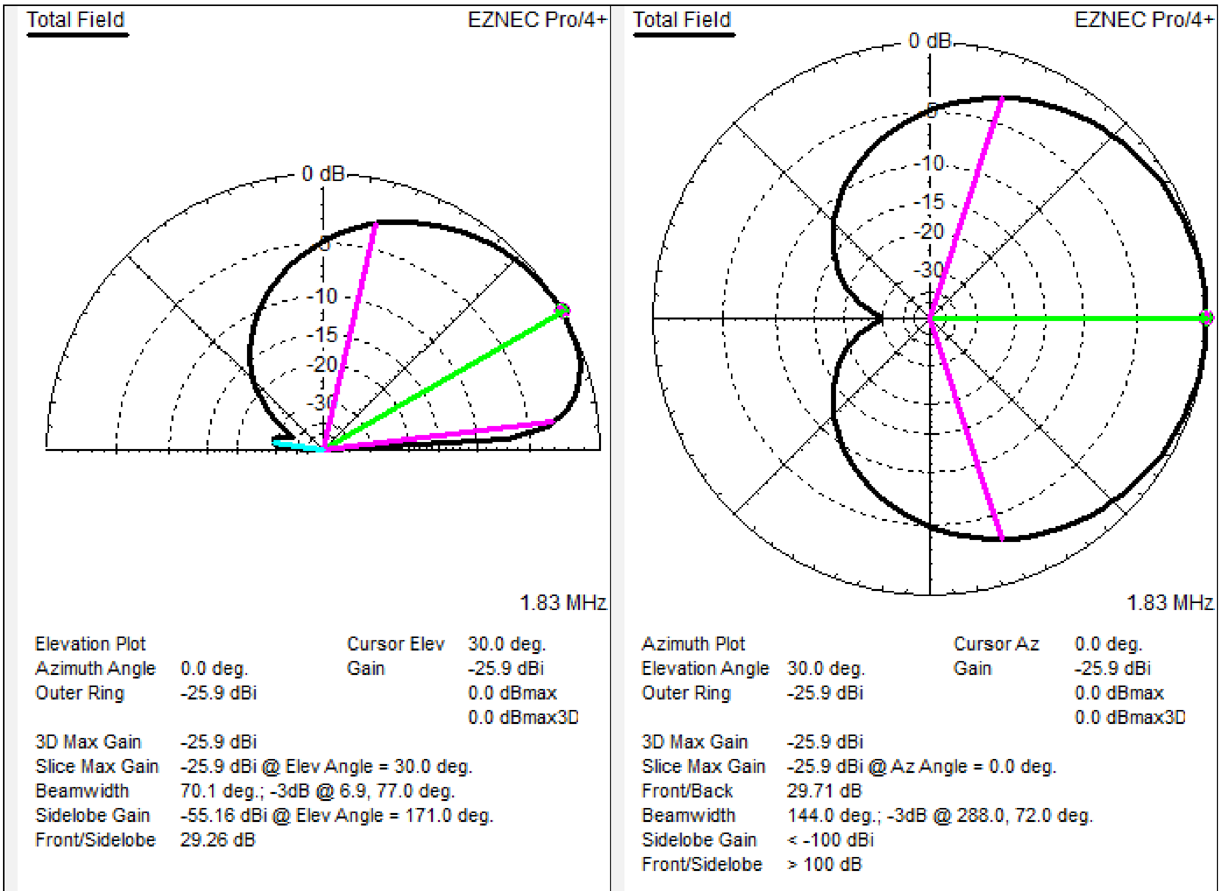


Figure 2 – Original Design 3D Pattern

In all of the models the antenna is pointed down the positive X-axis.

The elevation and azimuth pattern slices at the take off angle of maximum gain (30°) are:



Elevation Pattern	Azimuth Pattern

The directivity (RDF) of the loop is 7.7 dB. The maximum gain at the 30° take off angle is -25.9 dBi. A rear null of at least 30 degrees exists across the 15° to 30° elevation range.

The primary lobe is around 140 degrees wide.

The SWR is a low 1.031.

Initial Analysis of the 210 Combinations

SWR

Continuing with SWR as a characteristic, all 210 combinations never have an SWR greater than 1.272 which happens with a 425 Ohm termination resistor (X-axis).

