Antenna Modeling

Based on ARRL Antenna Book SW

Part I: EZNEC
Part II: TLW, YW, HFTA

Much cheaper (and faster) than (re)building them!

Larry Banks, W1DYJ
First licensed: 1962 (KN1VFX)
W1DYJ since 1966 – Amateur Extra
33 Blueberry Hill Road Woburn MA

"All models are wrong. Some are useful"
British Statistician *George Box*, 1976

https://www.qsl.net/w1dyj/

W1DYJ ~ Larry Banks

Abstract: Antenna Modeling: TLW, YW, HFTA

This presentation will start with some history detailing why Larry has always been interested in understanding antennas. It will then first go over the use of EZNEC, and then three applications: TLW, YW, and HFTA, from the ARRL Antenna Book. It will hopefully help you get a start at modeling your own antenna systems.

Larry was licensed in 1962 as novice KN1VFX and became W1DYJ in 1966. He was an engineer and manager for Hewlett-Packard Medical from 1969 to 1993. Moving to HP Education in 1993, he was responsible for technical and project management training. When Agilent split out of HP in 1999 he became Agilent Technology's global program manager for their Learning Management System. He "retired" in 2005 and then consulted for Avago Technologies (now Broadcom) on eLearning technologies through 2012.

Larry holds three degrees in EE from MIT. He holds 8BDXCC and 8BWAS, spending his time chasing DX and contesting in Woburn MA, traveling with his wife Maren, and attending as many jazz and classical concerts as they can. He is also the net manager and newsletter editor for the Minuteman Repeater Association, publications editor for HamXposition, and a member of the Yankee Clipper Contest Club.

Antenna Modeling ~ Agenda

- Why I became interested in antennas
- Part I
  - EZNEC
- Part II
  - TLW
  - YW
  - HFTA
- Appendix

The Goal:
You will learn some theory and gain some understanding about antennas.

An antenna story ~ the Gotham V80 (1962)

- New novice KN1VFX
- *I knew nothing about antennas*
- I built a HB 80m 807 CW [XTL] transmitter
- I fed my end-fed random wire out of my 2nd floor bedroom window [SWL]
- It didn't work

A 1962 QST Advertisement

- My first "real" antenna for 80M
- $16.95 was "big bucks" for a sophomore in HS in 1962 [~$130 today]

A beautiful example of *MARKETING!*

IS K6INI THE WORLD'S CHAMPION DX OPERATOR?

Judge for yourself! Read his letter and count the DX he has worked—with only 65 watts and a $16.95 Gotham V-80 Vertical Antenna.

2405 Bowditch, Berkeley 4, California
January 31, 1959

GOTHAM
1805 Purdy Avenue
Miami Beach 39, Florida

Gentlemen:

I just thought I would drop you a line and let you know how pleased I am with your V-80 vertical antenna. I have been using it for almost two years now, and am positively amazed at its performance with my QRP 65 watts input! Let me show you what I mean:

I have worked over 100 countries and have received very fine reports from many DX stations, including 599 reports from every continent except Europe (589)! I have also worked enough stations for my WAC, WAS, WAJAD and ADXC awards, and I am in the process of working for several other awards. And all this with your GOTHAM V-80 vertical antenna!

Frankly, I fail to see how anyone could ask for better performance with such low power, limited space and a limited budget. In my opinion, the V-80 beats them all in its class.

I am enclosing a list of DX countries I have worked to give you an idea of what I have been talking about.

Wishing you the best for 1959, I am

Sincerely yours,
Thomas G. Gabbert, K6INI (Ex-TI2TG)

List of 105 countries/stations worked with 65 watts and a V-80 vertical

BV1US	KG4AI	VK3YL
CE3DZ	KG6FAE	VK9XK
ZL5AA	KH6IJ	VK9AT
CO2WD	KL7BUZ	VKØCJ
CN2BK	KM6AX	VP2KFA
CN8FB	KP4ACF	VP2AY
CR9AH	KP6AL	VP2DW
CT1CB	KR6BF	VP2MX
CX2FD	KS4AZ	VP2LU
DL1FF	KV4AA	VP2SW
DU7SV	KW6CA	VP5CP
EA1FD	KX6AF	VP5BH
EI4N	KZ5CS	VP6TR
F8VQ	LA3SG	VP7NM
FB8ZZ	LU2DFC	LU1ZS
FG7XE	LZ1KSP	VP9BK
FK8AL	OA4AU	VR2DA
FM7WT	OE9EJ	VR3B
FO8AD	OH2TM	VS1HC
G3DOG	OK1FF	VS2DW
GC8DO	ON4AY	VS6LN
GI3WUI	KG1AX	XE1PJ
GM3GJB	OZ2KK	XW8AI
GW3LJN	PAØFAB	YN1JW
HA5KBP	PJ5AA	YU3FS
HC4IM	PJ2ME	YV5HL
HC8LUX	PY2EW	ZC5AL
HE9LAC	PYØNE	ZE1JV
HP1LO	SM5AQB	ZK1BS
I1MV	SP6BY	KH6MG/ZK1
JA1ANG	TI2LA	ZK2AD
JZØHA	UA1AU	ZL1ABZ
W1AW	UAØKKB	ZL3JA
KB6BJ	UQ2AB	ZM6AS
KC4AF	VE8OJ	ZS1OU

FACTS ON THE GOTHAM V-80 VERTICAL

- If K6INI can do it, so can you.
- Absolutely no guying needed.
- Radials not required.
- Only a few square inches of space needed.
- Four metal mounting straps furnished.
- Special B & W loading coil furnished.
- Every vertical is complete, ready for use.
- Mount it at any convenient height.
- No relays, traps, or gadgets used.
- Accepted design—in use for many years.
- Many thousands in use the world over.
- Simple assembly, quick installation.
- Withstands 75 mph wind-storms.
- Non-corrosive aluminum used exclusively.
- Omnidirectional radiation.
- Multi-band, V80 works 80, 40, 20, 15, 10, 6.
- Ideal for novices, but will handle a Kw.
- Will work with any receiver and xmitter.
- Overall height 23 feet.
- An effective modern antenna, with amazing performance. Your best bet for a lifetime antenna at an economical price.

73
GOTHAM

An antenna story ~ the Gotham V80

Radials not required

- I never worked anyone – Best DX was a 40M OO report: "Out of Band"
- As a result, I never really learned CW
- I have not believed advertisements since!
- I also learned that *you need to understand the physics* of antennas

→→→ Modeling (1993)

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CX2FD	KS4AZ	VP2LU
DL1FF	KV4AA	VP2SW
DU7SV	KW6CA	VP5CP
EA1FD	KX6AF	VP5BH
EI4N	KZ5CS	VP6TR
F8VQ	LA3SG	VP7NM
FB8ZZ	LU2DFC	LU1ZS
FG7XE	LZ1KSP	VP9BK
FK8AL	OA4AU	VR2DA
FM7WT	OE9EJ	VR3B
FO8AD	OH2TM	VS1HC
G3DOG	OK1FF	VS2DW
GC8DO	ON4AY	VS6LN
GI3WUI	KG1AX	XE1PJ
GM3GJB	OZ2KK	XW8AI
GW3LJN	PAØFAB	YN1JW
HA5KBP	PJ5AA	YU3FS
HC4IM	PJ2ME	YV5HL
HC8LUX	PY2EW	ZC5AL
HE9LAC	PYØNE	ZE1JV
HP1LO	SM5AQB	ZK1BS
I1MV	SP6BY	KH6MG/ZK1
JA1ANG	TI2LA	ZK2AD
JZØHA	UA1AU	ZL1ABZ
W1AW	UAØKKB	ZL3JA
KB6BJ	UQ2AB	ZM6AS
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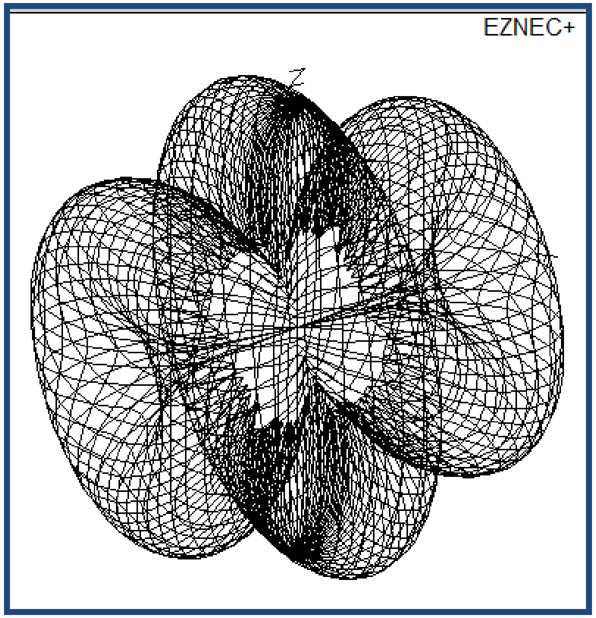
ARRL

International DX Association INDEXA

Antenna Modeling ~ Agenda



Part I

EZNEC

Basic Purpose: from an X-Y-Z "wires" description of an antenna, generate tabular and graphical outputs of SWR, far field response, RF antenna currents, etc.

EZNEC Agenda

- **NEC *Numerical Electromagnetics Code***
- **Modeling Software using NEC**
- **EZNEC**
  - **Inputs & Outputs (Simple 40M dipole)**
  - **Ground Characteristics**
  - **Example (40M Vertical)**

NEC: Numerical Electromagnetics Code

Uses a ***Method of Moments*** algorithm *(fields from many mutually-coupled straight-line segments are evaluated and vector-summed)*

- **NEC-2** (1980) – available to the public and free
- **NEC-4** (1992) **v4.2** (2011)
  - Requires license: $300+ from Lawrence Livermore Labs
  - Fixes stepped wires; wire junction; ground issues, etc.
- **NEC-5 x13** (2022)
  - Requires license: $110+ from Lawrence Livermore Labs
  - Allows buried conductors

Modeling Software using NEC

EZNEC — W7EL's (Roy Lewallen) >> now free

MultiNec >> AutoEZ (AC6LA) $79 (automates EZNEC)

NEC-Win Plus/Pro >> no longer available?

MMANA (free?)

4nec2 (free)

MiniNEC $29

Modeling Software >> EZNEC

EZNEC 6 W7EL's (Roy Lewallen) website: http://eznec.com

	• EZNEC v.6.0 Demo Version	**(20 segments)**	free	NEC-2
	• EZNEC v.6.0	**(500 segments)**	$ 99	NEC-2
The one I use:	• **EZNEC+ v. 6.0**	**(2K segments + more features)**	$149	NEC-2
	• EZNEC Pro/2 v.6.0	**(45K segments + more features)**	$525	NEC-2
	• EZNEC Pro/4 v.6.0	**(+ requires NEC-4 license)**	$625	NEC-4

Before 2022

NOW (W7EL has retired – there is no "official" support)

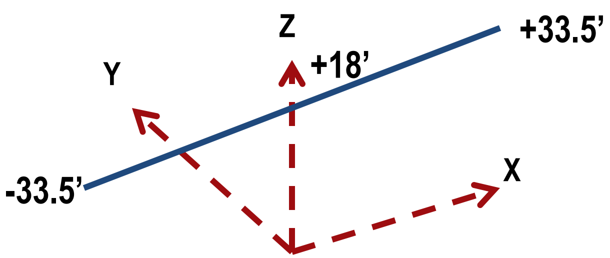
...lots of "YouTube's" and a groups.io group

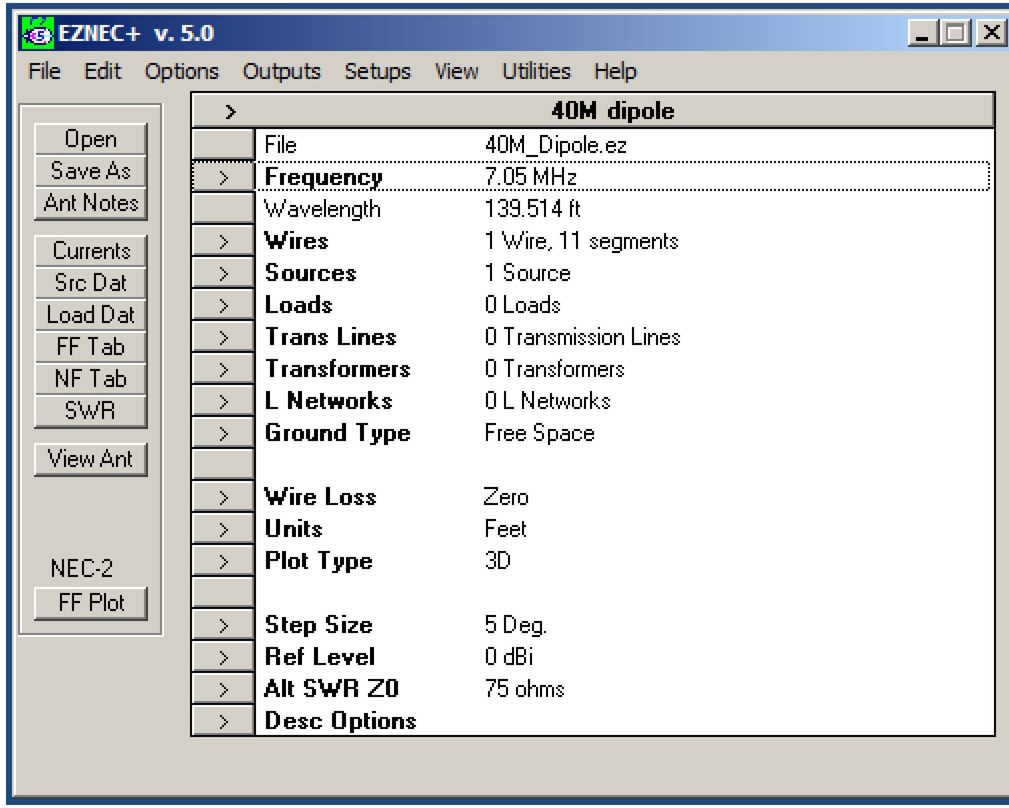
- **EZNEC Pro/2+ v7.0 FREE NEC-2 / 5 x13**
- **EZNEC Pro/4+ Free upgrade to Pro/4**

EZNEC Agenda

- **Modeling Software using NEC**
- **NEC *Numerical Electromagnetics Code***
- **EZNEC**
  - **Inputs & Output (Simple 40M dipole)**
  - Ground Characteristics
  - EZNEC Example (40M Vertical)

EZNEC Inputs ~ 40M dipole @ 7.05 MHz.



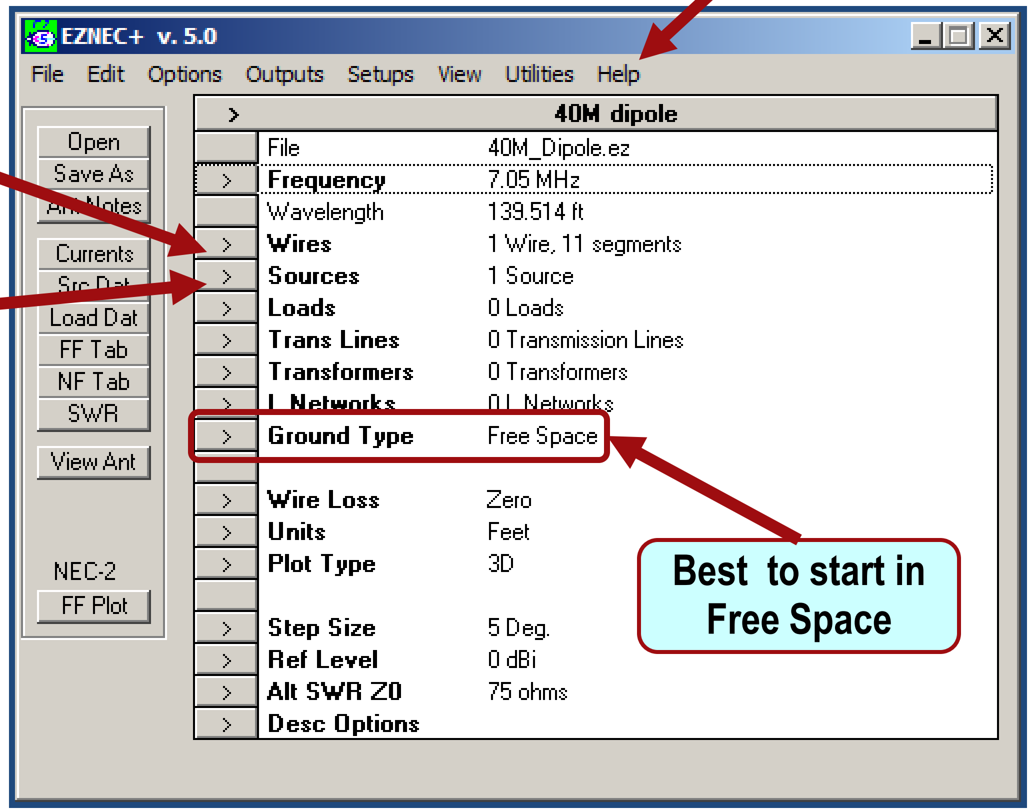


EZNEC Inputs ~ 40M dipole

Extensive HELP

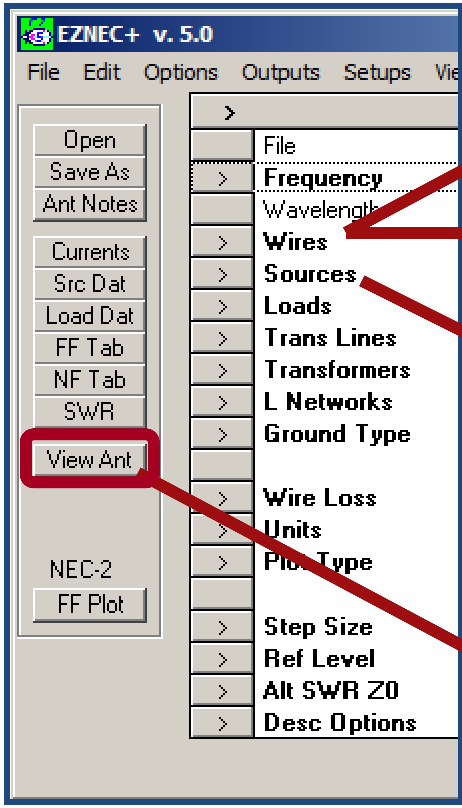
Start by entering the antenna dimensions in Cartesian coordinates

Add a source



Best to start in Free Space

EZNEC Inputs ~ 40M dipole

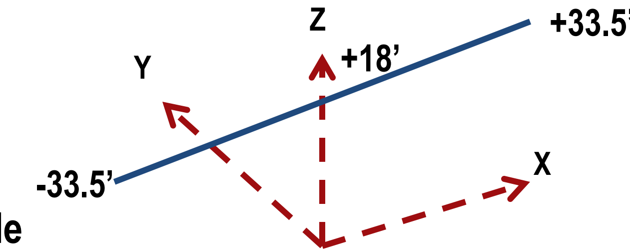


The "usual" equation

➔ L = 468 / F

➔ 468 / 7.05 MHz.

➔ ~66.38 ft ➔ 67 ft ➔ 33.5 ft/side

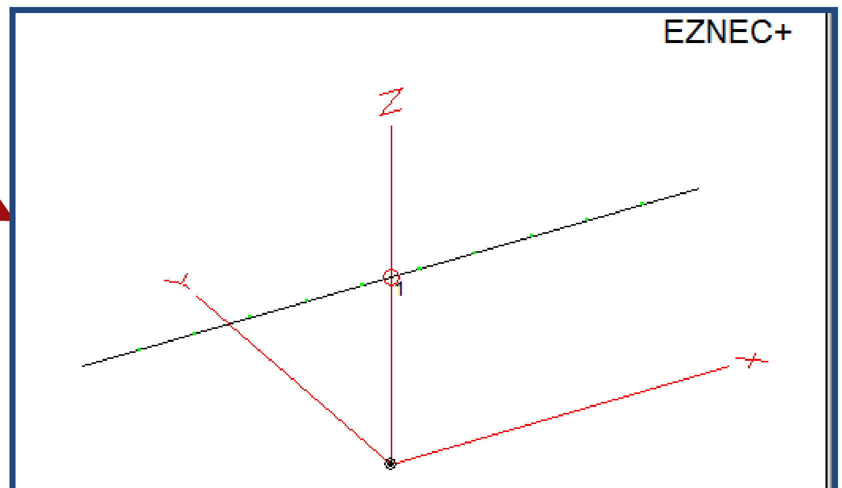


Wires

No.	End 1 X (ft)	End 1 Y (ft)	End 1 Z (ft)	End 1 Conn	End 2 X (ft)	End 2 Y (ft)	End 2 Z (ft)	End 2 Conn	Diameter (in)	Segs
1	-33.5	0	18		33.5	0	18		#12	11

Sources

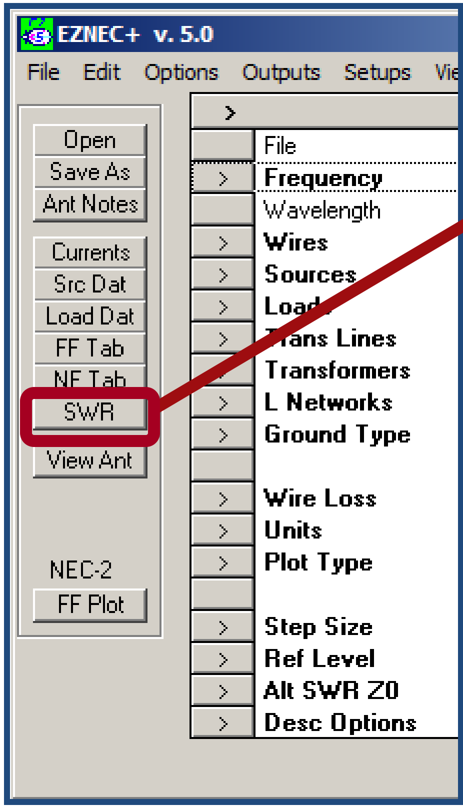
No.	Specified Pos. Wire #	Specified Pos. % From E1	Actual Pos. % From E1	Actual Pos. Seg	Amplitude (V, A)	Phase (deg.)	Type
1	1	50	50	6	1	0	I

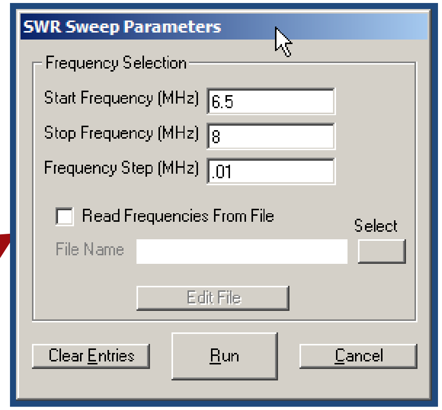


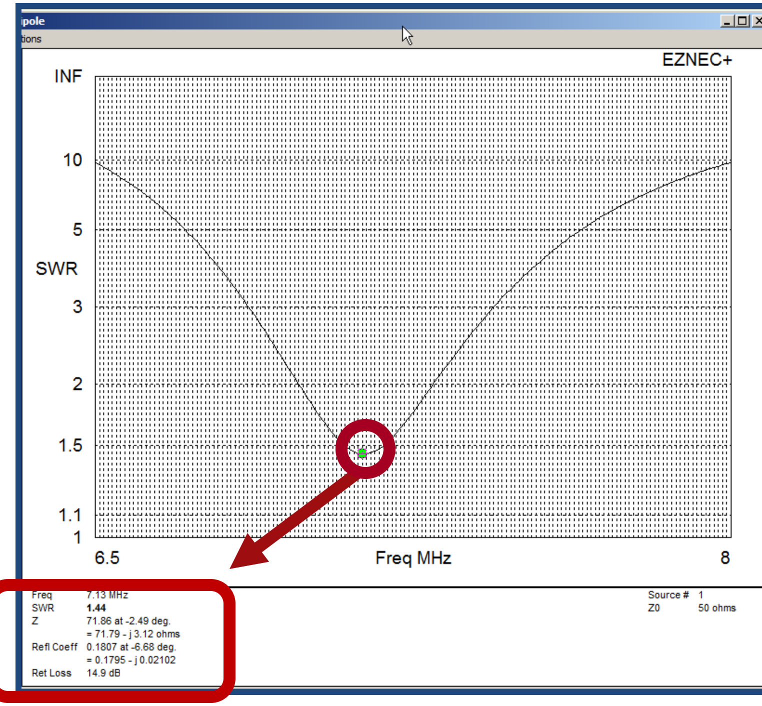
Segments: The number of individual "wires" the dipole consists of >> ODD #

EZNEC Output ~ 40M dipole

Free Space







F = 7.13 MHz

SWR = 1.44:1

Z = 71.79 – j 3.12 Ω

71.79 ohms resistive

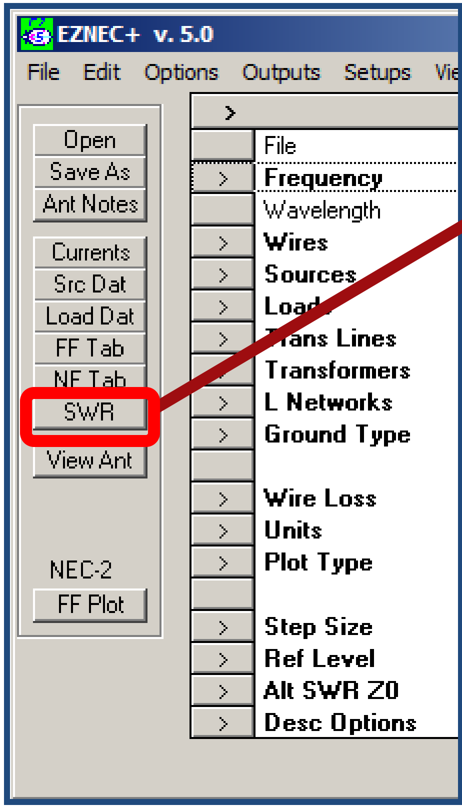
+

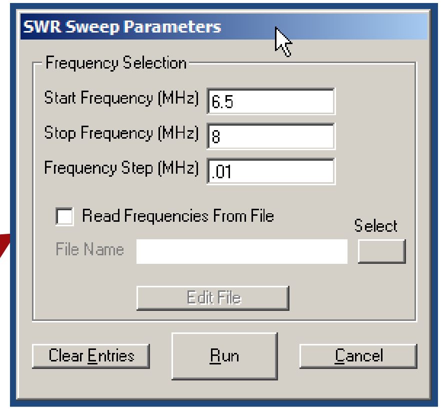
3.12 ohms capacitive

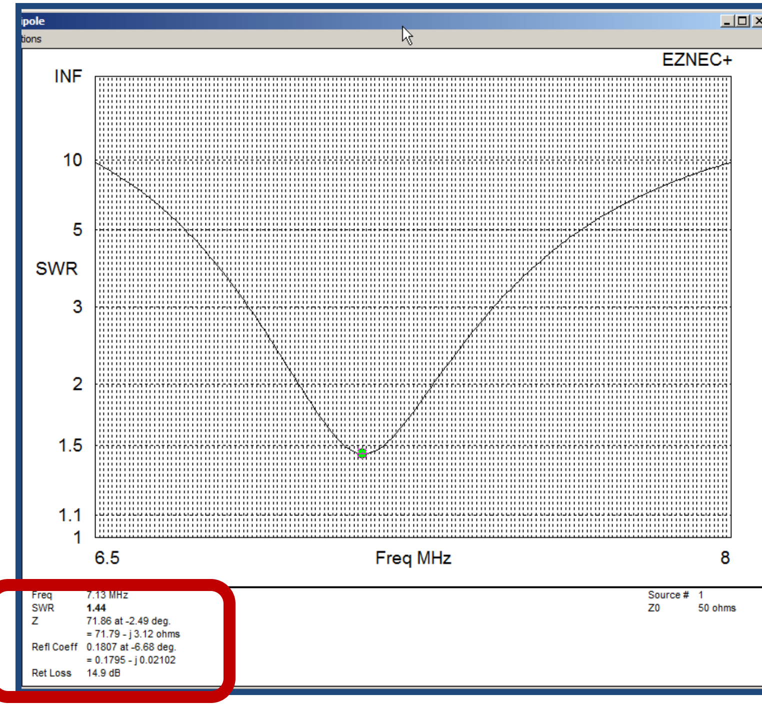
INDEXA

EZNEC Output ~ 40M dipole

Free Space







F = 7.13 MHz
SWR = 1.44:1
Z = 71.79 – j 3.12 Ω

Tweak Length:

F_{OLD} = 7.13 MHz F_{NEW} = 7.05 MHz L_{OLD} = 33.5'

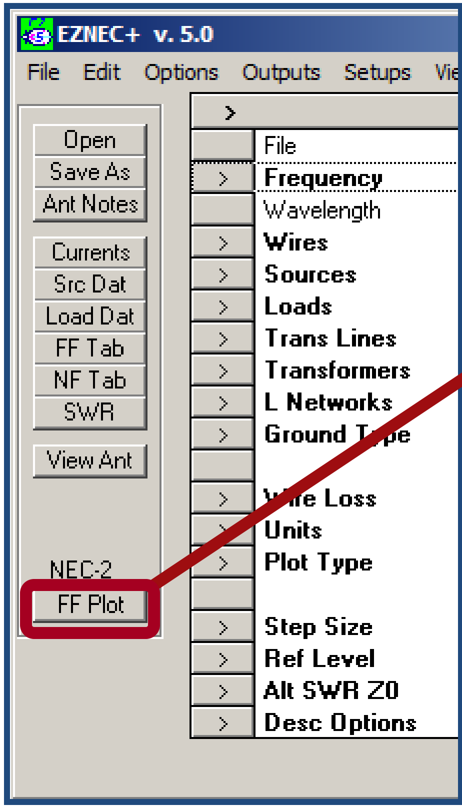
$L_{NEW} * F_{NEW} = L_{OLD} * F_{OLD}$ L_{NEW} * 7.05 = 33.5* 7.13 L_{NEW} = 33.9'

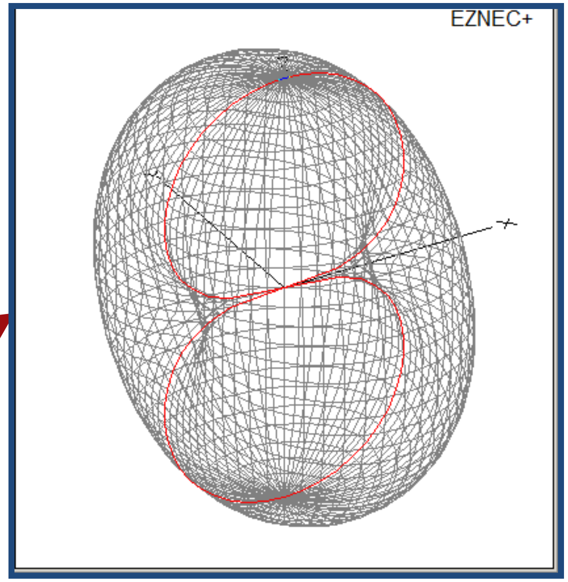
➔ F = 7.05 MHz   SWR = 1.44:1   Z = 71.9 – j 2.243

