A 10m FM Antenna

...to fit into my attic...

A λ/4 *"T-Top" Vertical with Spiral Counterpoise*

Larry Banks, W1DYJ

First licensed: 1962 (KN1VFX)

W1DYJ since 1966 – Amateur Extra

33 Blueberry Hill Road Woburn MA

9b-DXCC 8b-WAS 6m-VUCC [565+ grids]

Thanks to Greg Hebner, AG5FE, and his May 2022 QST article

Problem Statement

- Sunspots are increasing, 10m is becoming more active
- As the MMRA TIaOS Net Manager I'd like to have 10m FM capability. [The MMRA has 20+ repeaters from 10m to 900MHz covering Eastern MA.]
- I have a 6m vertical in my attic for the MMRA 6m repeater.

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- **I decided to put a 10m FM vertical in my attic without adding another coax run.**
- **Internal attic height is ~5'**
  - **10m verticals are ~ 8+'**
    with 16' diameter radials
- **This also gave me an opportunity to learn about using coax as a matching network**

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- Design of the Antenna
- Building It
- Results

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AI Free

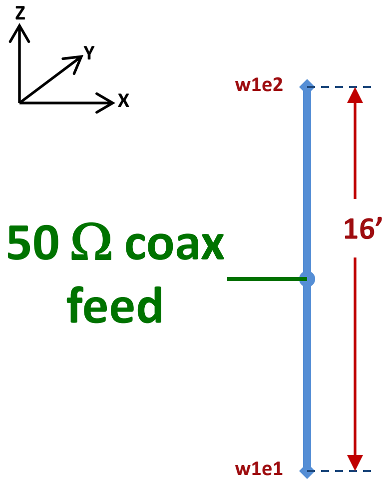
Any mistakes in this talk are strictly my own

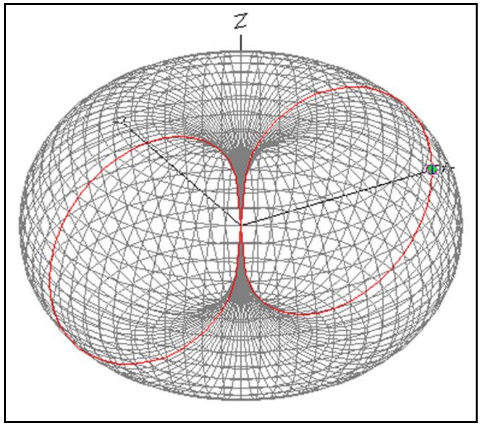
DESIGN OF THE ANTENNA

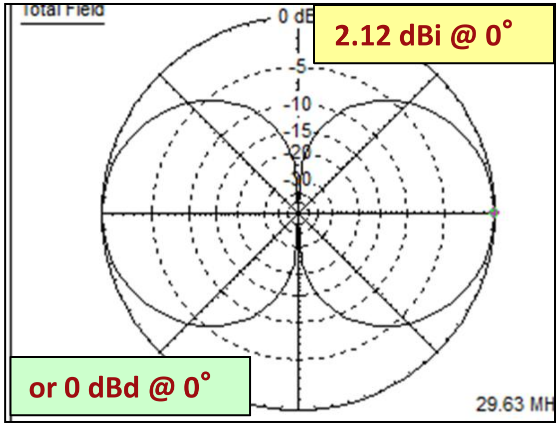
Start with the Fundamentals

- **Vertical Dipole (29.58/29.68)**
- Ground Plane Version
- Spiral Ground Plane *[based upon AG5FE]*
- Fitting it into my attic
- Matching it

Design of the Antenna: VERTICAL DIPOLE IN FREE SPACE [EZNEC]







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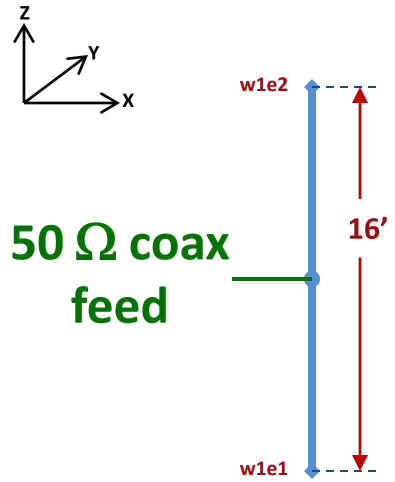

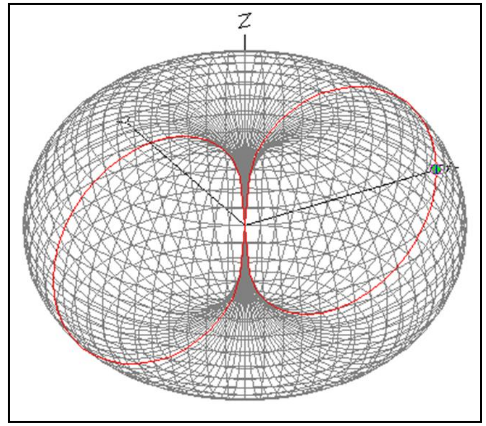

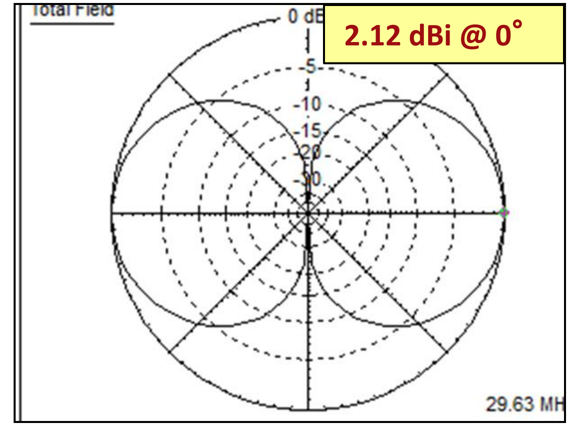

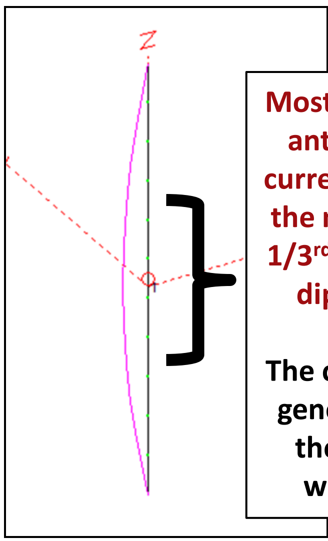

Most of the antenna current is in the middle 1/3rd of the dipole.

The current generates the EM wave.

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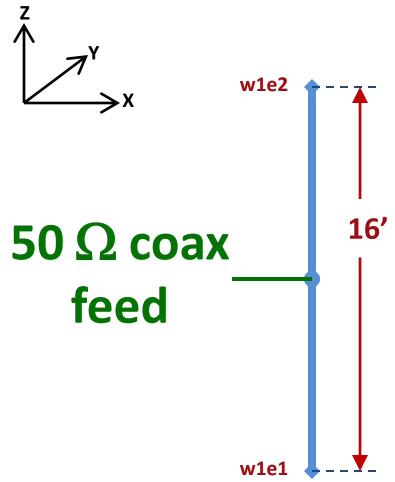

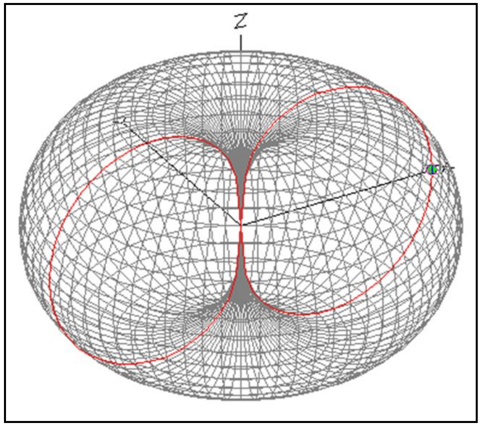

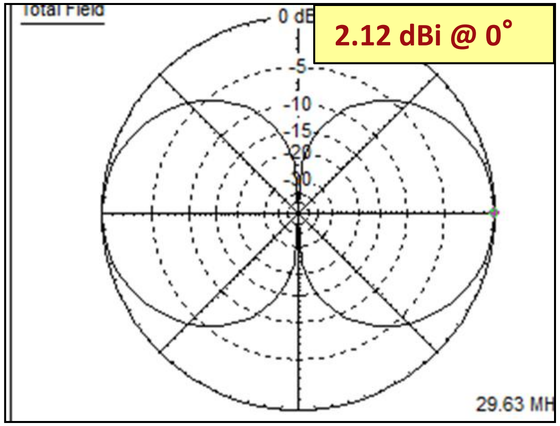

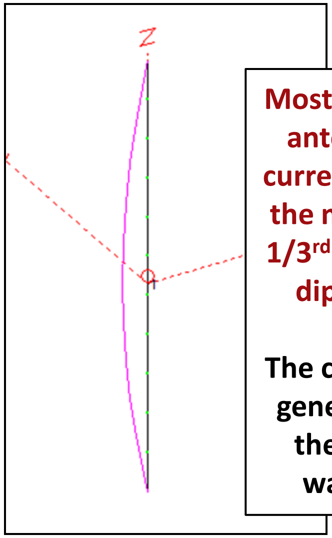

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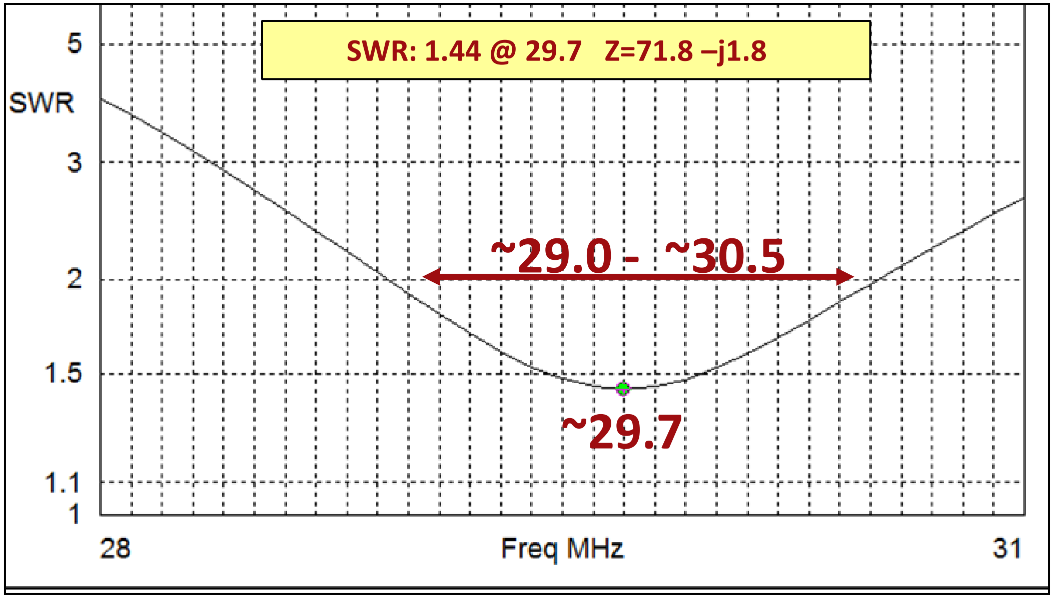
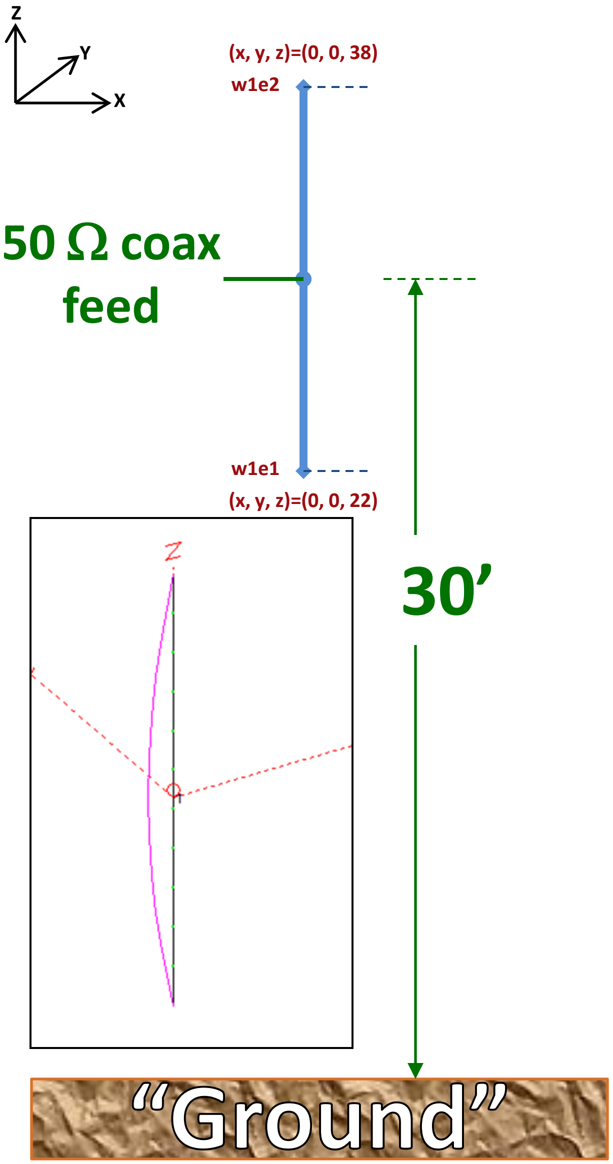
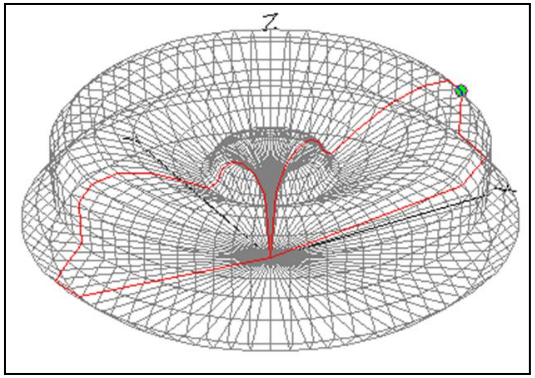
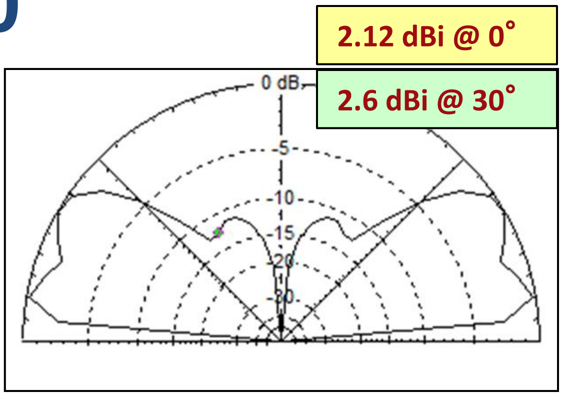


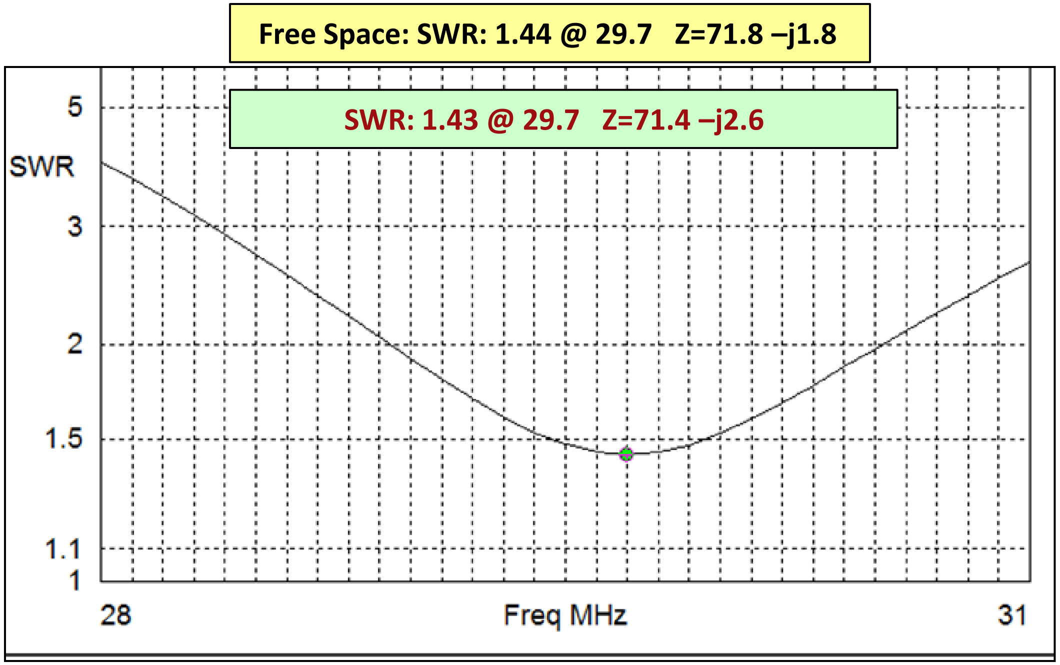
SWR = 1.44 *[72 Ω / 50 Ω]*

Design of the Antenna: Vertical Dipole @ 30’









Design of the Antenna

- Vertical Dipole
- **Ground Plane Version**
  - *No way I can fit this 16' tall into a 5' tall attic*
- Spiral Ground Plane *[based upon AG5FE]*
- Fitting it into my attic
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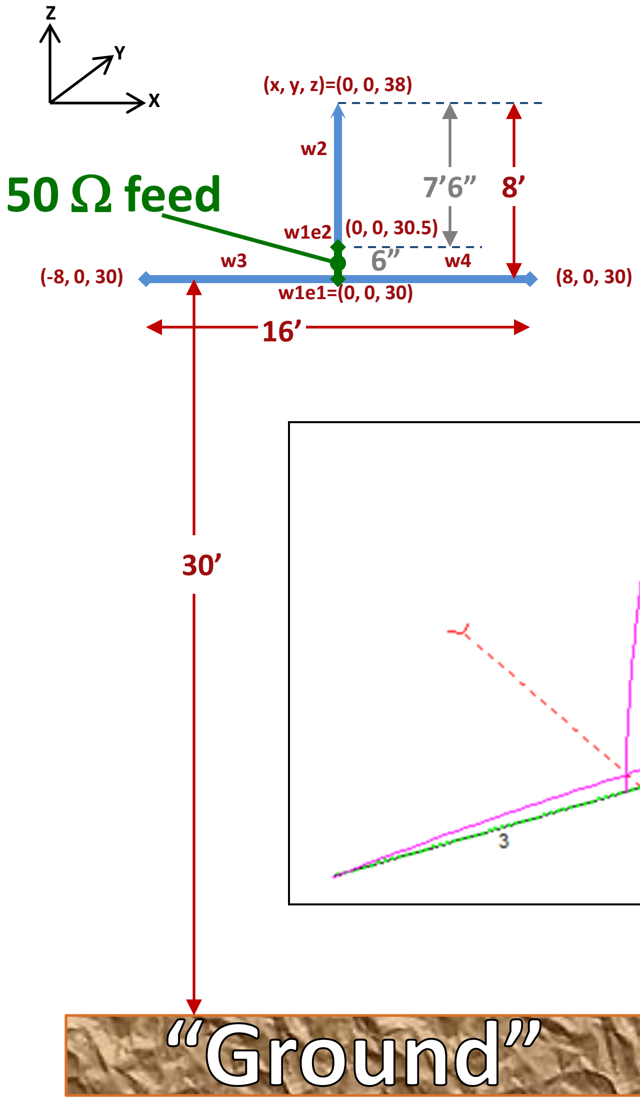
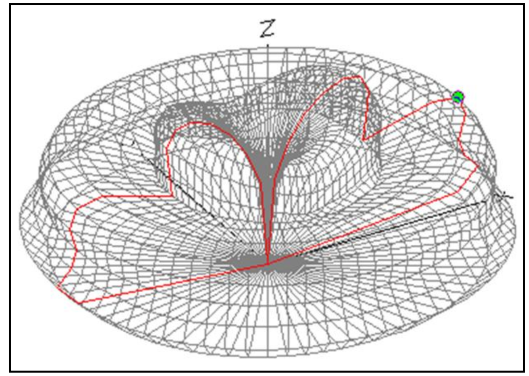
Design of the Antenna: Ground Plane #1 @ 30’