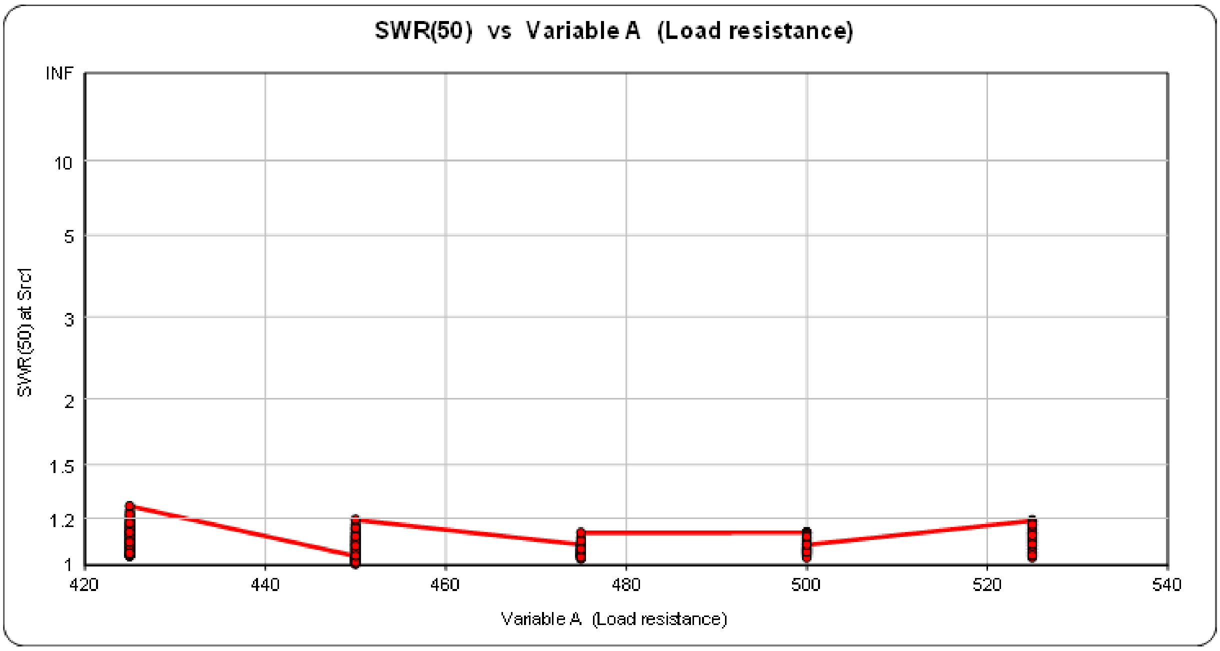


Figure 3 - All Combinations SWR versus Resistance

The highest SWR combination is a resistor of 425 Ohms, a length (L) of 52' (maximum), and a height (H) of 18' (maximum). The lowest SWR is 1.005. It occurs with a termination resistance of 450 Ohms, length of 32', height of 8'. Each vertical line represents the 42 variation (length and height) combinations at each resistor value.

Needless to say, in any configuration SWR is not an issue.

RDF (Directivity)

Perhaps the most important characteristic of the loop is the RDF (receiving directivity factor), also known in textbooks as *directivity*. The graph of all 210 combinations with the resistance on the X-axis is:

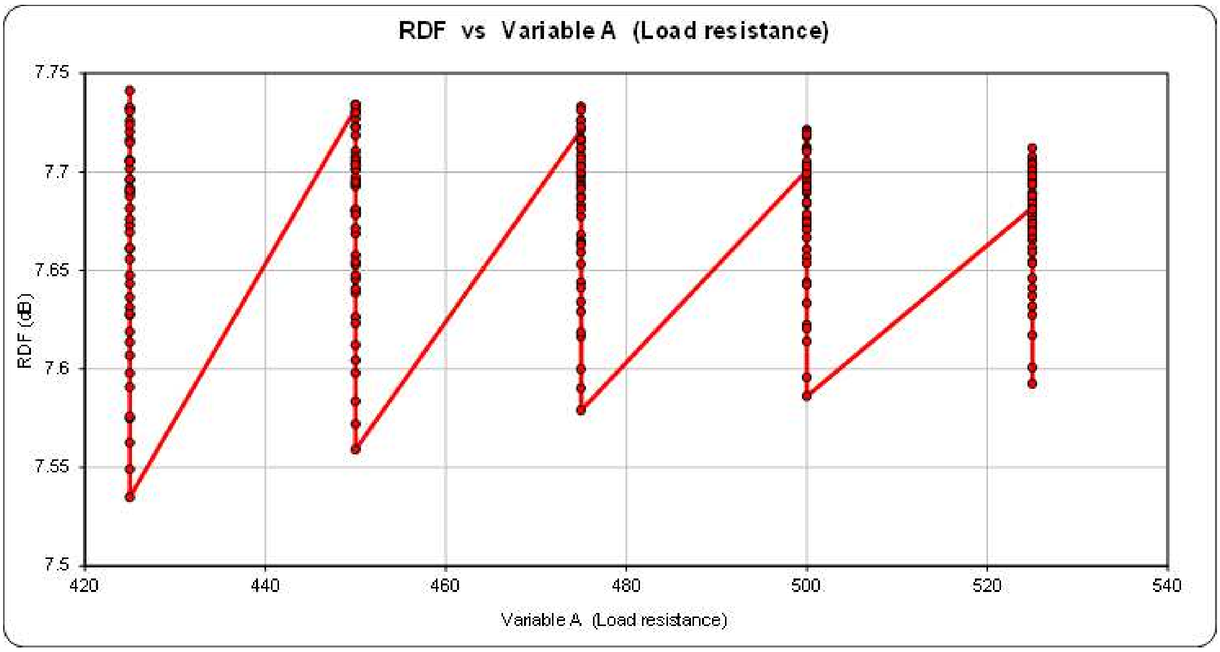


Figure 4 – RDF versus Resistance

The RDF ranges from a maximum of 7.74 dB down to 7.53 dB. The range is greatest with the 425 Ohm resistor. The larger the loop, the lower the RDF. The highest RDF occurs with the 28' length and 6' height, which is the smallest loop.

The RDF range is small, and I think it would be very hard to hear a difference in performance across this range.

Maximum Gain

The set of 210 variations maximum gain is:

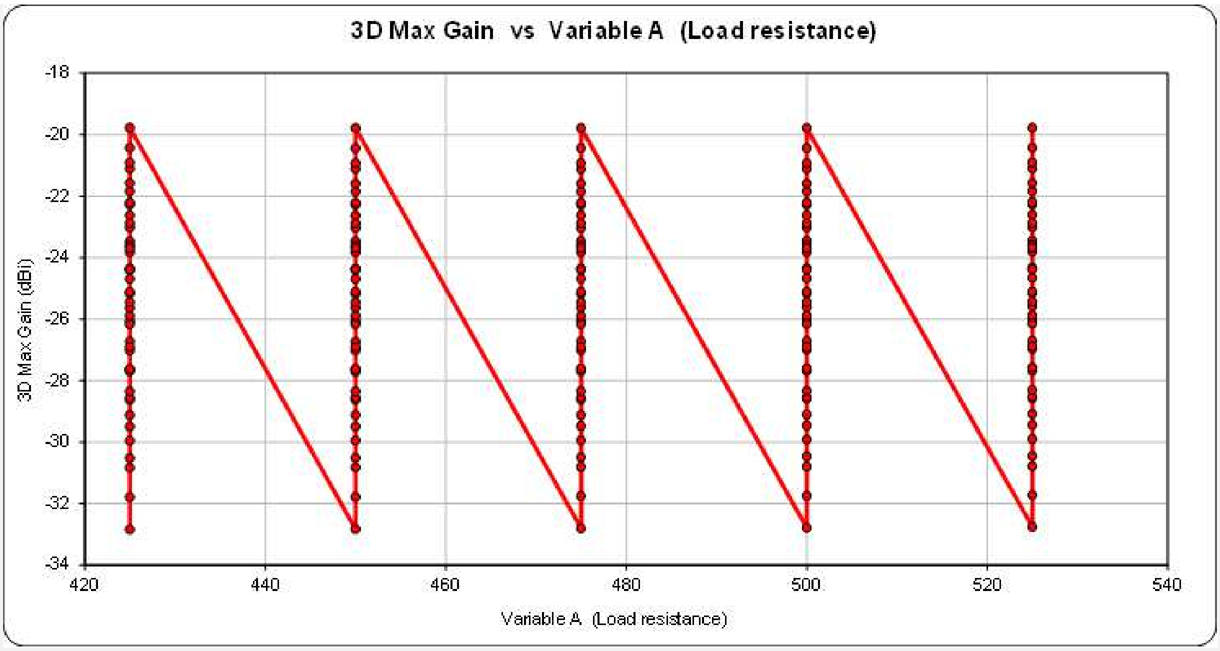


Figure 5 - Maximum Gain versus Resistance

The first thing to note is that the termination resistor value (X-axis) has no impact on the gain of the loop. What does determine the loop gain, however, is the length and height of the loop.