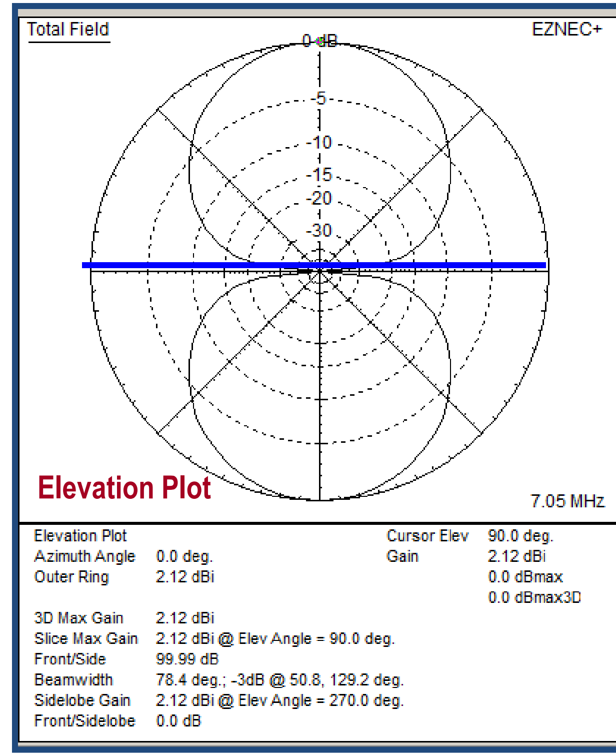
INDEXA

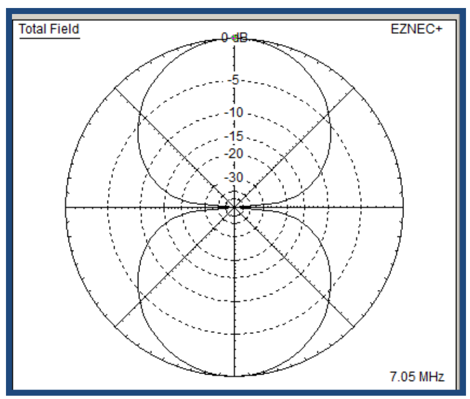
EZNEC Output ~ 40M dipole → 7.05 MHz

Free Space





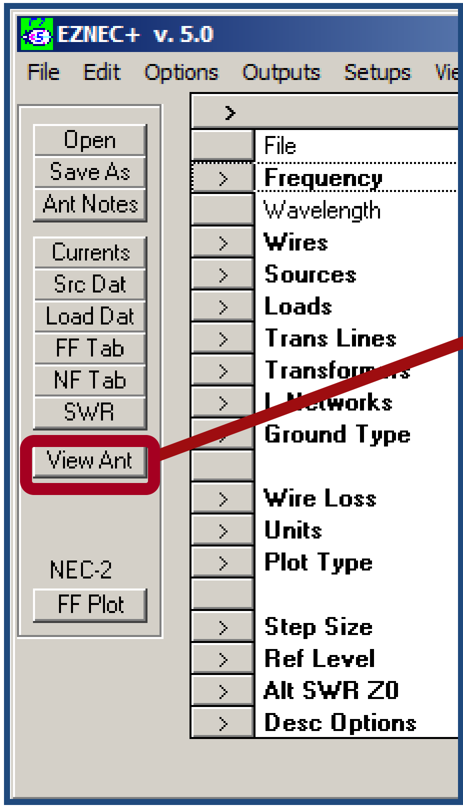


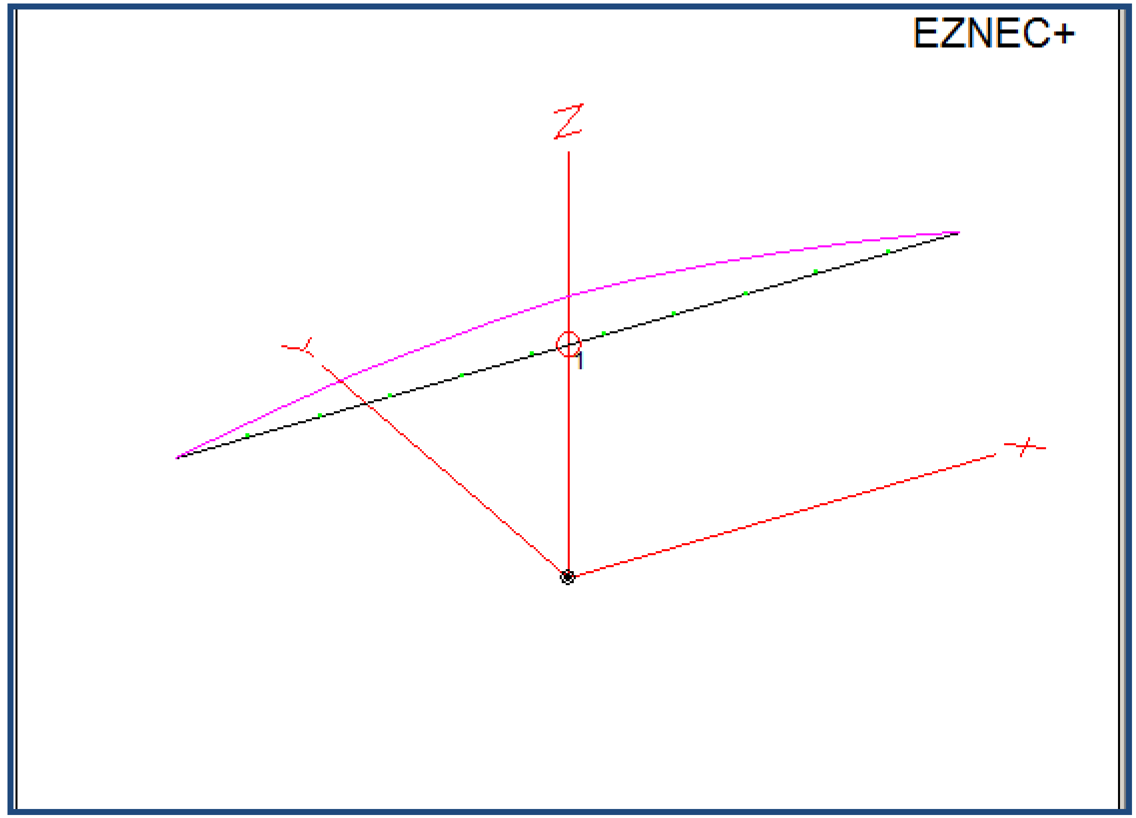


Azimuth Plot

EZNEC Output ~ 40M dipole — RF Current

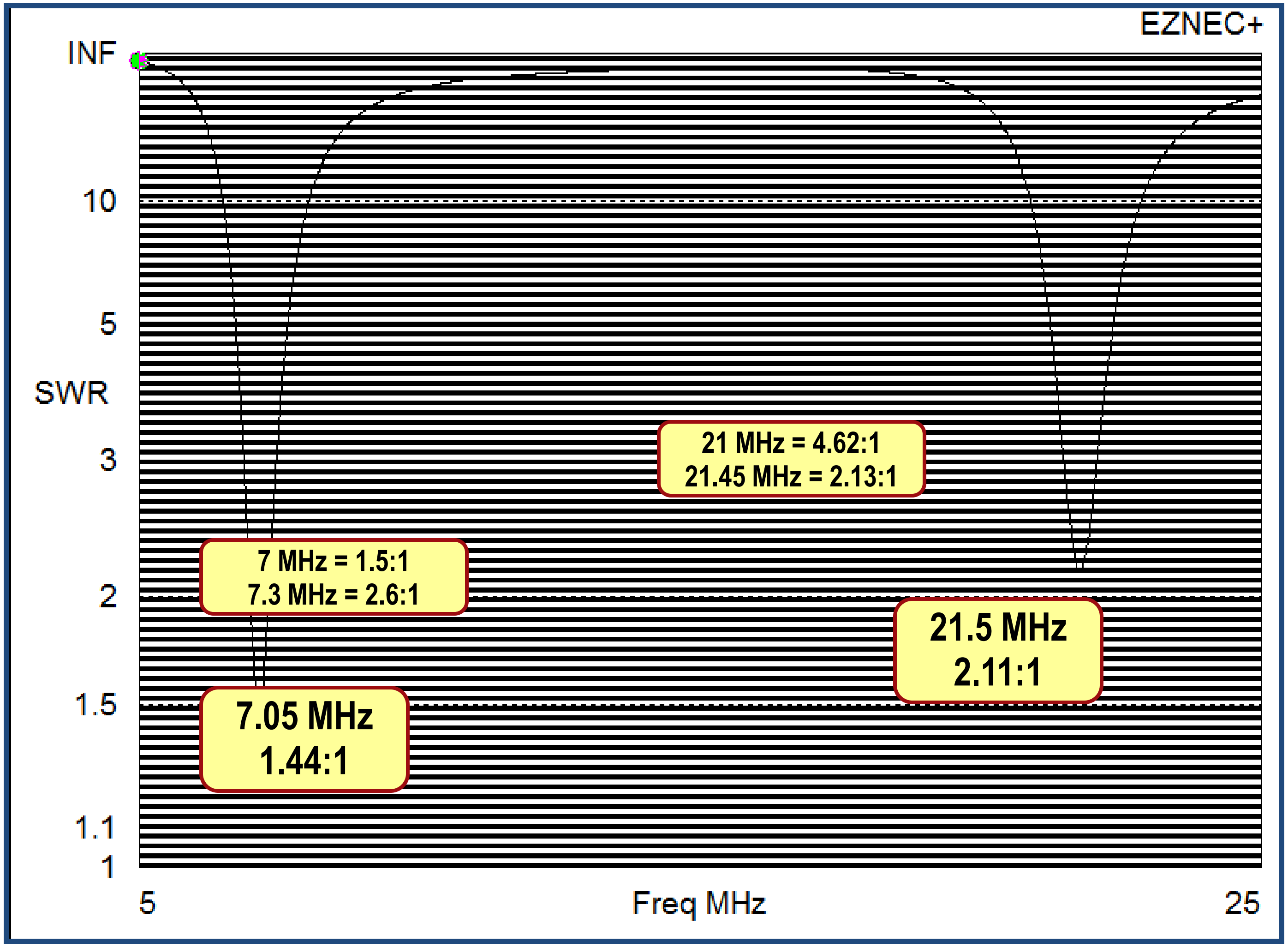
Free Space





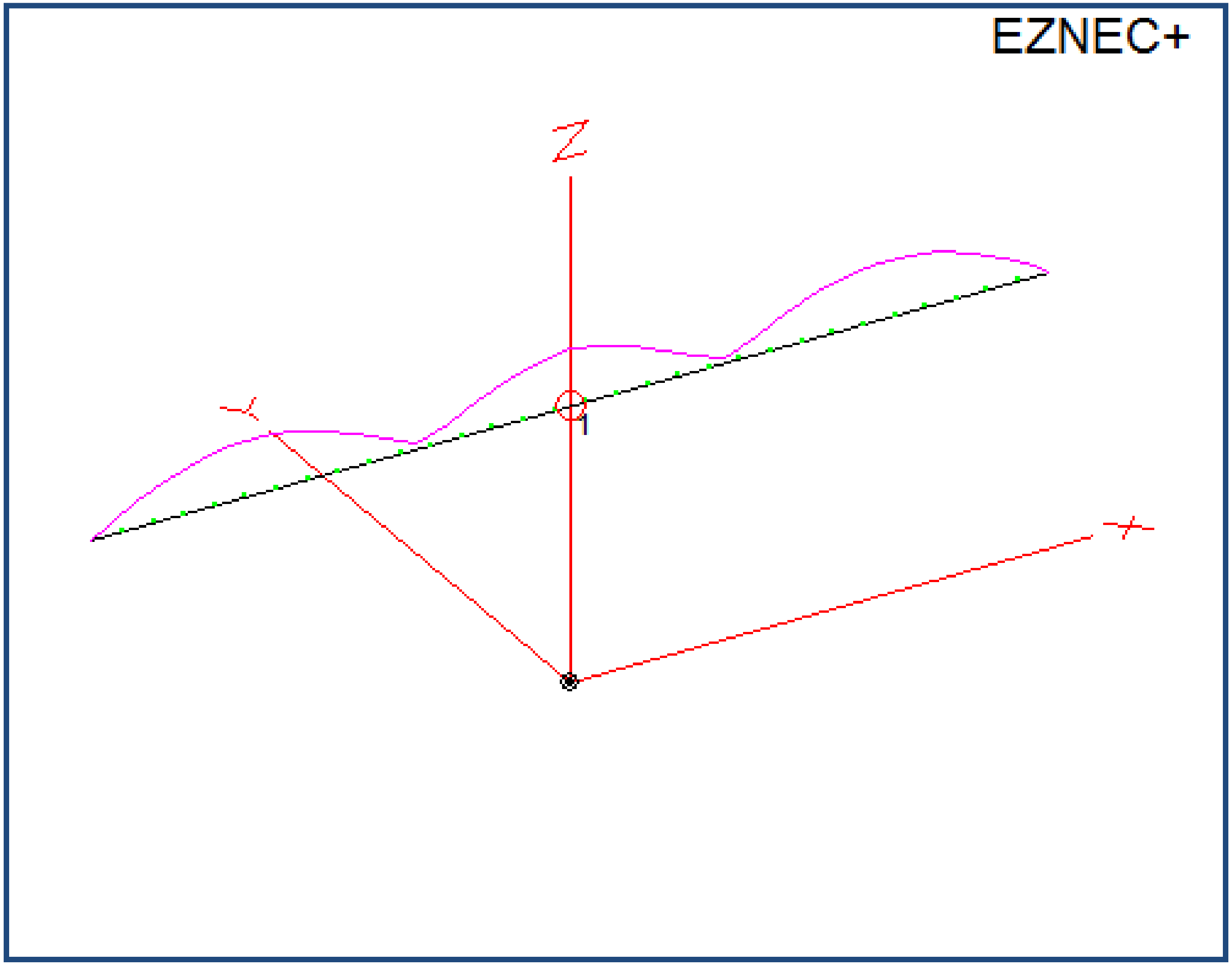
EZNEC Output ~ 40M dipole @ 15M?

Free Space



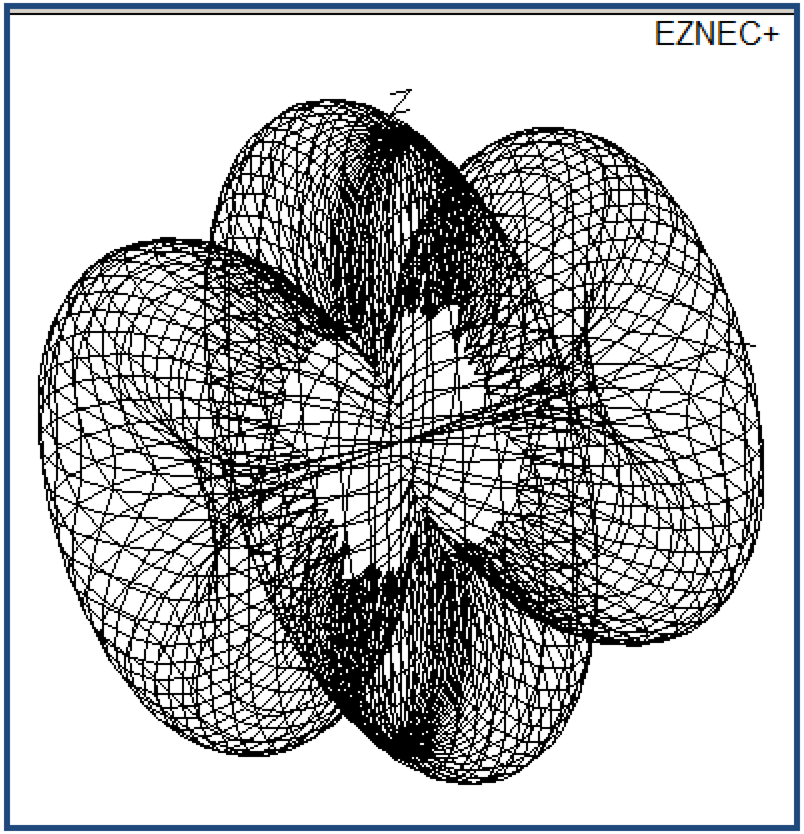
EZNEC Output ~ 40M dipole ➔ 21.1 MHz

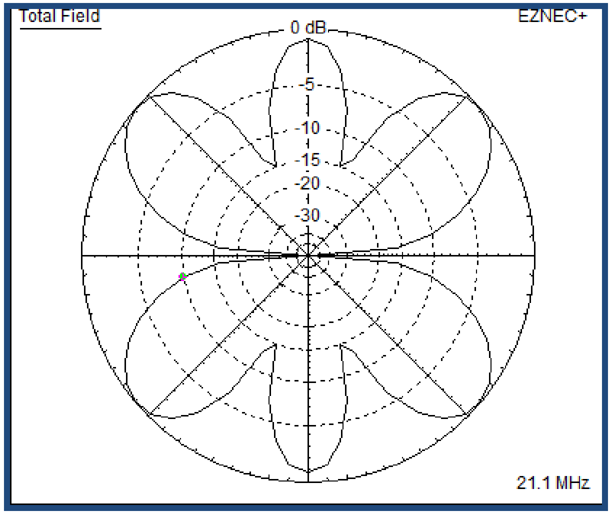
Free Space



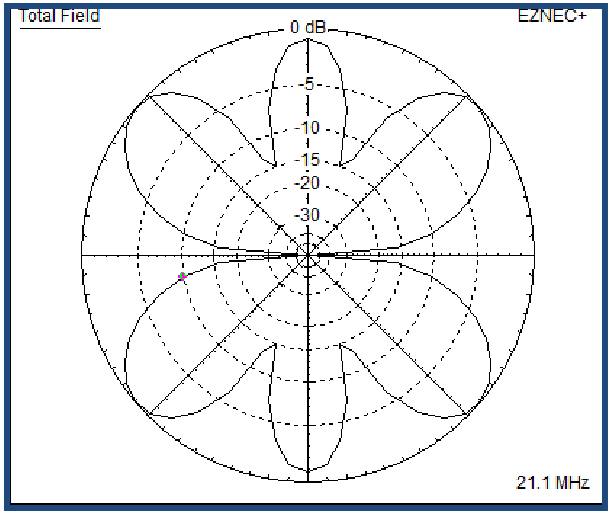
EZNEC Output ~ 40M dipole → 21.1 MHz

Free Space





Elevation Plot



Azimuth Plot

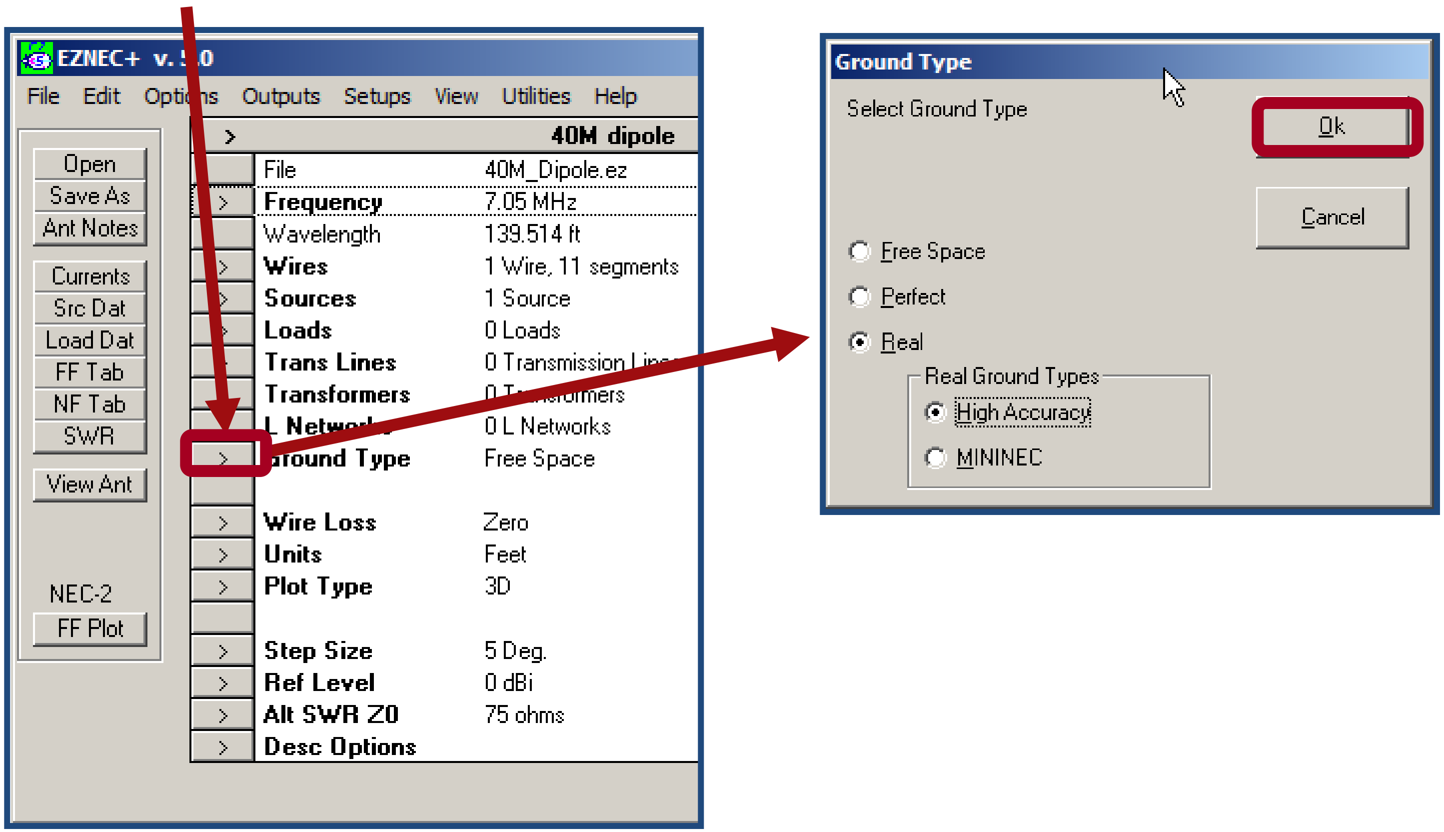
EZNEC Agenda

- Modeling Software using NEC
- NEC *Numerical Electromagnetics Code*
- **EZNEC**
  - Inputs & Output (Simple 40M dipole)
  - **Ground Characteristics**
  - EZNEC Example (40M Vertical)

Ground Characteristics – EZNEC inputs

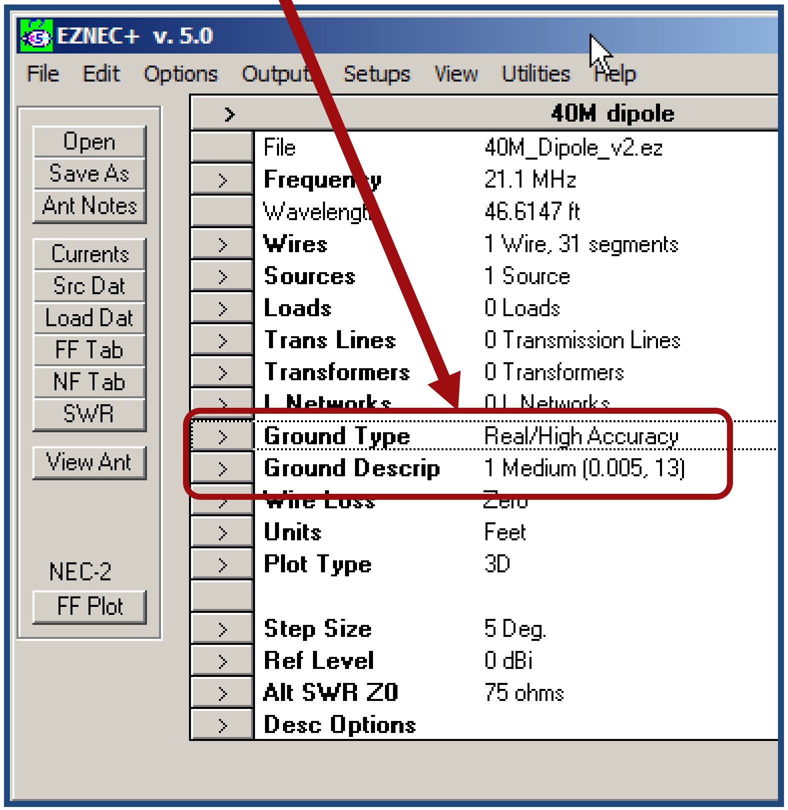
So far, this has been in "Free Space" – which doesn't exist here on earth.

Click on Ground Type



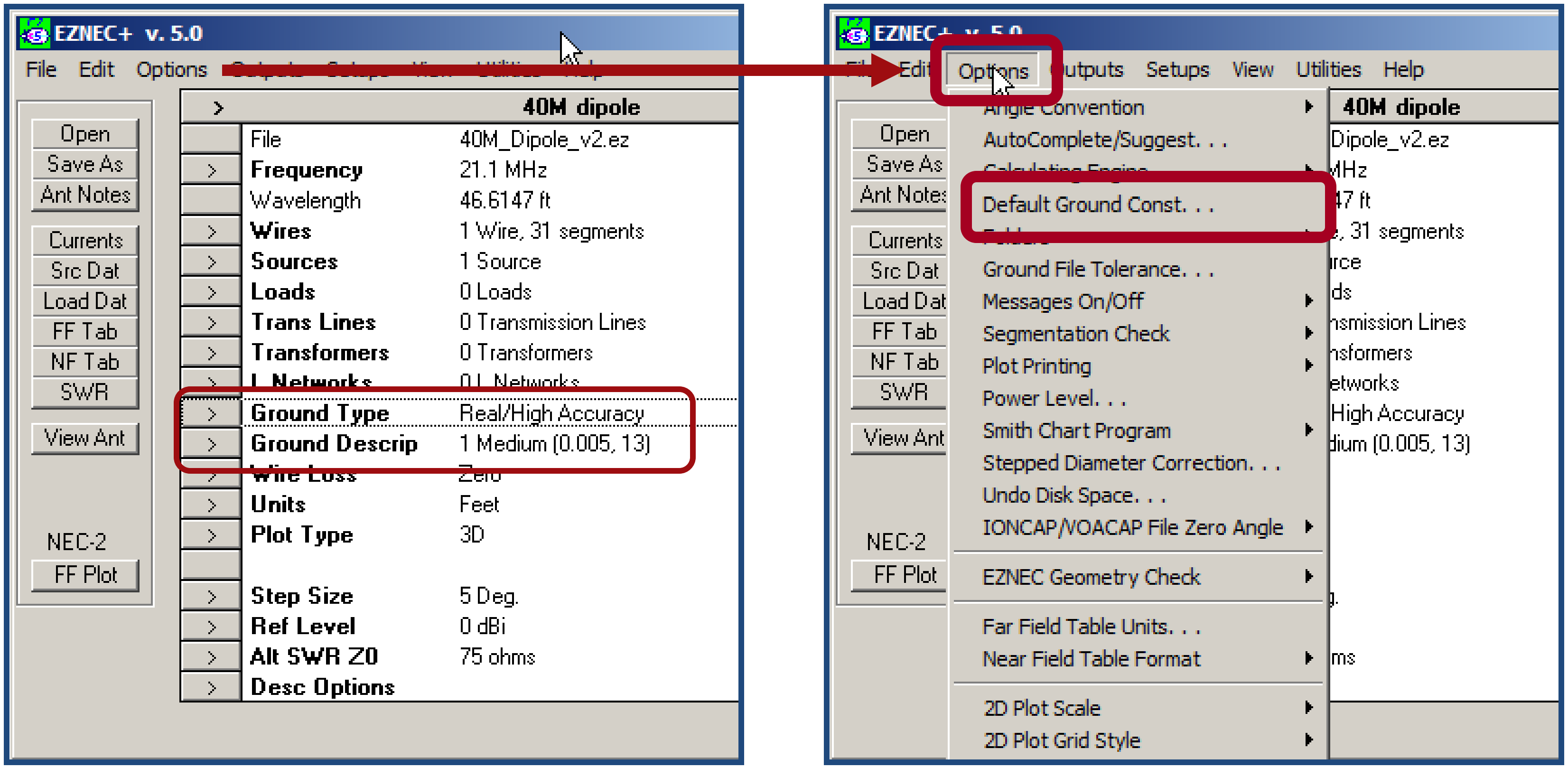
Ground Characteristics – EZNEC inputs

Choices change…



Ground Characteristics – EZNEC inputs

Choices change… Click on *Options* ➔ *Default Ground Construction*



Ground Characteristics – EZNEC inputs

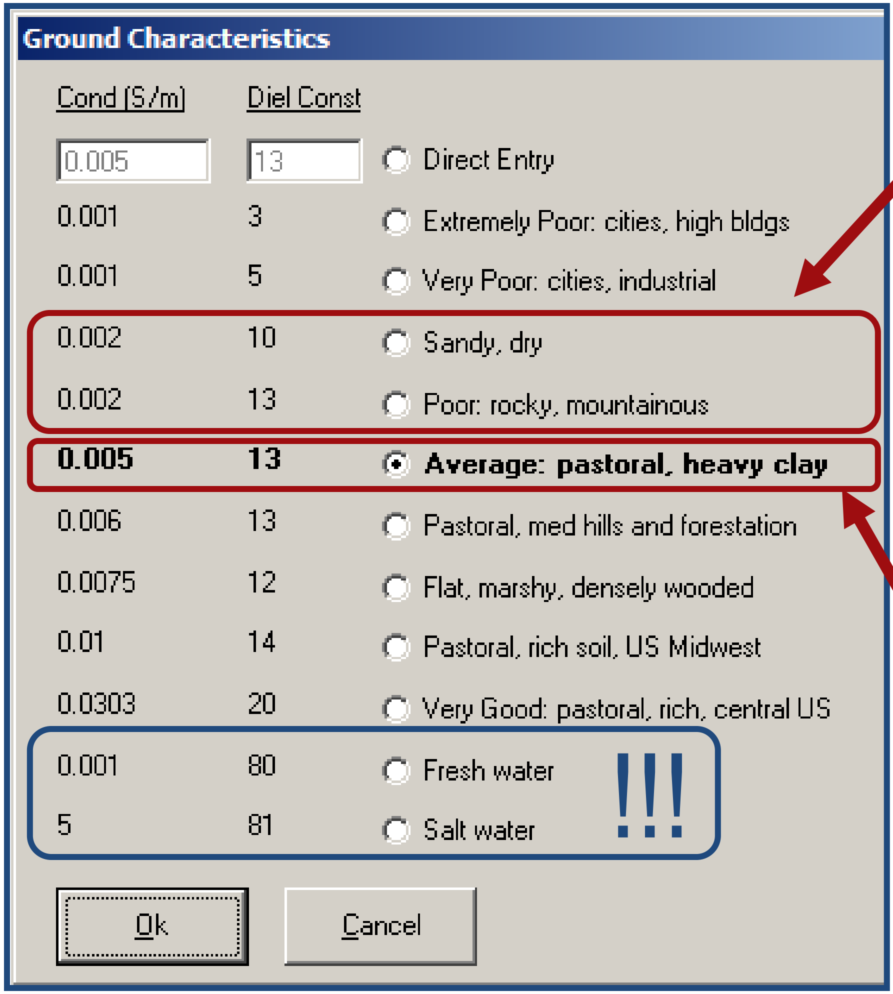
Ground Characteristics

Cond (S/m)	Diel Const	
0.005	13	Direct Entry
0.001	3	Extremely Poor: cities, high bldgs
0.001	5	Very Poor: cities, industrial
0.002	10	Sandy, dry
0.002	13	Poor: rocky, mountainous
0.005	**13**	**Average: pastoral, heavy clay**
0.006	13	Pastoral, med hills and forestation
0.0075	12	Flat, marshy, densely wooded
0.01	14	Pastoral, rich soil, US Midwest
0.0303	20	Very Good: pastoral, rich, central US
0.001	80	Fresh water
5	81	Salt water

Ok Cancel

What you see in most QST articles

Ground Characteristics – EZNEC inputs



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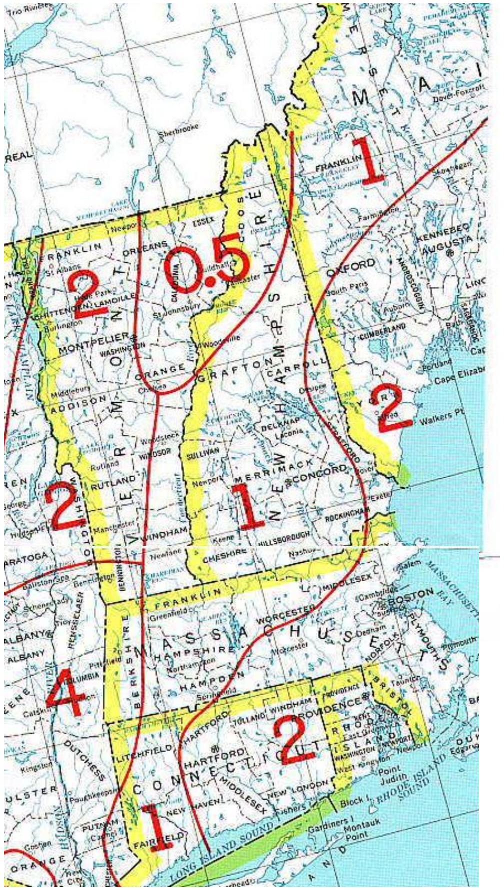
!!!