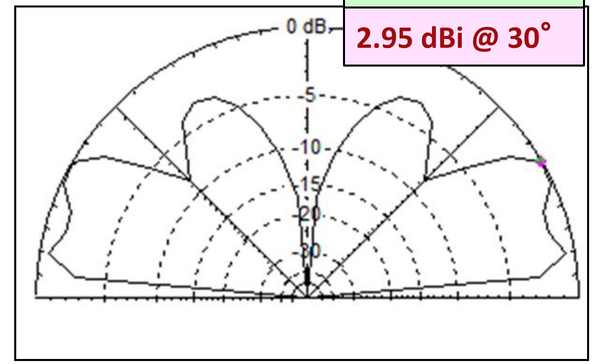
2.12 dBi @ 0°

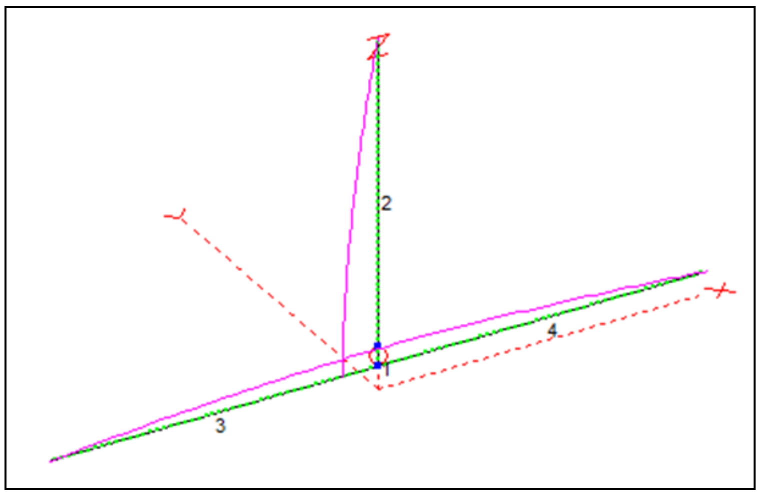
2.6 dBi @ 30°

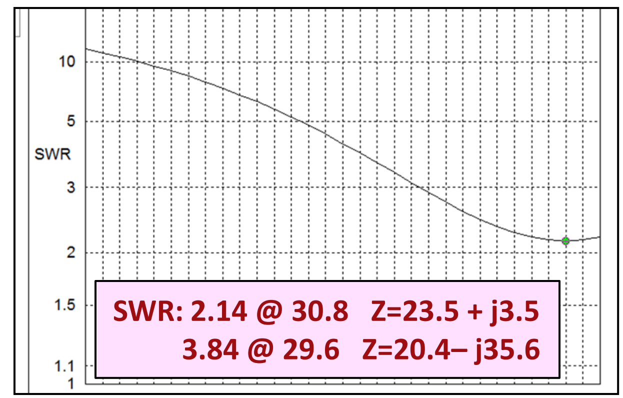
2.95 dBi @ 30°







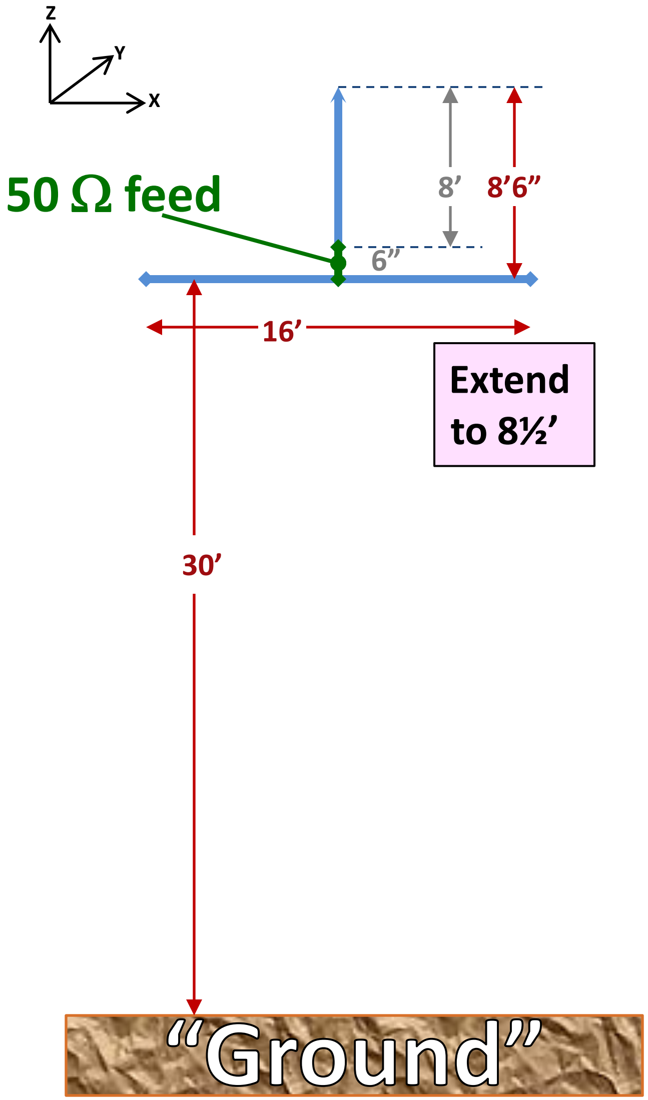


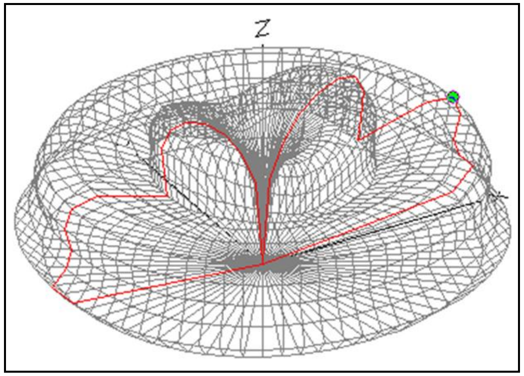


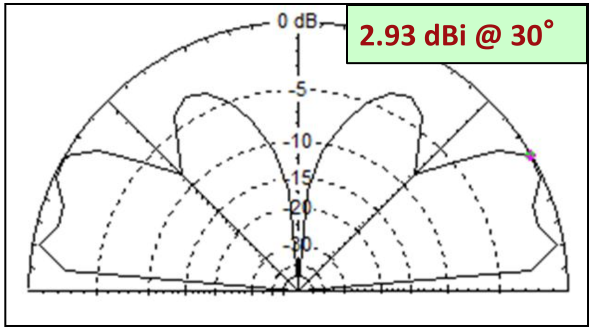
SWR: 2.14 @ 30.8 Z=23.5 + j3.5
3.84 @ 29.6 Z=20.4– j35.6

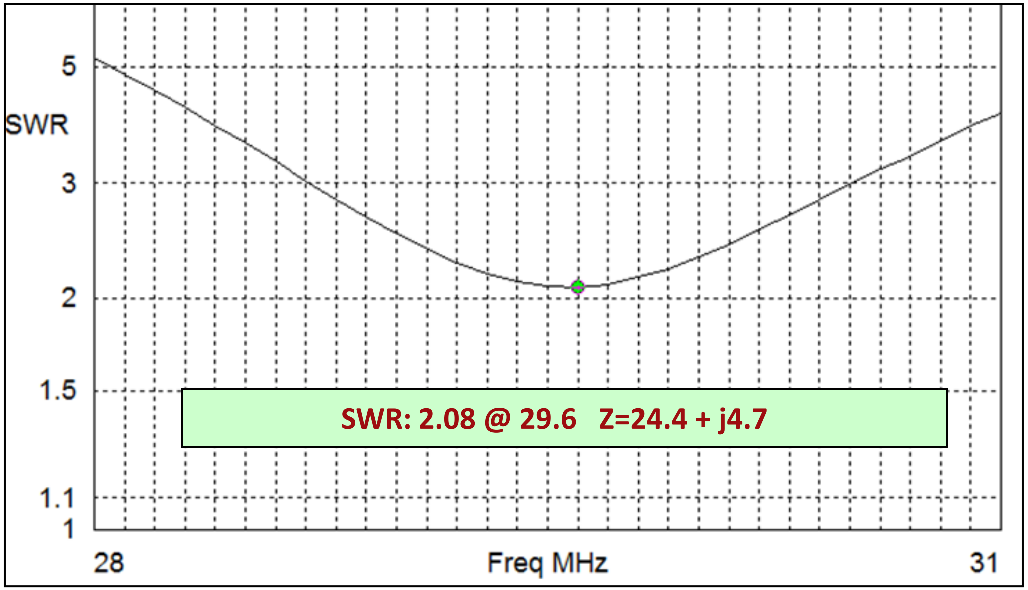
$F_{\text{Lowest SWR}}$ a bit too high

Design of the Antenna: GROUND PLANE #2 @ 30'









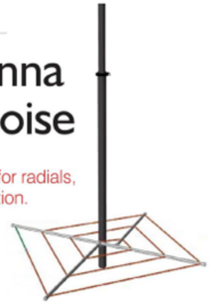
Design of the Antenna

- Vertical Dipole (29.58/29.68 → 29.63 MHz.)
- Ground Plane Version
- **Spiral Ground Plane**
  - A 16' long radial won't fit into my attic easily
- Fitting it into my attic
- Matching it

Design of the Antenna: SPIRAL GROUND PLANE

A Simple Vertical Antenna with a Spiral Counterpoise

If you don't have space for radials, this project offers a solution.



Greg Hebner, AG5FE

When I temporarily moved to the east coast from the southwestern desert, I had a yard with tall trees. I was finally able to put up 40-meter antennas and enjoy making DX contacts. This inspired me to design something that could work just as well from my permanent, treeless desert home.

I had some major constraints. The antenna had to be self-supporting and safe for backyard guests, but there was little space for radials. An internet search for a "coiled counterpoise" gave me some encouragement and prompted me to consider performance and antenna patterns compared to the classic quarter-wavelength vertical with many radials. To explore options, I used the free *4nec2* modeling software at **https://www.qsl.net/4nec2** and the costly *NEC-4.2* engine from Lawrence Livermore National Laboratories, informed by *The ARRL Handbook*.

Learning from a Model

My first model of a quarter-wavelength vertical (33 feet at 7.05 MHz) and a single, coiled counterpoise of similar length had poor gain and voltage standing wave ratios (VSWR). I struggled with questions and variables, such as the length of the wires, overall counterpoise dimensions, and how to use *4nec2* to optimize strange counterpoise shapes.

I realized that I could first choose a counterpoise shape that would fix the x and y coordinates of every wire. The *4nec2* program multiplies each coordinate by a single scaling number to arbitrarily stretch the relative shape and the total length of the spiral counterpoise. Adding a vertical wire to the spiral completed the design. The *4nec2* optimizer adjusts two terms, the length of the vertical and the spiral scale factor. This works to optimize the SWR and gain. To my surprise, the model converged on a design with a minimum VSWR of 1.1:1, an azimuthally constant gain of –0.7 dBi, and a 2:1 VSWR bandwidth of 280 kHz. The vertical length was 39 feet for a center frequency of 7.1 MHz, which is 15% longer than a quarter wavelength. The spiral counterpoise length was 33 feet, 7 inches, which is almost a quarter wavelength. No wonder my first attempt was so poor.

The antenna design study provided good insight on how to construct the physical antenna. The real impedance was dependent on the length of the vertical but weakly dependent on the number of spiral turns. The imaginary impedance depended almost equally on the vertical length and the number of spiral turns. Thus, the length of the spiral is tuned first to adjust the imaginary impedance. Then the length of the vertical is adjusted to tune the real impedance. I first trimmed the length of the spiral wire length to minimize the VSWR, irrespective of the minimum frequency. The vertical length was then trimmed to move the VSWR minimum to the desired operating frequency.

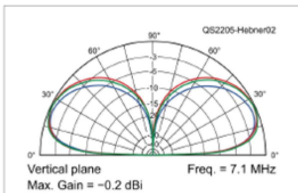


Figure 1 — The blue curve is my antenna, while the green and red represent a conventional quarter-wave vertical with above or in-ground radials.

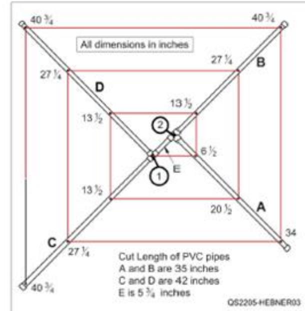


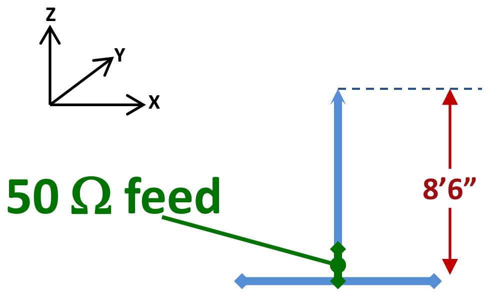
Figure 2 — The spiral frame assembled using five pieces of ¾-inch PVC. The points on arm A are measured from point 2.

Figure 3 — The spiral wire was secured with cable ties at each corner, and the inside end was connected to the balun. The vertical wire connects to the other output terminal of the balun.

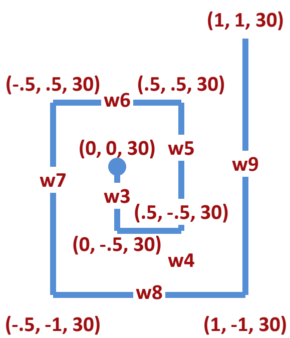
May 2022 QST

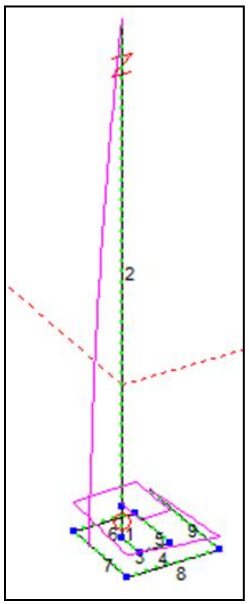
Greg Hebner AG5FE

Design of the Antenna: SPIRAL GROUND PLANE #1 @ 30’

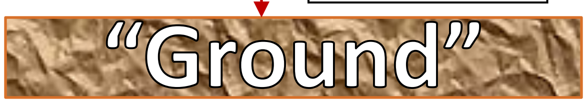


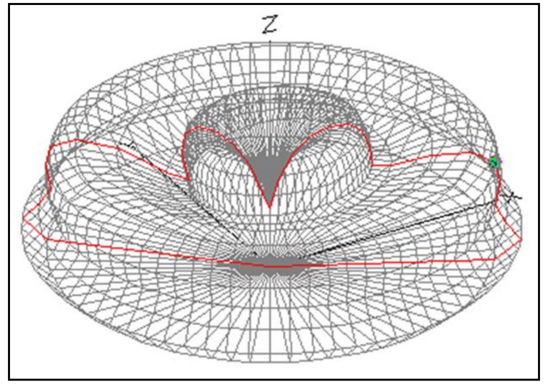
The “Ground Plane” (X-Y plane)

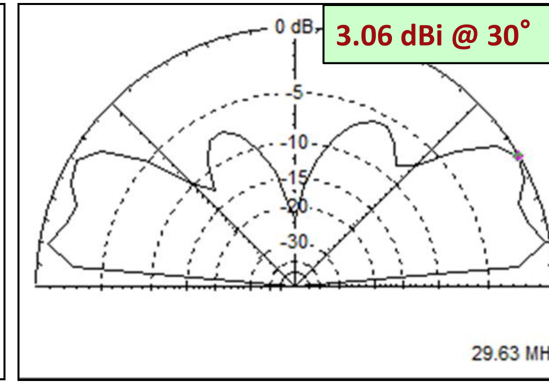


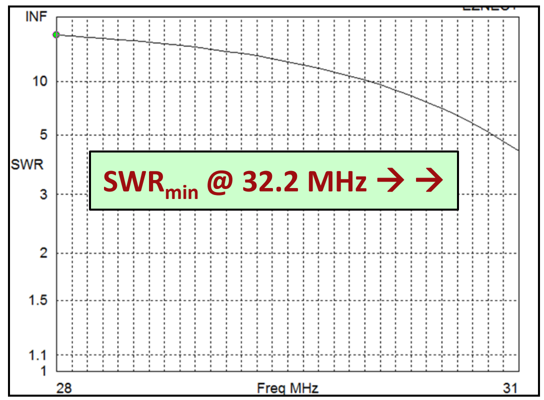


30’



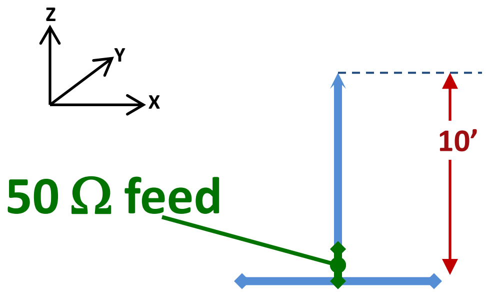




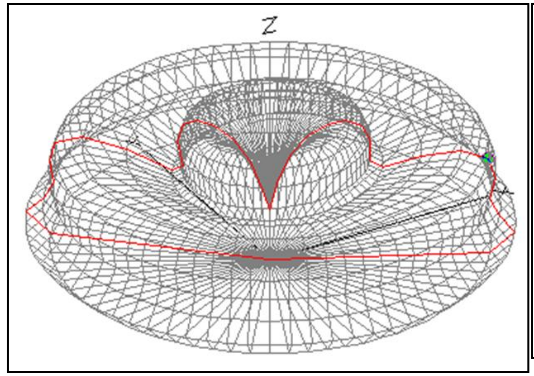


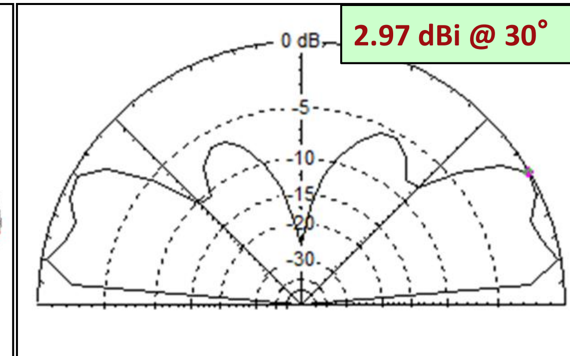
Consistent with Greg’s findings: His vertical radiator had to be 15% longer than a $\lambda/4$

Design of the Antenna: SPIRAL GROUND PLANE #2 @ 30’



Extend to 10’





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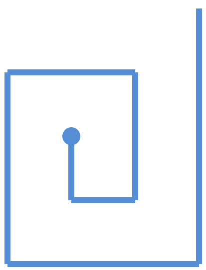

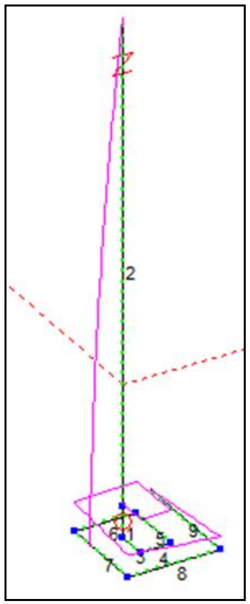

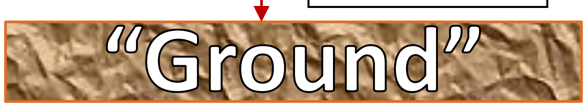

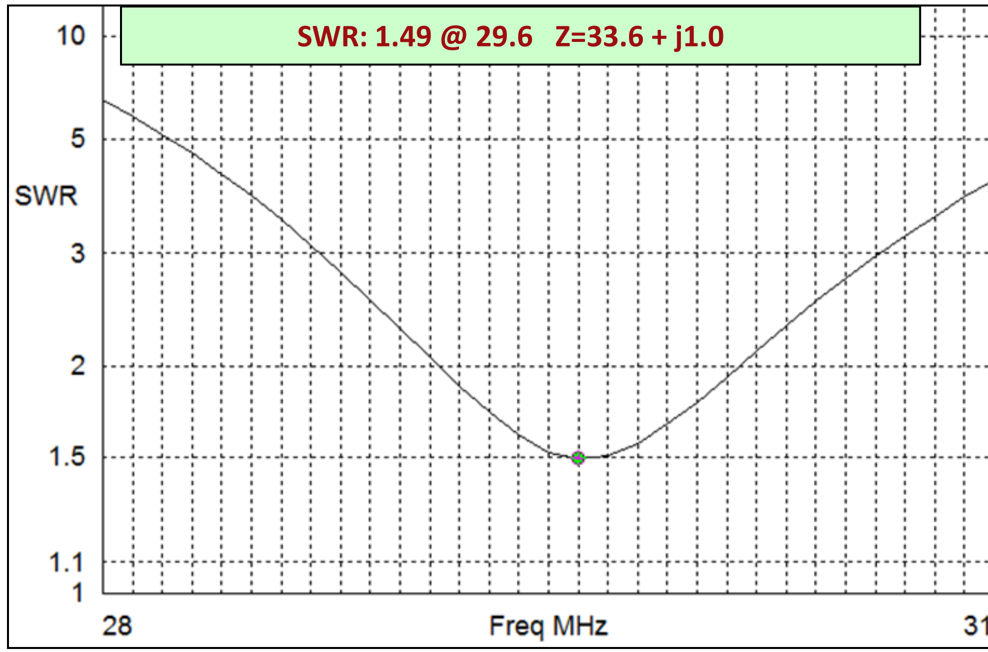

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  - **At 10’ tall it’s too tall for my 5’ tall attic…**
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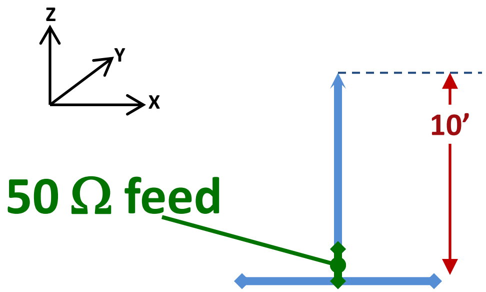