Here is the effect of the length which is now the variable on the X-axis:

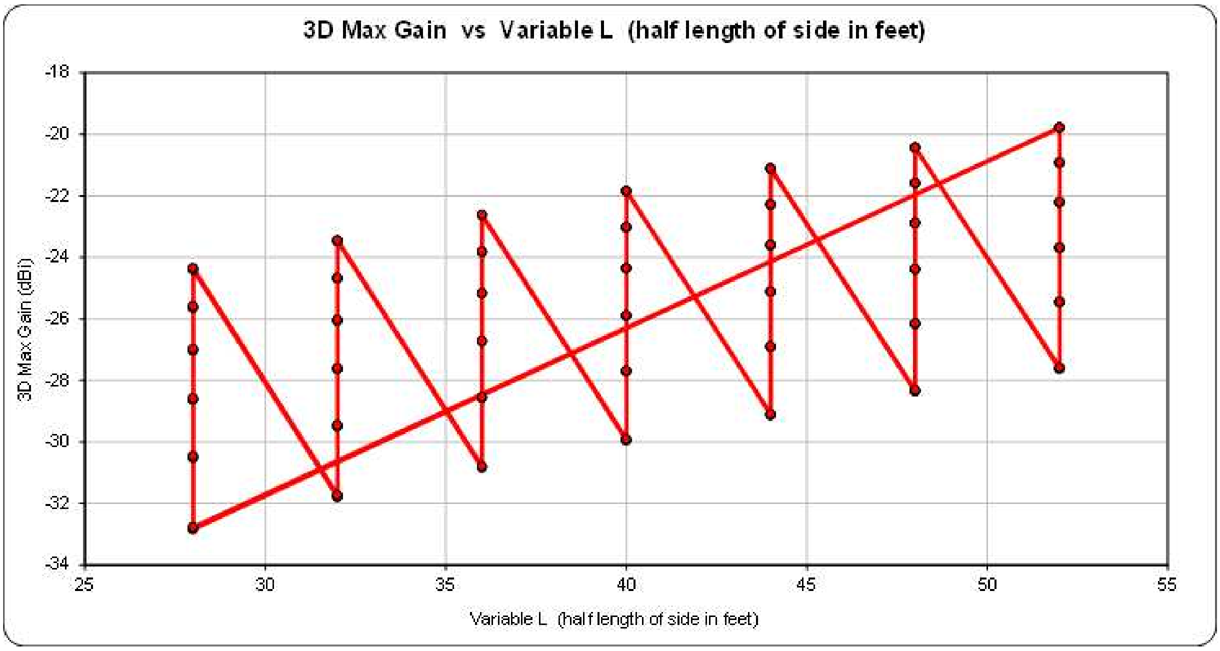


Figure 6 - Loop Length Effect on Gain

The longer the loop the higher the gain. The height interacts with the length in that for a given length more height is more gain. The height of the loop is the X-axis variable in the next graph.

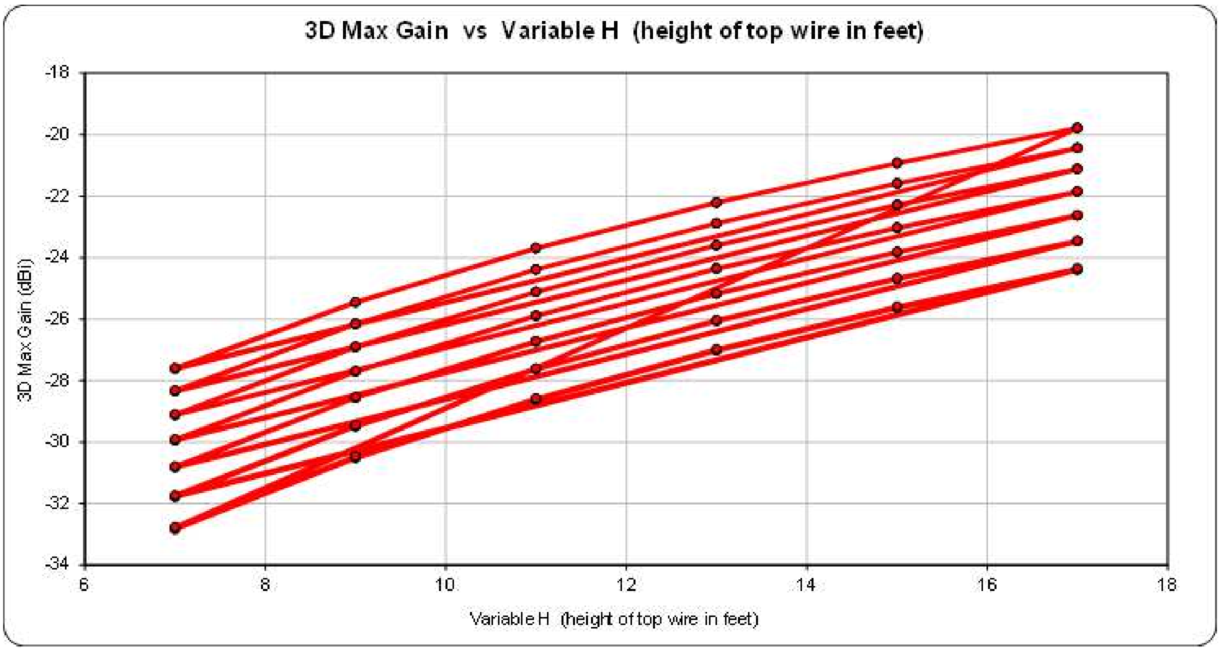


Figure 7 - Loop Height Effect on Gain

As the loop grows taller, the gain rises. Since both the length and height influence the loop gain it's fair to say that what matters is the loop *area*. More area means higher gain.