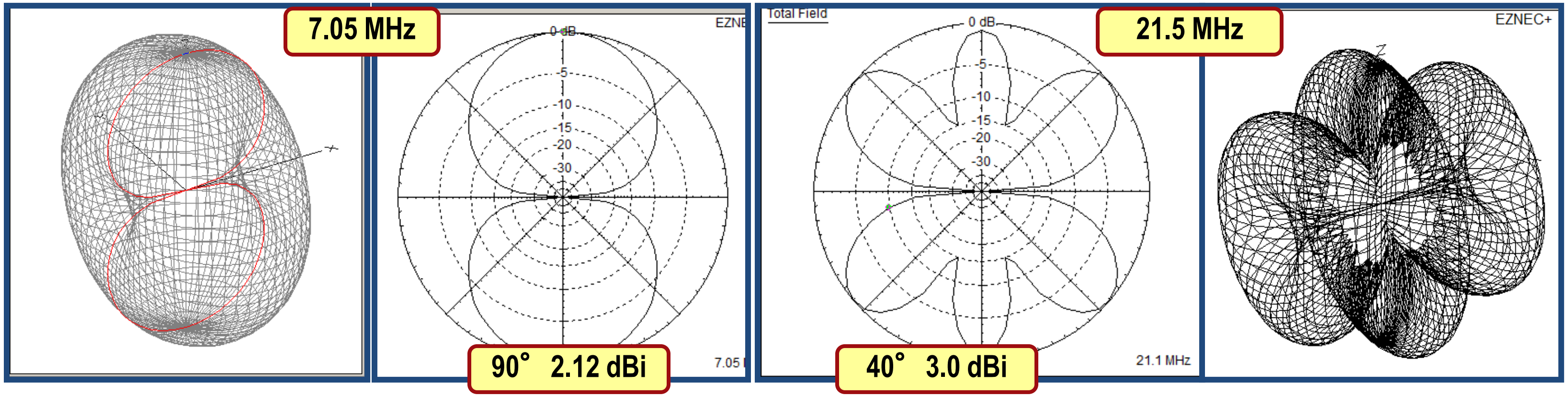
What we are on the New England coast

QST articles



Ground Characteristics – Change Ground

Free Space



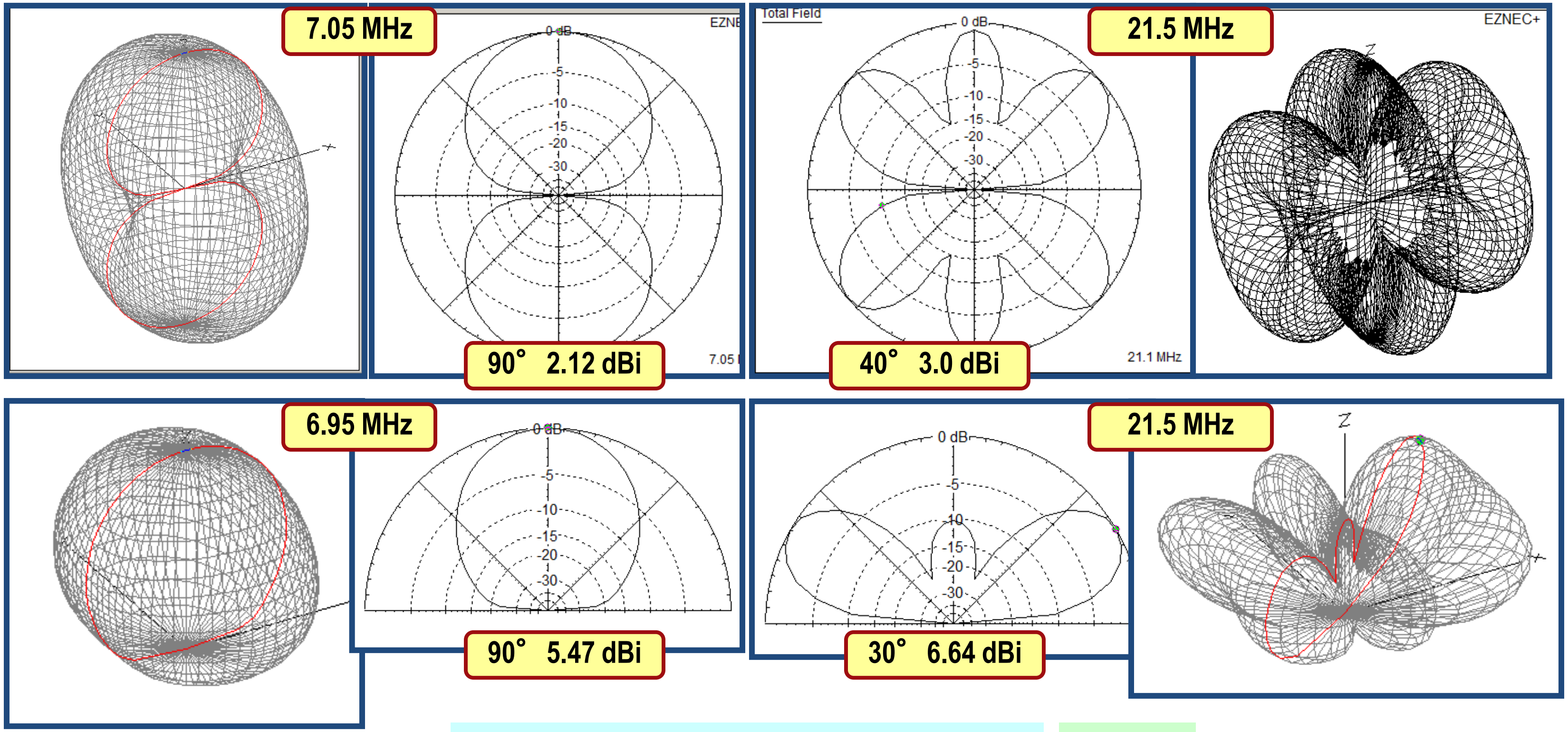
40M dipole in Free Space

A dipole (0 dBd) = 2.12 dBi

Ground Characteristics – Change Ground

Free Space

.005 S/m
DC=13
QST



~3/20 λ

40M dipole at 18'

~2/5 λ

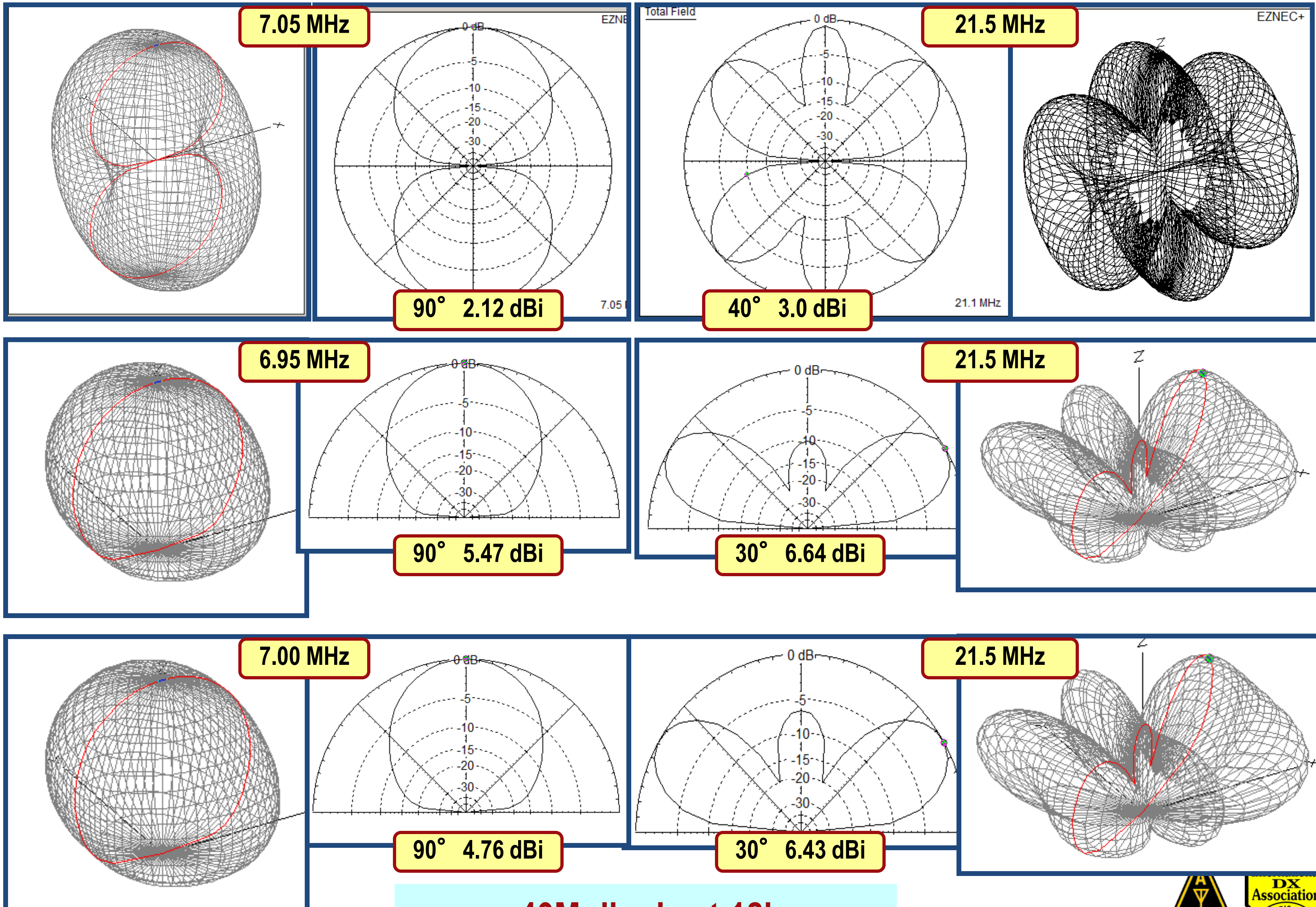
INDEXA

Ground Characteristics – Change Ground

Free Space

.005 S/m
DC=13
QST

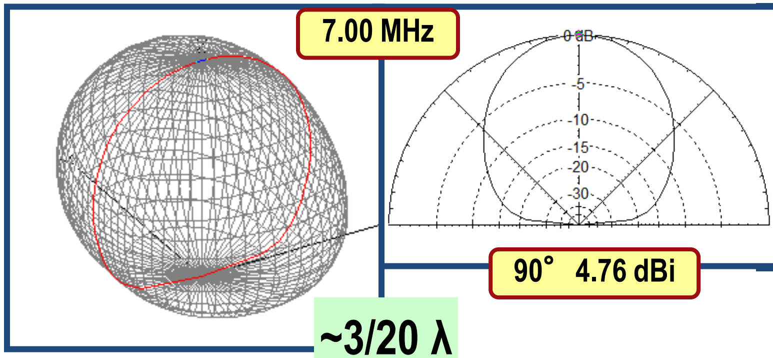
.002 S/m
DC=10
New Eng



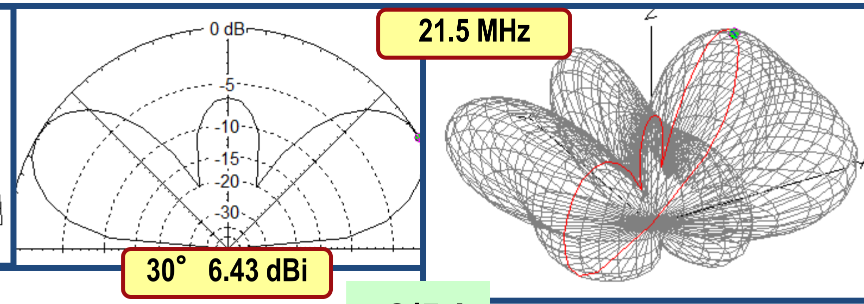
40M dipole at 18'

Ground Characteristics – Change Height

18’
.002 S/m
DC=10



~3/20 λ

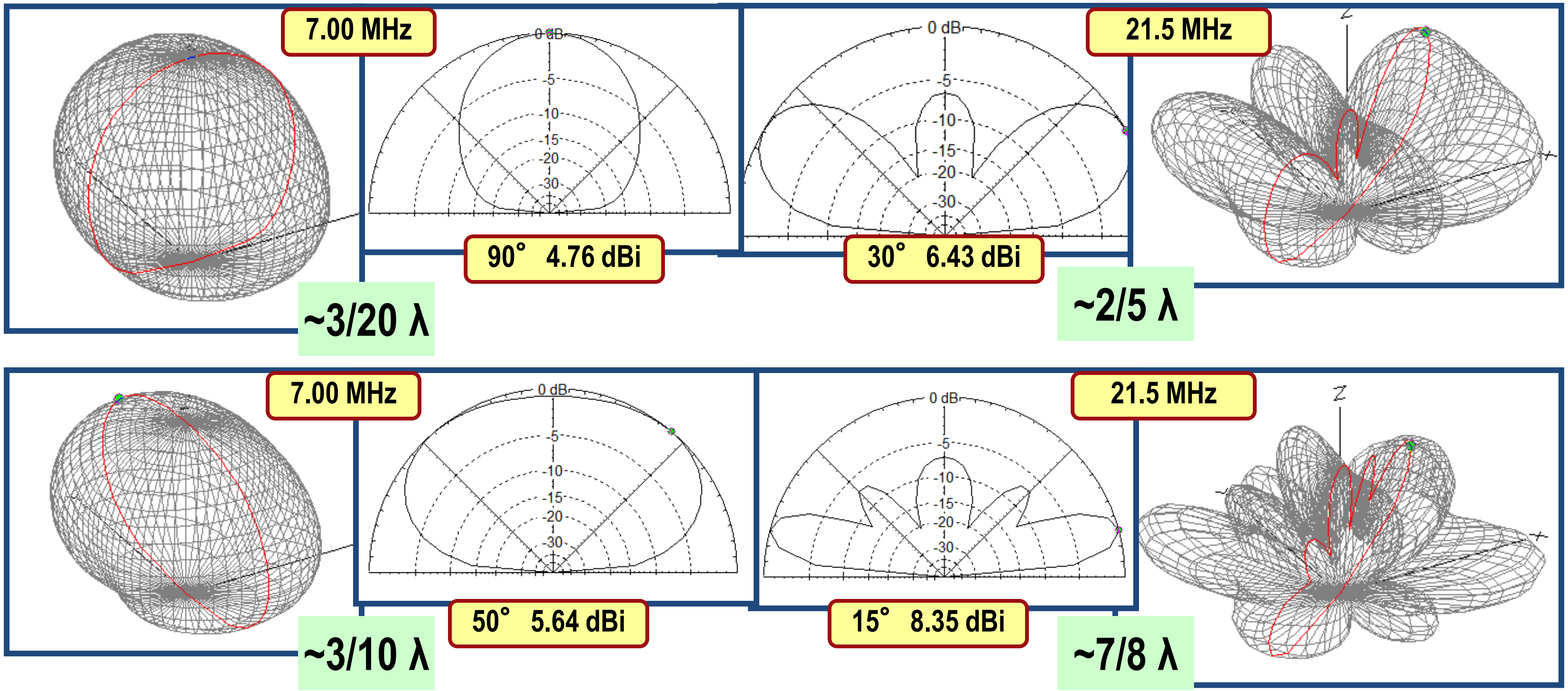


~2/5 λ

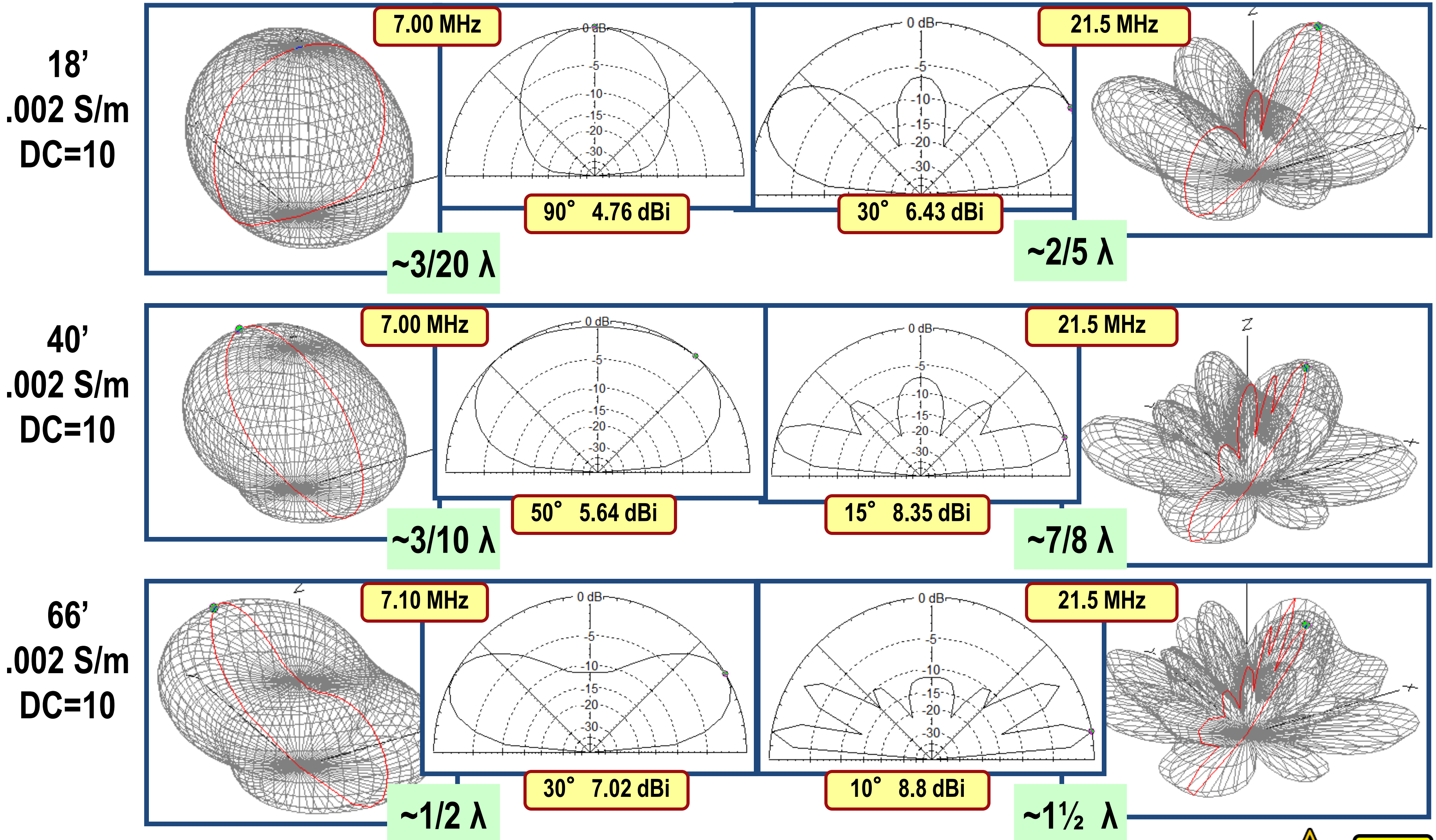
Ground Characteristics – Change Height

18’
.002 S/m
DC=10

40’
.002 S/m
DC=10



Ground Characteristics – Change Height

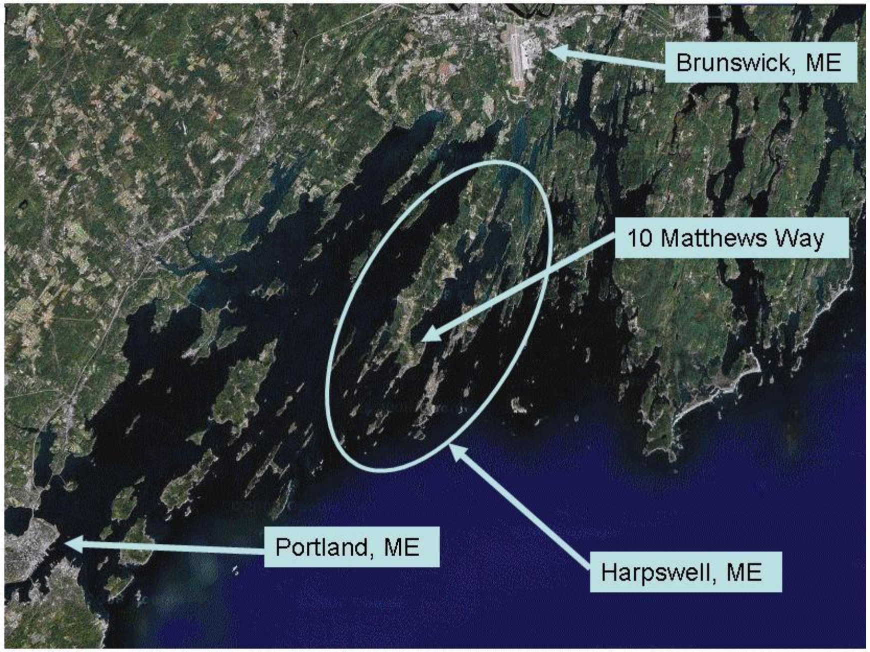


EZNEC Agenda

- **Modeling Software using NEC**
- **NEC *Numerical Electromagnetics Code***
- EZNEC
  - Inputs & Output (Simple 40M dipole)
  - Ground Characteristics
  - **EZNEC Example (40M Vertical)**

➔ A Practical Example in Harpswell, Maine

EZNEC Example – 40M Vertical [Harpswell, Maine]

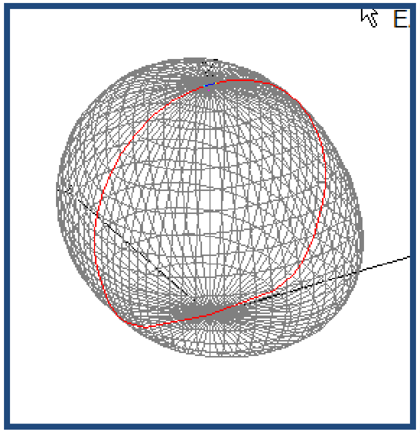


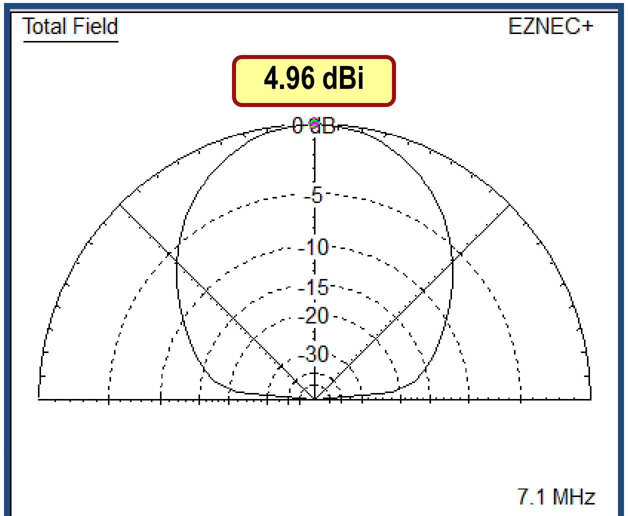
Situation (2010):

- I had DXCC on 10 / 15 / 20 and was working on 40M
- No tall trees ➔ Had a 40M dipole @ 18' high off my house
- What antenna would work better?

EZNEC Example – 40M Vertical [Harpswell, Maine]

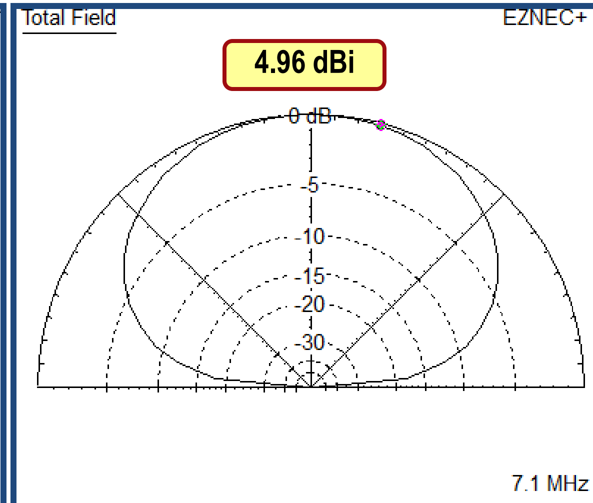
Original 40M dipole: 18' high: assumes ground = 0.002 S/m; Diel Const = 13





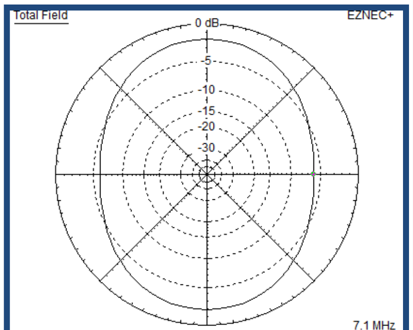
Elevation Plot		Cursor Elev	90.0 deg.
Azimuth Angle	0.0 deg.	Gain	4.96 dBi
Outer Ring	4.96 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	4.96 dBi		
Slice Max Gain	4.96 dBi @ Elev Angle = 90.0 deg.		
Beamwidth	64.0 deg.; -3dB @ 58.0, 122.0 deg.		
Sidelobe Gain	< -100 dBi		
Front/Sidelobe	> 100 dB		

Elevation @ 0° Azimuth



Elevation Plot		Cursor Elev	75.0 deg.
Azimuth Angle	90.0 deg.	Gain	4.81 dBi
Outer Ring	4.96 dBi		-0.15 dBmax
			-0.15 dBmax3D
3D Max Gain	4.96 dBi		
Slice Max Gain	4.96 dBi @ Elev Angle = 90.0 deg.		
Beamwidth	108.0 deg.; -3dB @ 36.0, 144.0 deg.		
Sidelobe Gain	< -100 dBi		
Front/Sidelobe	> 100 dB		

Elevation @ 90° Azimuth

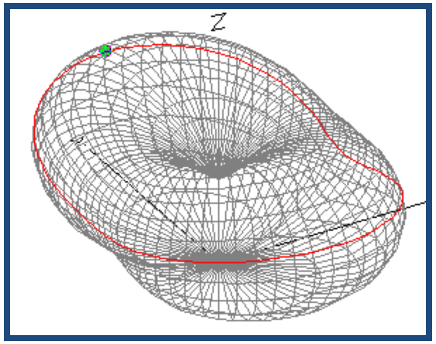


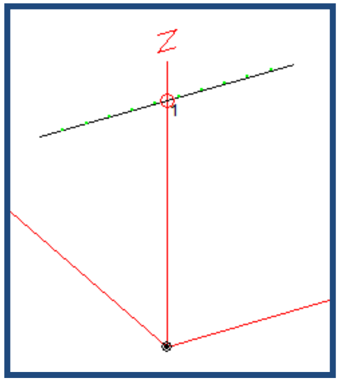
Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	45.0 deg.	Gain	-1.0 dBi
Outer Ring	4.96 dBi		-4.15 dBmax
			-5.97 dBmax3D
3D Max Gain	4.96 dBi		
Slice Max Gain	3.14 dBi @ Az Angle = 90.0 deg.		
Front/Side	4.14 dB		
Beamwidth	124.2 deg.; -3dB @ 27.9, 152.1 deg.		
Sidelobe Gain	3.14 dBi @ Az Angle = 270.0 deg.		
Front/Sidelobe	0.0 dB		

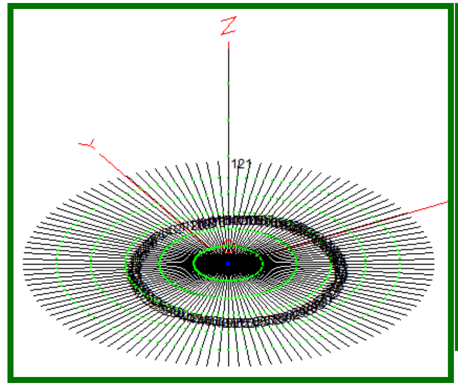
Azimuth @ 45° Elevation

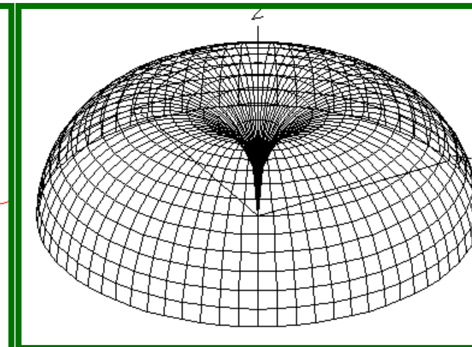
EZNEC Example – 40M Vertical [Harpswell, Maine]

"Perfect" Dipole 1/2 λ high | **Perfect GND** | **"Perfect" Vertical 120 radials *(@ 0.2')***

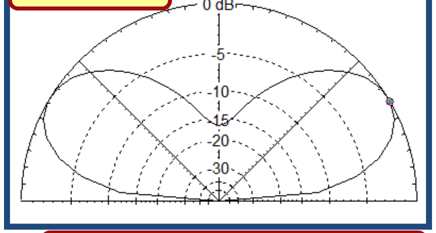




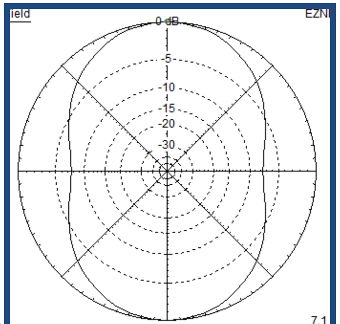




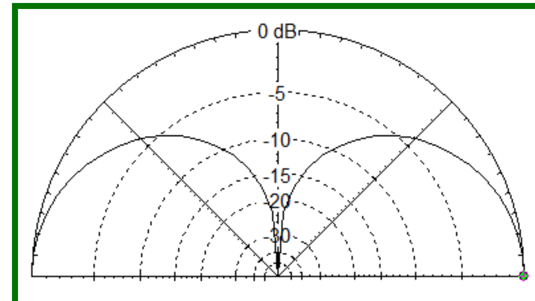
8.06 dBi



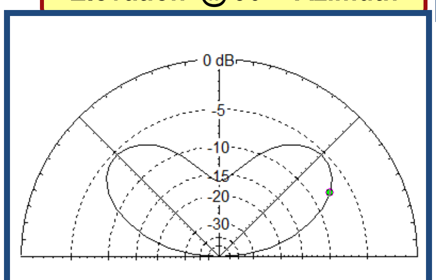
Elevation @ 90° Azimuth



Azimuth @ 30° Elev



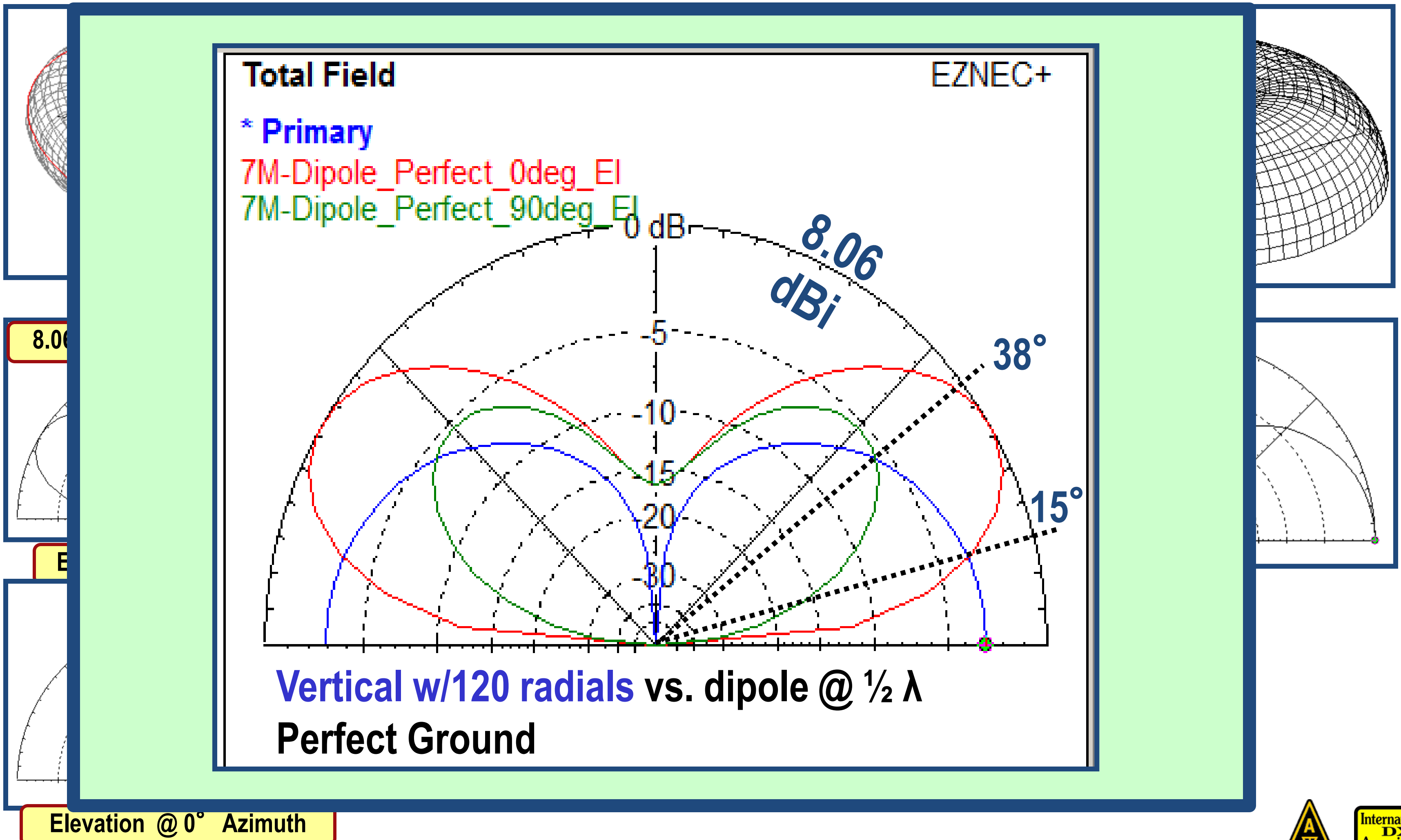
5.14 dBi



Elevation @ 0° Azimuth

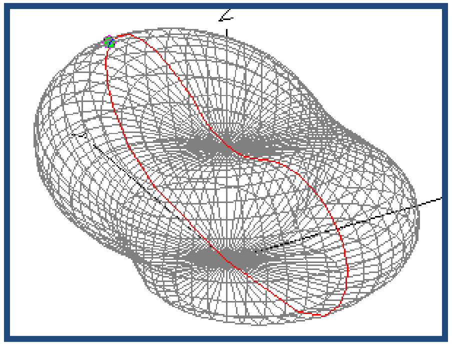
EZNEC Example – 40M Vertical [Harpswell, Maine]

"Perfect" Dipole 1/2 λ high | Perfect GND | "Perfect" Vertical 120 radials (@ 0.2')

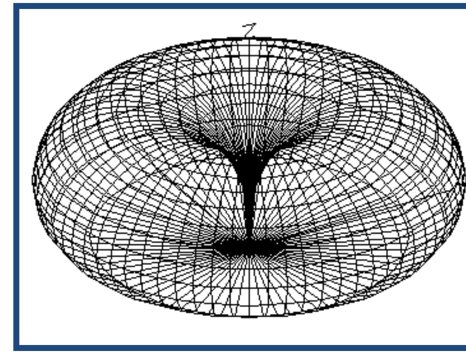


EZNEC Example – 40M Vertical [Harpswell, Maine]

Dipole 1/2 λ high



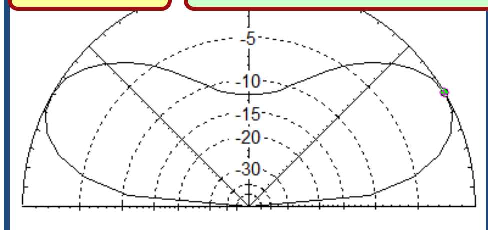
Vertical 120 radials *(0.2')*



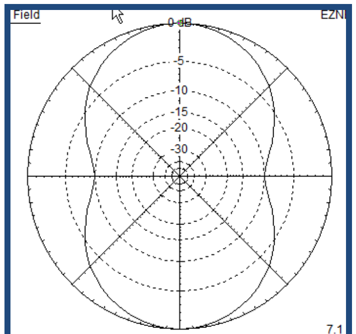
New England GND

Ground Characteristics affect verticals more than horizontals

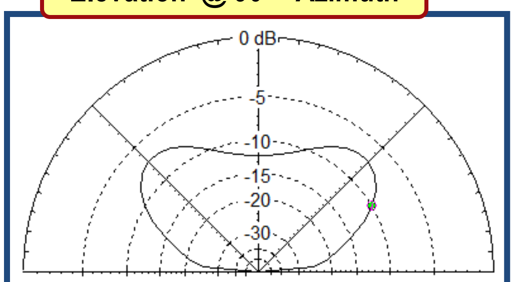
7.09 dBi | Was 8.06 dBi



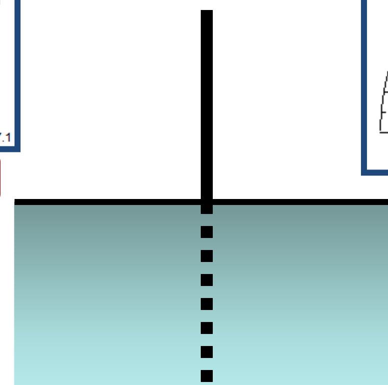
Elevation @ 90° Azimuth



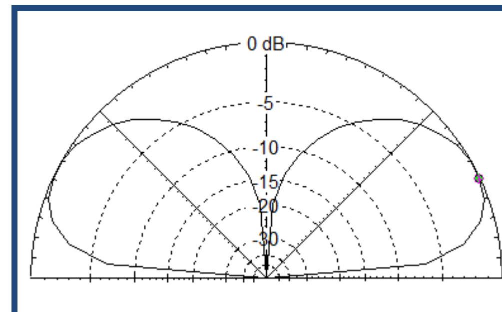
Azimuth @ 30° Elev



Elevation @ 0° Azimuth



A vertical is half a dipole, with the other half buried.