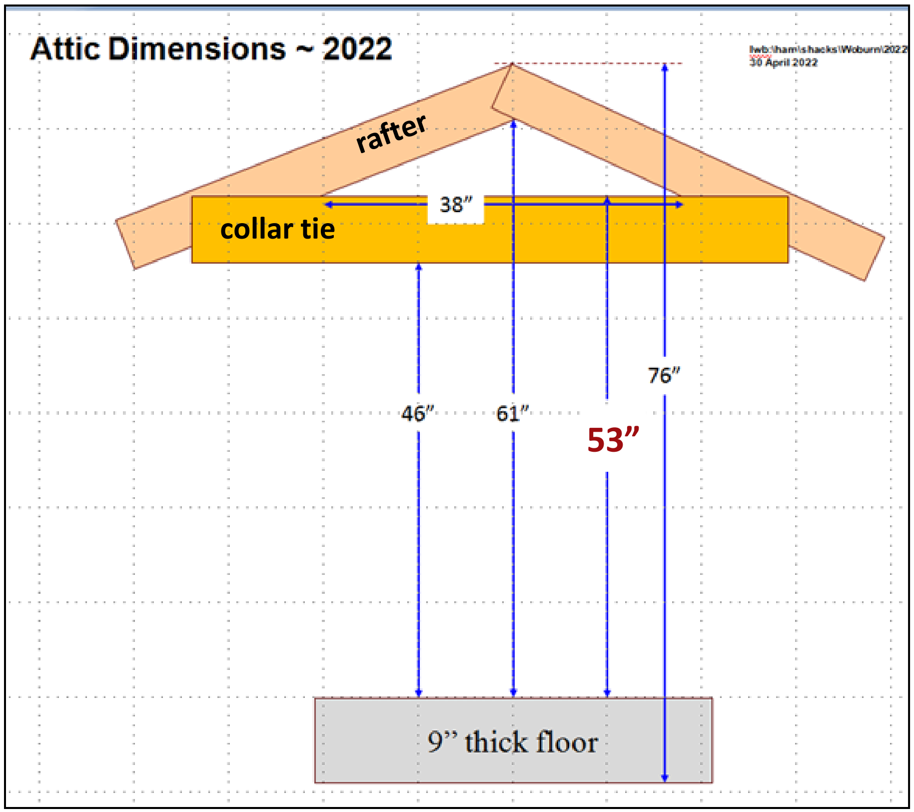

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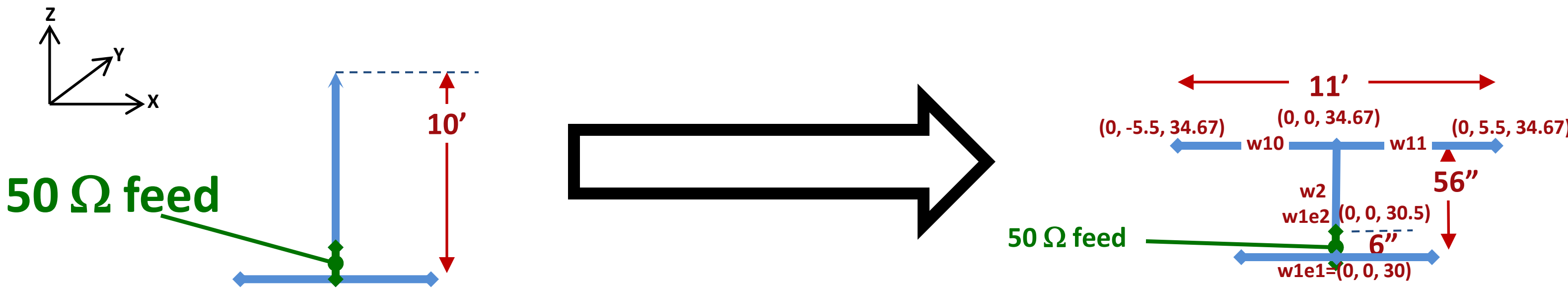
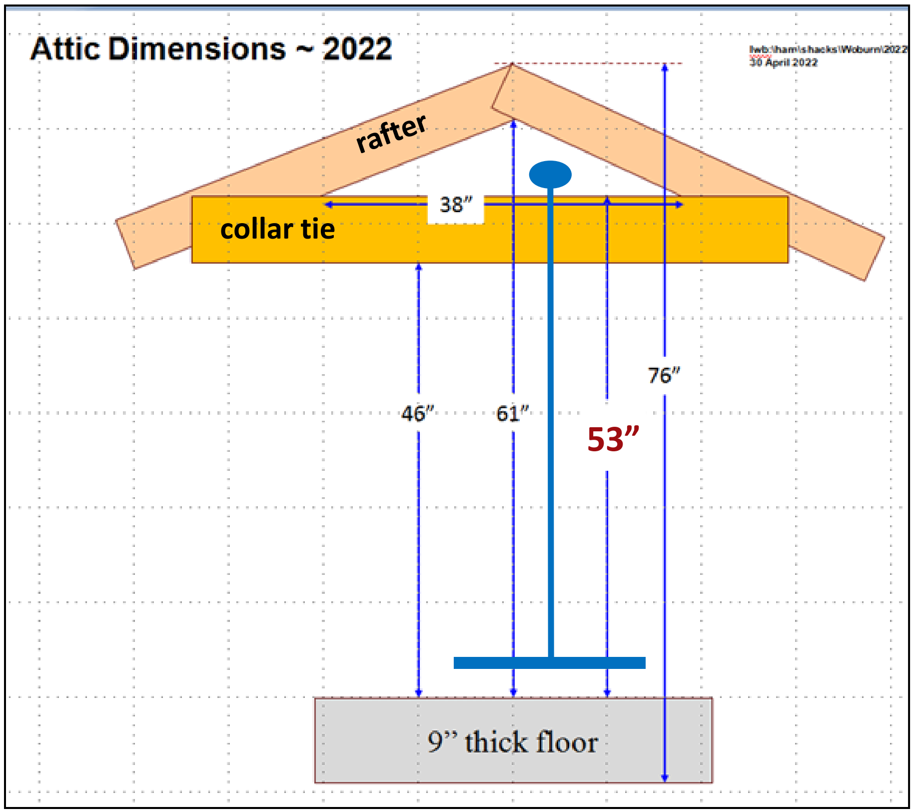
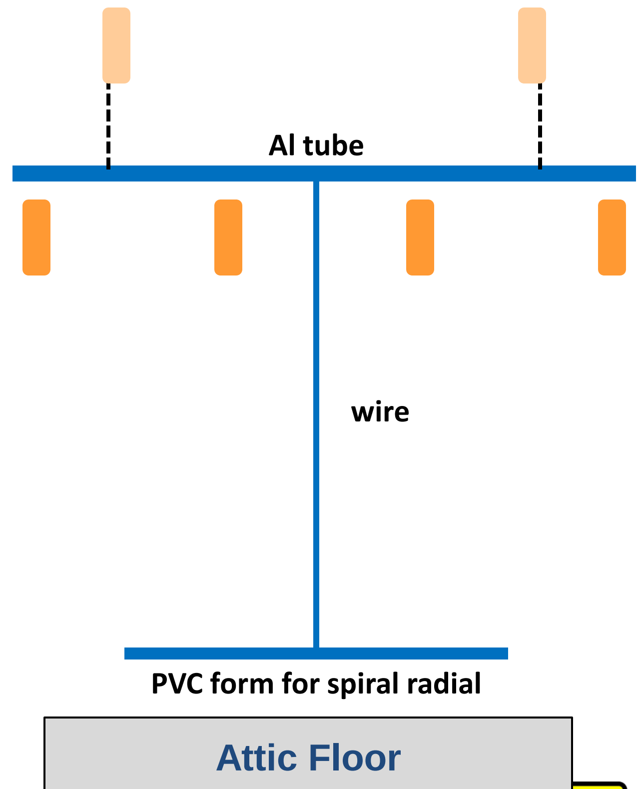
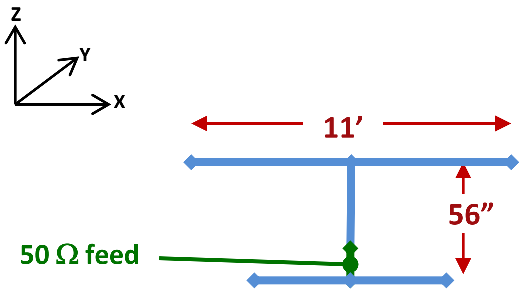
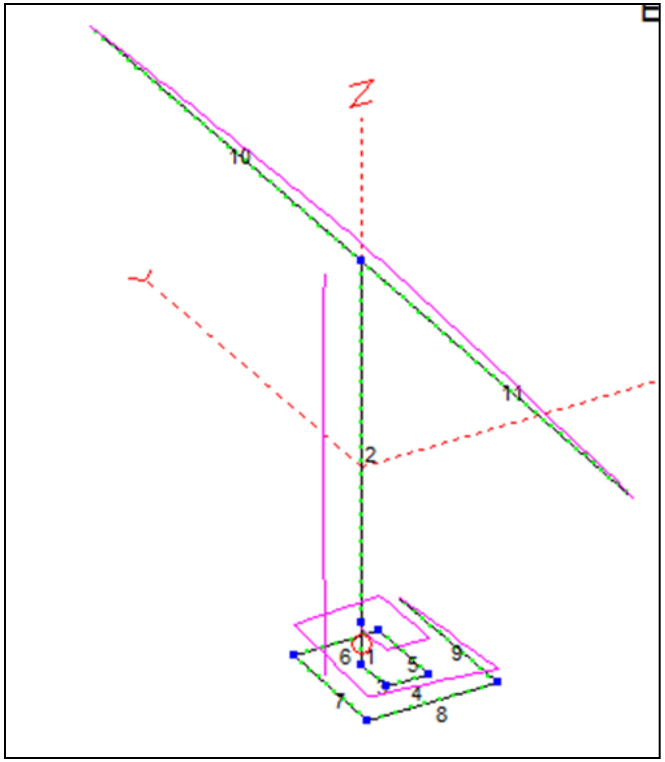


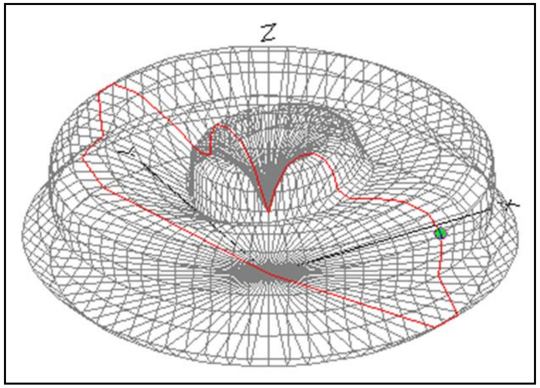


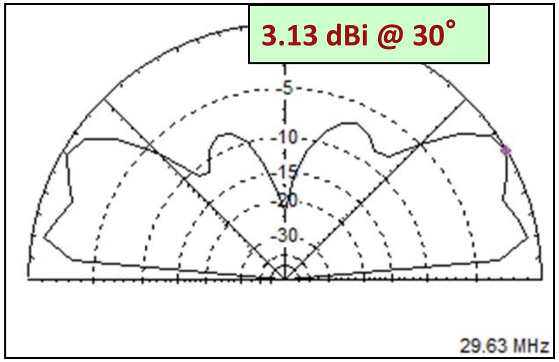


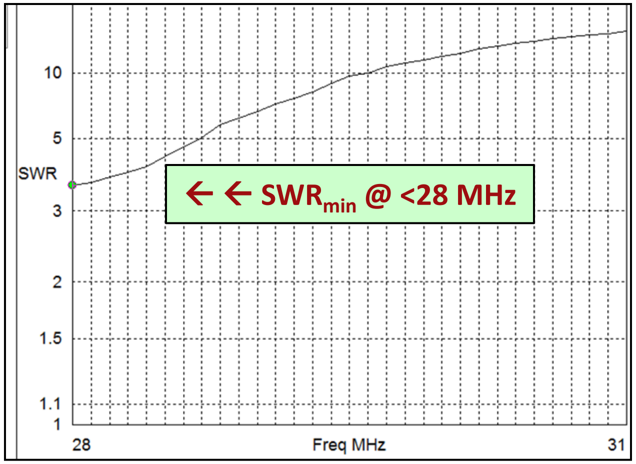
Design of the Antenna: "T-Top" Spiral GP #1 @ 30'



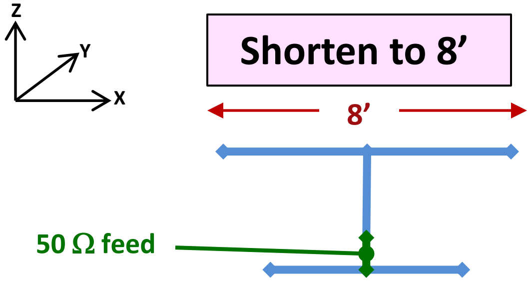


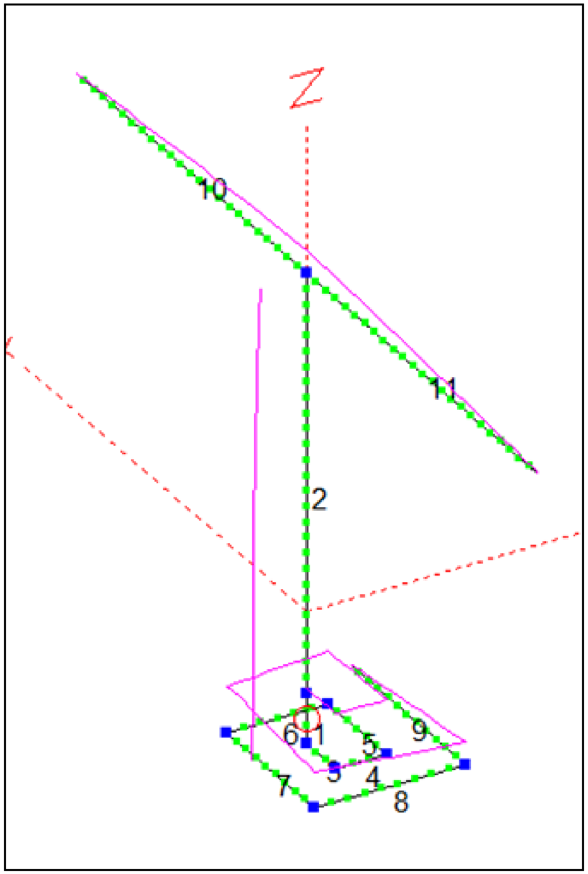


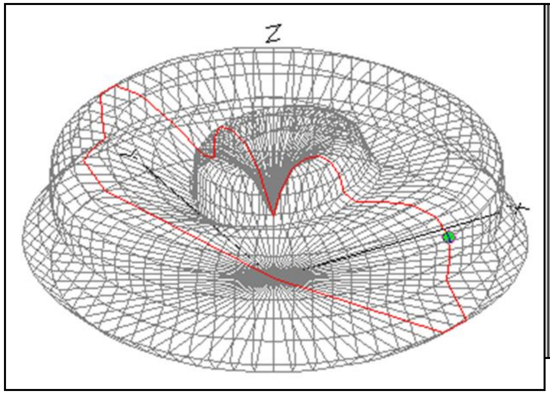


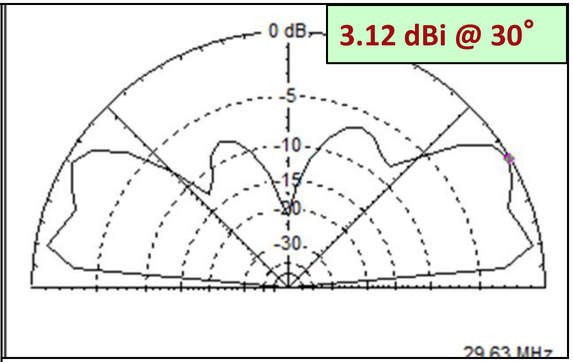


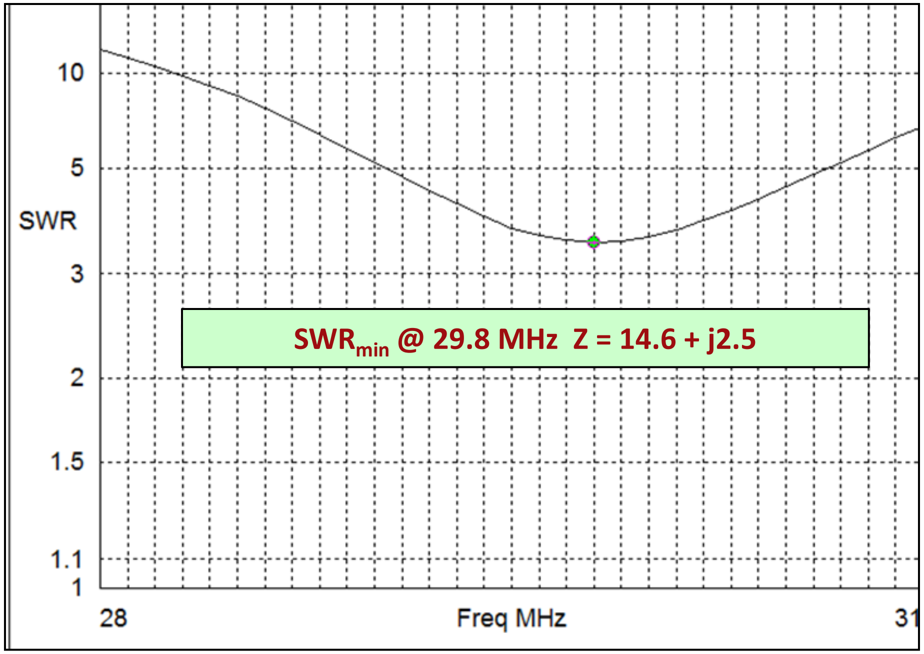
Design of the Antenna: “T-Top” Spiral GP #2 @ 30’











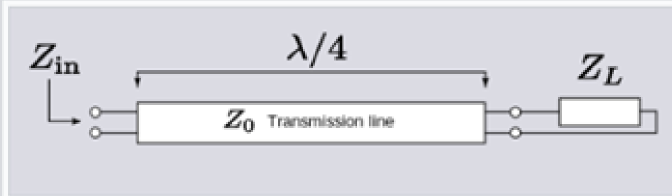
Works! BUT -- |Z| = ~15Ω how do I match it???

 MATCHING IT: Some Theory [WIKIPIDIA]

Quarter-wave impedance transformer

From Wikipedia, the free encyclopedia

A **quarter-wave impedance transformer**, often written as **λ/4 impedance transformer**, is a transmission line or waveguide used in electrical engineering of length one-quarter wavelength (λ), terminated with some known impedance. It presents at its input the dual of the impedance with which it is terminated.



Using a transmission line as an impedance transformer.