Many of the small receiving antennas have gains around -25 to -28 dBi. A very small DO Loop, at around -33 dBi, is a bit deafer. A large DO Loop, however, at -19 dBi, has a lot of gain, only challenged by a long Beverage.

The original DO Loop gain, at around -26 dBi, is a typical value for receiving antennas in the loop category.

Elevation Angle of Maximum Gain

The elevation angle of maximum gain (take off angle) impacts the usefulness of the antenna for DX reception. A pattern that points straight up (90°) would be a good *cloud warmer* or local antenna. For DX operation on 160 meters, however, a much lower take off angle of around 25° is more useful.

The next graph plots the elevation angle of maximum gain against the load resistance.

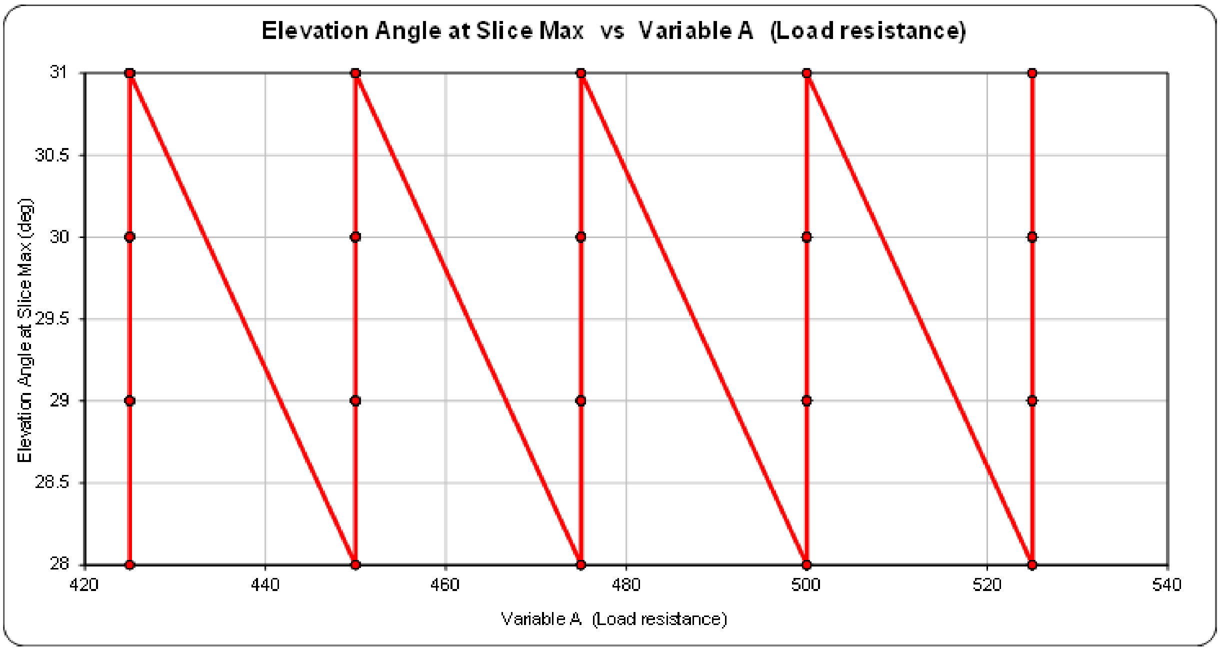


Figure 8 - Elevation Angle versus Resistance

The termination resistance value (X-axis) does not influence the take off angle gain. The take off angle varies between 28 and 31 degrees.

What does influence the take off angle is the length of the loop. A longer loop results in a higher take off angle, as shown in this next rather odd-looking graph of the elevation angle versus length.