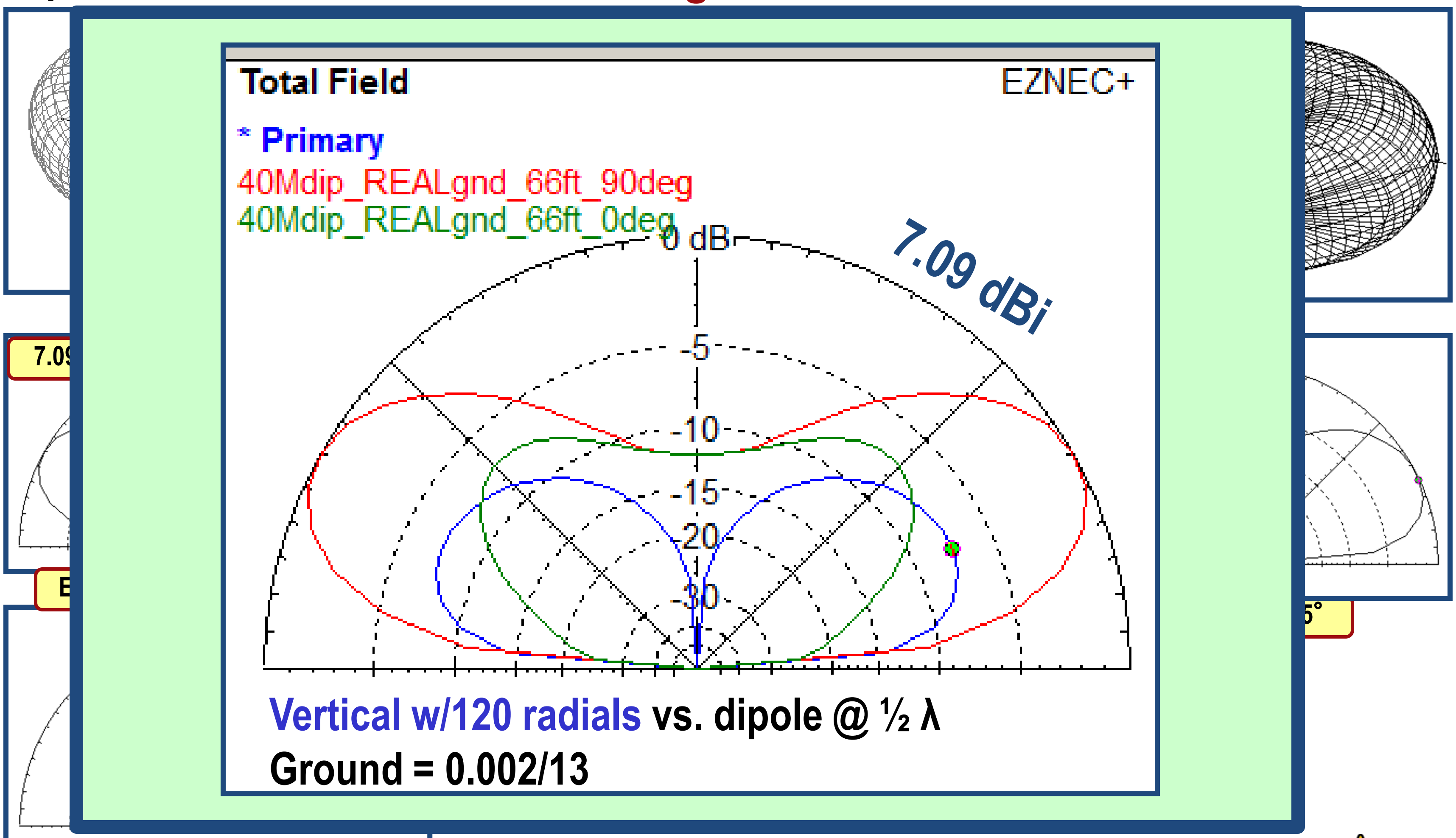


-0.27 dBi @ 25°

Was 5.14 dBi

EZNEC Example – 40M Vertical [Harpswell, Maine]

Dipole 1/2 λ high **New England GND** **Vertical 120 radials *(0.2')***

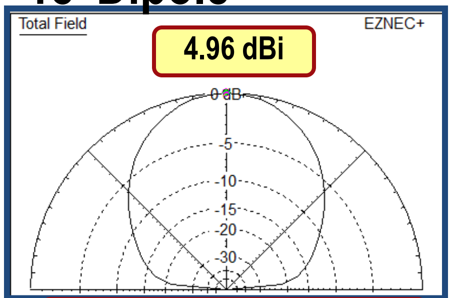


Elevation @ 0° Azimuth

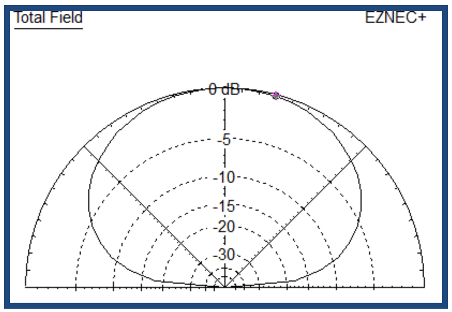
EZNEC Example – 40M Vertical [Harpswell, Maine]

New England GND

18' Dipole



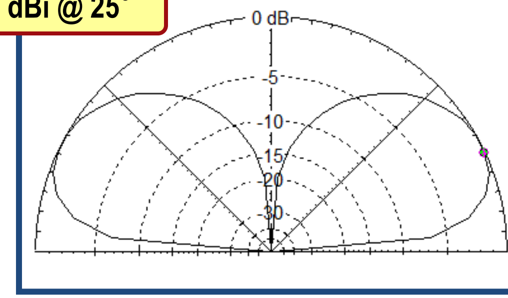
Elevation @ 0° Azimuth

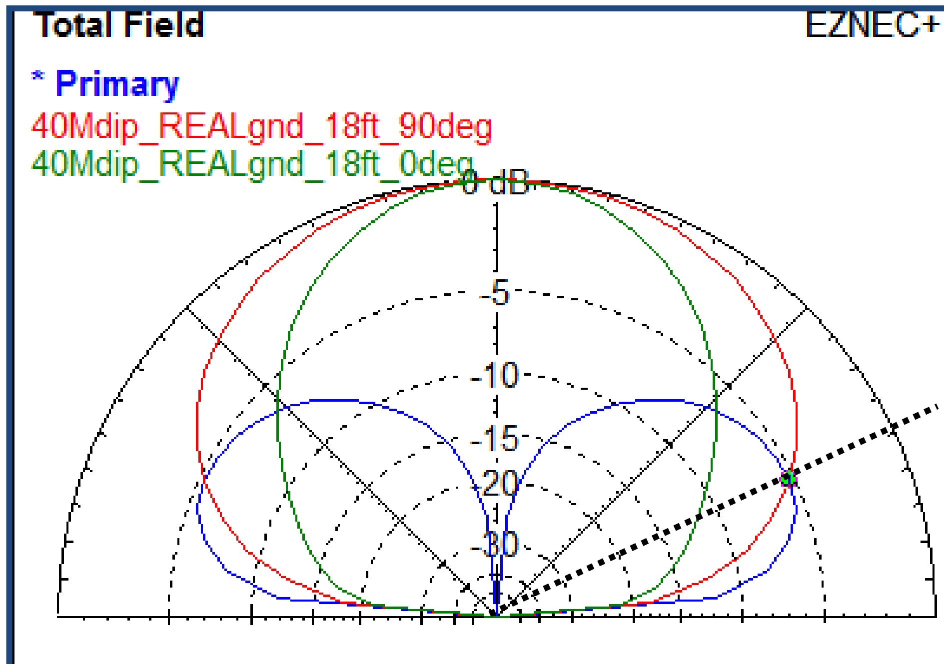


Elevation @ 90° Azimuth

Vertical 120 radials *(0.2')*

-0.27 dBi @ 25°





25°

Vertical w/120 radials
vs. dipole @ 18'
Ground = 0.002/13

40m Vertical – Radial Choice

From the ARRL Antenna Book:

Practical Suggestions For Vertical Ground Systems

At least 16 radials should be used if at all possible. Experimental measurements and calculations show that with this number, the loss resistance decreases the antenna efficiency by 30% to 50% for a 0.25 wavelength vertical, depending on soil characteristics. *In general, a large number of radials (even though some or all of them must be short) is preferable to a few long radials for a vertical antenna mounted on the ground.*

a. If you install only 16 radials they need not be very long - 0.1 lambda is sufficient.

b. If you have the wire, the space and the patience to lay down 120 radials (optimal configuration), they should be 0.4 lambda long. This radial system will gain about 3 dB over the 16-radial case.

c. If you install 36 radials that are 0.15 lambda long, you will lose 1.5 dB compared to optimal configuration.

40m Vertical – Radial Choice

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From QST, March 2010, pp 30-33:

An Experimental Look at Ground Systems for HF Verticals (and references)

Rudy Severns, N6LF

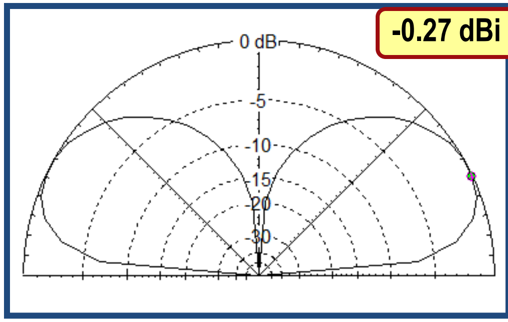
…four elevated radials at a height of 48 inches are within 0.2 dB of 64 radials lying on the ground.

Assume four elevated radials high enough to be safe: → 10 ft

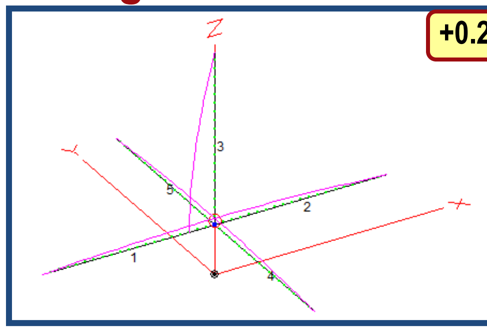
EZNEC Example – 40M Vertical [Harpswell, Maine]

Vertical 120 Radials

-0.27 dBi @ 25°

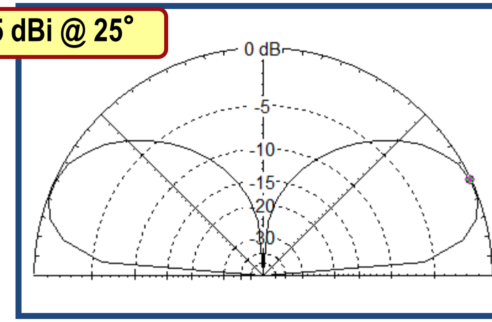


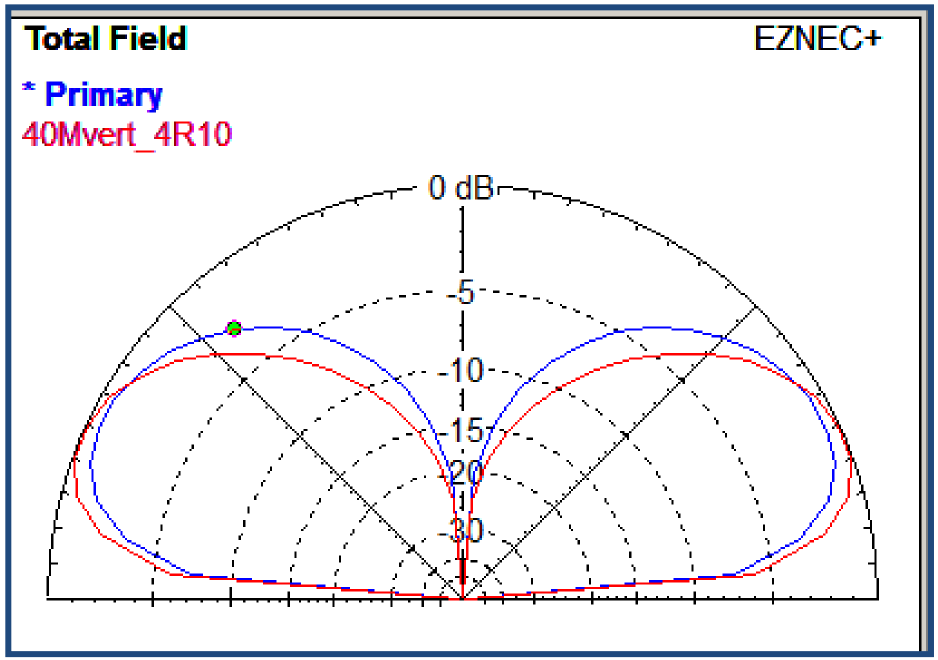
New England GND



Vertical w/4 raised radials

+0.25 dBi @ 25°





Vertical w/4 elevated radials

vs. Vertical 120 radials

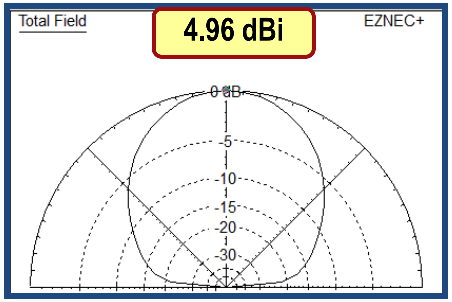
Ground = 0.002/13

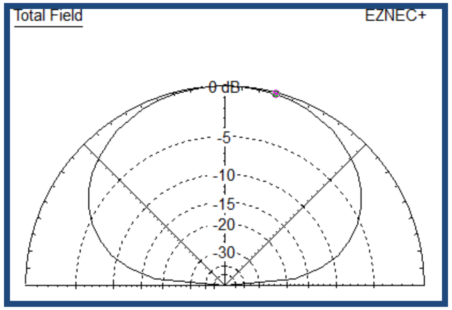
EZNEC Example – 40M Vertical [Harpswell, Maine]

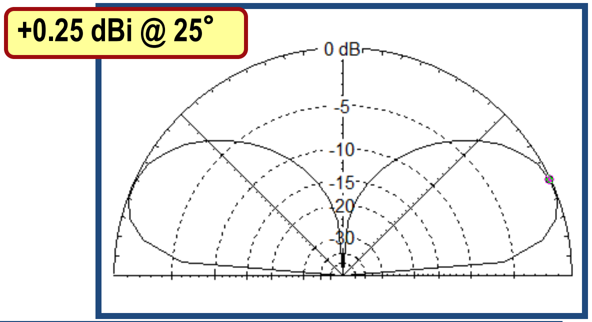
18' Dipole

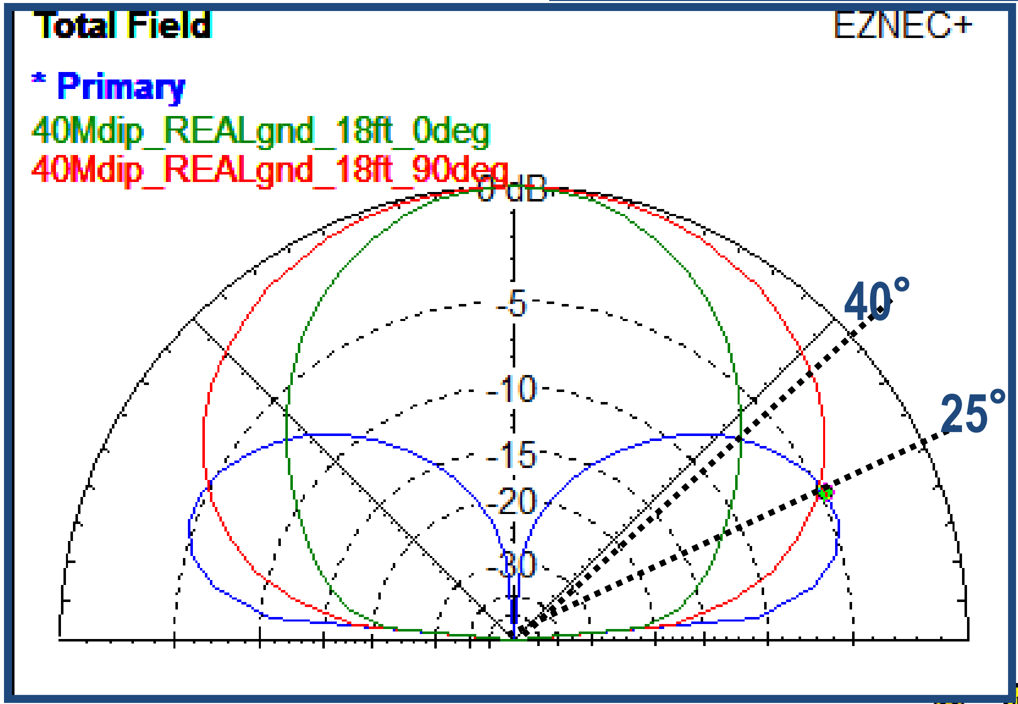
New England GND

Vertical w/4 raised radials



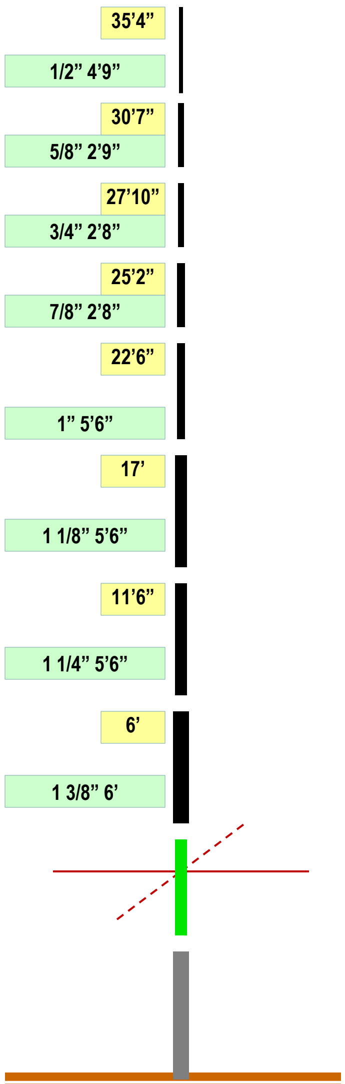






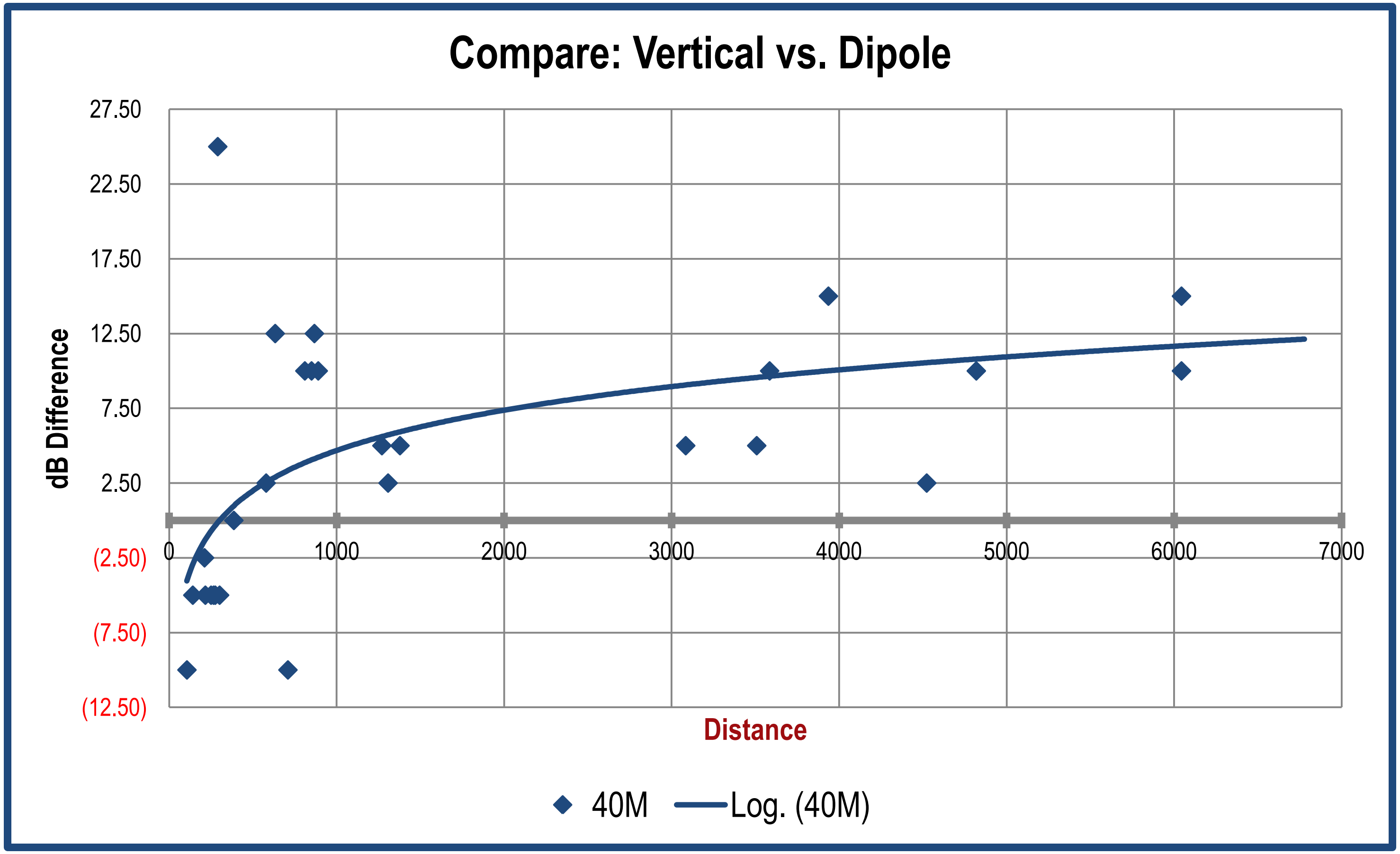
Vertical w/4 elevated radials
vs. dipole @ 18'
Ground = 0.002/13

The Actual Antenna



COMPARE ~ 40M Reality

Noise:
Worse on Vertical by ~1-1.5 S-units

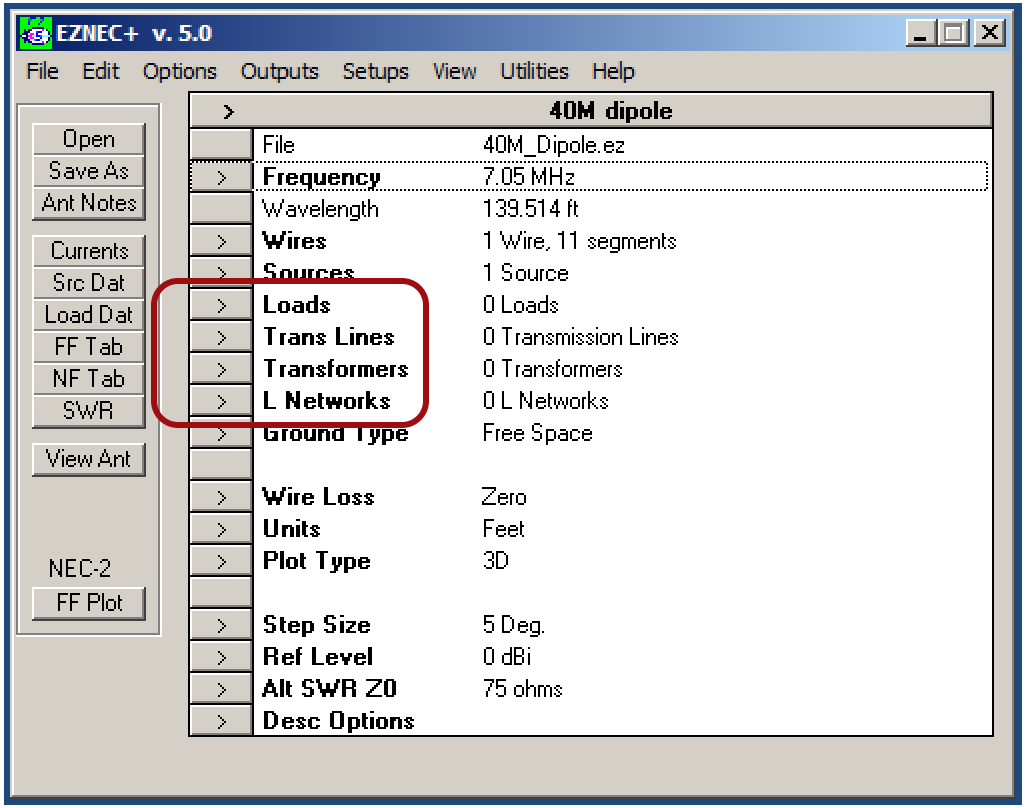


<u>Coax feed: Δ = – 0.25 dB @ 7.1 MHz.</u>

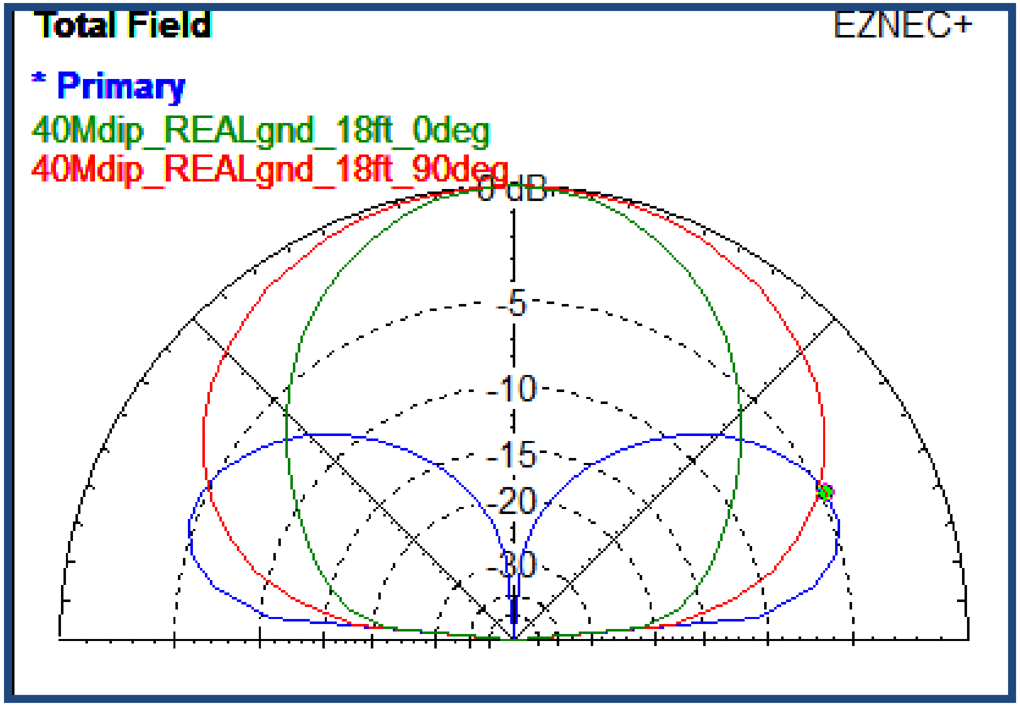
Dipole → 35' of RG8x = 0.25 dB @ swr 1.5:1 = .29 dB

Vertical → 15' of RG8x + 105' of Bury-Flex = 0.5 dB. @ swr 1.5:1 = .55 dB

EZNEC:
Lots of functionality left for your homework



EZNEC



Complicated, but allows you to model and discover antennas and compare them to reality, AND LEARN.

Conclusions

- **You Can't Beat Physics**
- Understanding antennas
  →understanding ANTENNA SYSTEMS
  - HOW YOU WANT TO USE YOUR ANTENNA
  - EFFECTS OF TRANSMISSION LINES
  - LOCAL TERRAIN
  - GROUND CHARACTERISTICS
- All antennas are COMPROMISES
- All models are SIMPLE EXAMPLES of reality
- Your real antenna WILL NOT MATCH your model

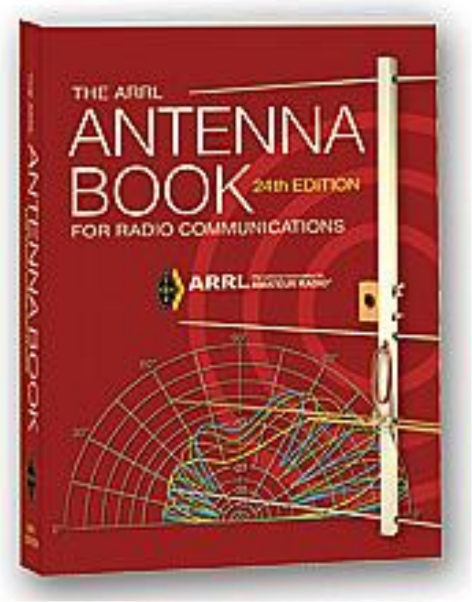
"All models are wrong. Some are useful"

British Statistician *George Box*, 1976

Antenna Modeling ~ Agenda

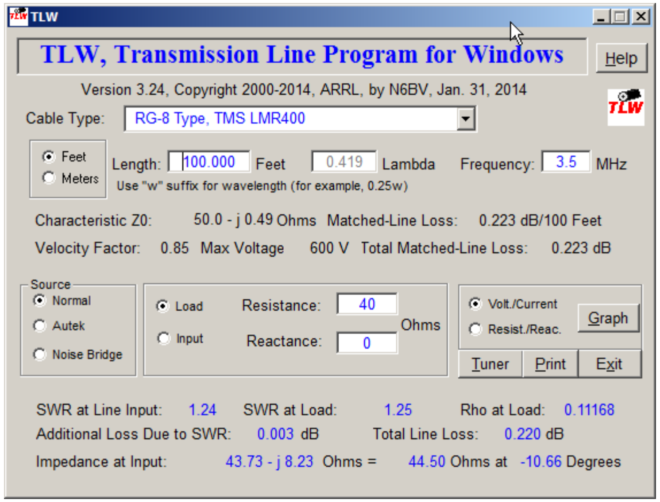
- **Part II**

- **TLW**
- YW
- HFTA



TLW – Transmission Line Program for Windows

R. Dean Straw ~ N6BV ©ARRL



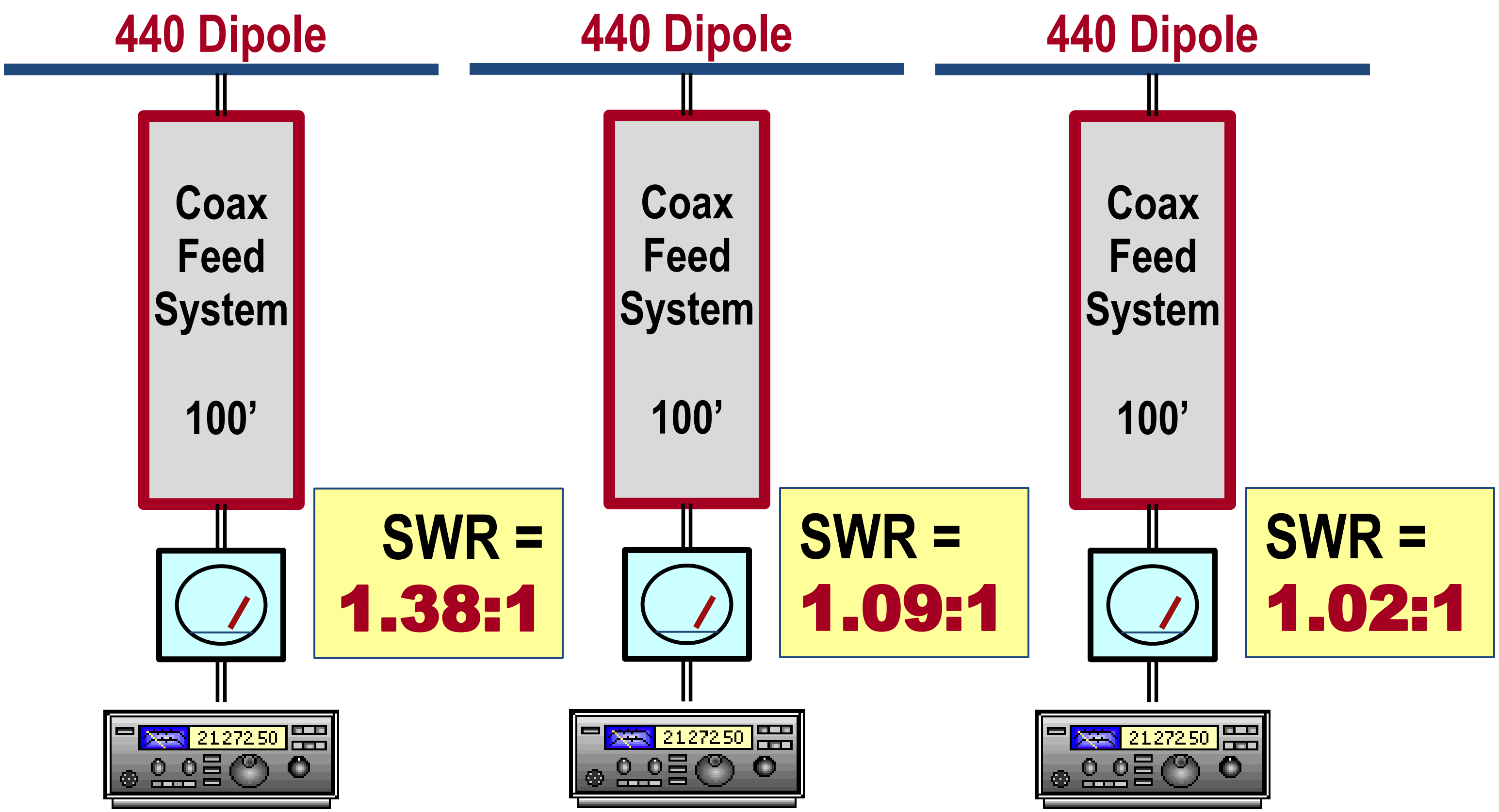
Basic Purpose:

- Input = cable type, frequency, dimensions, and load impedance
- Output = SWR at input, load, and feedline loss

INDEXA

A Spot Quiz!