It is a similar concept to a stub; but, whereas a stub is terminated in a short (or open) circuit and the length is chosen so as to produce the required impedance, the λ/4 transformer is the other way around; it is a pre-determined length and the termination is designed to produce the required impedance.

The relationship between the characteristic impedance, Z_0, input impedance, Z_{in} and load impedance, Z_L is:

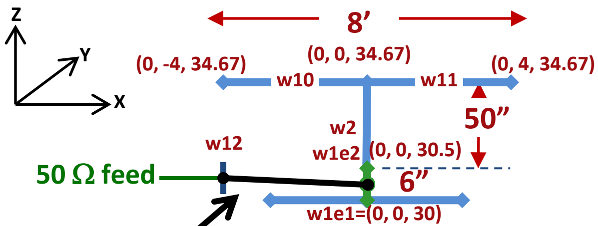
$$\frac{Z_{in}}{Z_0} = \frac{Z_0}{Z_L}$$

$Z_{coax} = 50\Omega$ → $Z_{matching\ network} = Z_{geometric\ mean}$ → $Z_{antenna} = \sim 15\Omega$

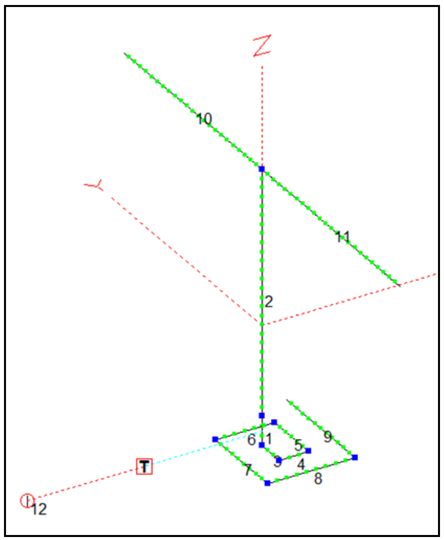
$$Z_{match} = \sqrt{Z_{ant} * Z_{coax}} = \sqrt{15*50} = \sim 27\Omega$$

Use parallel ¼ wave lengths of 50Ω coax

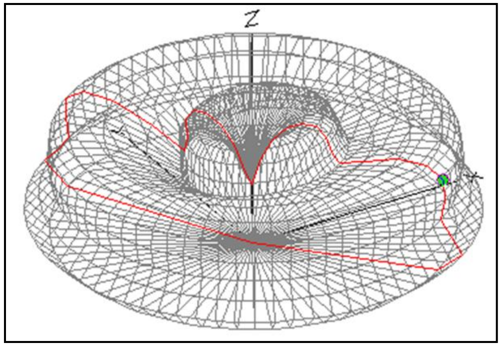
Design of the Antenna: "T-TOP" SPIRAL GP W/COAX

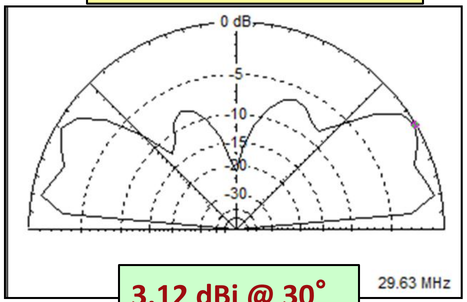


8' of "perfect"
25 Ω coax



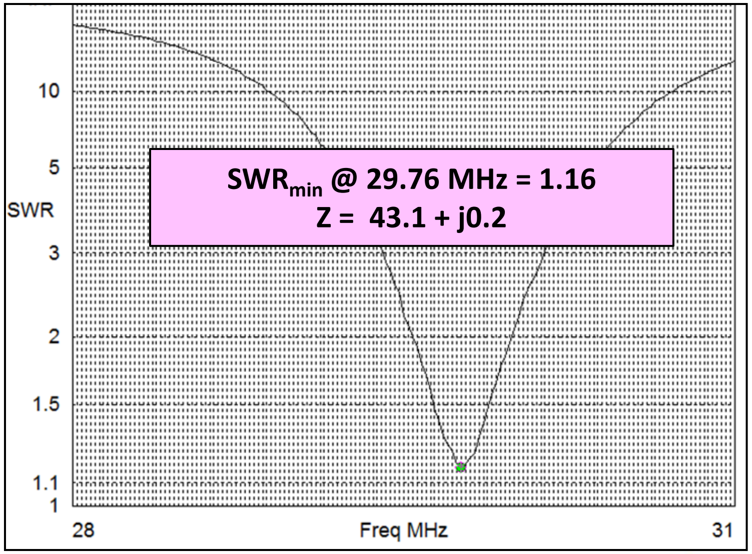
Was: 3.12 dBi @ 30˚





3.12 dBi @ 30˚

Was: SWR_{min} @ 29.8 MHz Z = 14.6 + j2.5



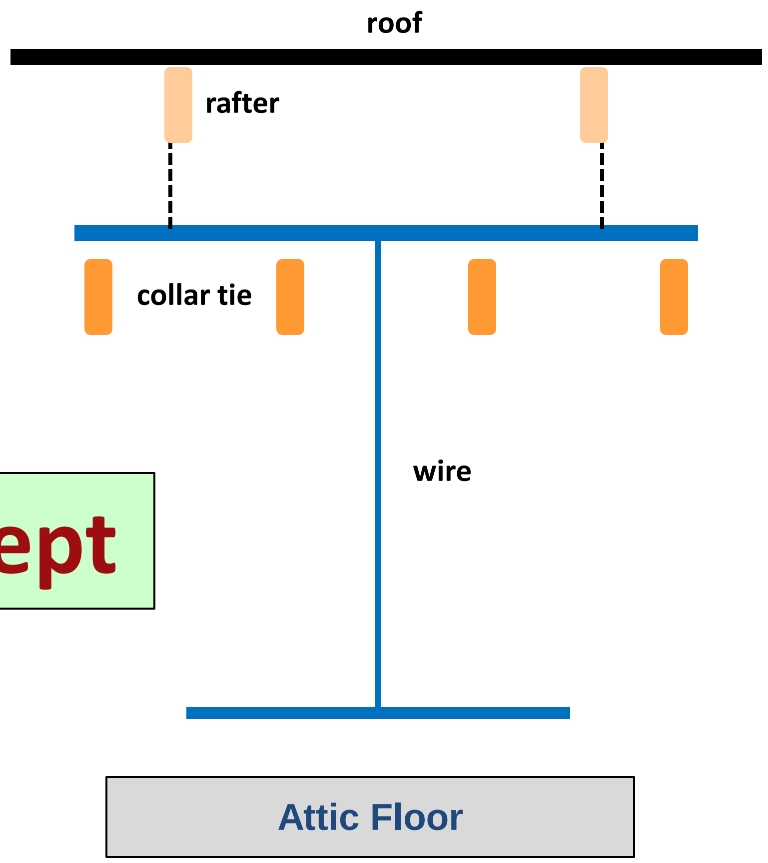
SWR_{min} @ 29.76 MHz = 1.16
Z = 43.1 + j0.2

BUILDING IT – THE USEFUL (AND MORE *DIFFICULT*) STUFF!

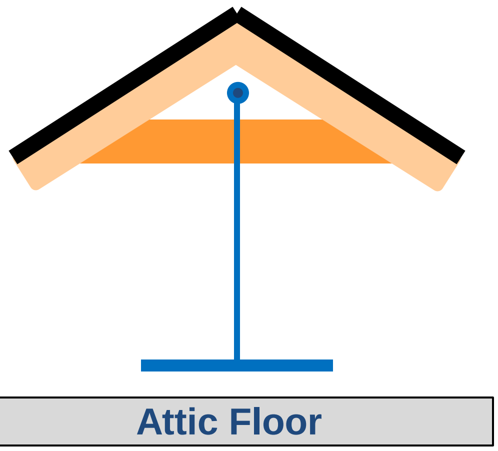
- **The 10m “Vertical”**
- **Matching with the 6m GP**
- **Results**

Building It

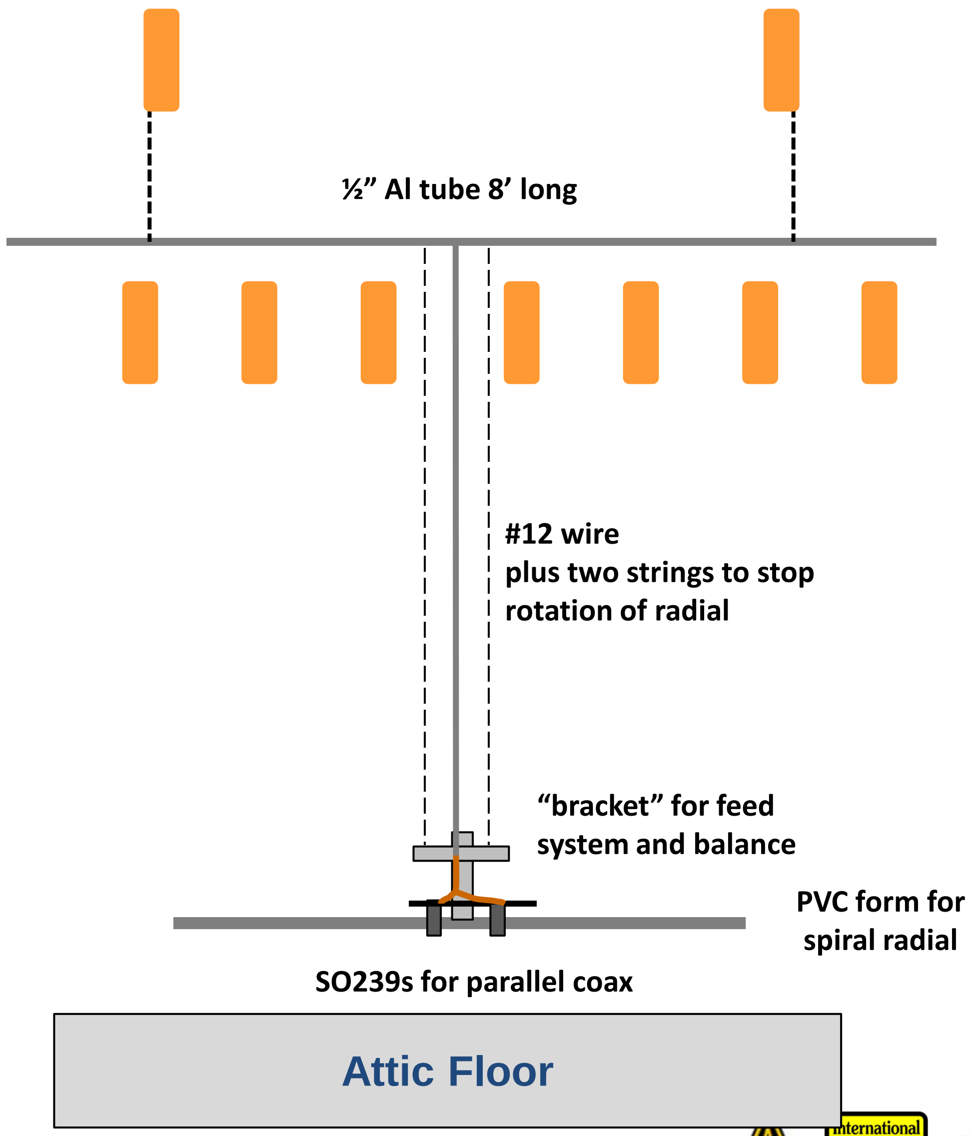
- **The 10m "Vertical"**
- Matching with the 6m GP
- Results



Concept

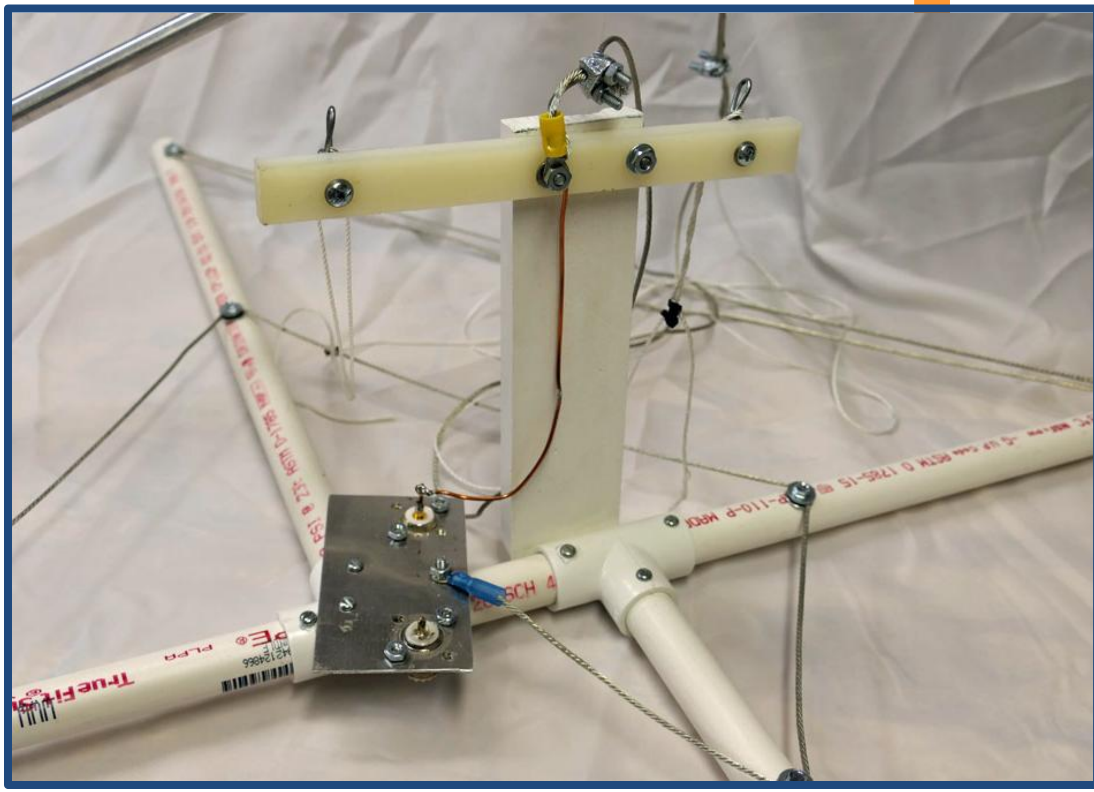


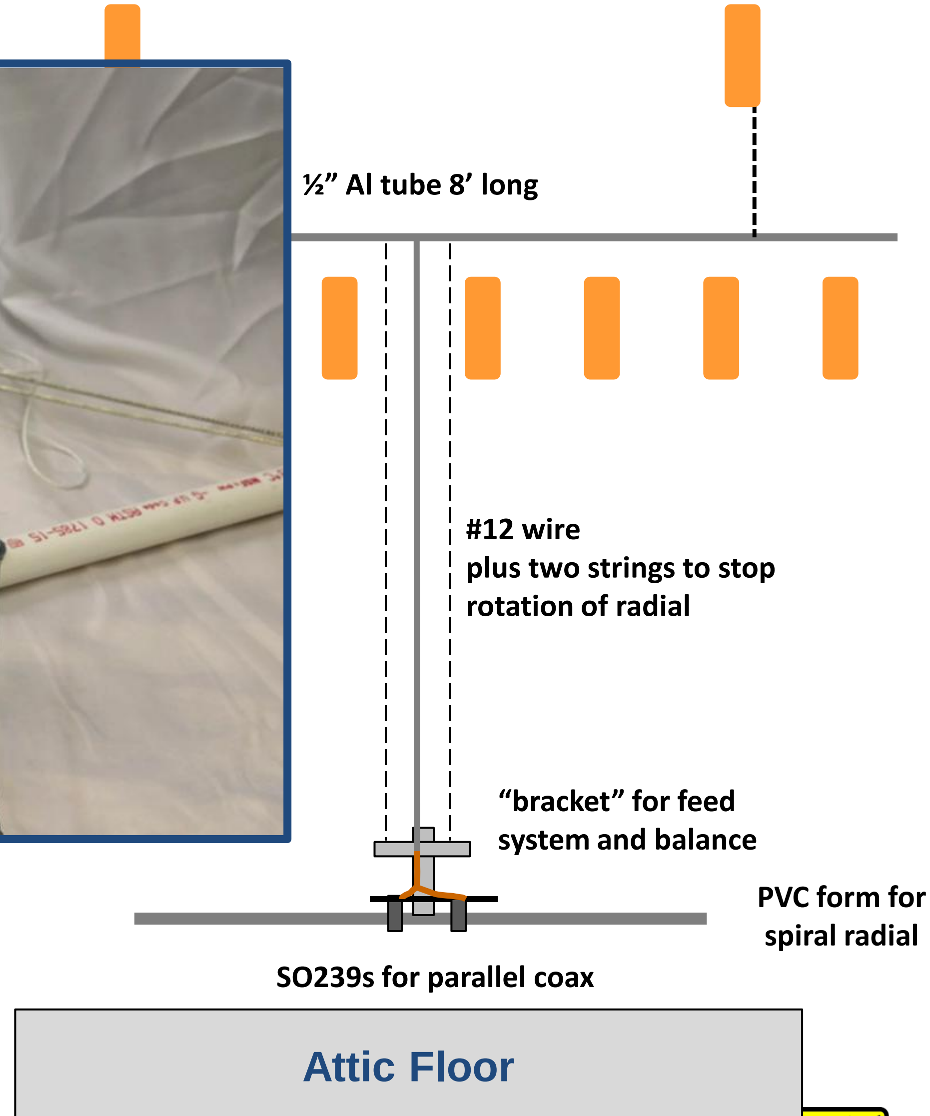
Building It



½" Al tube 8' long
#12 wire
plus two strings to stop
rotation of radial
"bracket" for feed
system and balance
PVC form for
spiral radial
SO239s for parallel coax
Attic Floor