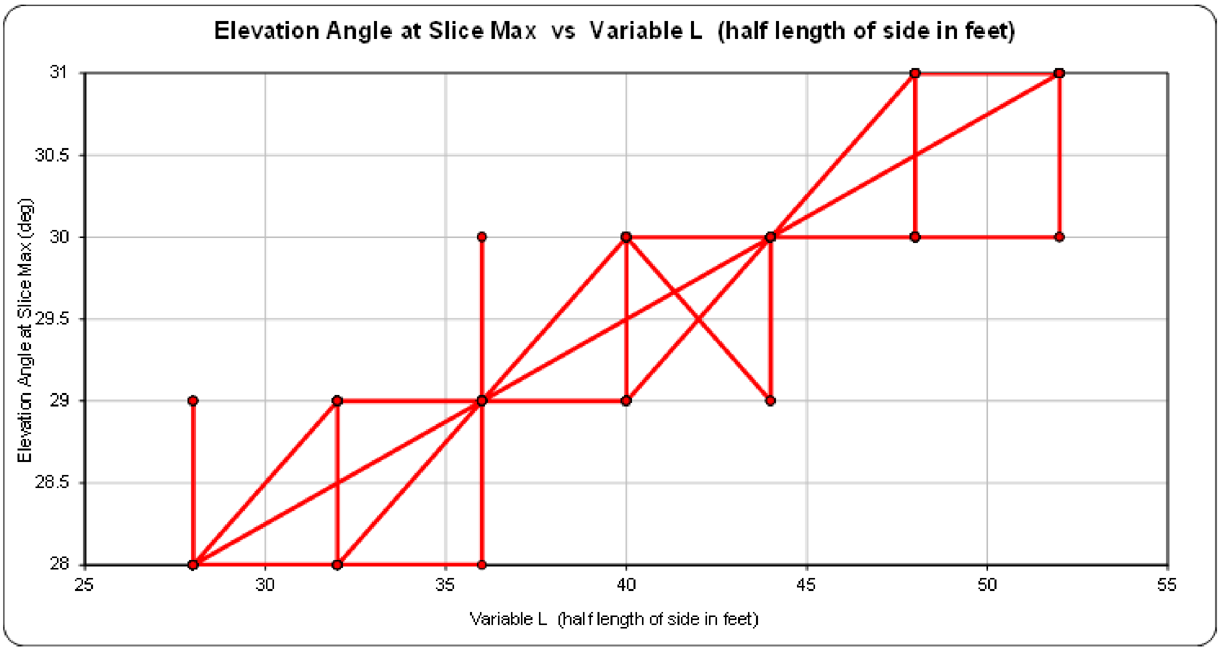


Figure 9 - Elevation Angle versus Length

Inband SWR

Here is the graph of SWR with the original size loop on 160m. It's obviously very low and flat.

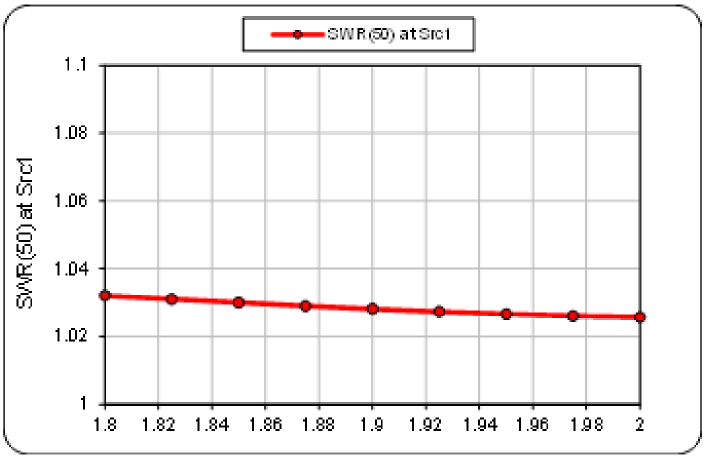


Figure 10 - 160m SWR with Original Size DO Loop

Conclusion

The DO Loop offers consistent performance across a range of sizes. The antenna characteristic that changes the most with antenna size changes is gain. Fortunately, for receiving antennas gain is usually not the most important consideration – directivity is. To achieve higher gain simply make the loop larger. While the gain rises, the RDF decreases and the take off angle rises, neither of which is desirable for DX operation.

Unless gain is the only characteristic that matters, I can't see a reason to go larger than the original dimensions of 40' X 10' for 160m operation. If you don't have sufficient room for that size, don't feel bad about reducing the size. The smallest 28' X 6' loop in this note offers good performance, although some folks would run it with a preamp because of the reduced gain. It would probably be a good idea to put a bandpass filter in front of a preamp to reduce the possibility of overload at other frequencies. The smaller loop has increased directivity and a lower take off angle but also reduced gain.

The elevation angle of the rear null does not move up and down with changes in the termination resistor value. Having a variable resistance to improve dynamic performance is of little value.

Termination Resistor and Ground

The termination resistance seen by the loop is the combination of the physical resistor represented in the model/reality added to the ground resistance actually present in the antenna-earth connection.

In my models the MININEC ground has zero resistance. This means that the resistor in the model provides all of the resistance. In reality this is usually over optimistic. The ground connection will have some resistance and that should be taken into account when determining the value of the actual physical resistor.