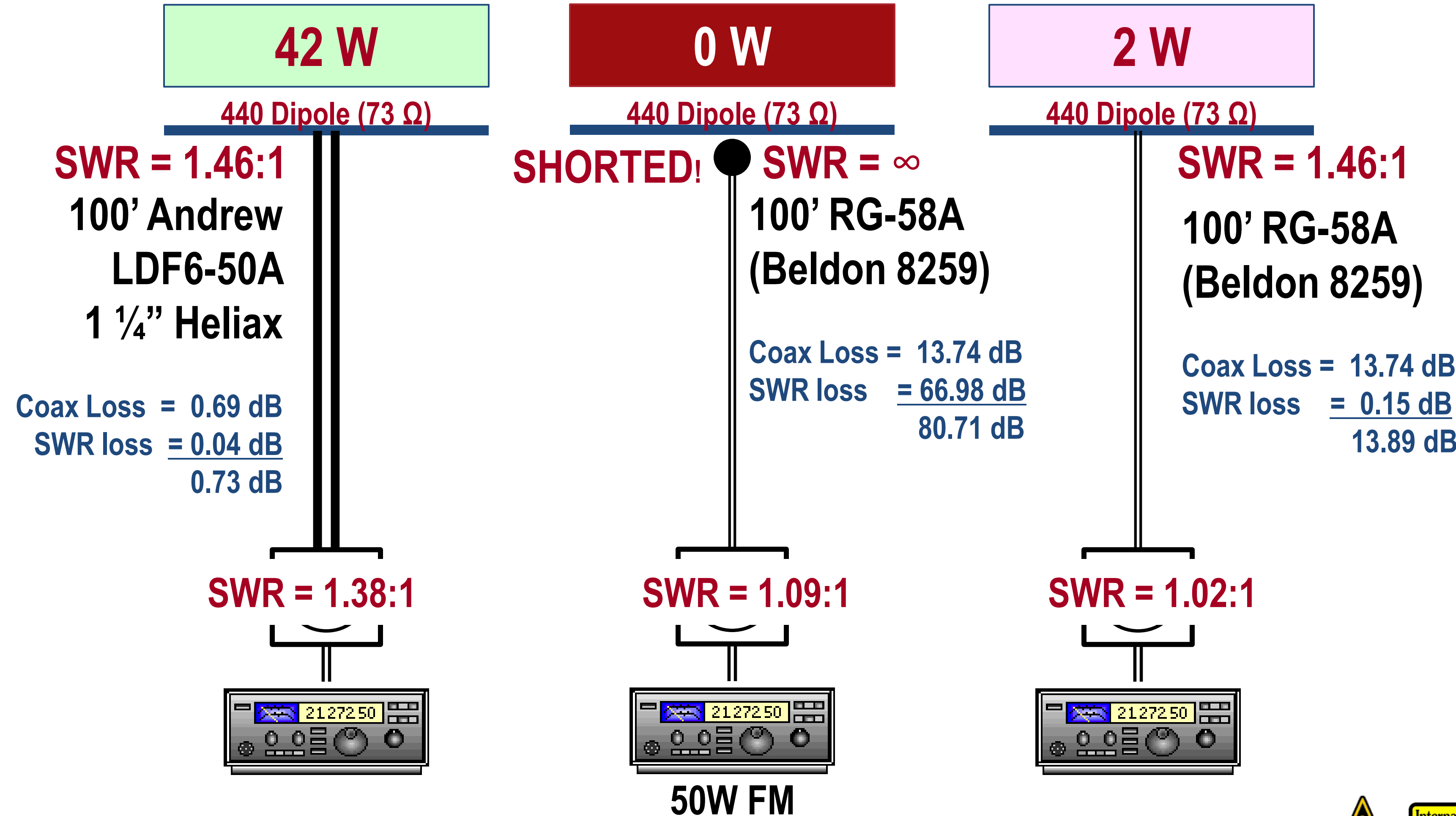
Question: Which is the better situation?



50W FM

A Spot Quiz!

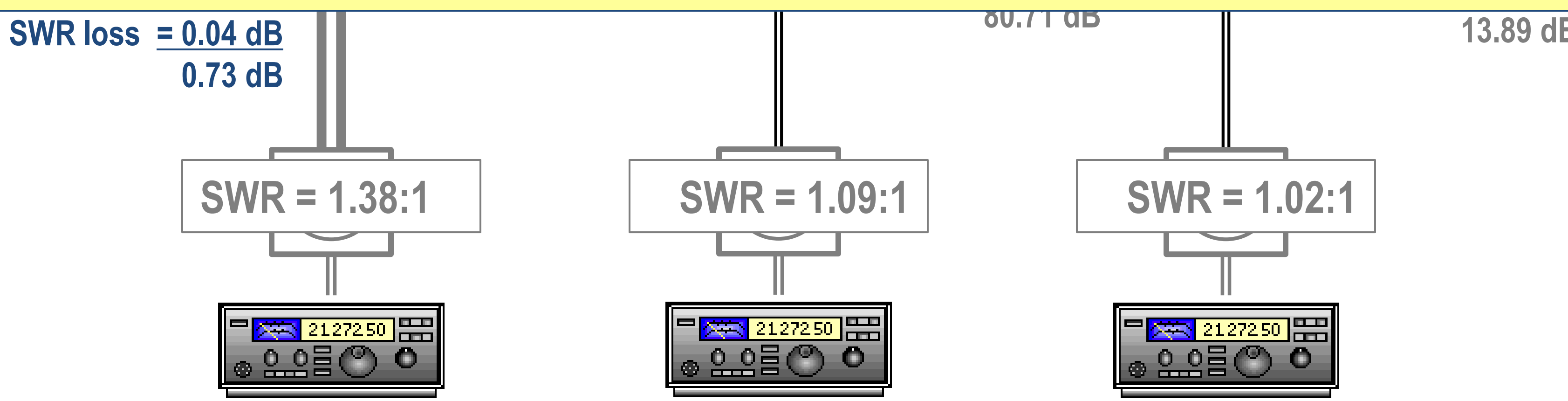
Answer: ***Beware the Myth of Low SWR!***



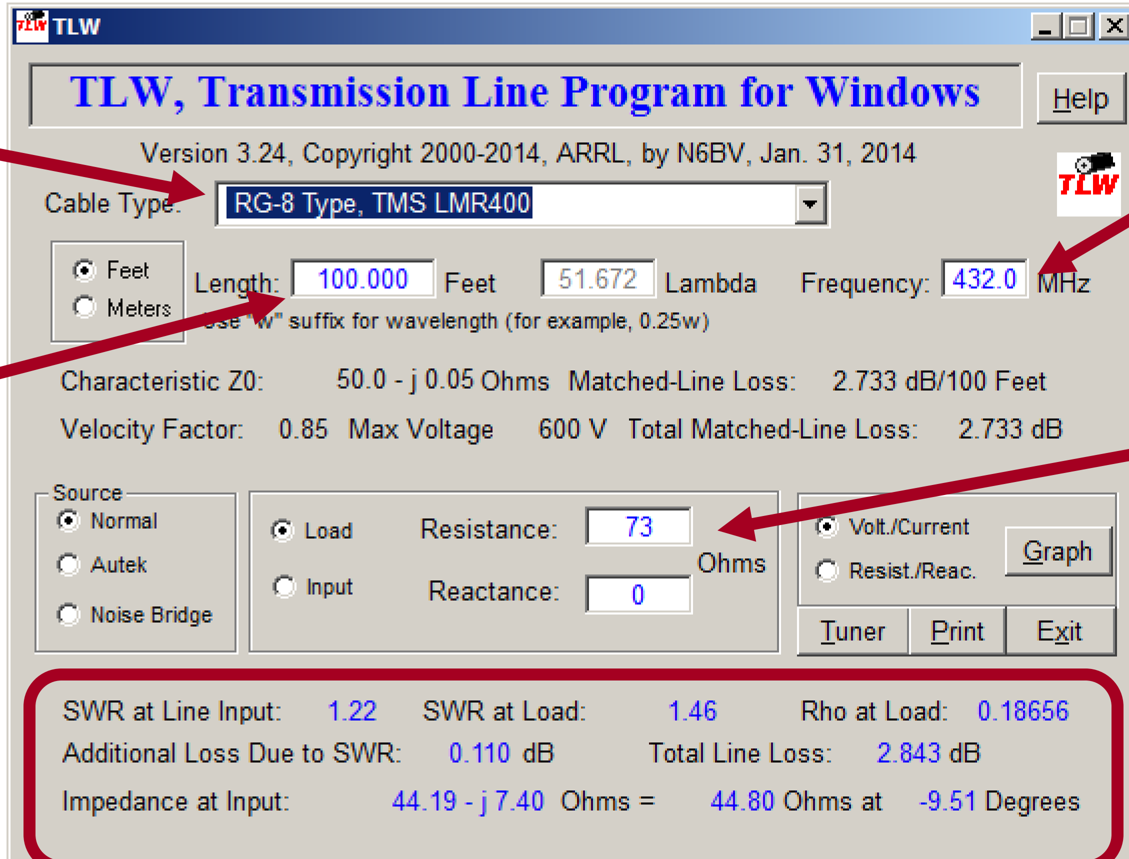
A Spot Quiz!

It's really too bad that SWR is so easy to measure in the shack – it can be very misleading.

Remember: the "ideal" SWR is generated with a broadband, matched dummy load!



TLW – Transmission Line Program for Windows



(1) Choose cable type

(2) Choose cable length

(3) Specify frequency

(4) Enter load (antenna) impedance

(5) The Results

TLW – Transmission Line Program for Windows

Coax	SWR @70cm	Total Loss @70cm	Delivered Power
			70cm
1 ¼" Heliax	1.38:1	0.73 dB	42 W
½ " Heliax	1.31:1	1.54 dB	35 W
LMR 400 "RG8"	1.22:1	2.83 dB	26 W
8267 RG213	1.12:1	5.28 dB	15 W
LMR 240"RG8X"	1.12:1	5.37 dB	14 W
LMR 200 "RG58"	1.08:1	7.14 dB	10 W
9258 "RG8X"	1.05:1	9.08 dB	5 W
8259 "RG58A"	1.02:1	13.89 dB	2 W

50 W @ Transmitter / 100' Coax / 73 Ω Antenna

$dB = 10 \log_{10} (W_i/W_o) \rightarrow W_o = W_i / 10^{dB/10}$

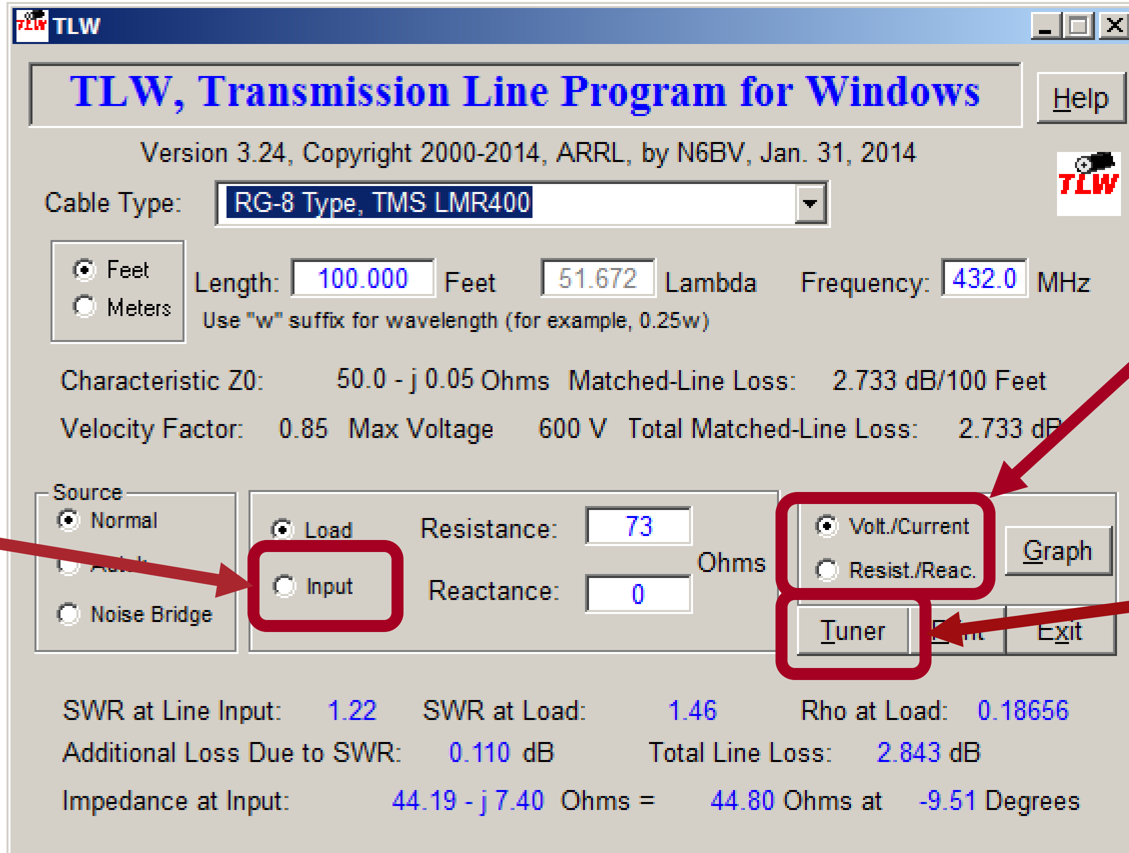
TLW – Transmission Line Program for Windows

Coax	SWR @70cm	Total Loss @70cm	Delivered Power			
			70cm	2M	10M	80M
1 ¼” Heliax	1.38:1	0.73 dB	42 W	46	48	49
½ ” Heliax	1.31:1	1.54 dB	35 W	41	46	49
LMR 400 “RG8”	1.22:1	2.83 dB	26 W	34	43	47
8267 RG213	1.12:1	5.28 dB	15 W	26	38	46
LMR 240”RG8X”	1.12:1	5.37 dB	14 W	25	37	45
LMR 200 “RG58”	1.08:1	7.14 dB	10 W	19	33	43
9258 “RG8X”	1.05:1	9.08 dB	5 W	16	32	43
8259 “RG58A”	1.02:1	13.89 dB	2 W	9	25	40

50 W @ Transmitter / 100’ Coax / 73 Ω Antenna

TLW – Transmission Line Program for Windows

Left to you for Homework…



If you know the impedance in your shack, you can estimate the load impedance

You can look at the Voltage, Current, Resistance, and Reactance on the transmission line

You can use TLW to help you design a TransMatch.

NOTE: Antenna Tuners DO NOT tune anything!

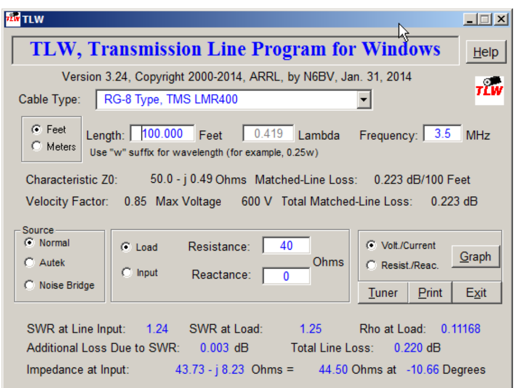
TLW – Transmission Line Program for Windows

Summary:

- It's really too bad that SWR is so easy to measure in the shack
- It is only one parameter in the understanding of your ***Antenna System***
- However, do measure it, document it, and use it as one measure of your ***Antenna System's*** health – it will tell you if something has changed

TLW – Transmission Line Program for Windows

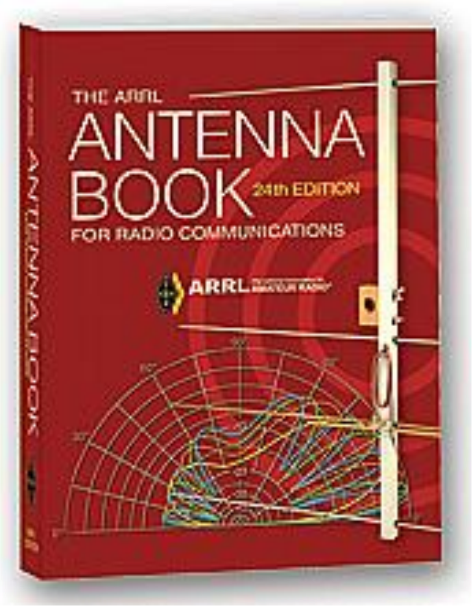
Helps you understand and design your Antenna System



Antenna Modeling ~ Agenda

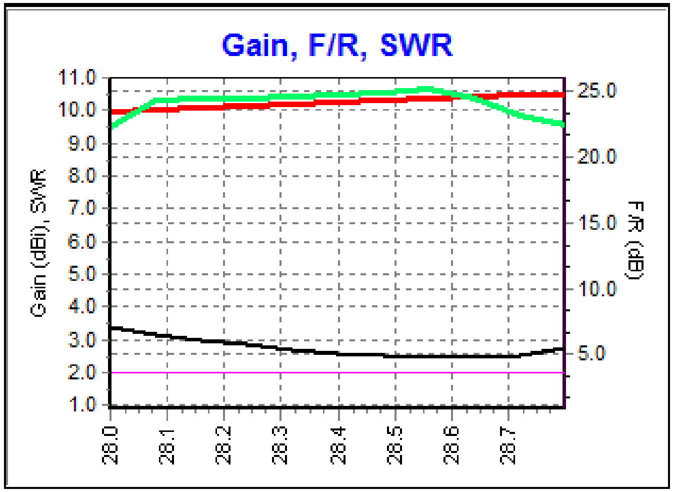
- **Part II**

- TLW
- YW
- HFTA



YW – Yagi for Windows

R. Dean Straw ~ N6BV ©ARRL



Purpose:

- Input = dimensions of a traditional monoband Yagi, its height and its matching
- Output = graphs/patterns of Gain, F/R, SWR

YW – Yagi for Windows

Description

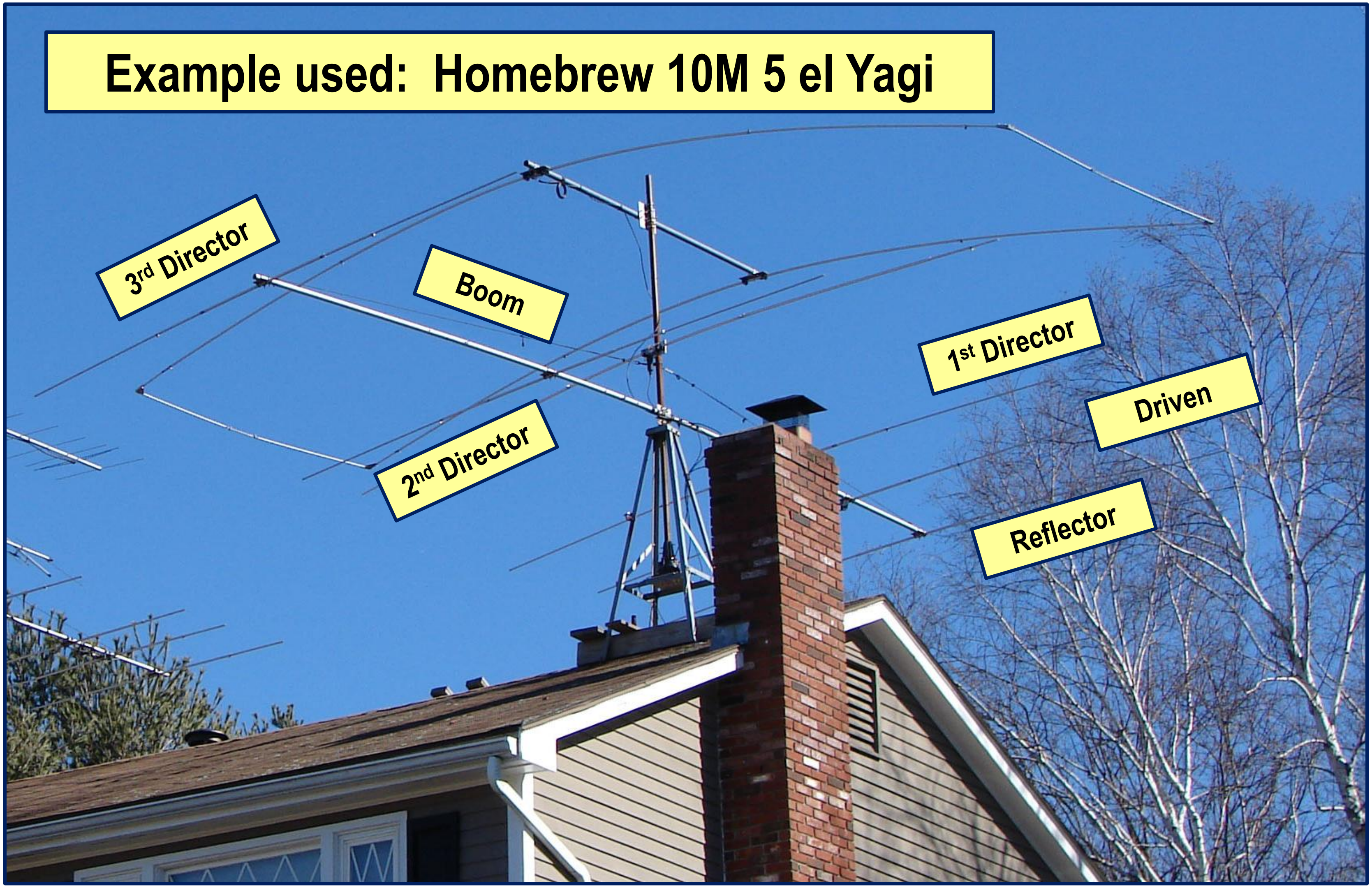
- Similar to earlier DOS based program: YO from Brian Beezley
- Computes Gain, worse-case F/R, SWR, E- & H-plane patterns
- Generates on-screen graphs
- Results compare closely with YO, EZNEC, NEC-4
- Runs much faster
- Includes design files for 80+ Yagi designs included in ARRL Antenna Book

YW – Yagi for Windows

Limitations

- Works only for “traditional” monoband Yagis
- Evaluations done over flat “perfect” ground
- Not accurate below height of λ/8
- Not accurate in stacks, near other antennas, etc.
- Does not generate output data files
- No optimization routine – like YO

33 Blueberry Hill Rd – Woburn Antennas



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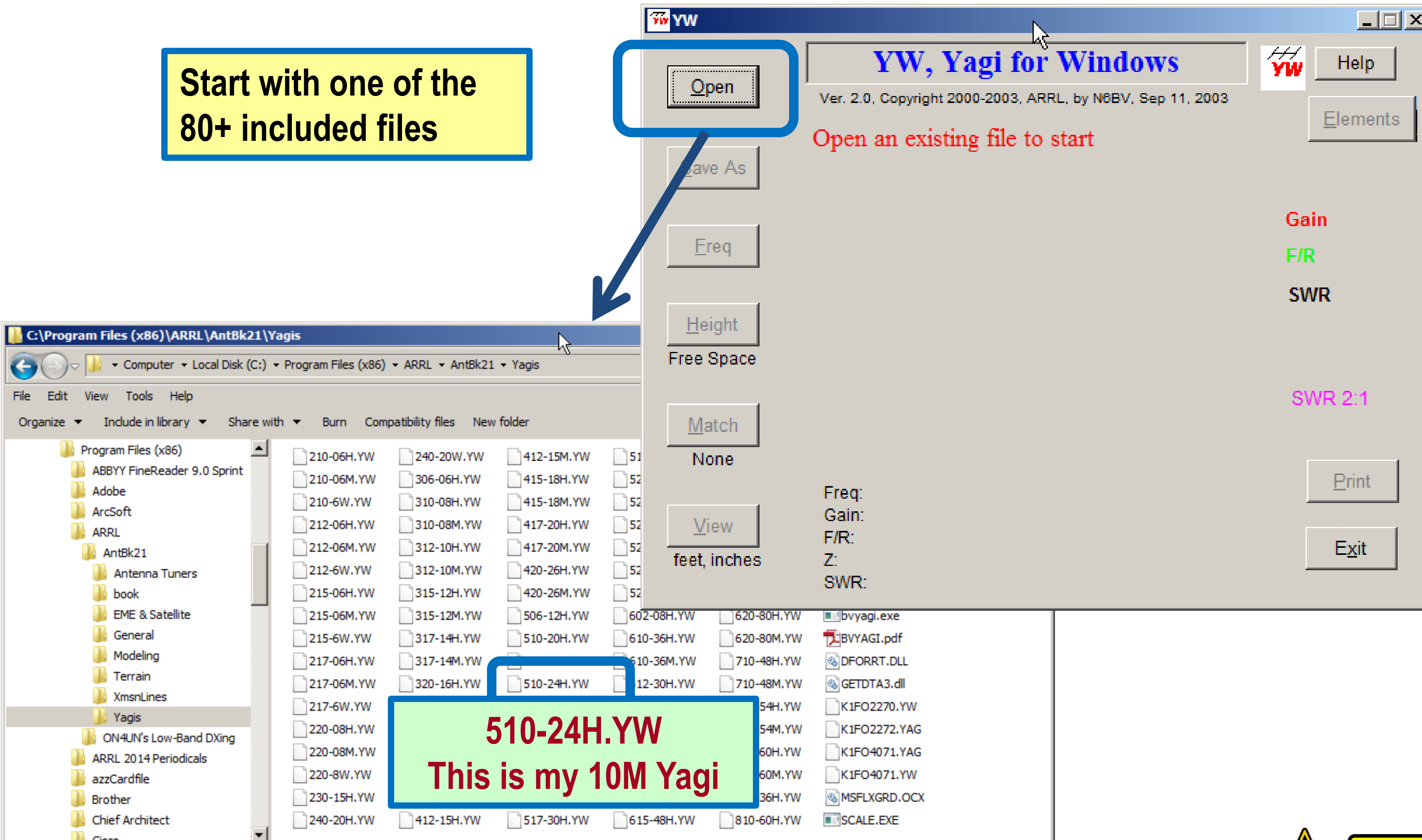
YW Example: 5el 10M yagi

Initial Screen

Click *OPEN*

YW Example: 5el 10M yagi

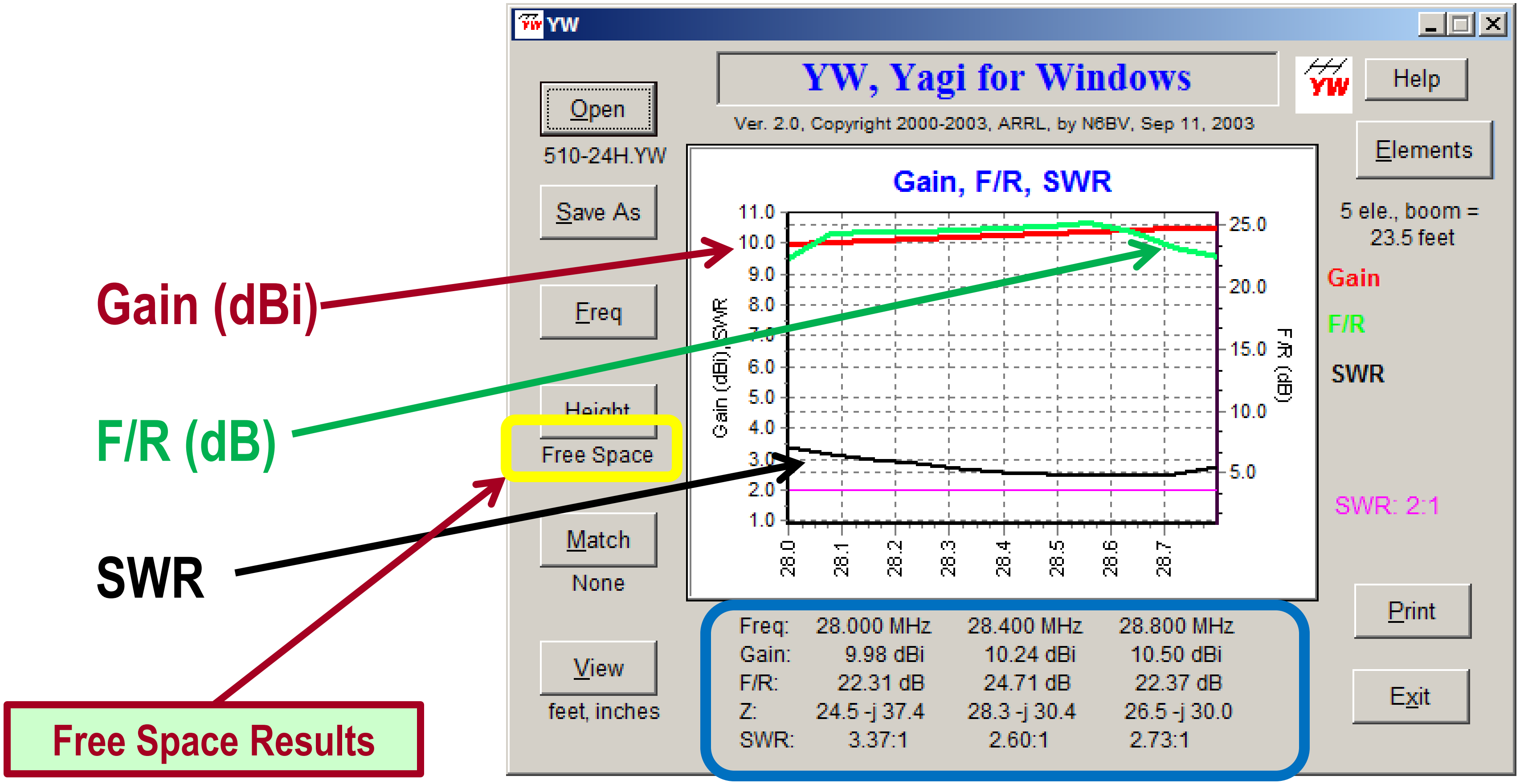
Start with one of the 80+ included files



510-24H.YW
This is my 10M Yagi

INDEXA

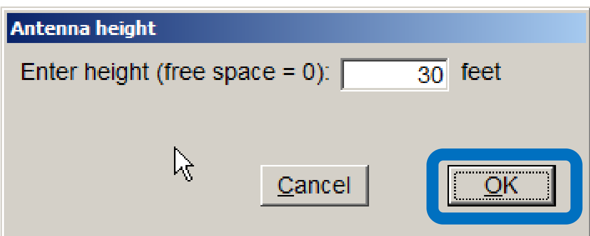
YW Example: 5el 10M yagi

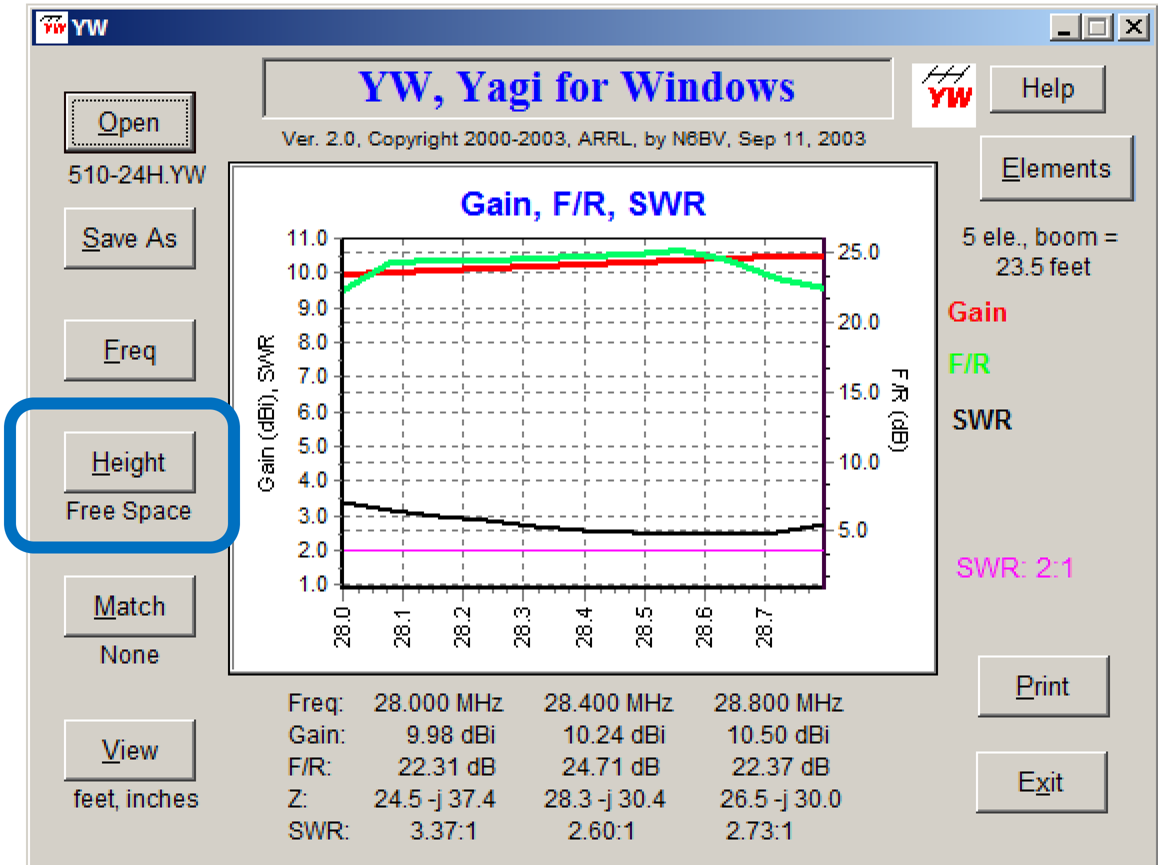


Free Space, unmatched

YW Example: 5el 10M yagi

Enter Yagi height

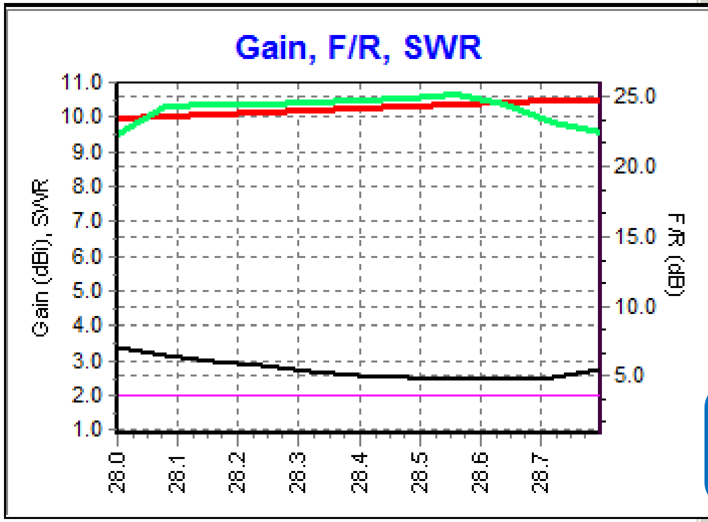




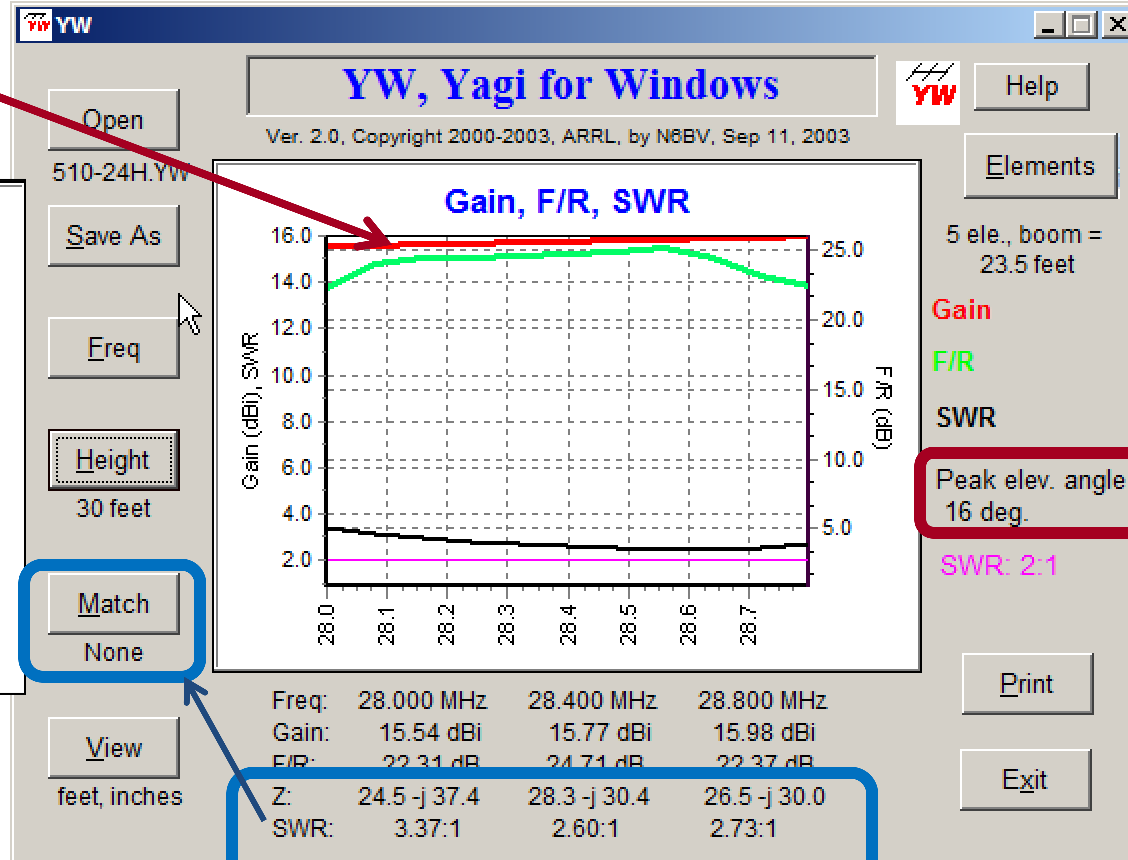
YW Example: 5el 10M yagi

30’ High, unmatched

Note that Gain has increased, @ 16° elevation angle.