Building It





½" Al tube 8' long
#12 wire
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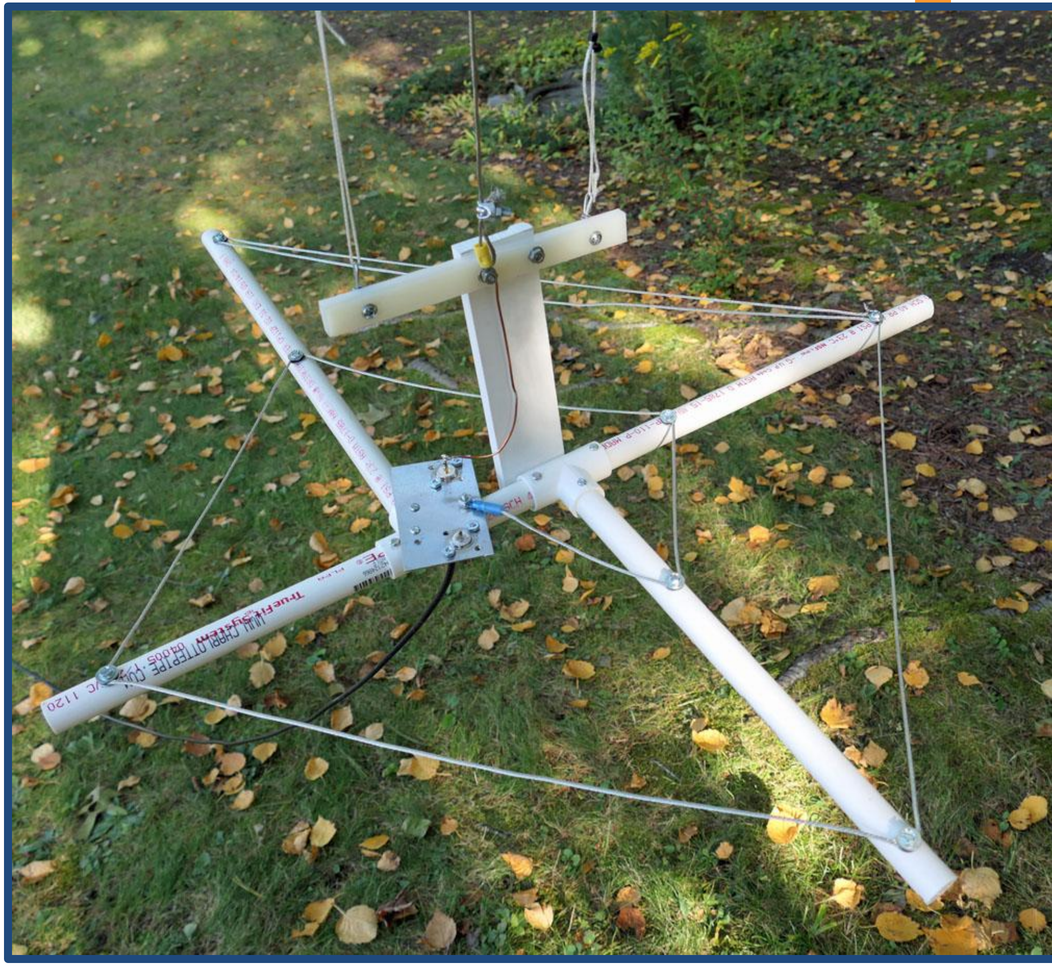
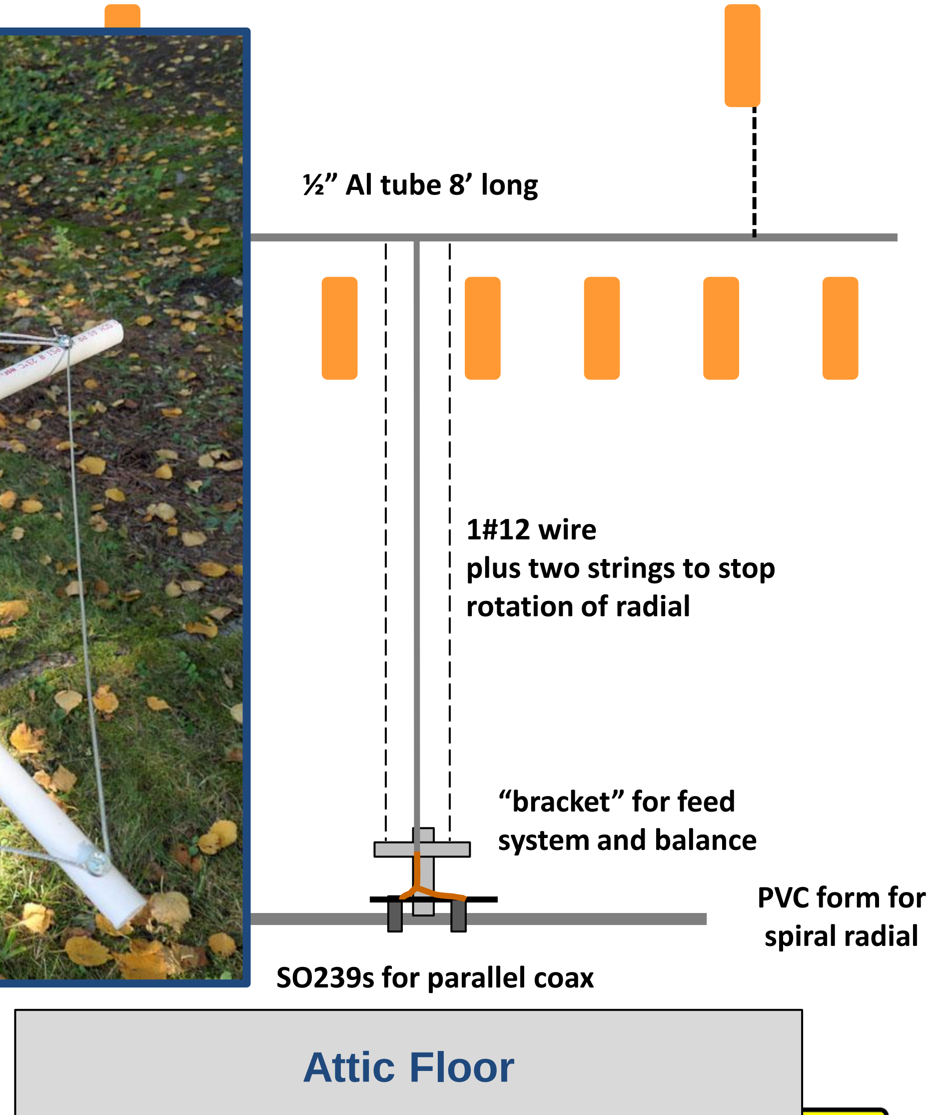
system and balance
PVC form for
spiral radial
SO239s for parallel coax
Attic Floor

Building It





½" Al tube 8' long
1#12 wire
plus two strings to stop
rotation of radial
"bracket" for feed
system and balance
PVC form for
spiral radial
SO239s for parallel coax
Attic Floor

BUILDING IT: TESTED AT 3' ABOVE GROUND – WITH TWO 50 Ω COAXS

The match with two λ/4 50 Ω coaxes in parallel was terrible!

Forget the 25Ω coax!

Building It: Tested at 3' Above Ground – with *TWO* 50 Ω Coaxs

The match with two $\lambda/4$ 50 Ω coaxes in parallel was terrible!

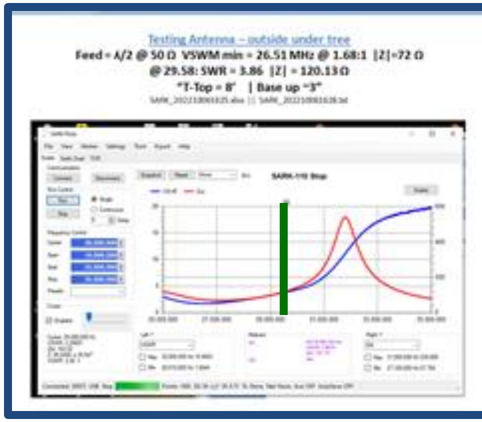
Forget the 25Ω coax!

"All Models are wrong. Some are useful."

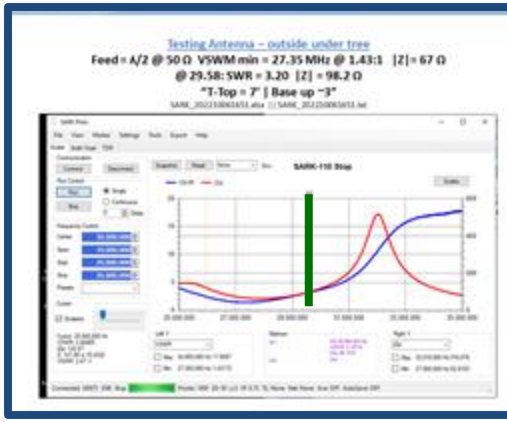
British Statistician *George Box*, 1976

BUILDING IT: TESTED AT 3' ABOVE GROUND – WITH *ONE* 50 Ω COAX

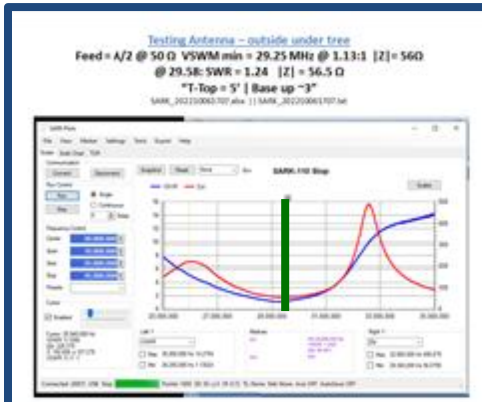
Frequency Scan: 25 – 35 MHz *29.58MHz*



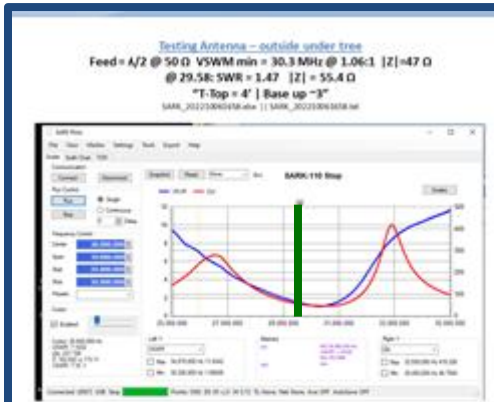
T=Top = 8'
VSWR scale: 0-20 | |Zs| scale = 0-600



T=Top = 7'
VSWR scale: 0-20 | |Zs| scale = 0-600

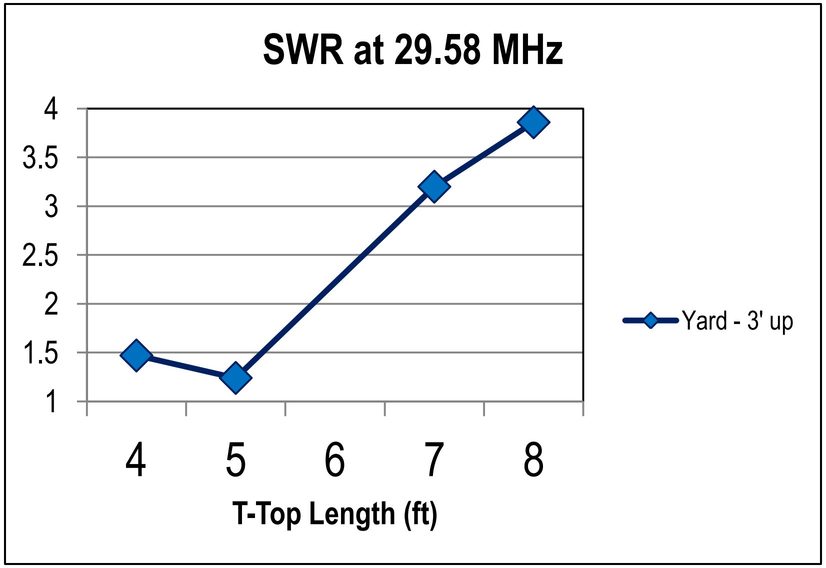


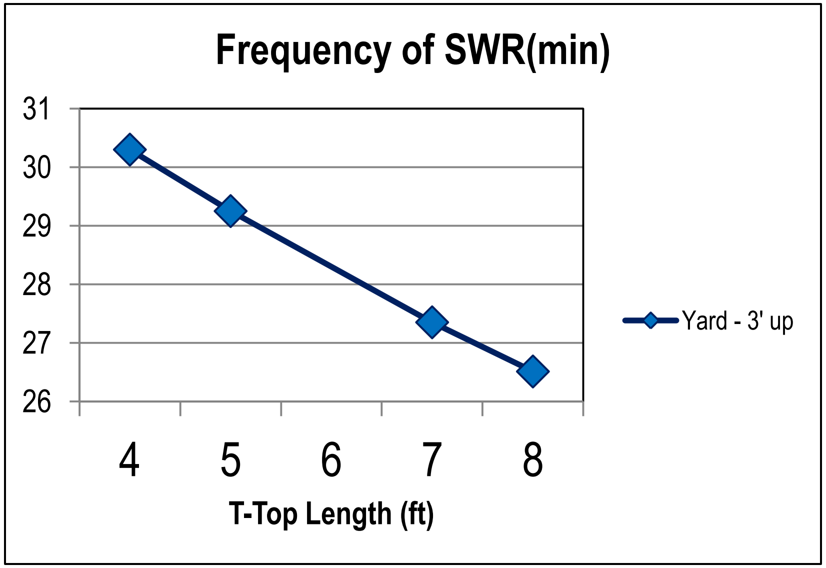
T=Top = 5'
VSWR scale: 0-16 | |Zs| scale = 0-500

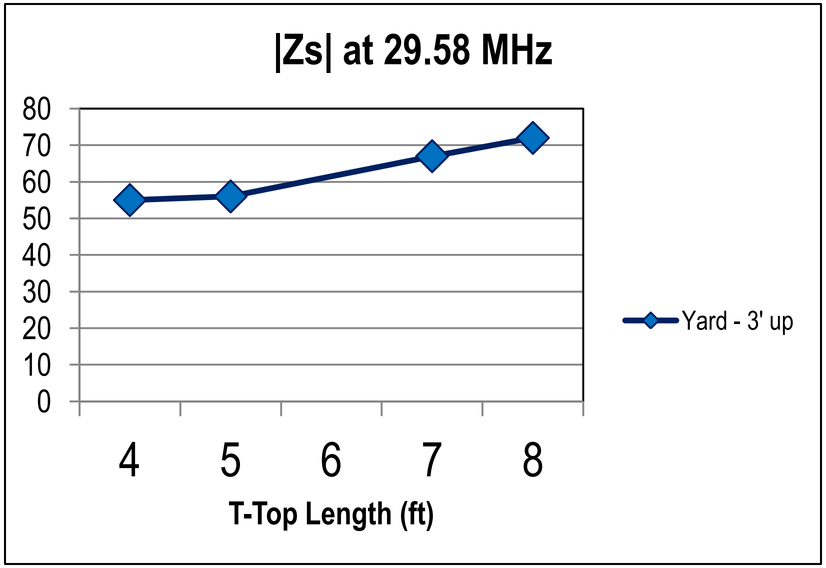


T=Top = 4'
VSWR scale: 0-16 | |Zs| scale = 0-500

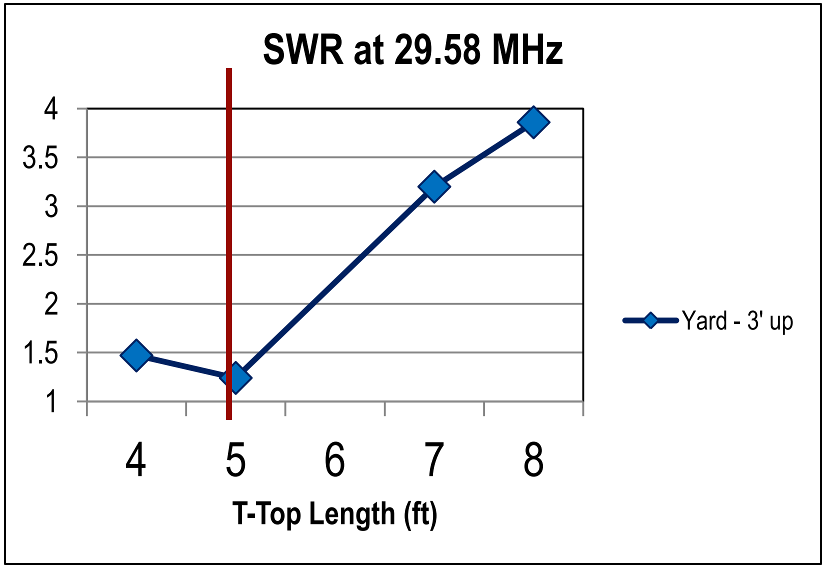
Building It: Results of 3' Above Ground

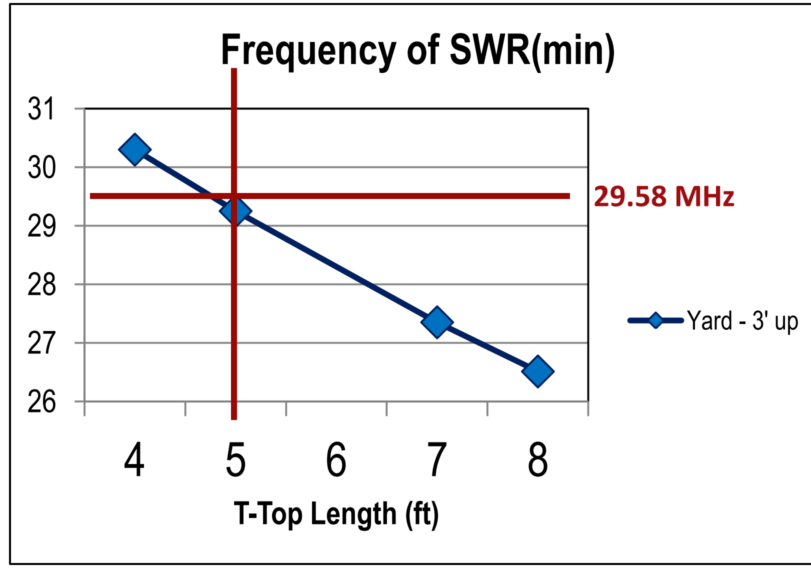


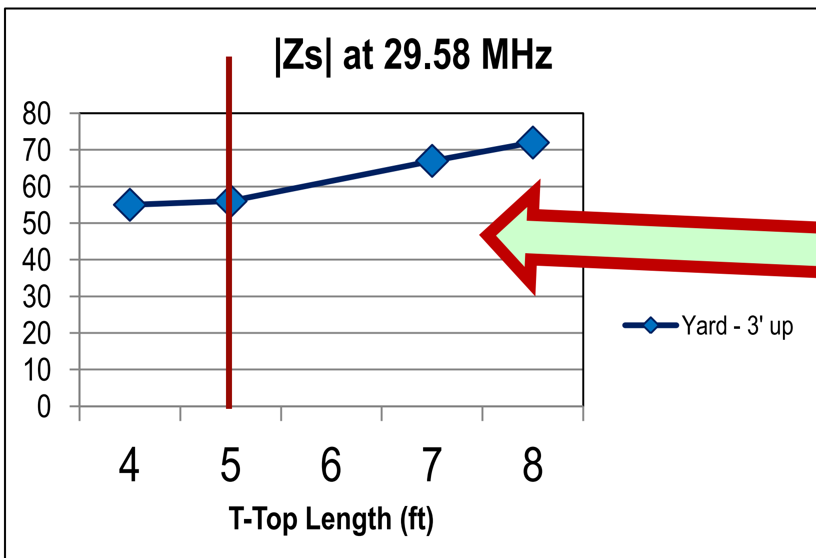




Building It: Results of 3' Above Ground







Best match @ “T-Top” = 5’

|Zs| =~ 55 Ω

Building It

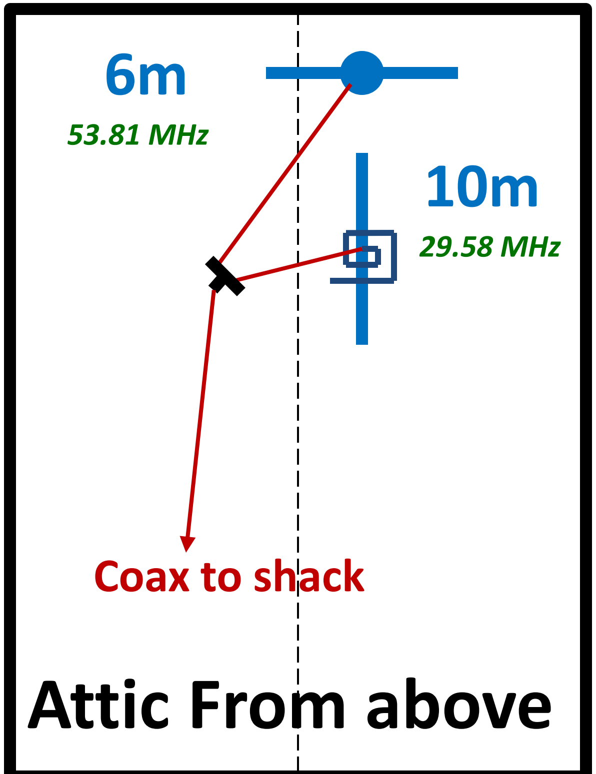
- The 10m Vertical
- **Matching with the 6m GP**
- Results

- I have a 6m vertical in my attic
- I want to put the 10m FM vertical in my attic without adding another coax run.

My 6m GP in my attic

Building It

- The 10m Vertical
- **Matching with the 6m GP**
- Results



Challenge: Feeding them in parallel without messing either of them up.