Let’s say the actual resistance of the antenna ground rod is 25 Ohms. If the desired termination resistance is 475 Ohms, then the physical resistor should be 450 Ohms since:

450 + 25 = 475 Ohms.

Another factor to be aware of is seasonal variations in ground resistance due to factors such as rain and temperature. If the ground resistance changes then that will change the DO Loop resistance. Fortunately, the resistance value does not need to be precisely controlled with the DO Loop. The antenna has good performance across a range of termination resistances. A more extensive ground system (rods and/or radials) is usually more stable across the entire year and all four seasons.

Other Bands?

The various small loop antennas with non-resonant dimensions and resistive terminations tend to operate over a wide range of frequencies. By that I mean that the general pattern remains a consistent and desirable shape. The problem on the low frequency side is lower and lower gain so that the antenna is eventually too deaf. On the high frequency side some dimension approaches a resonant length, and the pattern of the antenna becomes undesirable, even if the gain is rising.

So, we can and should ask – how broadband is the DO Loop?

I modeled two loops, the original 40’ X 10’ size and the smaller 28’ X 6’ size. The black trace is the original size, and the blue trace is the smaller size.

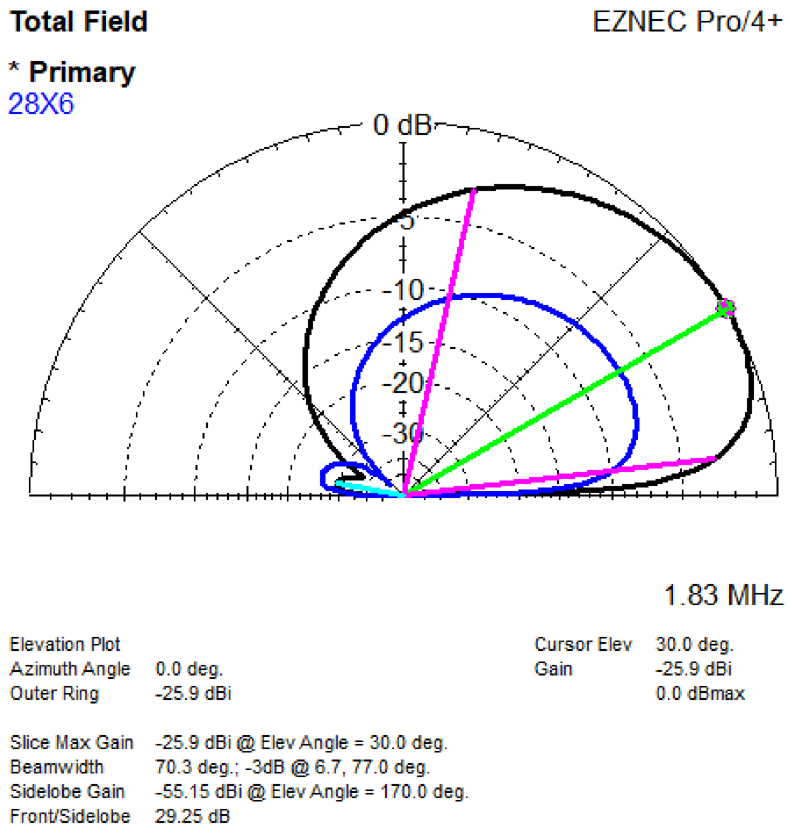


Figure 11 – Original Size and Small Loop at 1.83 MHz

Both patterns are very similar on 160m and the only real advantage of the larger loop is the additional gain of around 6 dB.

The same models were then run at 3.65 MHz. The elevation comparison is:

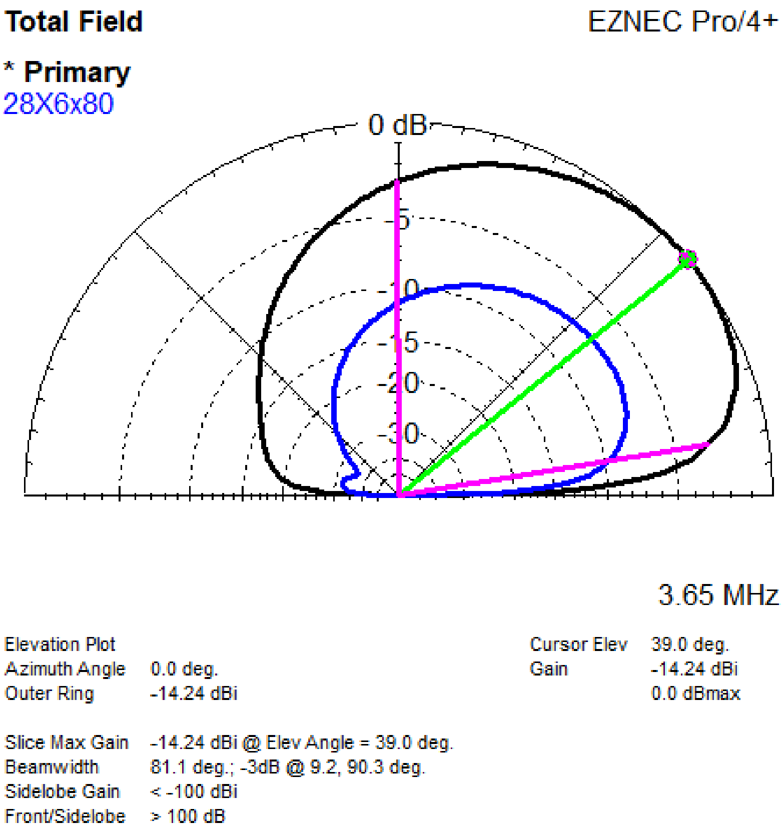


Figure 12 - Original Size and Small Loop at 3.65 MHz

The larger loop elevation pattern is starting to become a blob shape. The smaller loop, however, still has a more focused shape with a lower take off angle.

Finally, the same two loops were modeled at 7.1 MHz.

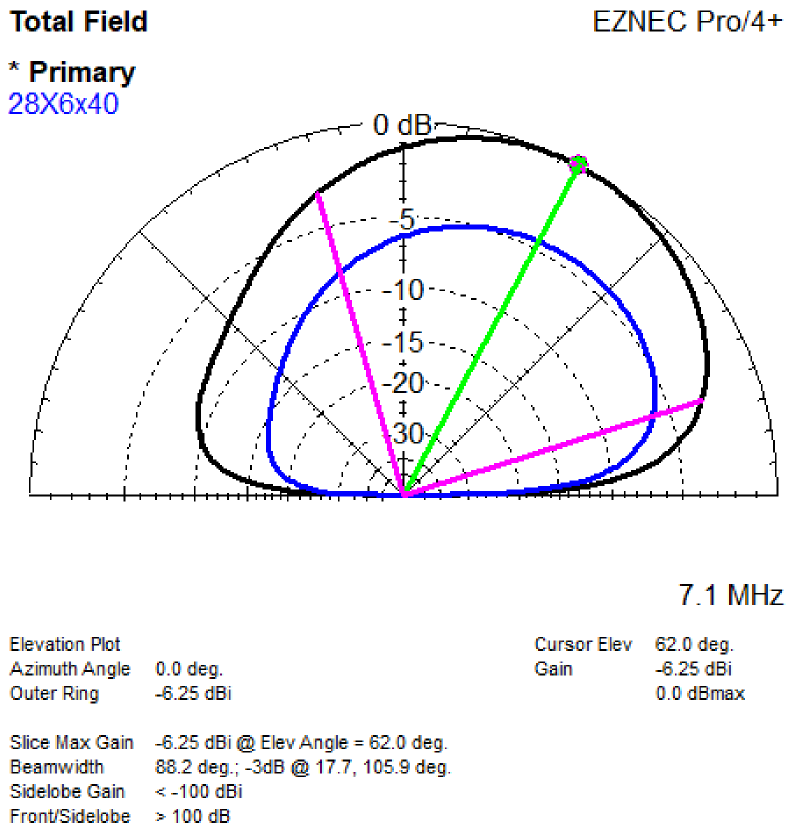


Figure 13 -- Original Size and Small Loop at 7.1 MHz

Both DO Loop sizes are becoming a blob on 40 meters. It turns out that the blob shape has a higher SWR.

Although the modeling here has not been extensive, I'm tempted to draw the following conclusions.

1. The DO Loop is most easily configured (sized) as a single band antenna.
2. Two adjacent band operation is possible, but the loop dimensions will need to be carefully selected to straddle the two bands with good performance.
3. Three band operation (e.g. 160m, 80m, 40m) with good performance does not appear possible.
4. With the original 40' X 10' dimensions, the loop is targeted for 160m. Good performance should extend down into the AM band.
5. A smaller loop size, for example 28' X 6', shows good performance on 160m and 80m.

Based upon these models I'm willing to say that the DO Loop is not as broadband as some of the other small receiving loops that can be used from 160m up to 40m, and even down into the AM band.

Other Sources of Information

https://ok1rr.com/antennas/the-ve3do-receiving-loop/

http://www.k9yc.com/VE3DO.pdf

https://www.contestuniversity.com/wp-content/uploads/2022/05/W3LPL-Easy-to-Build-Low-Band-Receiving-Antennas-for-Small-and-Large-Lots-2022.pdf

https://www.onallbands.com/ham-radio-tech-simple-low-band-receiving-antennas/

http://lists.contesting.com/archives//html/Topband/2013-02/msg00115.html