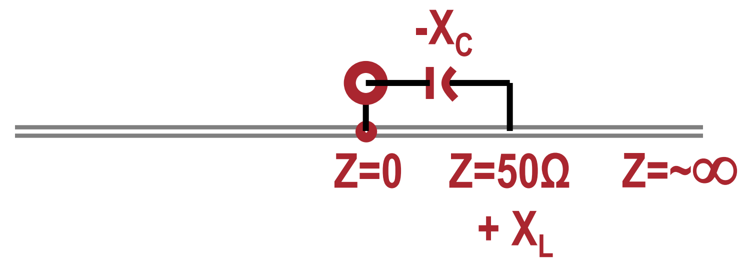
Free Space

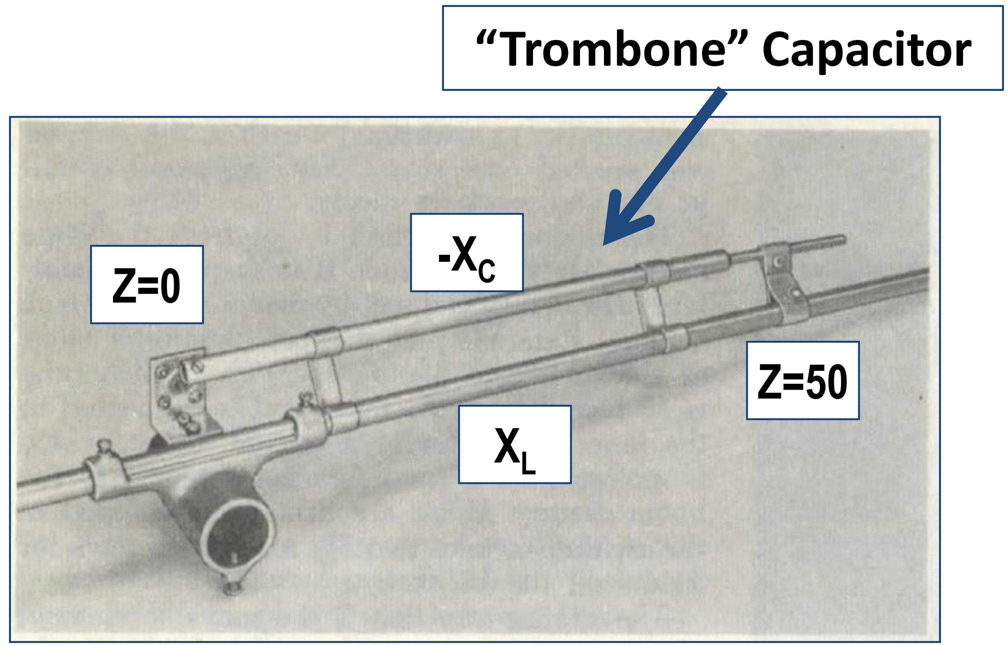


SWR unchanged - Now we need to match it

Choose a Gamma Match

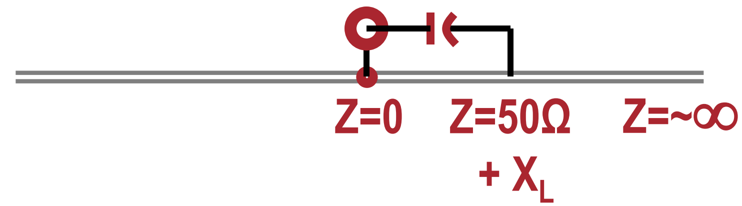
YW Example: What is a GAMMA Match?

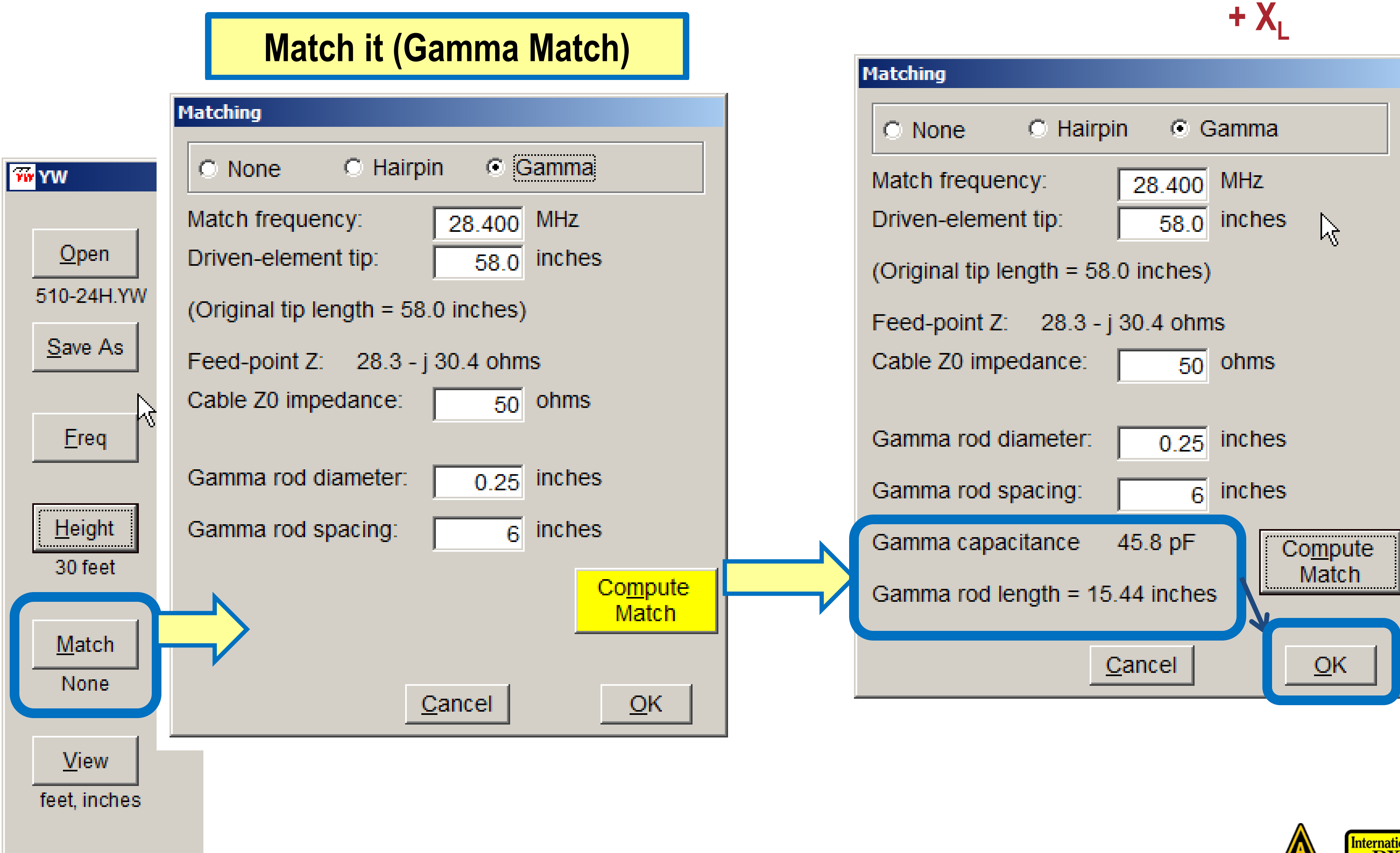




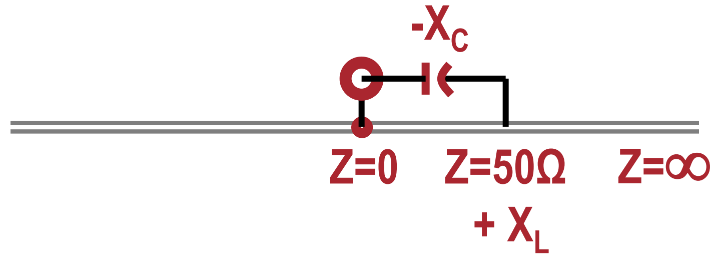
ARRL V.H.F. Manual © 1965

YW Example: 5el 10M yagi

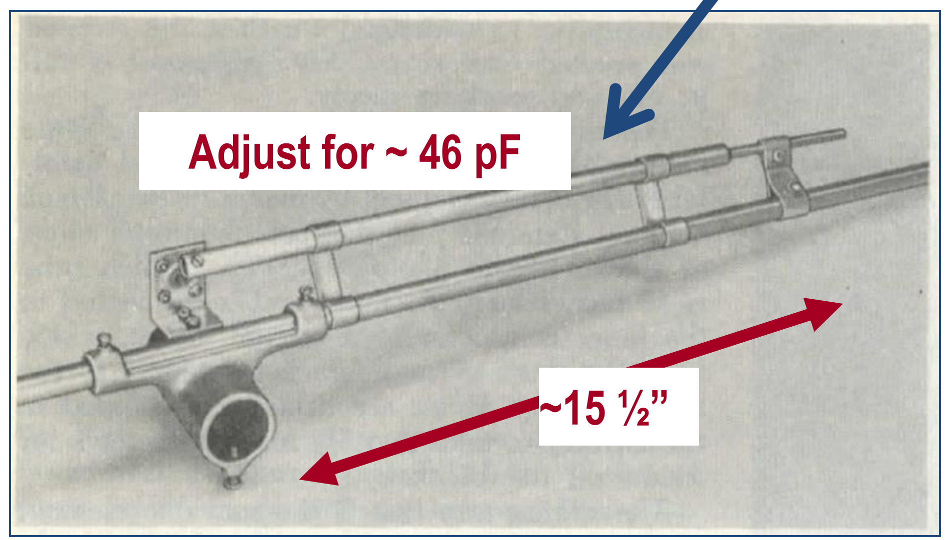




YW Example: What is a GAMMA Match?



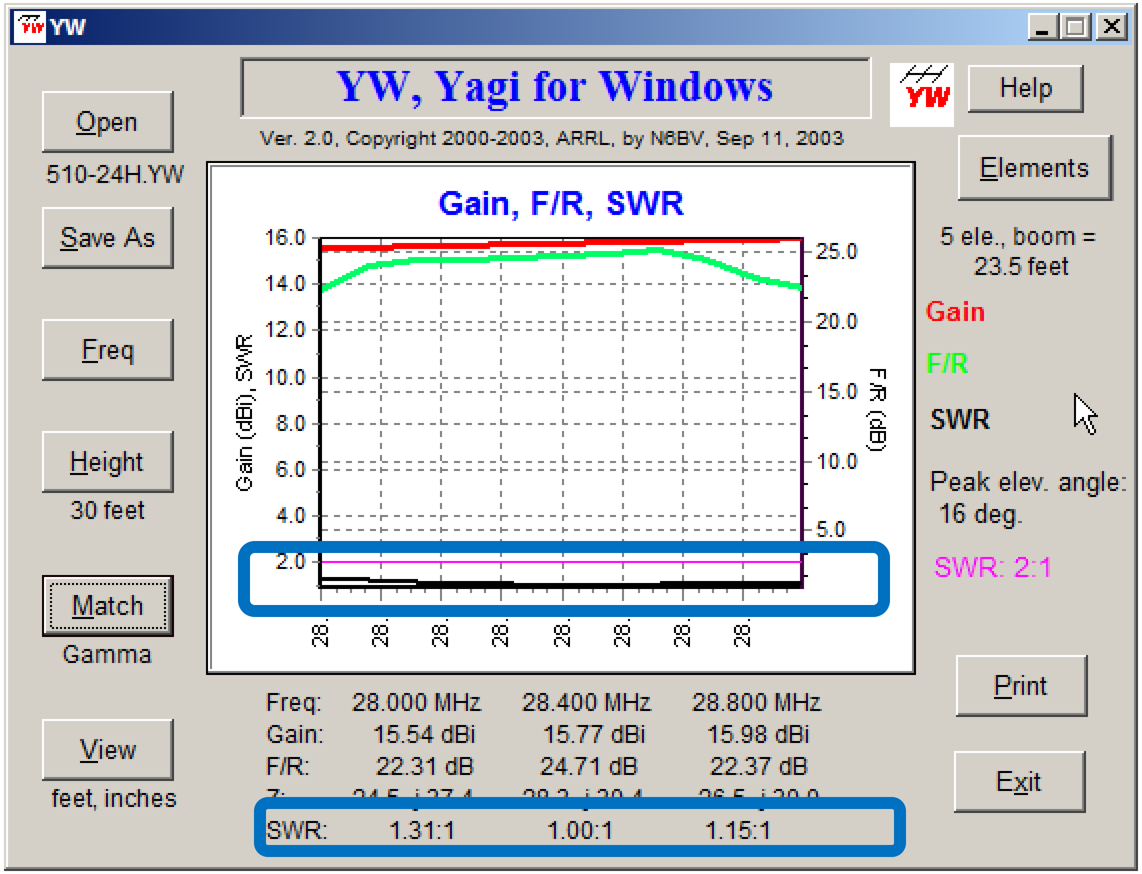
“Trombone” Capacitor



ARRL V.H.F. Manual © 1965

YW Example: 5el 10M yagi

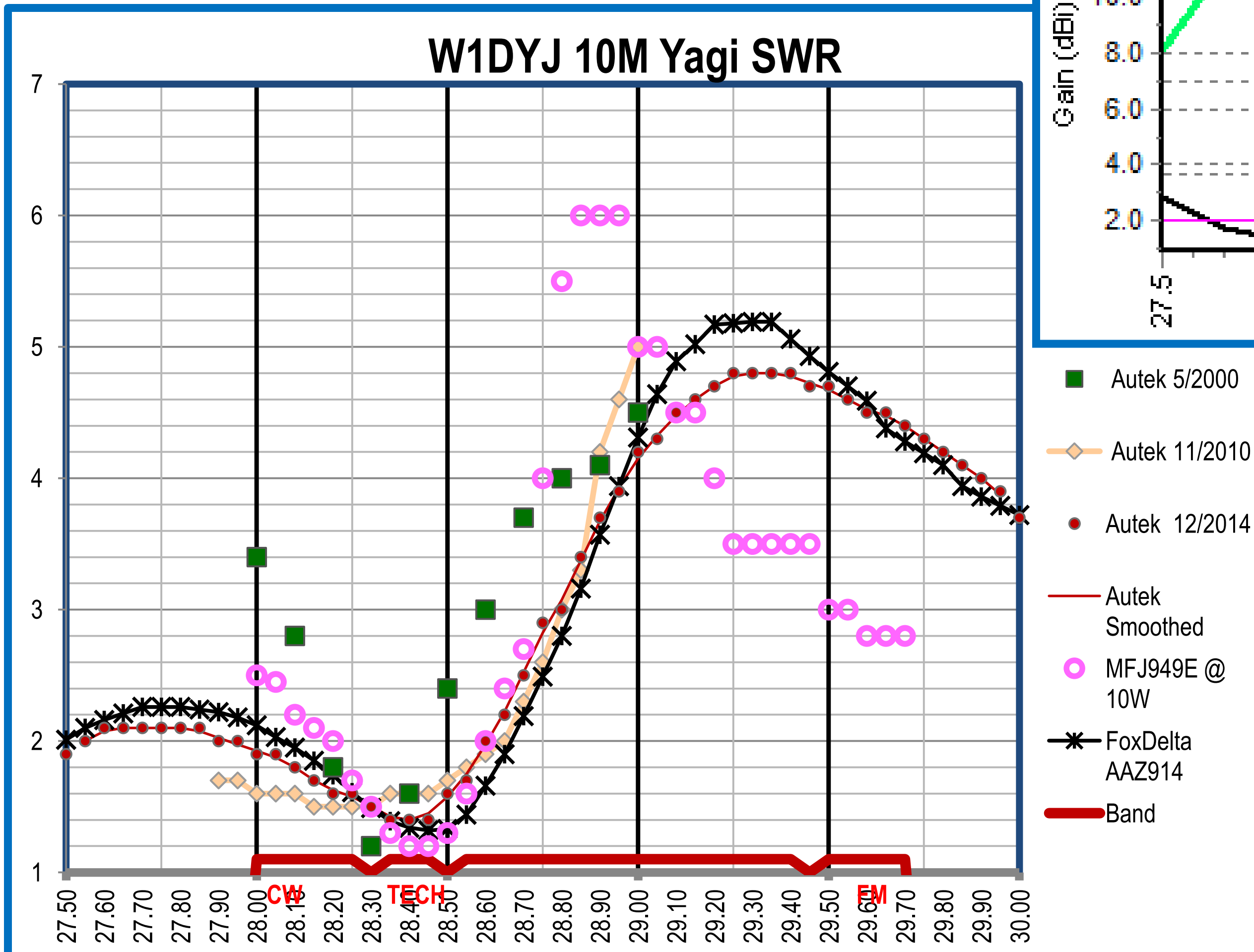
30' high, matched

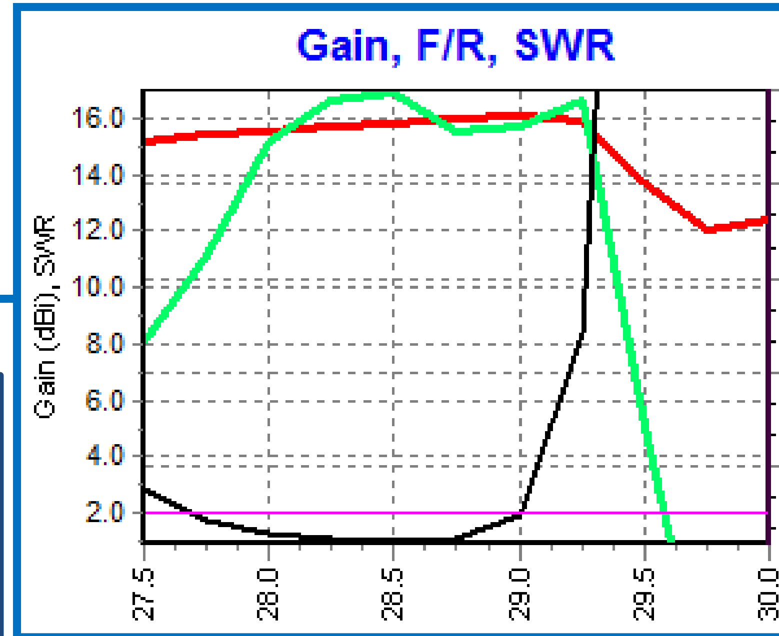


SWR is "tamed".

YW Example: 5el 10M yagi

Compare to Actuals





27.5 MHz. → 30MHz.

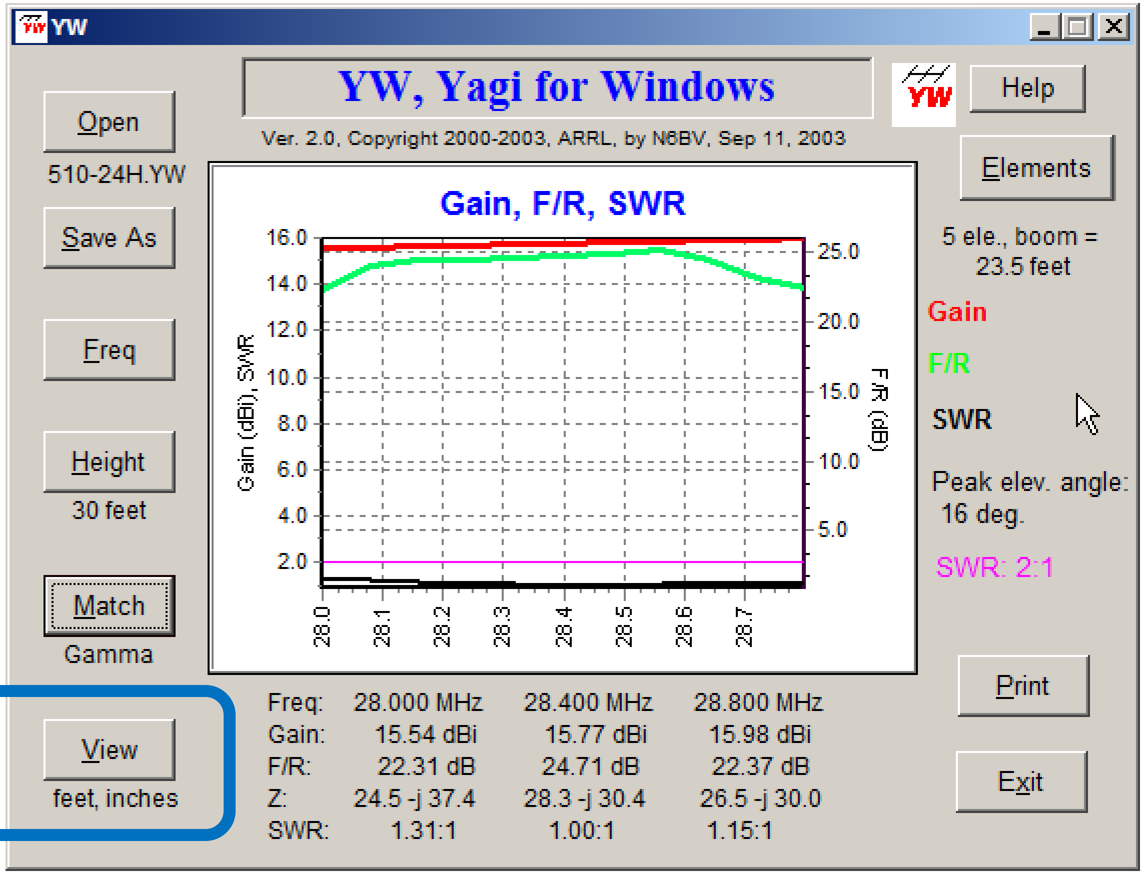
INDEXA

YW Example: 5el 10M yagi

SWR is NOT the only criteria!

Antennas are PASSIVE: they generate "gain" by redirecting the RF.

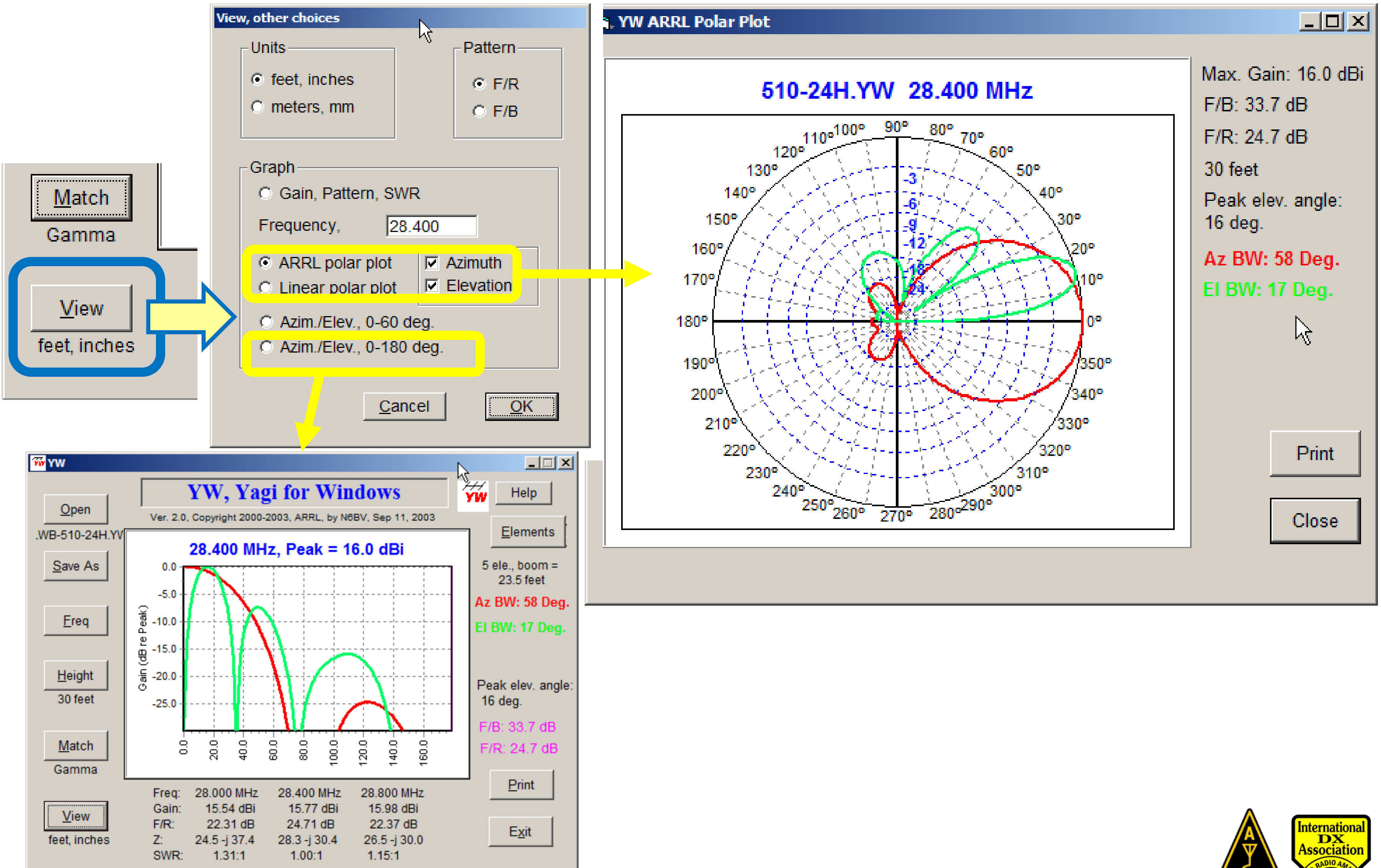
WHERE is the RF going?!