BUILDING IT

- The 10m Vertical
- **Matching with the 6m GP**
- Results

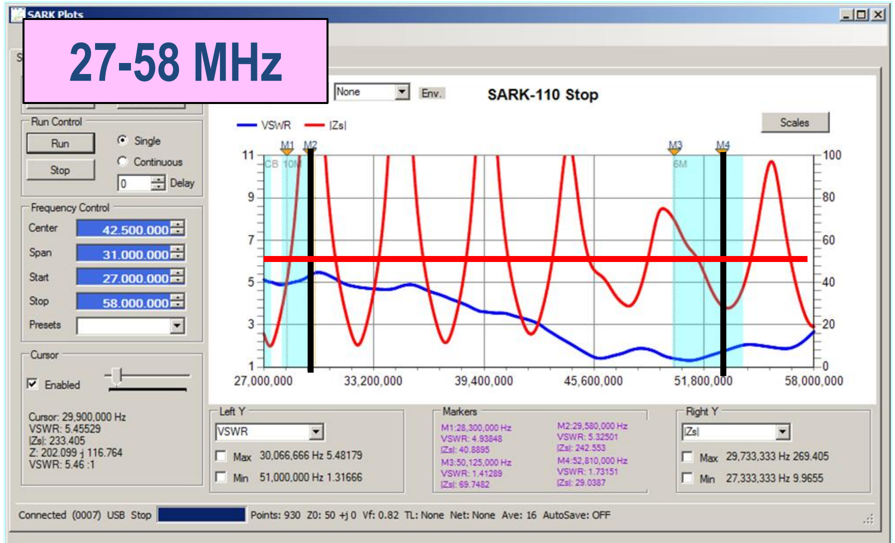
Gather Some Data

1. Measure the 6m GP by itself
2. Position the unconnected 10m GP and measure the 6m GP by itself again
   - Does the presence of the 10m GP affect to 6m GP?
3. Disconnect the 6m GP, connect the 10m GP, and measure the 10m GP
   - How does the 10m GP work in the attic?
4. Develop the matching scheme
5. Finally, connect them together and measure them

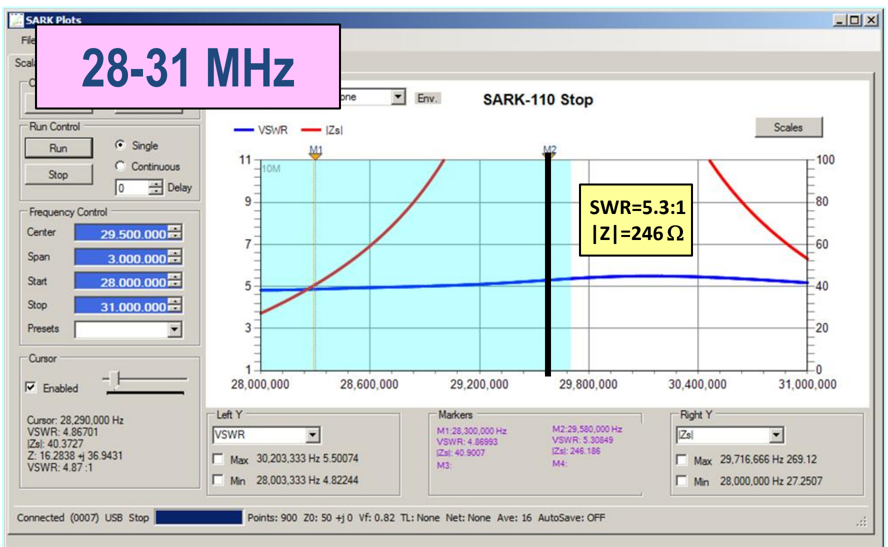
BUILDING IT: REAL DATA: SWEEP OF THE 6M GROUND PLANE BY ITSELF

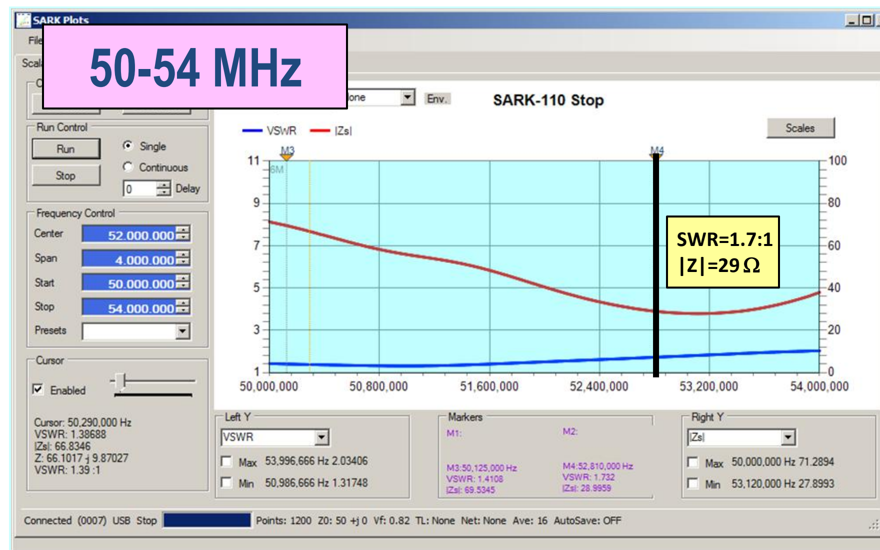
Scales:
VSWR: 1-11
|Zs|: 0-100

Measurements taken in the shack with ~60' of RG-8x between my SARK-110 and the antennas.

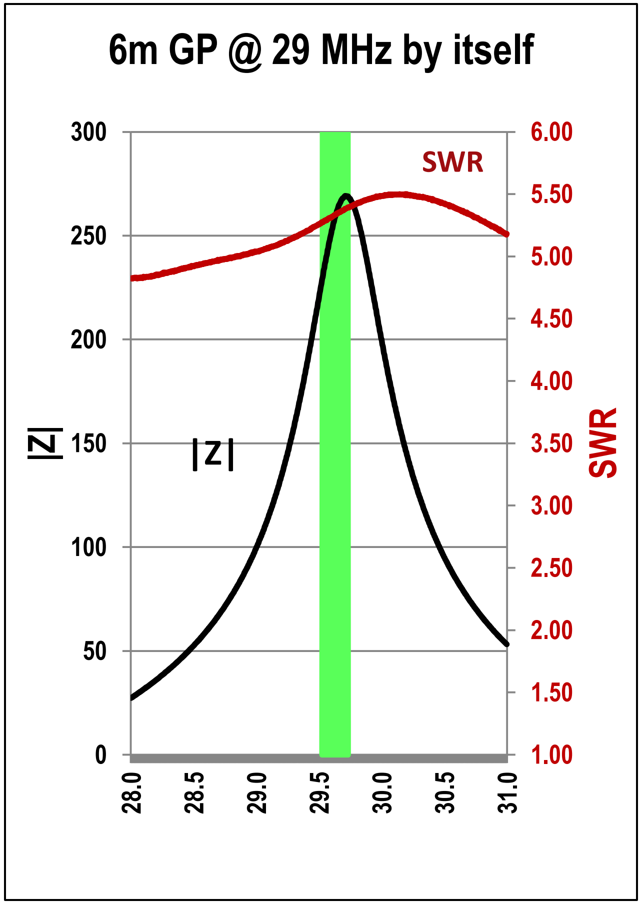


This is an example of the detailed scans for the four setups.

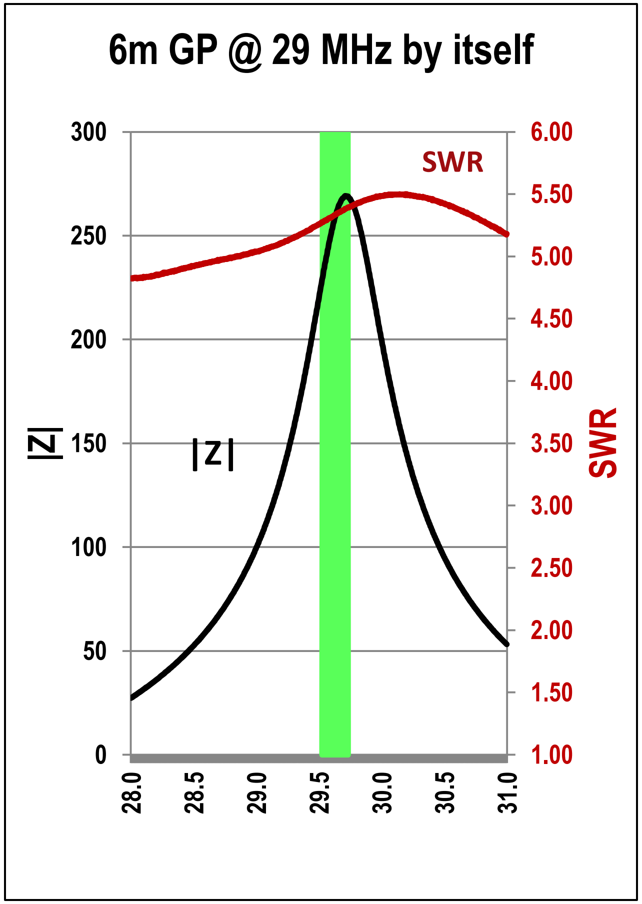


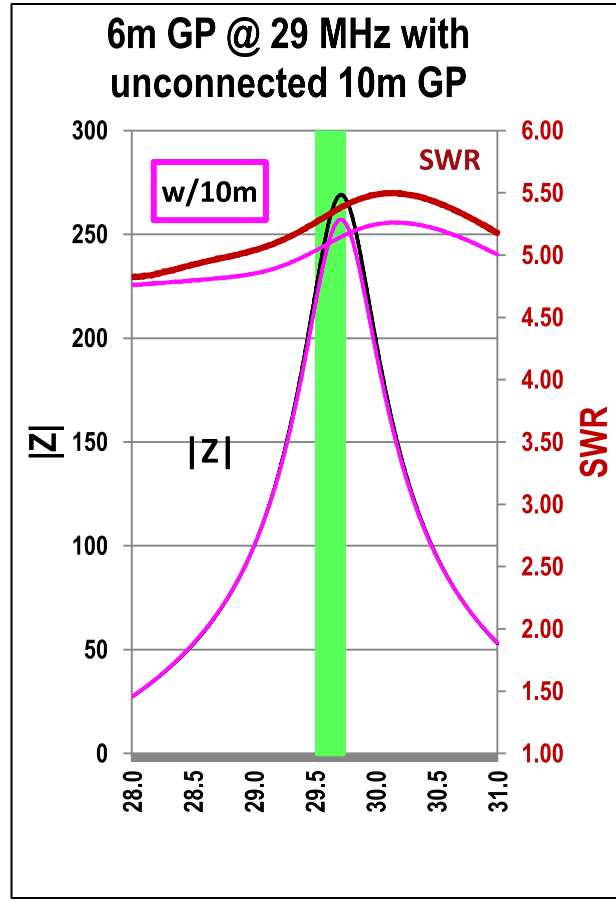


Building It: Real Data: 6m GP @ 29 MHz



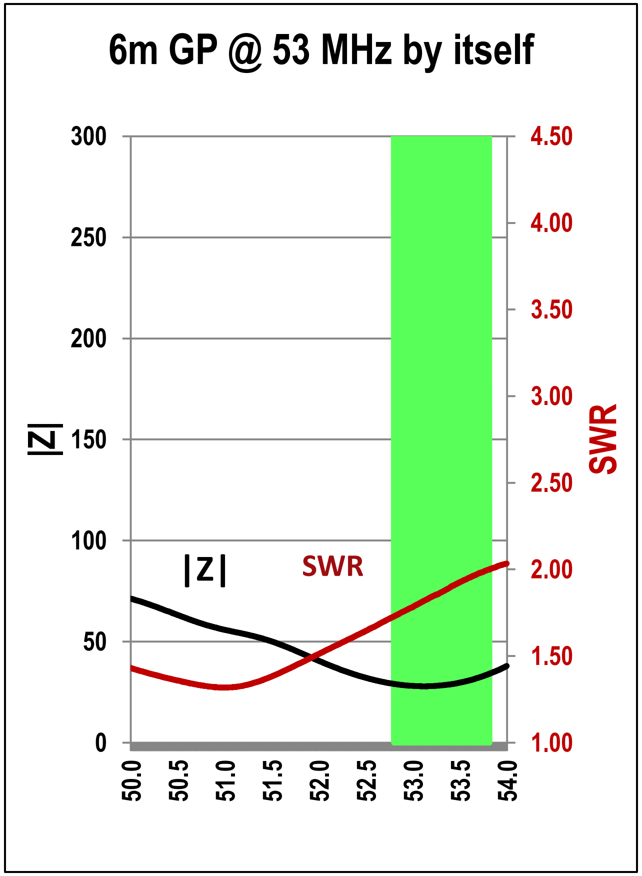
BUILDING IT: REAL DATA: 6M GP @ 29 MHZ



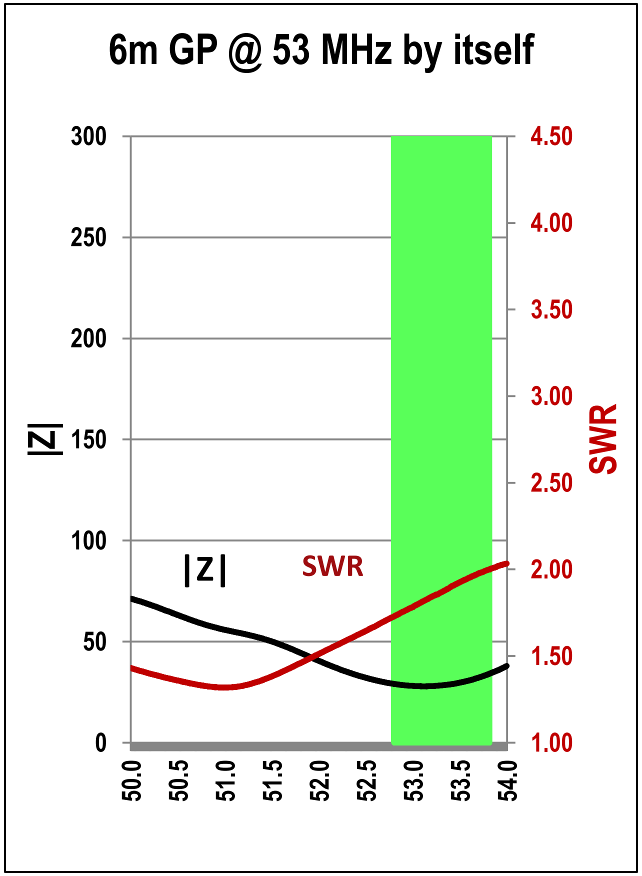


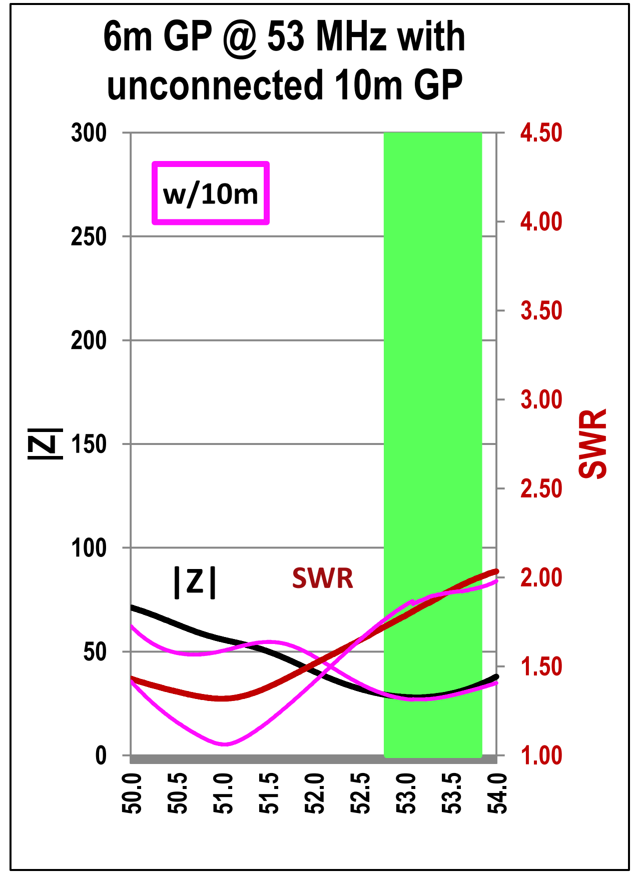
Conclusion: At 29 MHz, the presence of the 10m GP has little affect on the 6m GP and has High |Z|

BUILDING IT: REAL DATA: 6M GP @ 53 MHZ



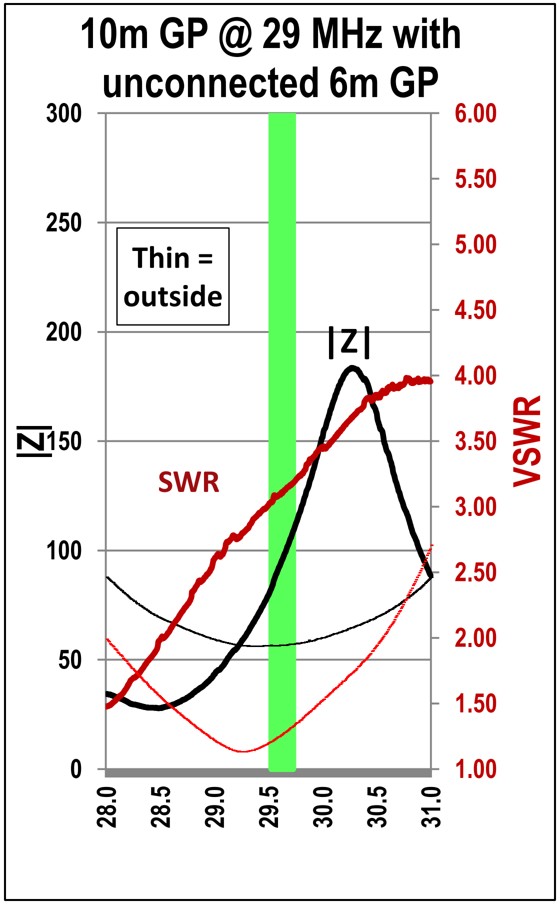
Building It: Real Data: 6m GP @ 53 MHz





Conclusion: At 53 MHz, the presence of the 10m GP does not affect the 6m GP very much, and 6m has *decent SWR*

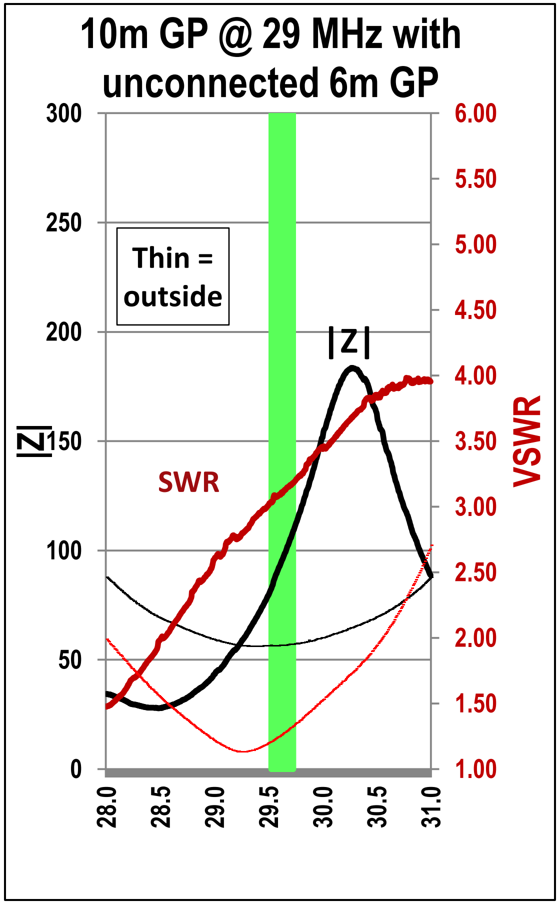
BUILDING IT: REAL DATA: 10M GP @ 29 MHZ

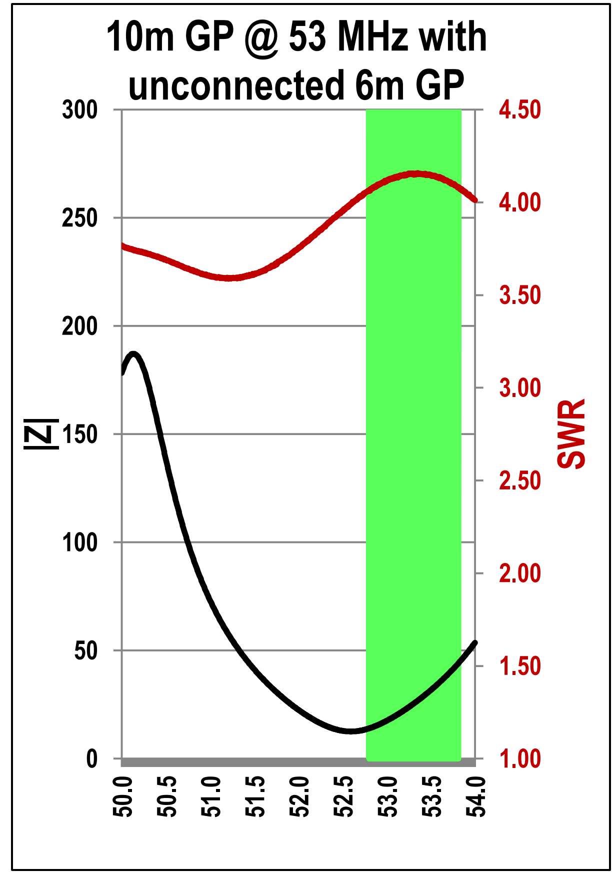


"OK" – not great. Could use adjusting. Moving from ground level to attic lowered resonant frequency ~1+ MHz.