Plot the patterns

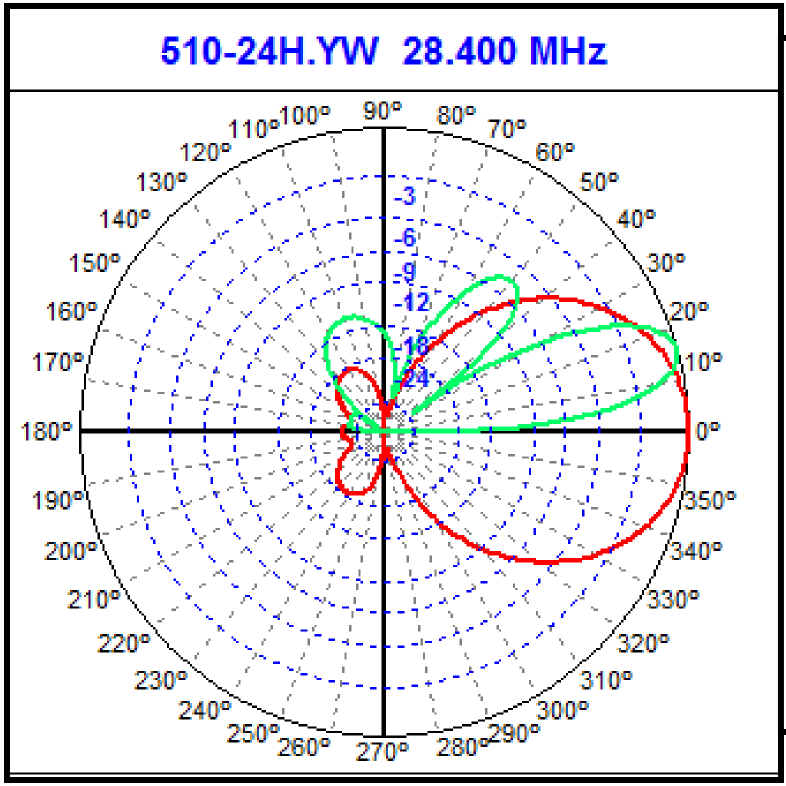
YW Example: 5el 10M yagi

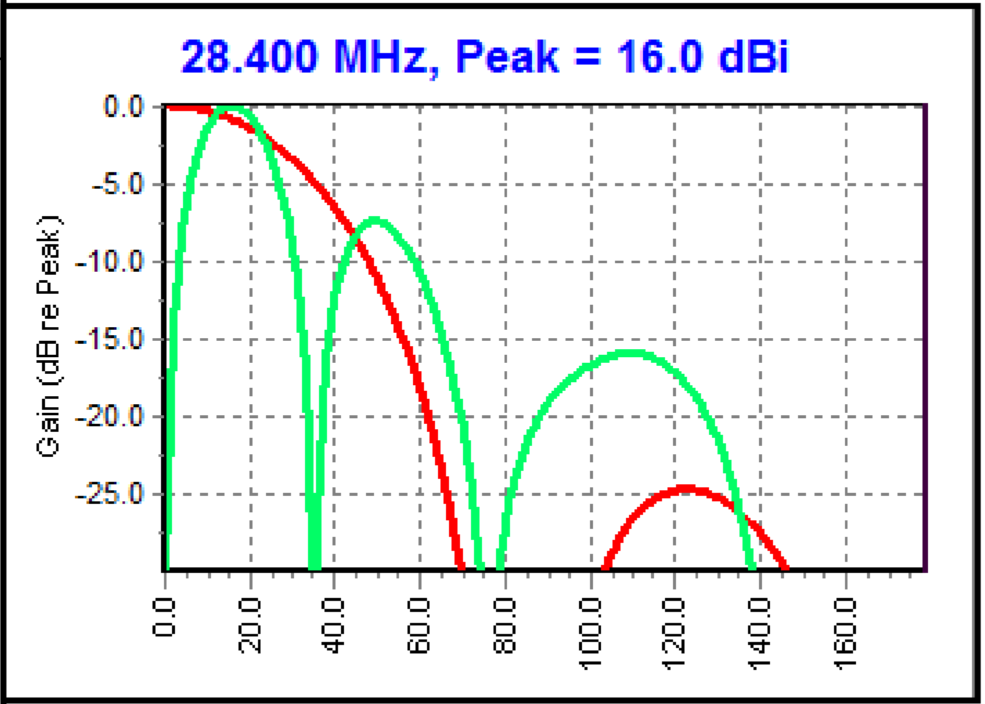
30' high, matched



YW Example: 5el 10M yagi

30' high, matched





POLAR Plot

Same Data

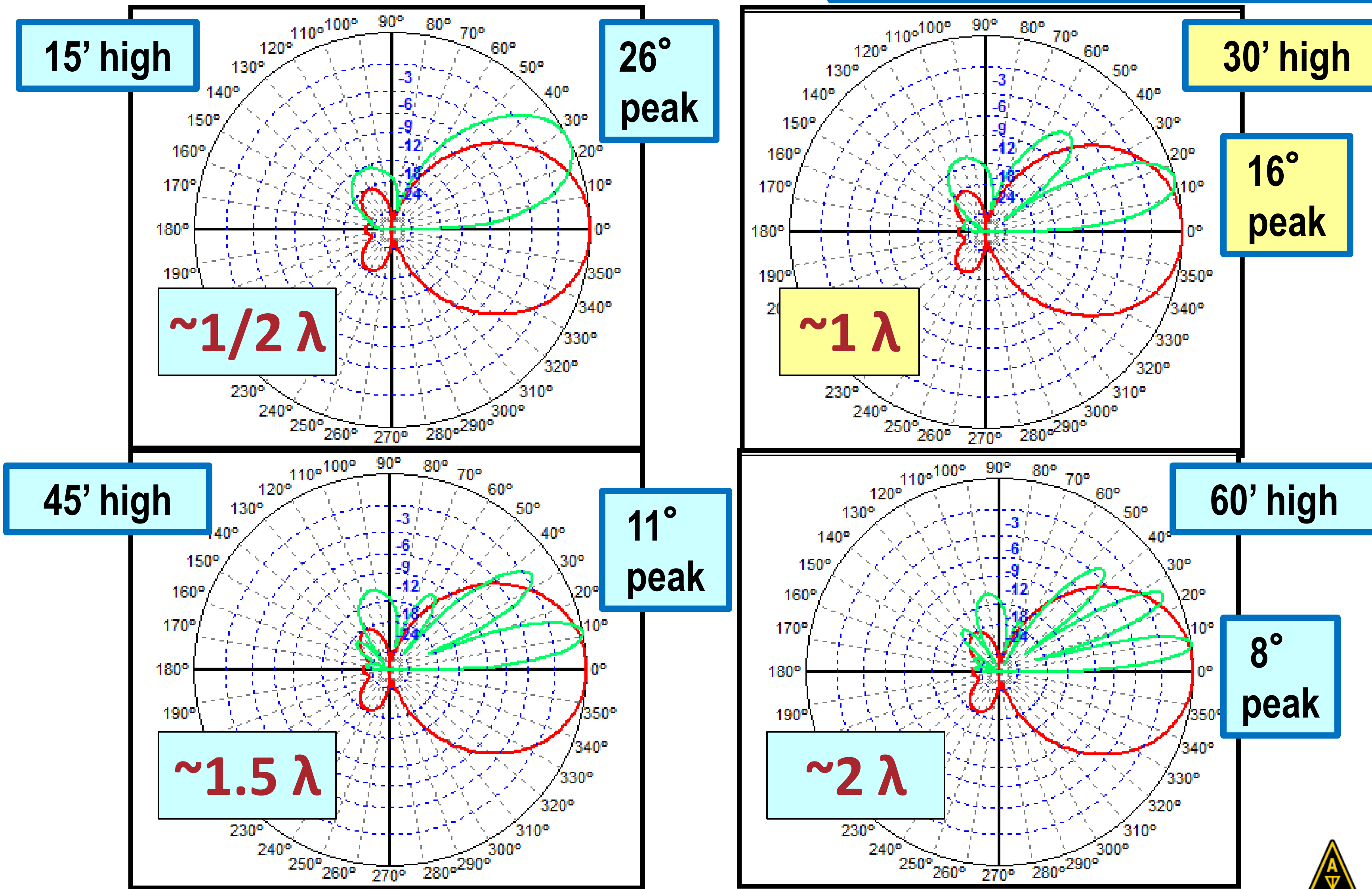
CARTESIAN Plot

Elevation

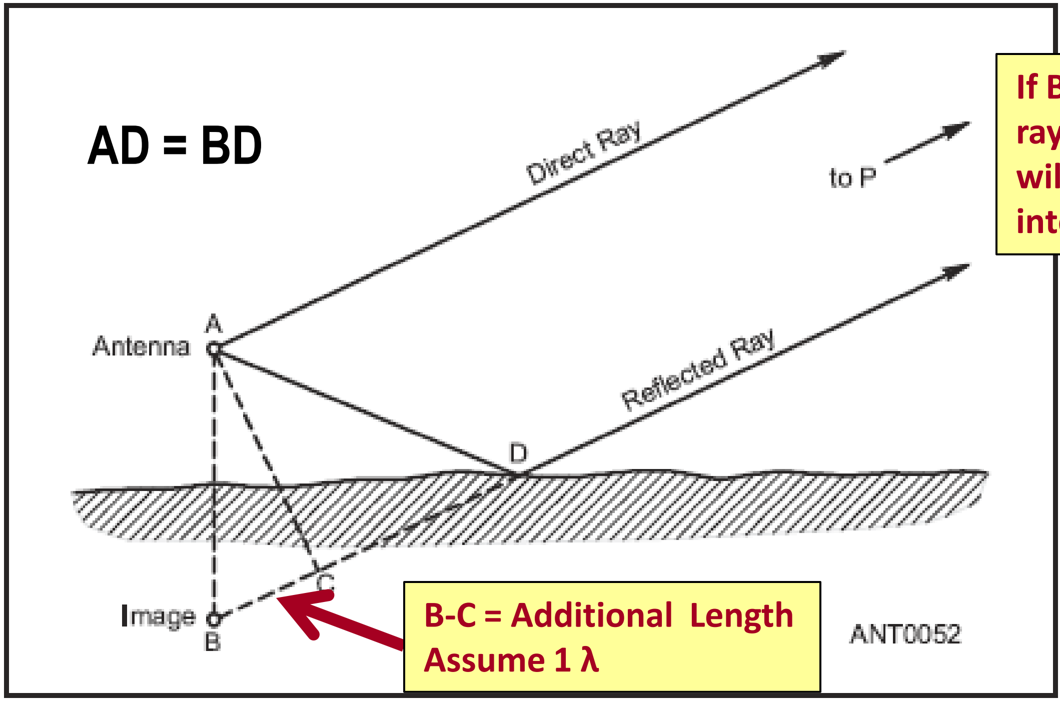
Azimuth

YW Example: 5el 10M yagi

Idealized pattern at different heights



YW Example:
What's really going on with different heights?



If B-C = 1 λ, then the two rays are in phase, there will be constructive interference >> a peak

B-C = Additional Length
Assume 1 λ

Figure 3.38 — At any distant point, P, the field strength will be the vector sum of the direct ray and the reflected ray. The reflected ray travels farther than the direct ray by the distance BC, where the reflected ray is considered to originate at the image antenna.

YW Example:
What's really going on with different heights?

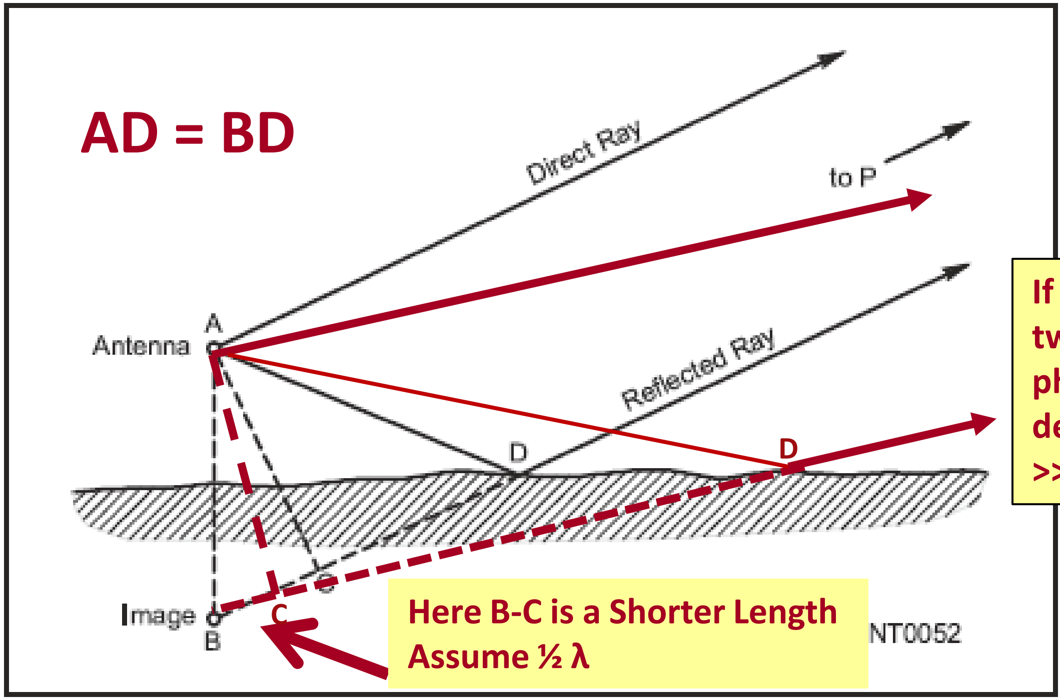
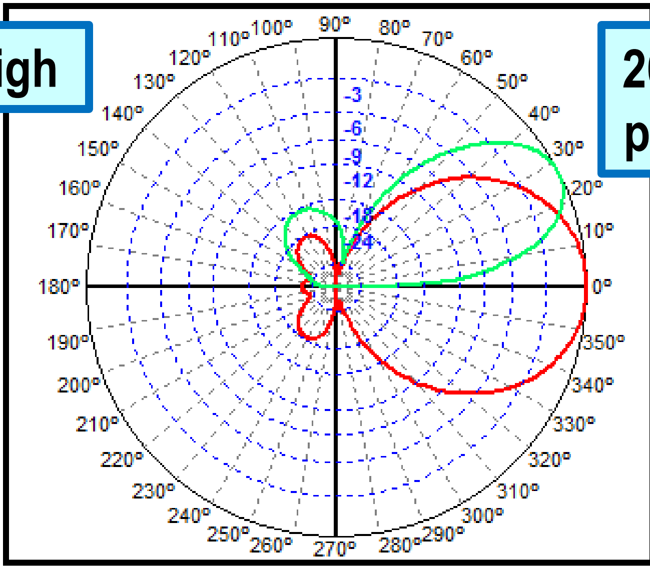


Figure 3.38 — At any distant point, P, the field strength will be the vector sum of the direct ray and the reflected ray. The reflected ray travels farther than the direct ray by the distance BC, where the reflected ray is considered to originate at the image antenna.

If B-C = 1/2 λ, then the two rays are out of phase, there will be destructive interference >> a null

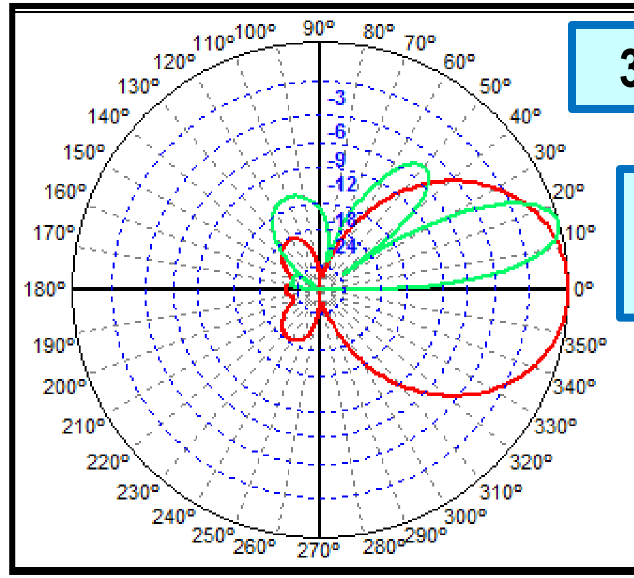
YW Example: 5el 10M yagi

15’ high

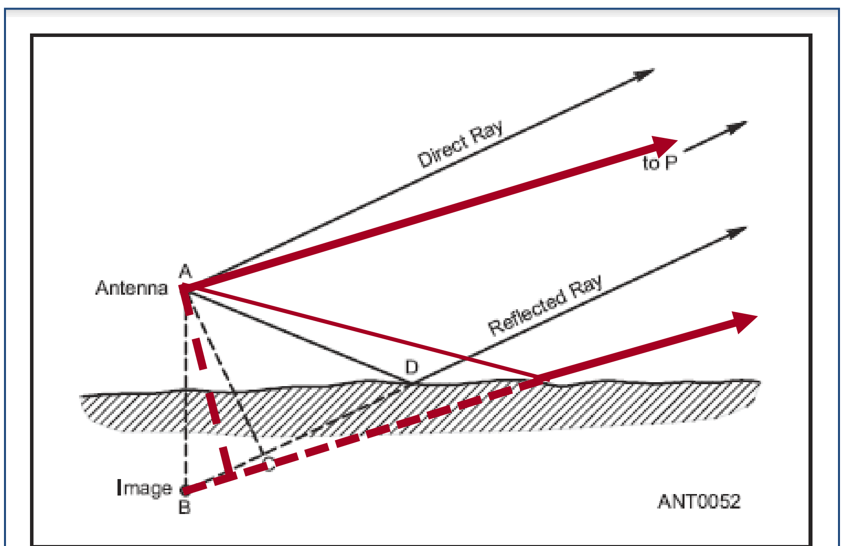


26° peak

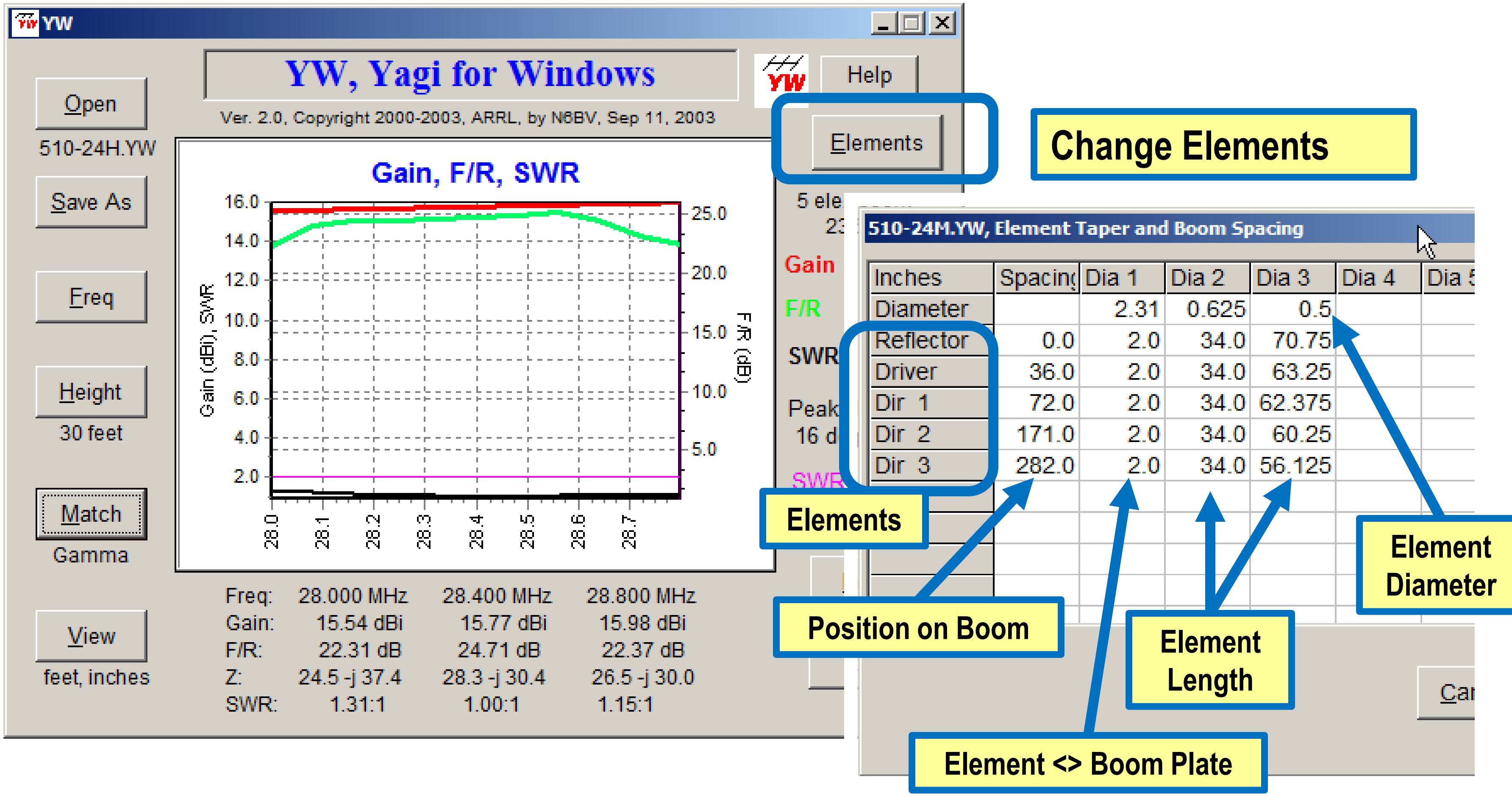
30’ high



16° peak



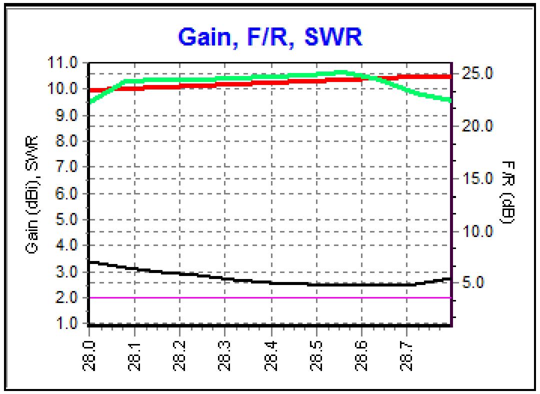
YW Example: 5el 10M yagi → Redesign



YW does not have the "automatic" optimization routine that YO had.

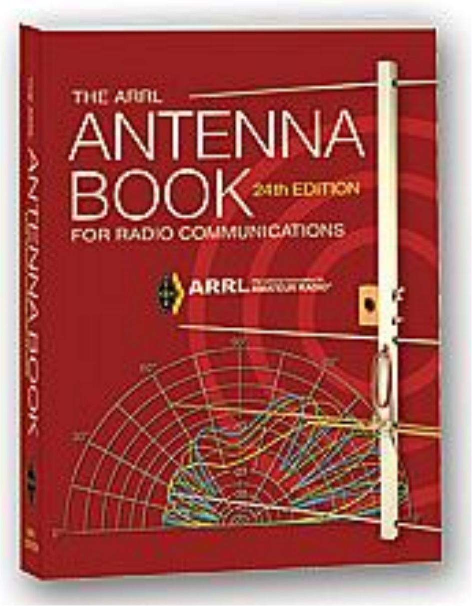
YW – Yagi for Windows

Helps you understand/design your monoband Yagis,
but – assumes flat, perfect ground



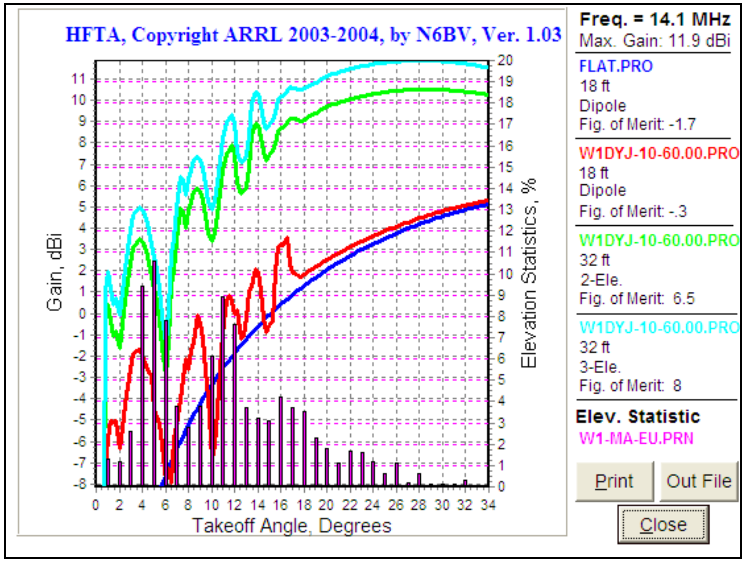
Antenna Modeling ~ Agenda

- **Part II**
- TLW
- YW
- **HFTA**



HFTA – High Frequency Terrain Assessment

R. Dean Straw ~ N6BV ©ARRL



<u>Purpose</u>:

Assesses the effect of uneven local terrain on the transmission and reception of HF signals.

HFTA – High Frequency Terrain Assessment

Agenda

- Overview of HFTA
- What are Elevation Statistics?
- What are Terrain Files?
- Using HFTA

HFTA – High Frequency Terrain Assessment

What problem does HFTA attempt to solve?

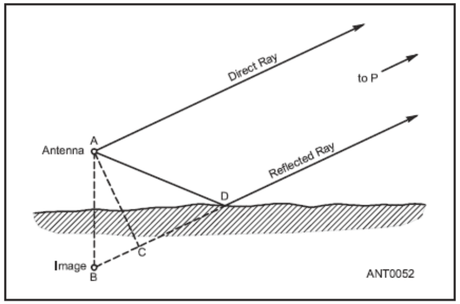


Figure 3.38 — At any distant point, P, the field strength will be the vector sum of the direct ray and the reflected ray. The reflected ray travels farther than the direct ray by the distance BC, where the reflected ray is considered to originate at the image antenna.

YW assumes flat ground

HFTA – High Frequency Terrain Assessment

What problem does HFTA attempt to solve?

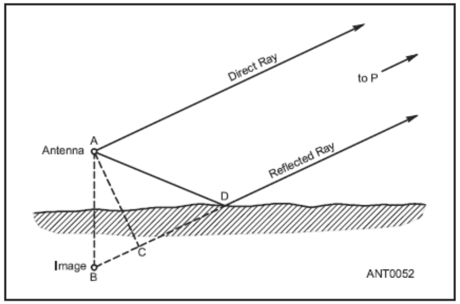


Figure 3.38 — At any distant point, P, the field strength will be the vector sum of the direct ray and the reflected ray. The reflected ray travels farther than the direct ray by the distance BC, where the reflected ray is considered to originate at the image antenna.

YW assumes flat ground

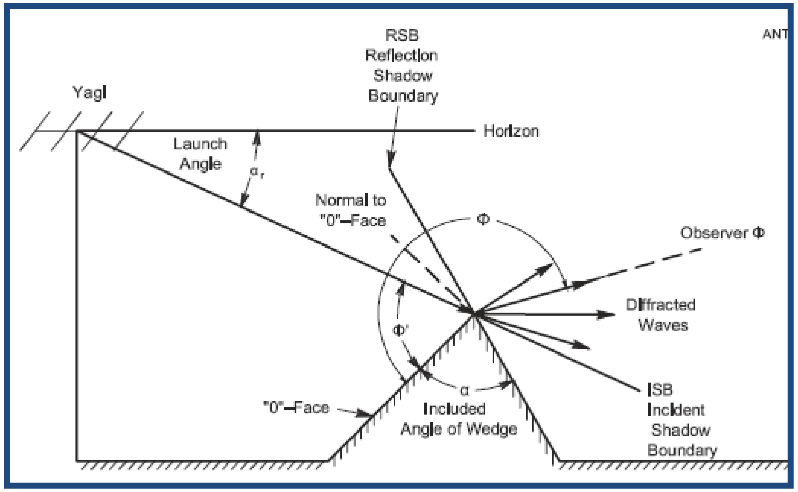


Fig 14.29
©ARRL Antenna Book

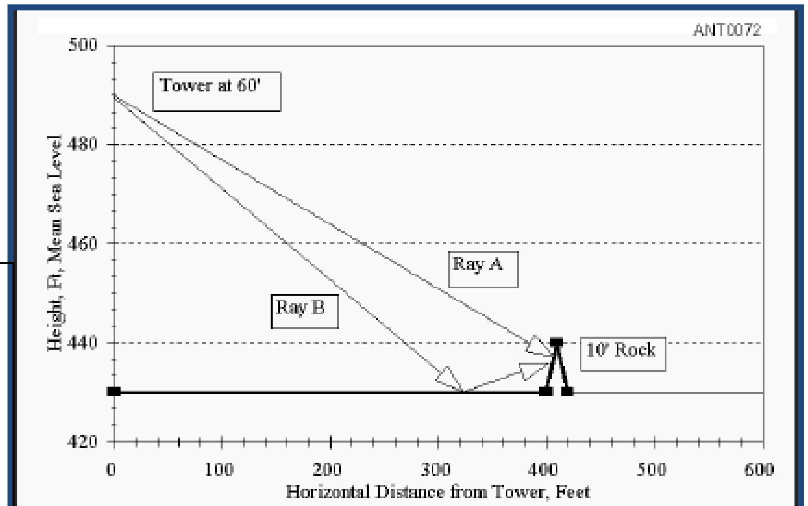


Fig 14.30
©ARRL Antenna Book

HFTA takes into account diffraction and local terrain

HFTA – High Frequency Terrain Assessment

Attributes

- HFTA is a ray-tracing program designed to evaluate the effect of foreground terrain on the elevation pattern of up to four multi-element HF monoband Yagis in a stack.
- Models horizontally polarized Yagis, and "works" with simple horizontal dipoles
- Takes into account the effects of Fresnel horizontal ground-reflection
- Takes into account diffraction
- Includes *Elevation Statistics Files* ~ the angle the RF comes from
- Latest version of earlier "YT" program

HFTA – High Frequency Terrain Assessment

Limitations

- Does not work with vertical polarization
- Free-space gain assumed for default Yagis;
  example: model is 8.5 dBi
- Does not take into account mutual impedance ground effects

Additional Requirement

- Requires a *Terrain Data File*

HFTA – High Frequency Terrain Assessment

Agenda

- Overview of HFTA
- What are Elevation Statistics?
- What are Terrain Files?
- Using HFTA

Elevation Statistics

Fundamentally → Where is the DX?

At what angle (from the horizon) does the RF arrive?

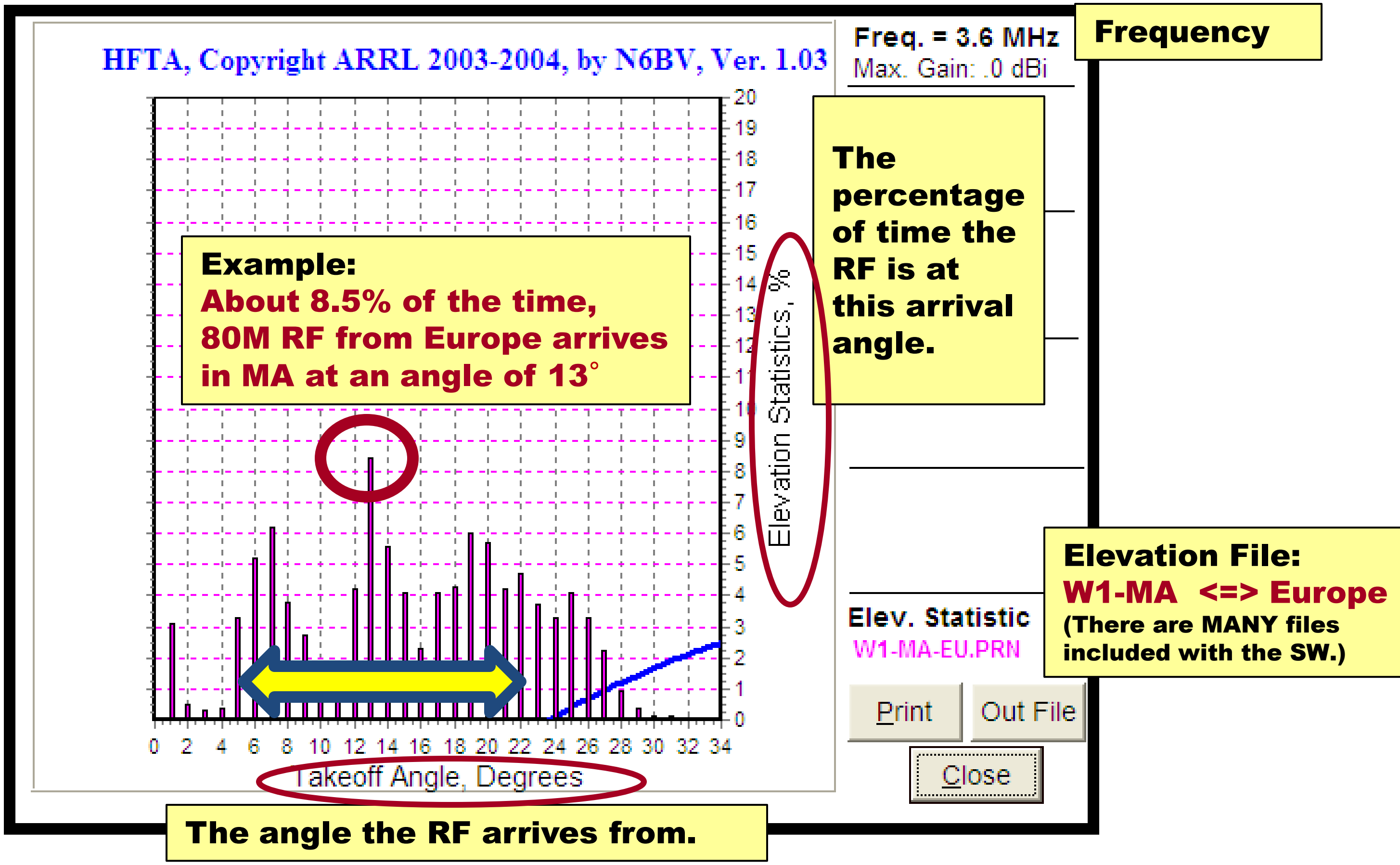
We must always remember this simple truth:

The ionosphere controls the elevation angle of the received RF at your location, not your antenna!

HFTA ~ Elevation Statistics Example: 80M: MA →EU

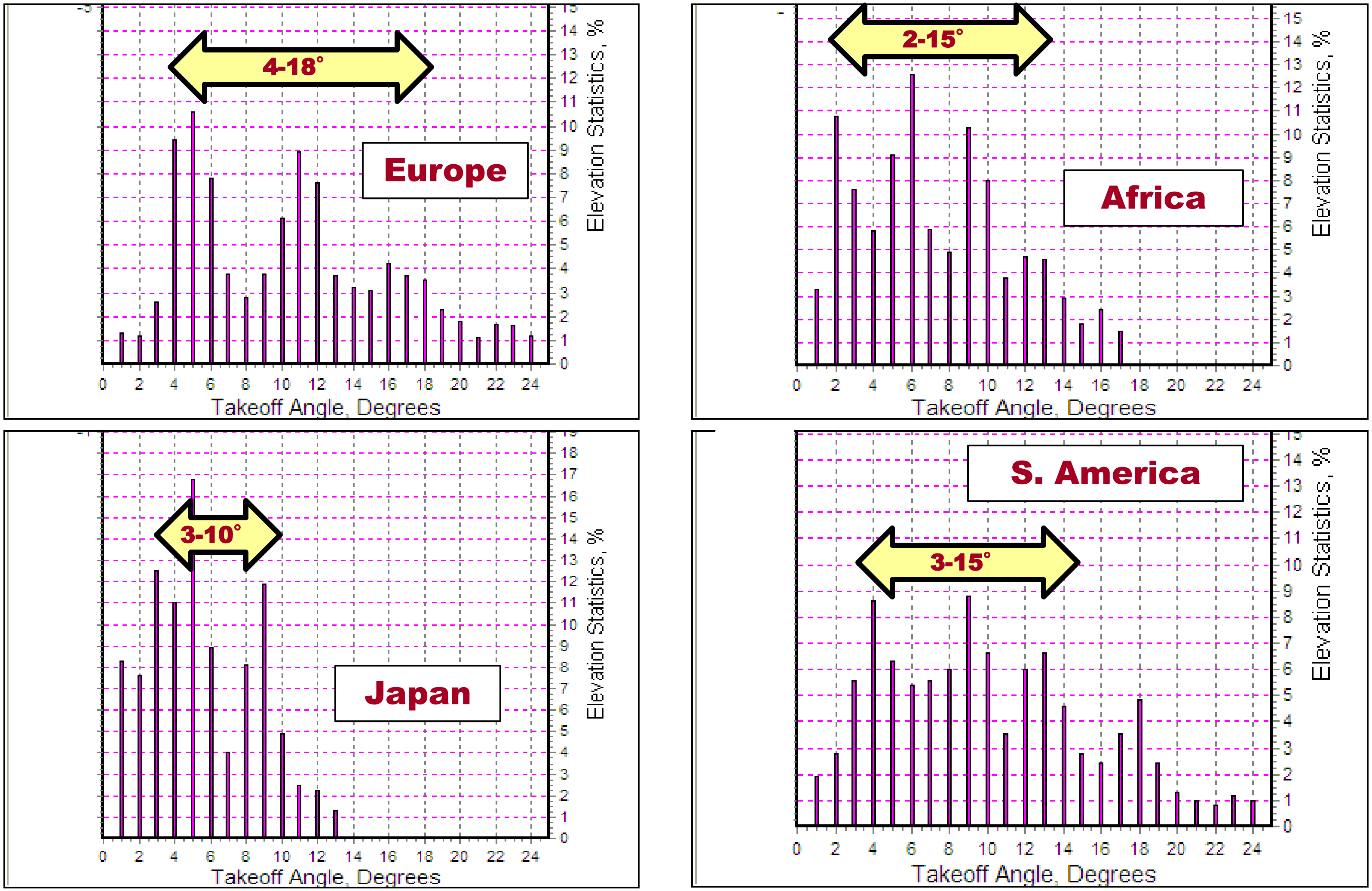
Note:
This data is an overall average of all time; i.e. for any time, any day, any season, any part of the 11-year sunspot cycle.

Specific propagation "today" will be very limited in angle.



Conclusion, <u>from this one graph</u>:
About 80% of the time, European 80M RF arrives at arrival angles between 5 → 22°

HFTA ~ Elevation Statistics Example: 20M in MA



HFTA – High Frequency Terrain Assessment

Agenda

- Overview of HFTA
- What are Elevation Statistics?
- What are Terrain Files?
- Using HFTA

Terrain File → Unique to your location

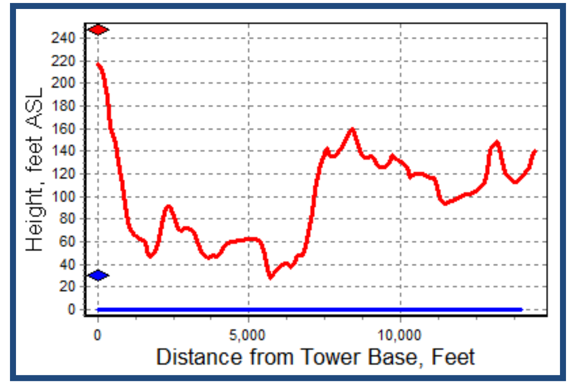
ASCII files that describe the terrain in all 360 degree directions from your antenna site.