But the 6m GP is not affecting it much if at all, as the curves are similar.

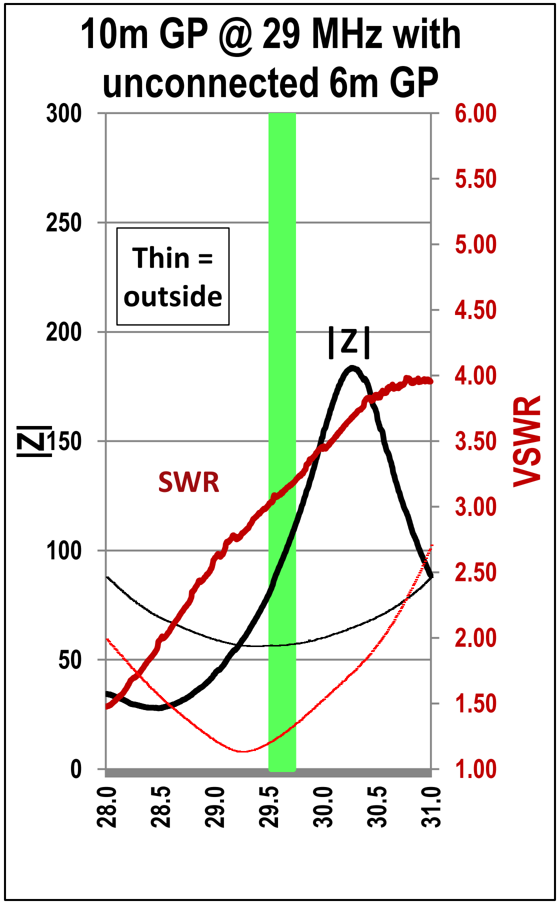
Building It: Real Data: 10m GP @ 29 MHz & 53 MHz

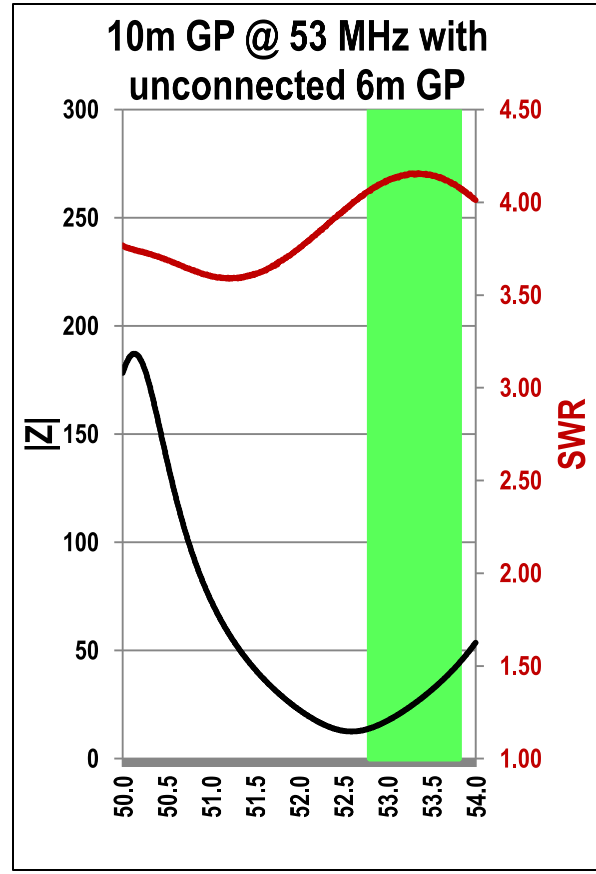




Conclusion: The 10m GP is not being effected by the 6m GP very much.

Building It: Real Data: 10m GP @ 10m & 6m





Connect them and see what happens!

But How???

BUILDING IT: MORE THEORY – λ/4 AND λ/2 COAX

A "special case" of the quarter-wave matching transformer: the "stub"

$Z_I(f) = \infty$ → **λ/4 LENGTH OF COAX @ *f*** → $Z_L(f) = 0$ "shorted"

$Z_I(f) = 0$ → **λ/4 LENGTH OF COAX @ *f*** → $Z_L(f) = \infty$ "open"

1/4 wave length of coax "inverts" the impedance

{assumes lossless coax!}

BUILDING IT: MORE THEORY – $\lambda/4$ AND $\lambda/2$ COAX

A "special case" of the quarter-wave matching transformer: the "stub"

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1/4 wave length of coax "inverts" the impedance

$Z_I(f) = 0$ → $\lambda/2$ LENGTH OF COAX @ f → $Z_L(f) = 0$

$Z_I(f) = \infty$ → $\lambda/2$ LENGTH OF COAX @ f → $Z_L(f) = \infty$

½ wave length of coax repeats the impedance

Building It: More Theory – λ/4 and λ/2 coax

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1/4 wave length of coax "inverts" the impedance

$Z_I(f) = 0$ → λ/2 LENGTH OF COAX @ *f* → $Z_L(f) = 0$

$Z_I(f) = \infty$ → λ/2 LENGTH OF COAX @ *f* → $Z_L(f) = \infty$

½ wave length of coax repeats the impedance

→*Field Day:*

Building It: More Theory – λ/4 and λ/2 coax

A "special case" of the quarter-wave matching transformer: the "stub"

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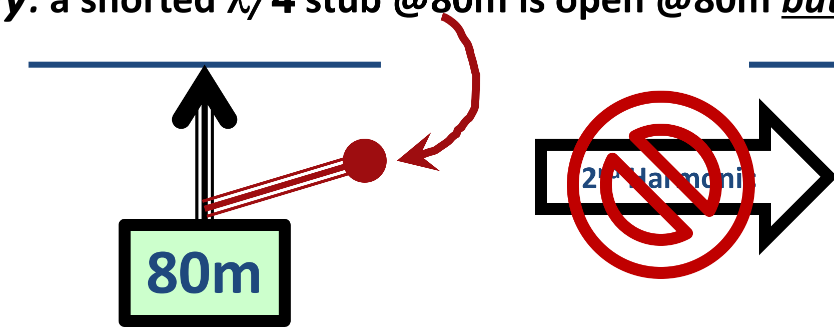
1/4 wave length of coax "inverts" the impedance

$Z_I(f) = 0$ → **λ/2 LENGTH OF COAX @ *f*** → $Z_L(f) = 0$

$Z_I(f) = \infty$ → **λ/2 LENGTH OF COAX @ *f*** → $Z_L(f) = \infty$

½ wave length of coax repeats the impedance

→***Field Day***: a shorted λ/4 stub @80m is open @80m ***but @ 40m it is a λ/2 stub and shorted and therefore shorts the 2nd harmonic***

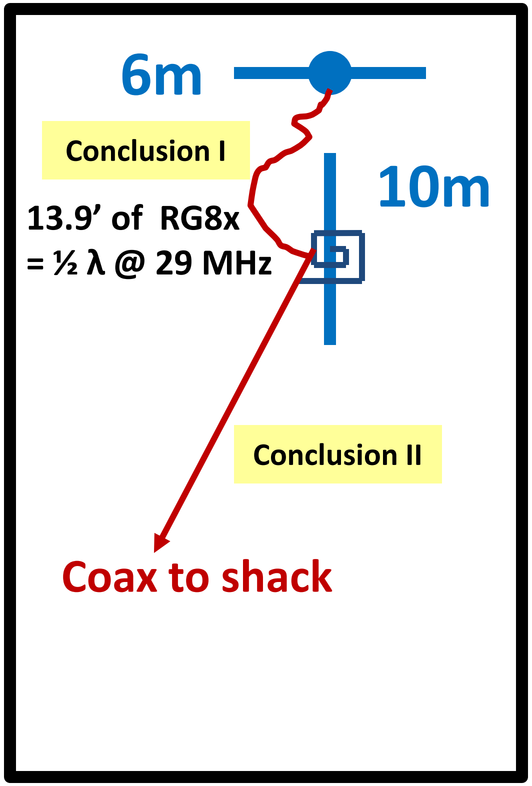


BUILDING IT: MATCHING THEM

Conclusion I: Connect them so that at 10m the 6m GP retains it's high impedance.
Conclusion II: The presence of the 6m GP does not affect the 10m GP very much.

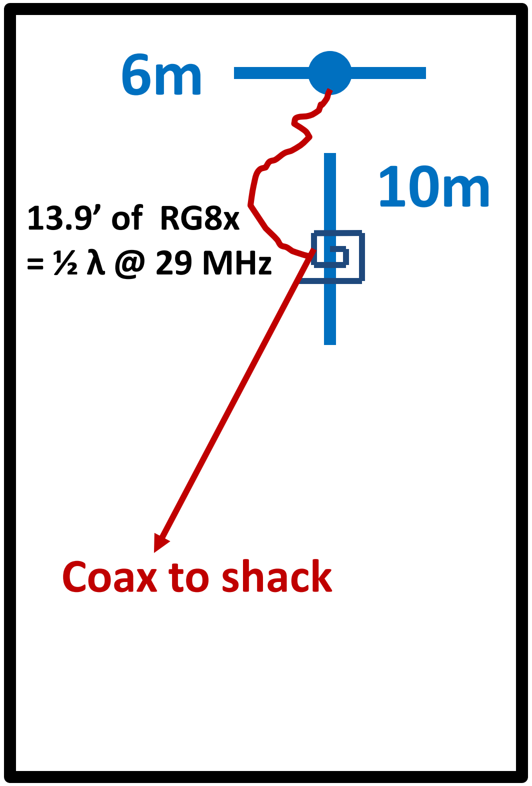
Building It: Matching Them

Conclusion I: Connect them so that at 10m the 6m GP retains it's high impedance.
Conclusion II: The presence of the 6m GP does not affect the 10m GP very much.



Use a ½ wave section @ 10m between the 10m & 6m GPs, which should repeat the high impedance @10m of the 6m GP

Building It: Matching Them



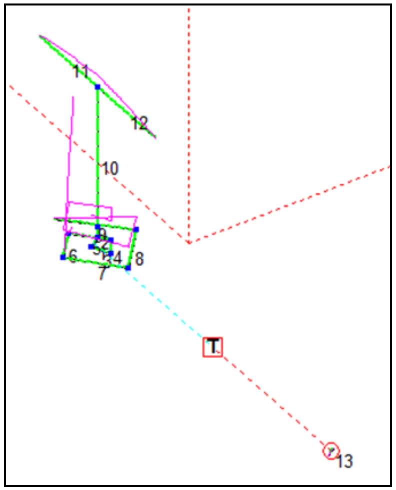
Let's model this.

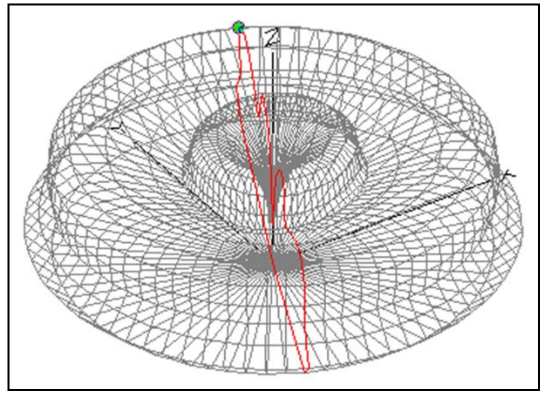
BUILDING IT: MODELING THE TWO GPS WHEN CONNECTED

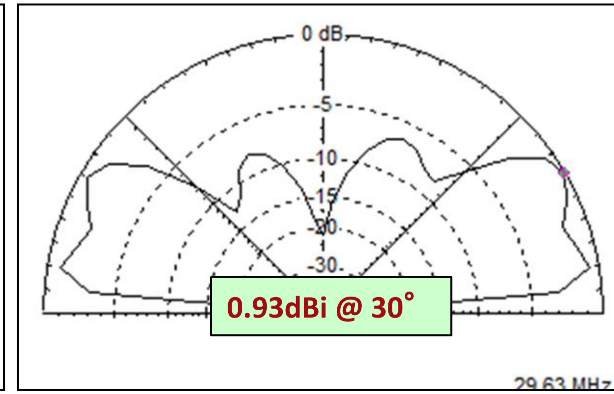
10M GP @ 10M

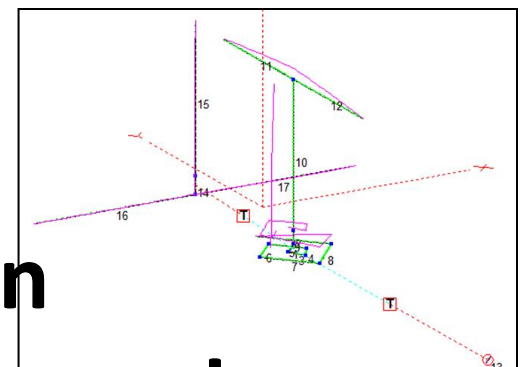
Modeled @ 30’ & 29.3 MHz

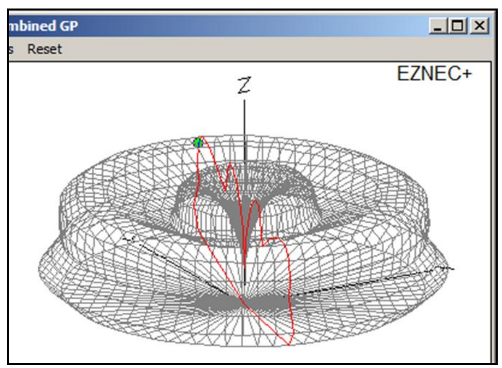
By Itself

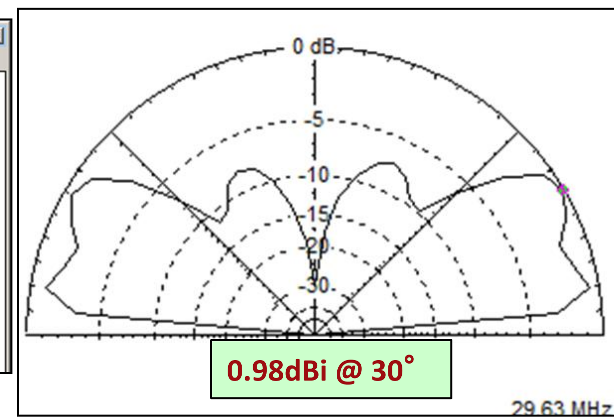












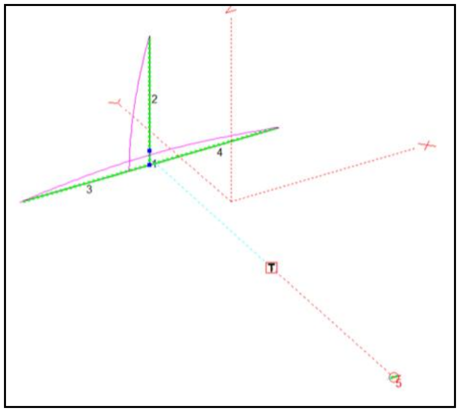
When connected

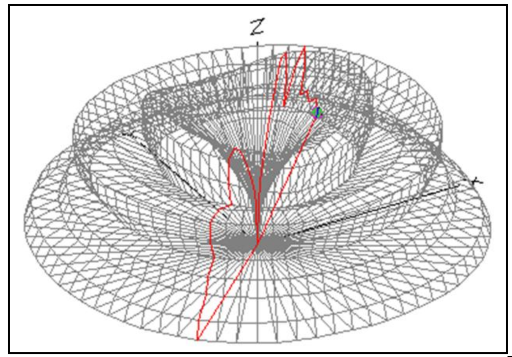
BUILDING IT: MODELING THE TWO GPs WHEN CONNECTED

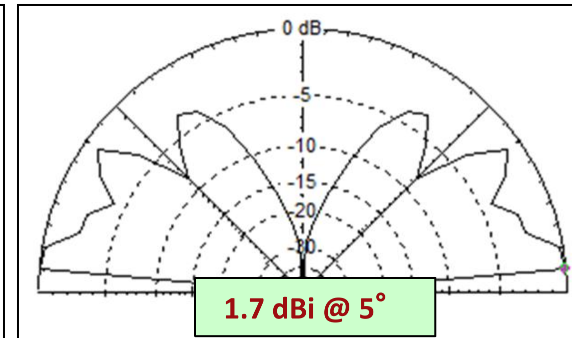
6M GP @ 6M

Modeled @ 30' & 53.5 MHz

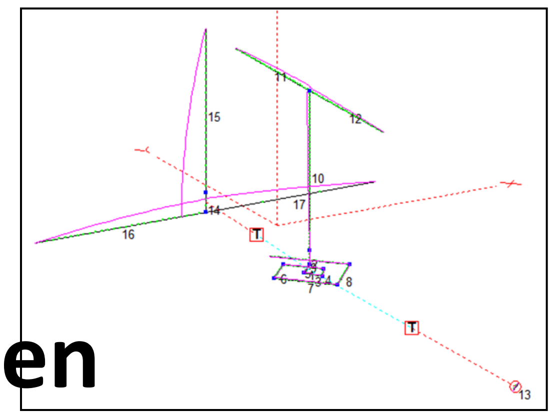
By Itself

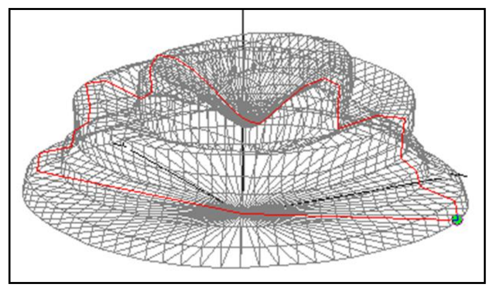


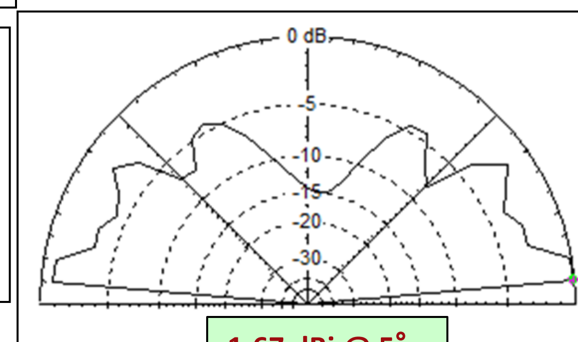




1.7 dBi @ 5˚





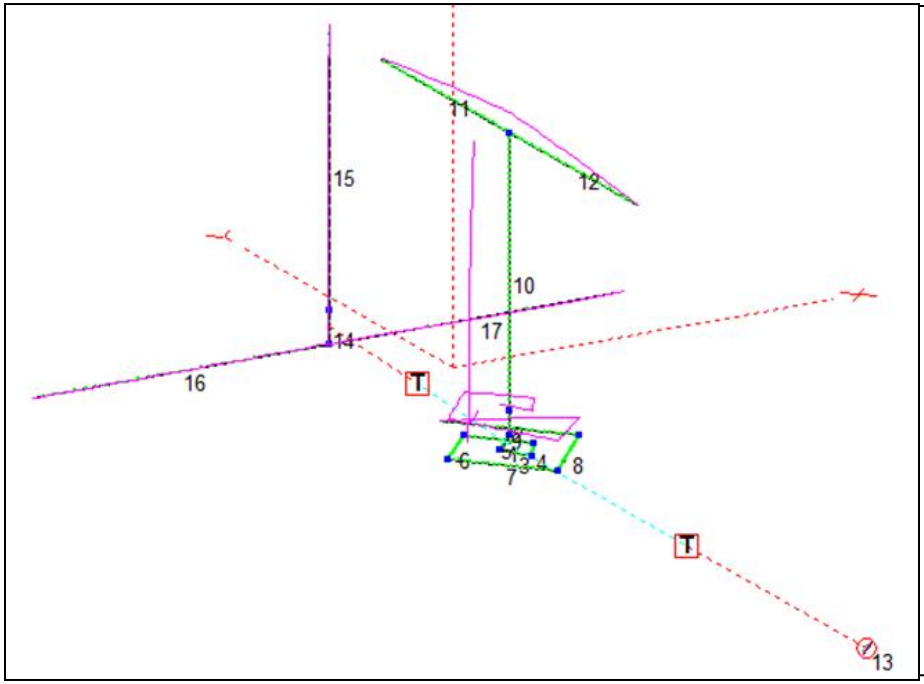


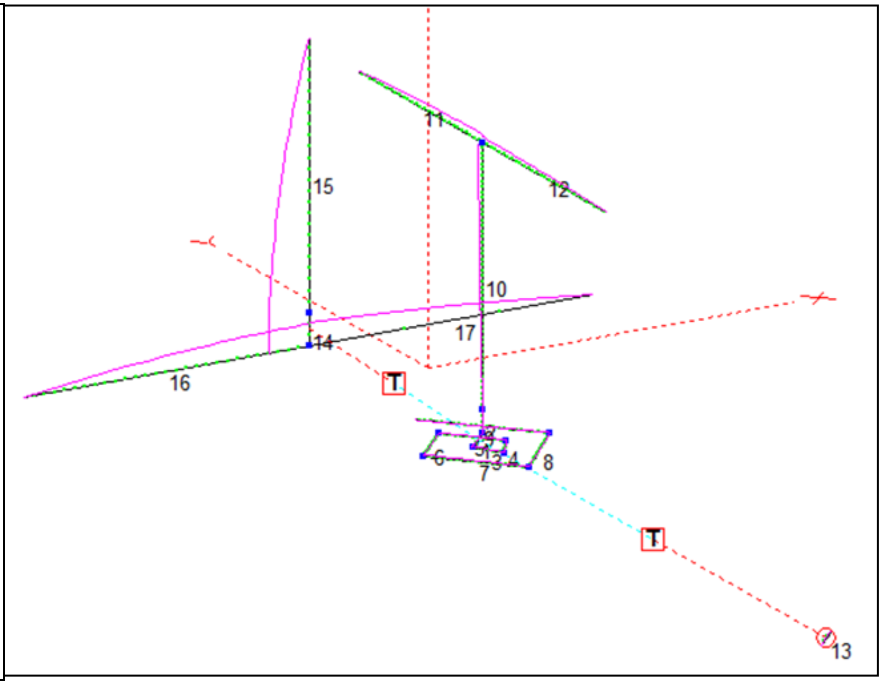
1.67 dBi @ 5˚

When connected

Building It: Modeling the two GPs when connected

@ 10m   Antenna Current   @ 6m

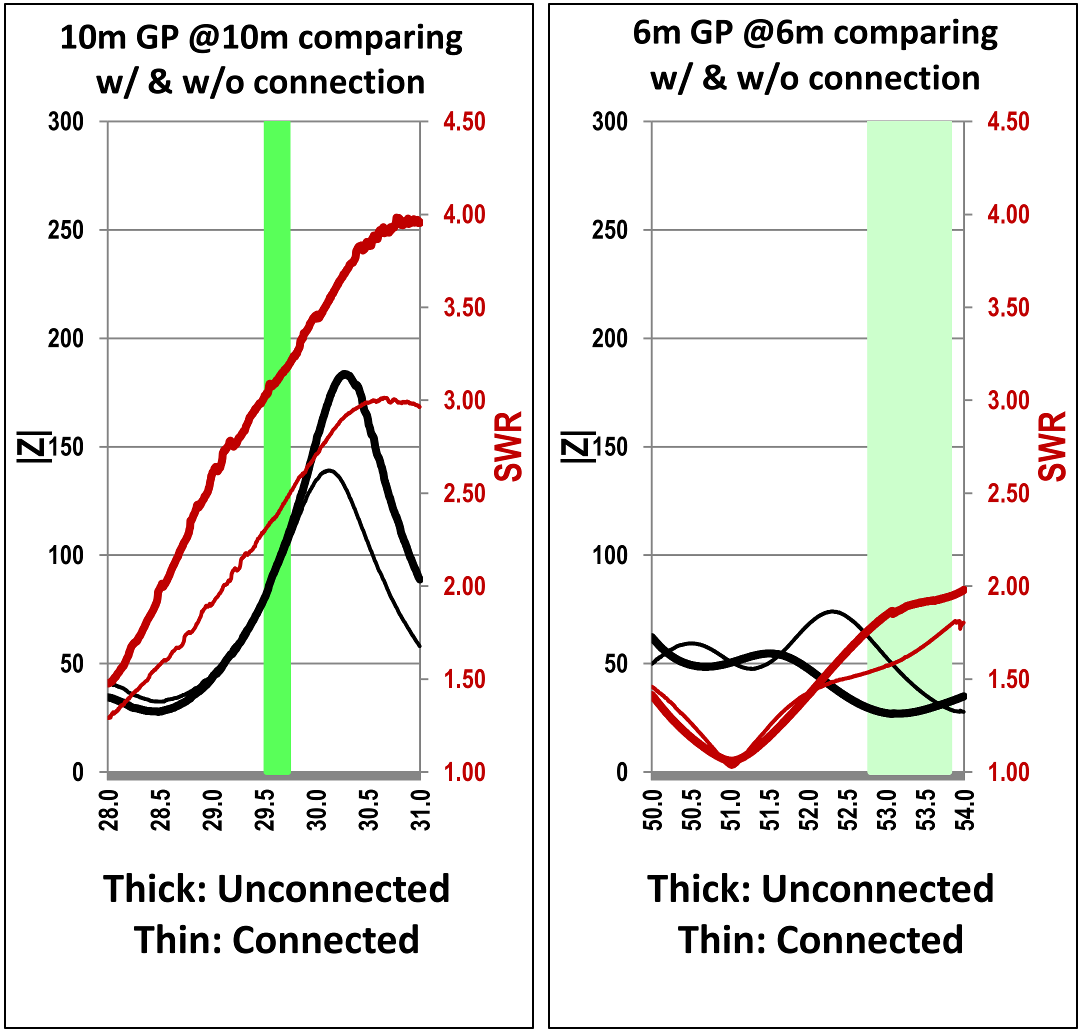




Building It

- The 10m Vertical
- Matching with the 6m GP
- **Results**

BUILDING IT: REAL DATA: RESULTS



RESULTS *"There's no meters like 10 meters"*

First station activated – and heard faintly: *DB0PM – Housham Germany*

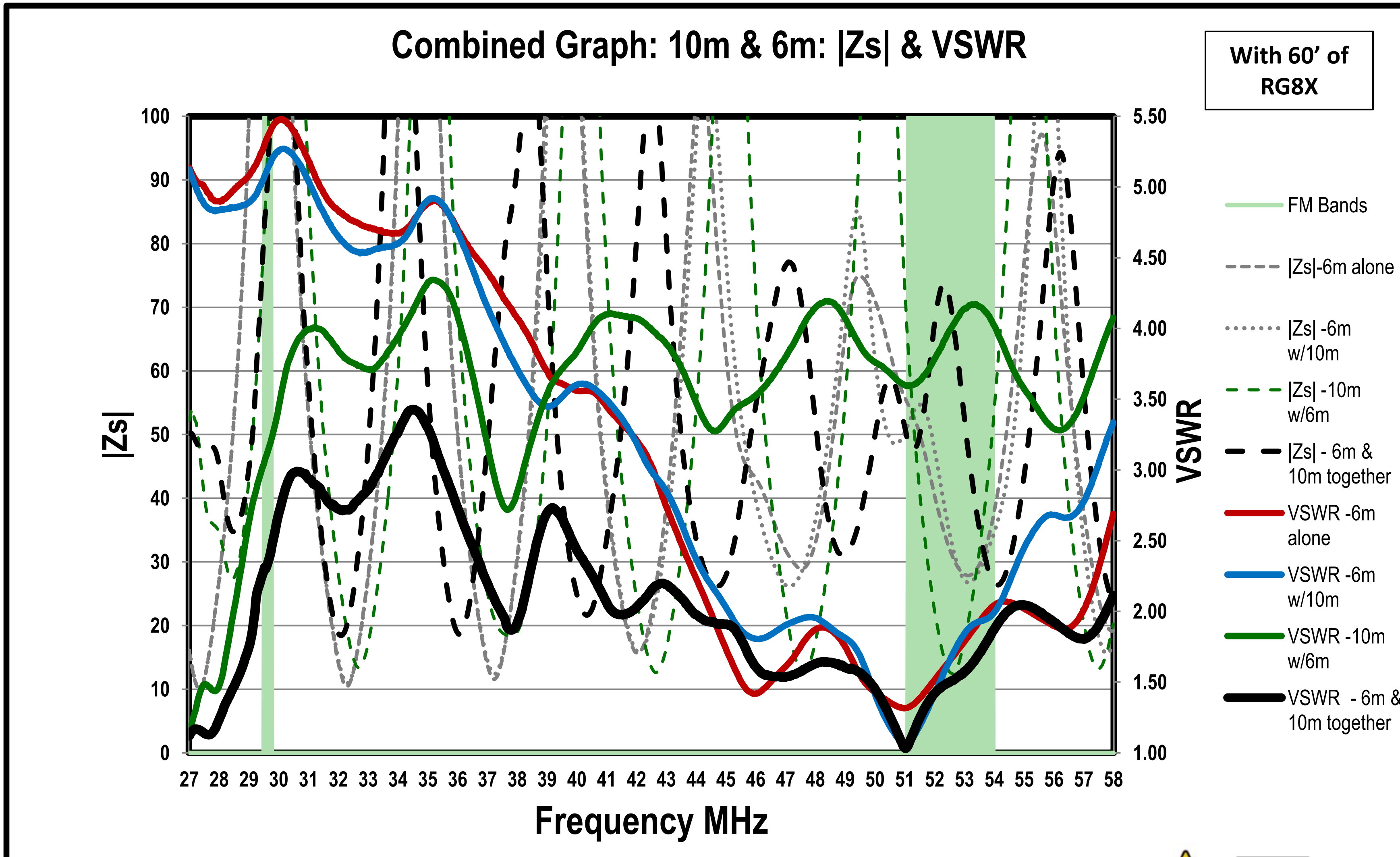
Date	Time (local)	SFI*	Freq	PL	Station	Location
13 Oct 22	8:00	141	29.58/68	131.8	DB0PM	Housham, Germany
10 Jan 23	11:21	191	29.56/66	na	W5DFW	Richardson TX
12 Dec 23	16:10	126	29.58/68	100	WA5AIR	Houston TX

*** Solar Flux Index: a better index than sunspots**
More or less: SFI > 150 is good
More or less: SSN ~ SFI * 0.75

Thank You

Appendix

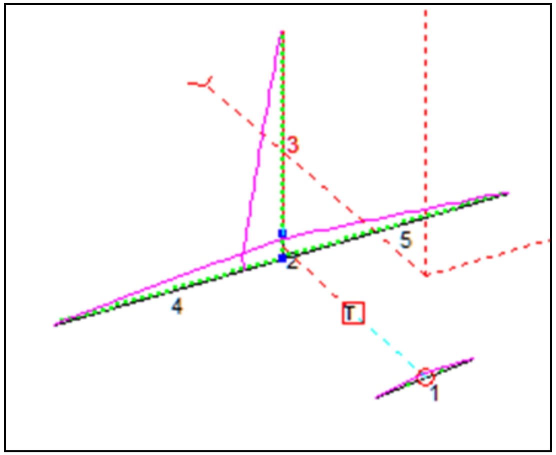
BUILDING IT: REAL DATA: RESULTS 27 – 54 MHz SCAN

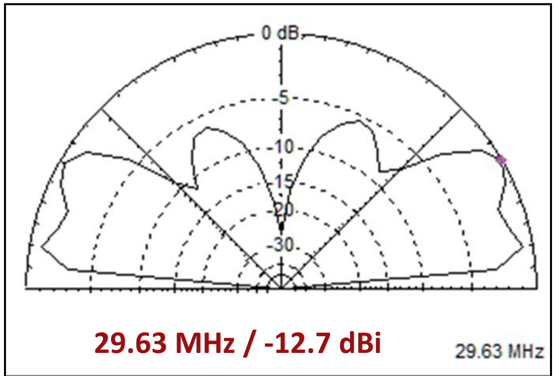


INDEXA

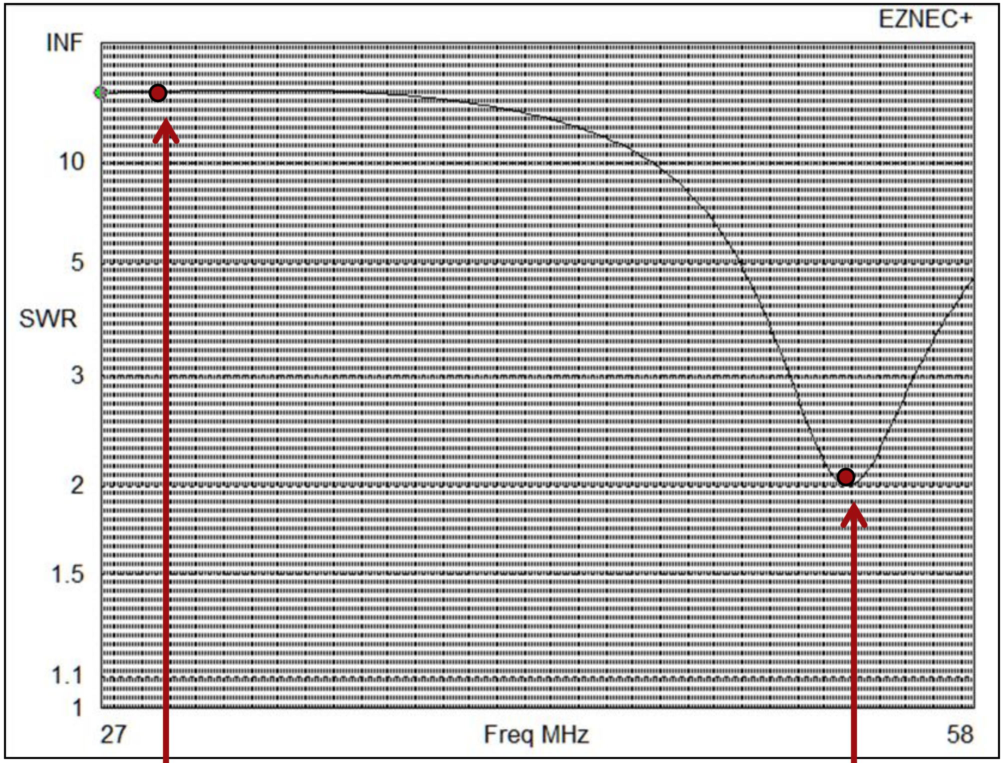
CHECK – MODEL 6M FROM 10M POSITION

With 16' of RG8X





Elevation Plot		Cursor Elev	30.0 deg.
Azimuth Angle	355.0 deg.	Gain	-12.74 dBi
Outer Ring	-12.74 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	-12.74 dBi		
Slice Max Gain	-12.74 dBi @ Elev Angle = 30.0 deg.		
Beamwidth	34.3 deg.; -3dB @ 5.0, 39.3 deg.		
Sidelobe Gain	-13.03 dBi @ Elev Angle = 150.0 deg.		
Front/Sidelobe	0.29 dB		



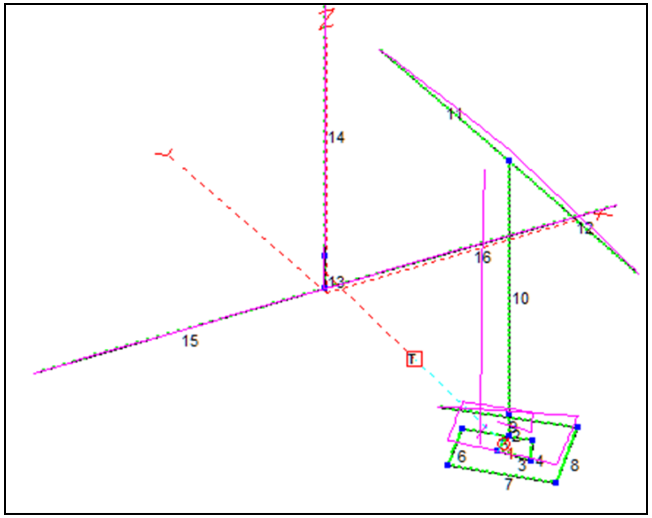
29.3 MHz
SWR: 26.4:1
Z: 777 +j 648

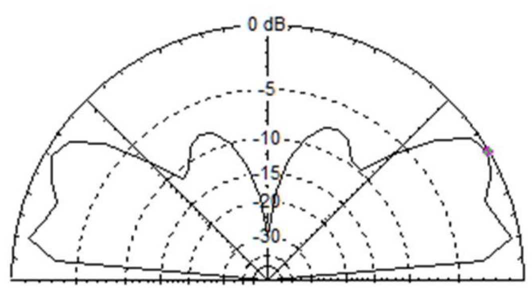
53.5 MHz
SWR: 2.01:1
Z: 37.3 –j 27.9

INDEXA

Check – Model Both from 10m Position

With 16' of RG8X

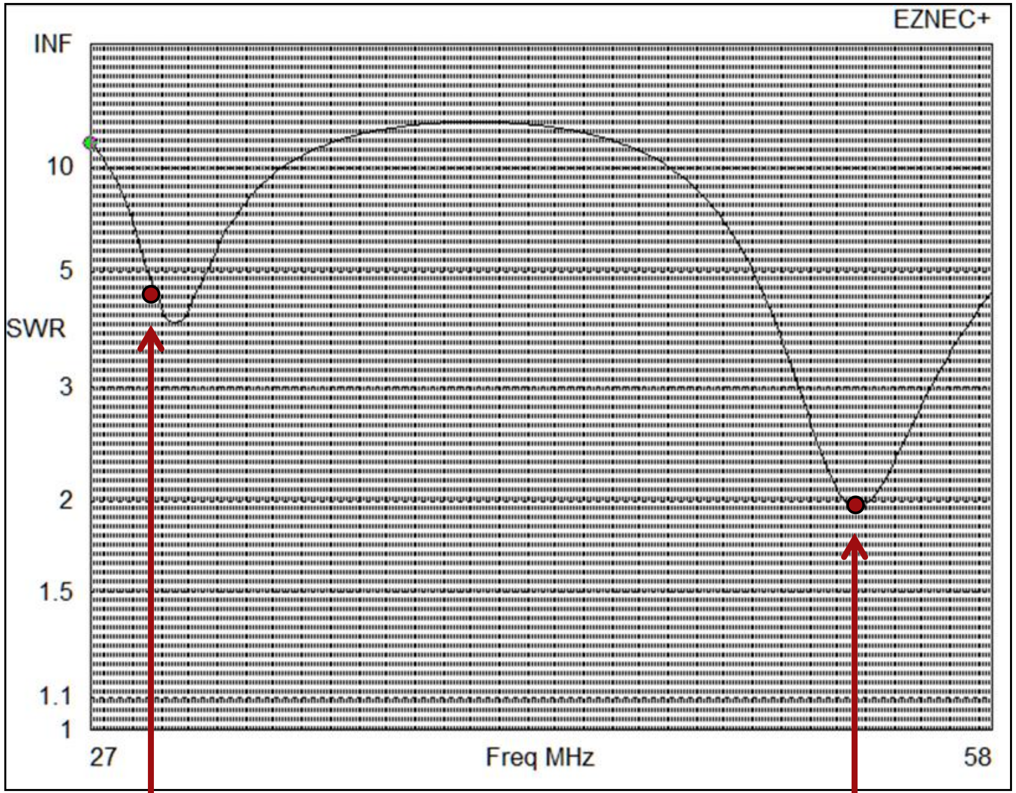




29.63 MHz / 3.01dBi

29.63 MHz

Elevation Plot		Cursor Elev	30.0 deg.
Azimuth Angle	80.0 deg.	Gain	3.01 dBi
Outer Ring	3.01 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	3.01 dBi		
Slice Max Gain	3.01 dBi @ Elev Angle = 30.0 deg.		
Beamwidth	35.6 deg.; -3dB @ 5.0, 40.6 deg.		
Sidelobe Gain	2.55 dBi @ Elev Angle = 150.0 deg.		
Front/Sidelobe	0.46 dB		



29.3 MHz
SWR: 4.42:1
Z: 12.2 -j 13.9

53.5 MHz
SWR: 1.96:1
Z: 34.9 –j 24.4

ABSTRACT

A 10m FM Antenna to fit into my Attic

In my role as the MMRA TIaOS Net Manager, I should be able to monitor all of our repeaters. I didn't have 10m FM capability.

I have a homebrew 6m FM ground plane in my attic to monitor the MMRA 6m repeater. I decided to put a 10m FM antenna in my attic without adding another coax run. The attic height is ~5' and a 10m ground plane is at least 8' tall with ~16' diameter radials, so I had to shorten both the height and the length of the radials.

And how do I feed it in parallel with the 6m GP? This gave me an opportunity to learn about using coax as a matching network. This is the story.