AZI-0.00.PRO - Notepad

File Edit Format View Help

meters

0	66.2
30	63.1
60	60.1
90	58.5
120	57.4
150	54.8
180	50.9
210	45.5
240	43.3
270	43.3
300	44.0
330	46.4
360	48.8
390	50.1
420	49.5
450	49.4
480	50.1
510	49.9
540	49.6
570	49.1
600	48.9
630	48.8
660	48.0
690	47.1
720	48.2
750	48.2
780	46.5
810	43.8
840	44.9
870	48.2
900	50.2



It used to be difficult to obtain:

- *Measure from a topo map*
- *Pull from xxx.gov web site*
- *Use MicoDEM to generate*

Now it's easy:

- ***https://paas.k6tu.net***
- ***Create a free account***
- ***>> HF Terrain Analysis***
  - ***At bottom under "Documentation"***
- ***Read directions & request a Profile***
- ***Download***

HFTA – High Frequency Terrain Assessment

Agenda

- Overview of HFTA
- What are **Elevation Statistics**?
- What are **Terrain Files**?
- **Using HFTA**

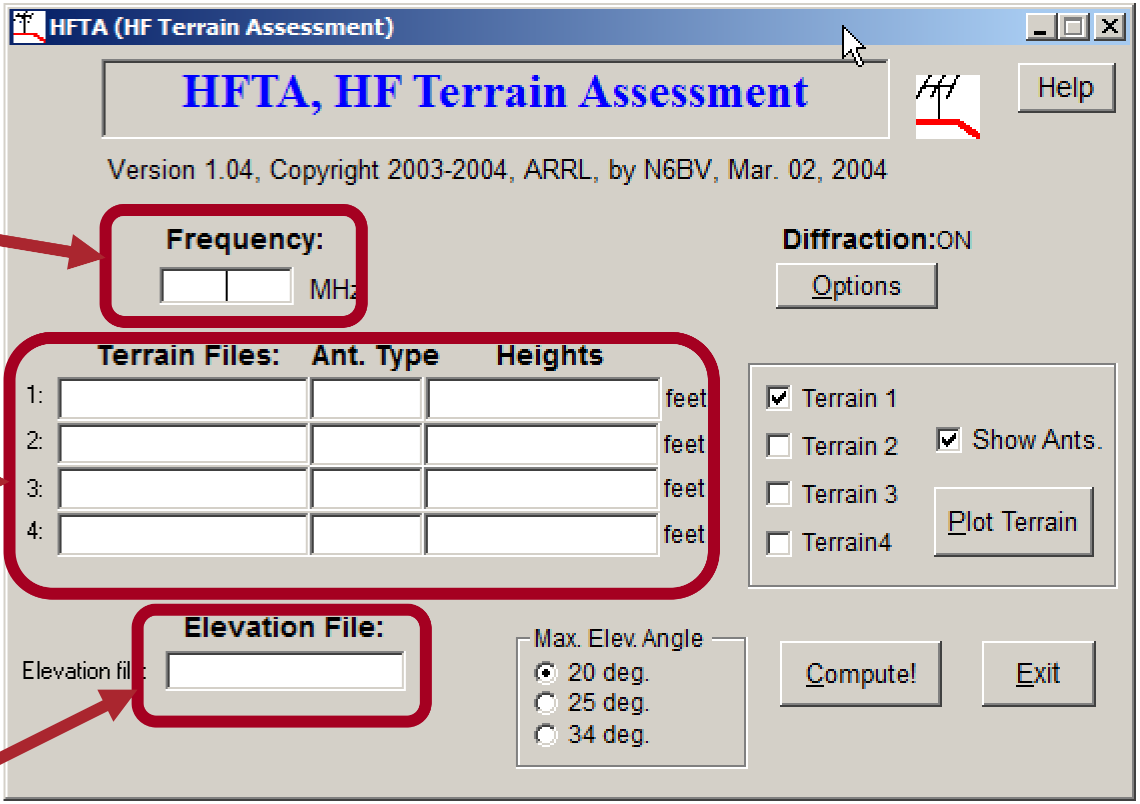
Using HFTA

Initial Screen

Enter the frequency of interest

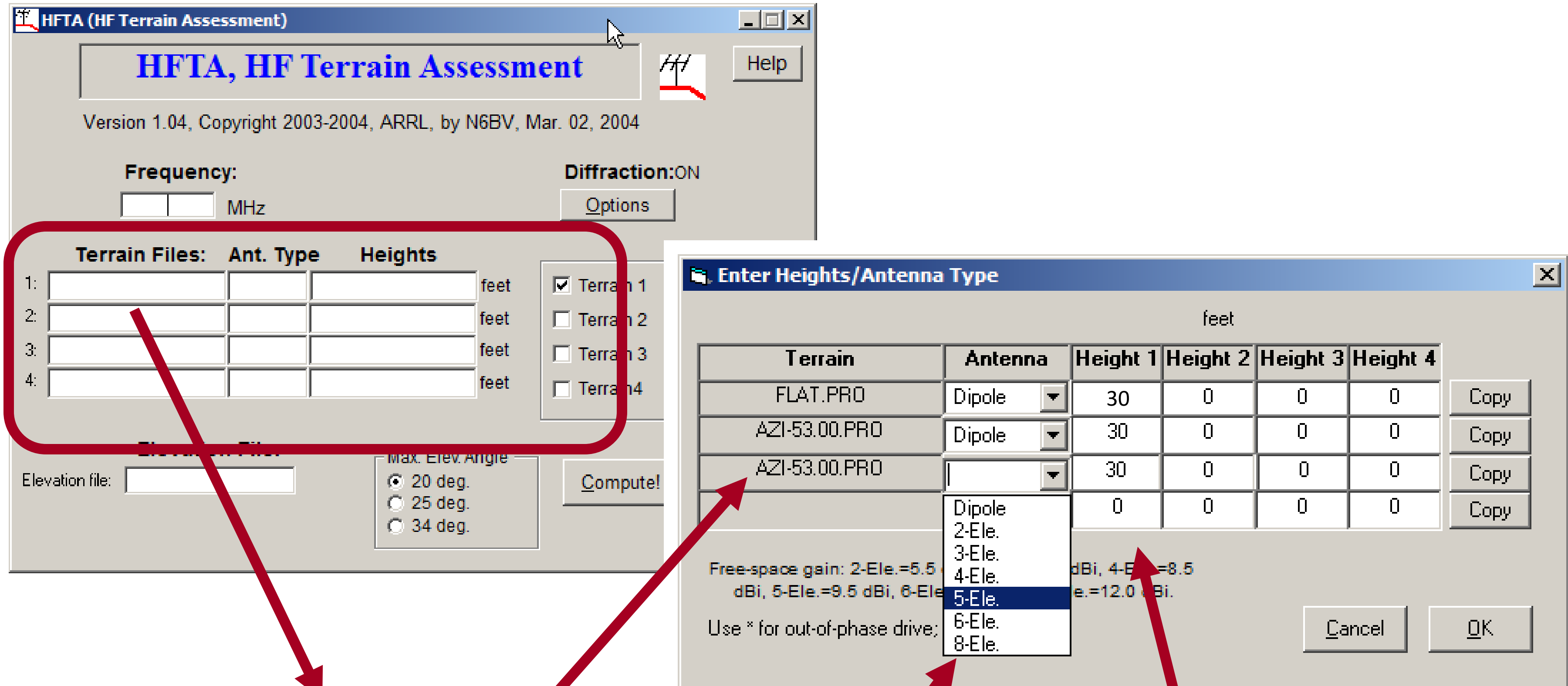
Select your **terrain file,** antennas, & heights

Choose one of HFTA's **elevation statistic** files



Using HFTA

Select Antenna Types & Heights



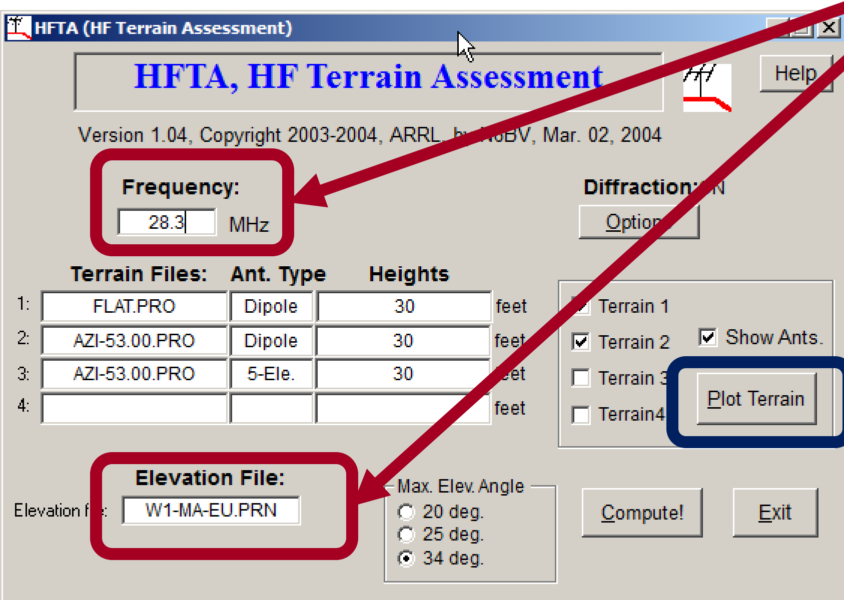
Clicking here opens up the folder with your terrain files

Then select the antenna type…

…and enter the height

Using HFTA

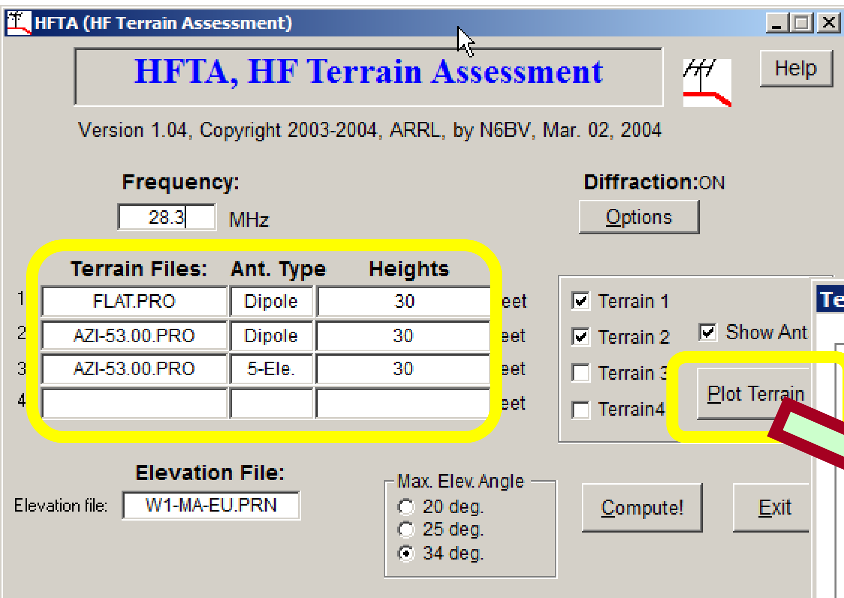
Enter Freq / Select Elevation File



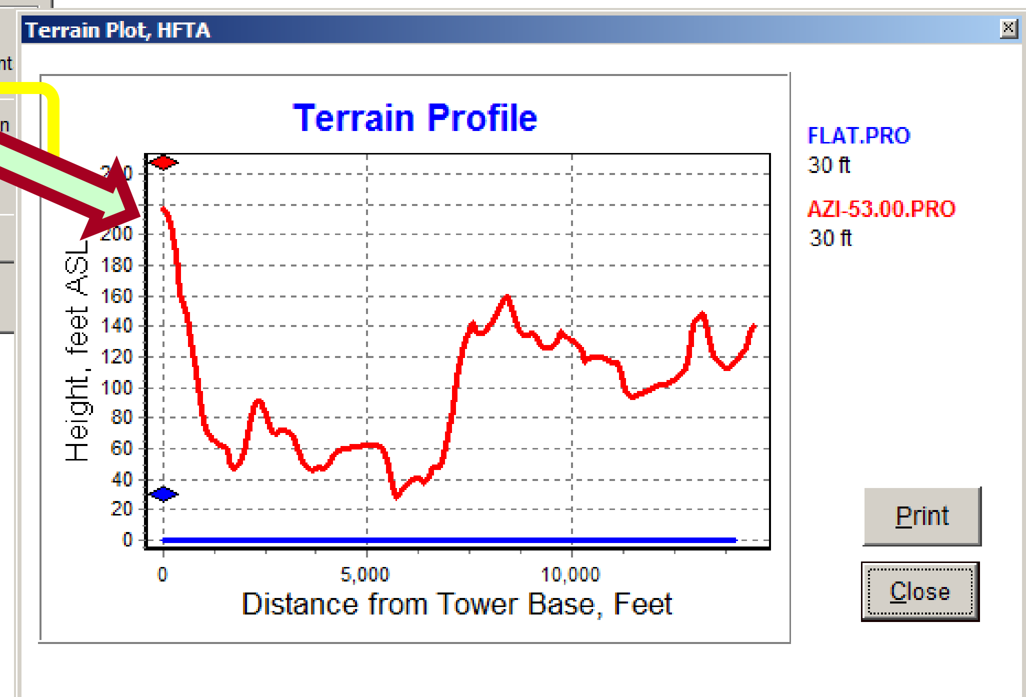
As a check, first click on ***Plot Terrain***

Elevation File:
W1-MA <=> Europe

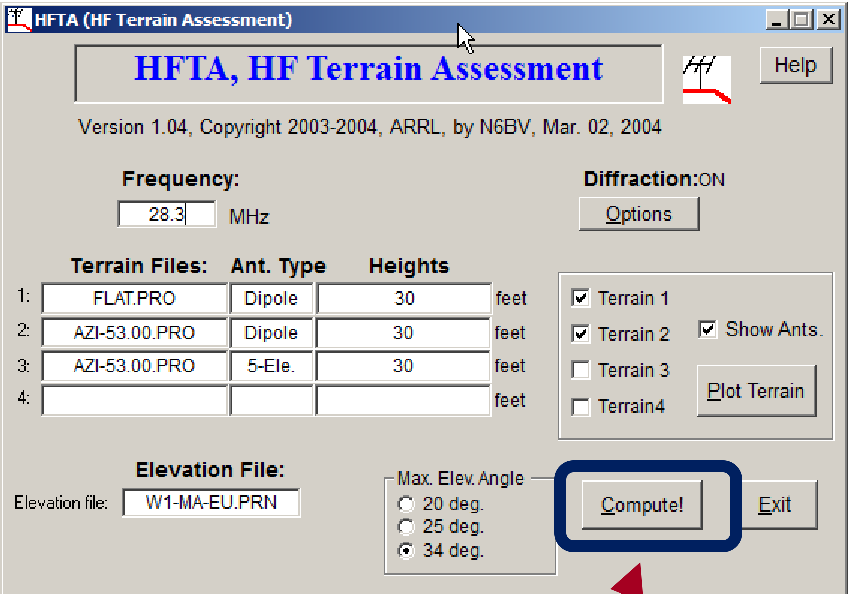
Using HFTA



Terrain from
W1DYJ @ 53° → England

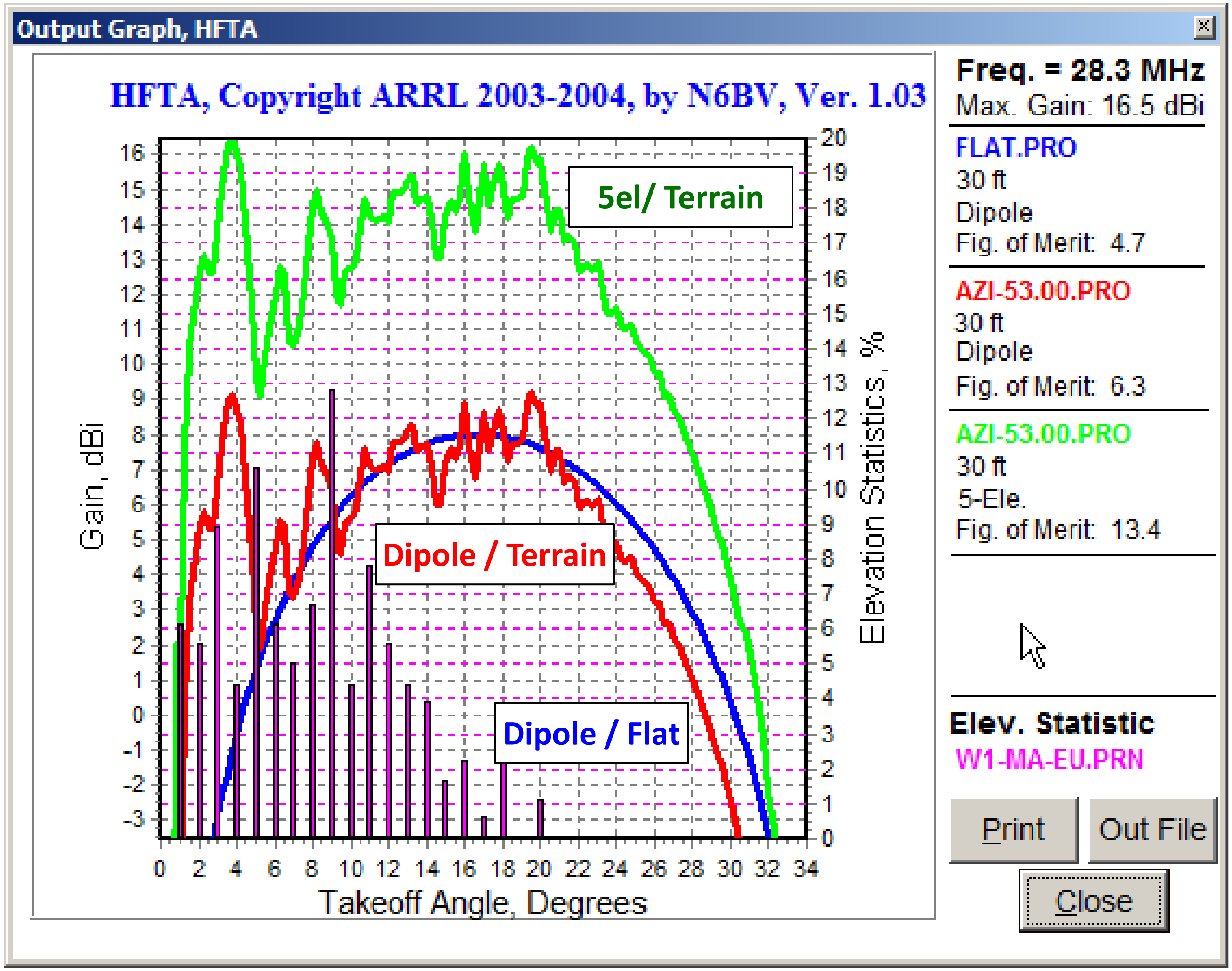


Using HFTA



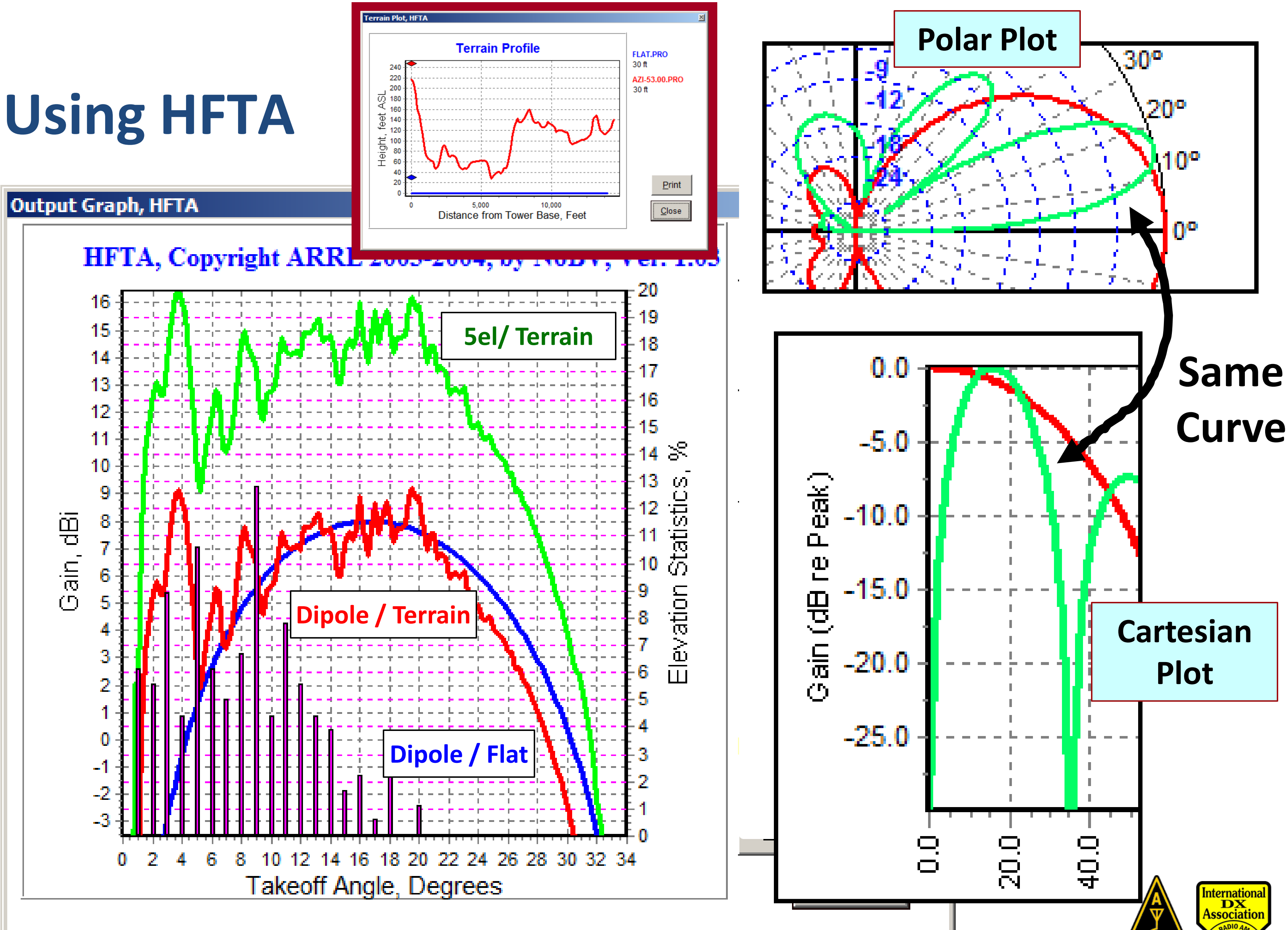
Then : Compute

Using HFTA



Output Graph, HFTA
HFTA, Copyright ARRL 2003-2004, by N6BV, Ver. 1.03
5el/ Terrain
Dipole / Terrain
Dipole / Flat
Gain, dBi
Elevation Statistics, %
Takeoff Angle, Degrees
Freq. = 28.3 MHz
Max. Gain: 16.5 dBi
FLAT.PRO
30 ft
Dipole
Fig. of Merit: 4.7
AZI-53.00.PRO
30 ft
Dipole
Fig. of Merit: 6.3
AZI-53.00.PRO
30 ft
5-Ele.
Fig. of Merit: 13.4
Elev. Statistic
W1-MA-EU.PRN
Print
Out File
Close

Using HFTA



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Using HFTA

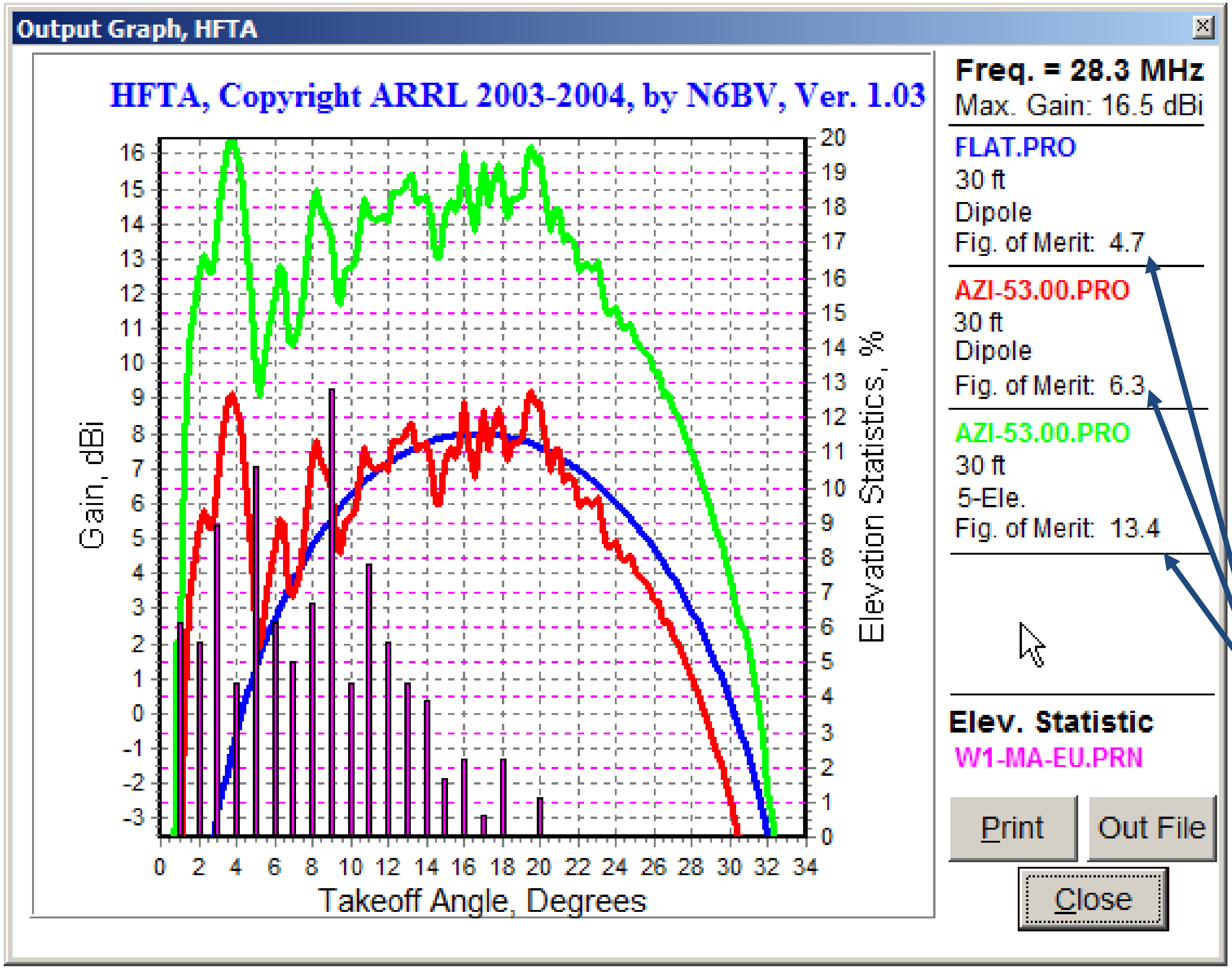
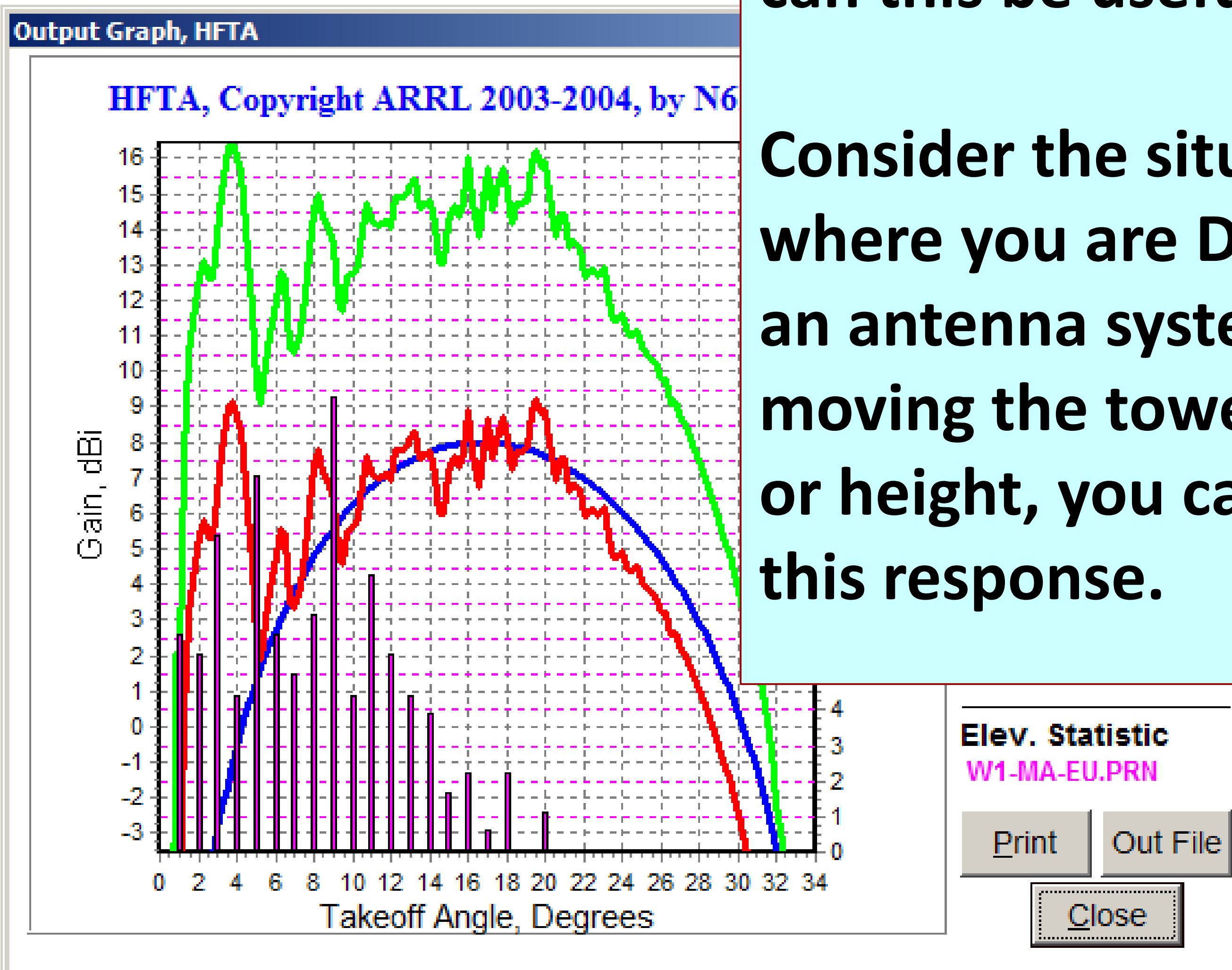


Figure of Merit (dB):
Weighted statistical average of gain times % open.

Using HFTA

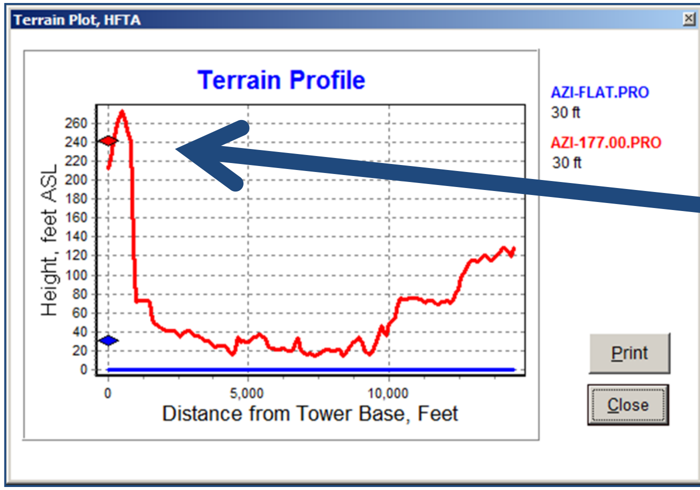


This is an analysis. How can this be useful?

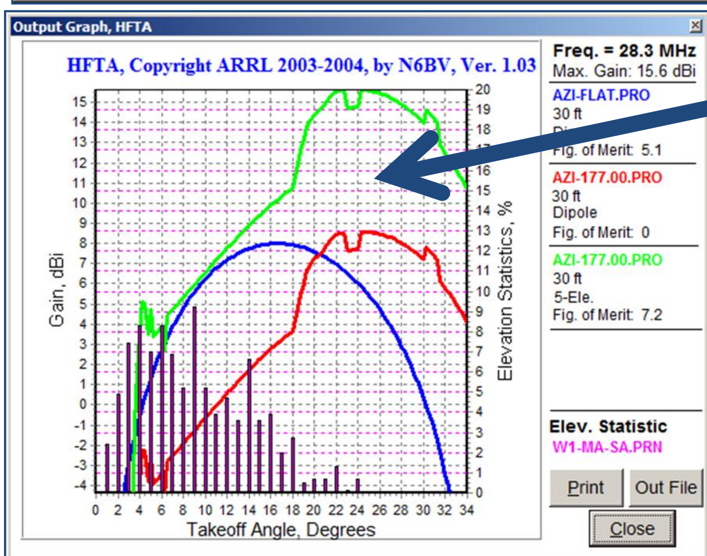
Consider the situation where you are DESIGNING an antenna system. By moving the tower location or height, you can optimize this response.

HFTA– HB 5 el 10M Yagi @ 33 BBHR

Example: How to improve my 10M yagi to South America



Note that my yagi is BEHIND the hill to my south…



…and as a result, the yagi's response is where there are no signals being receive from South America

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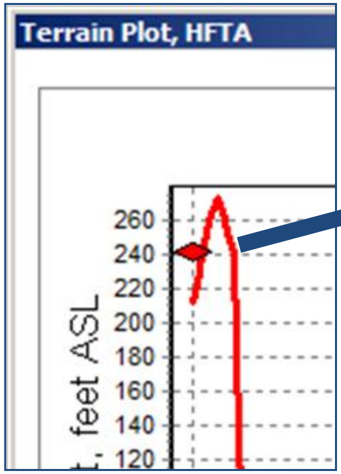
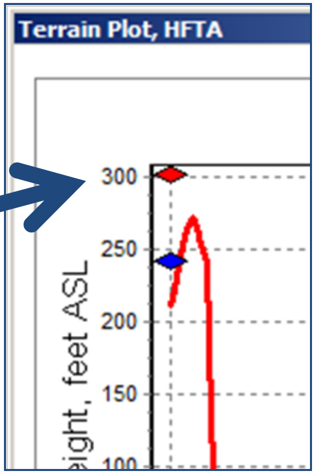
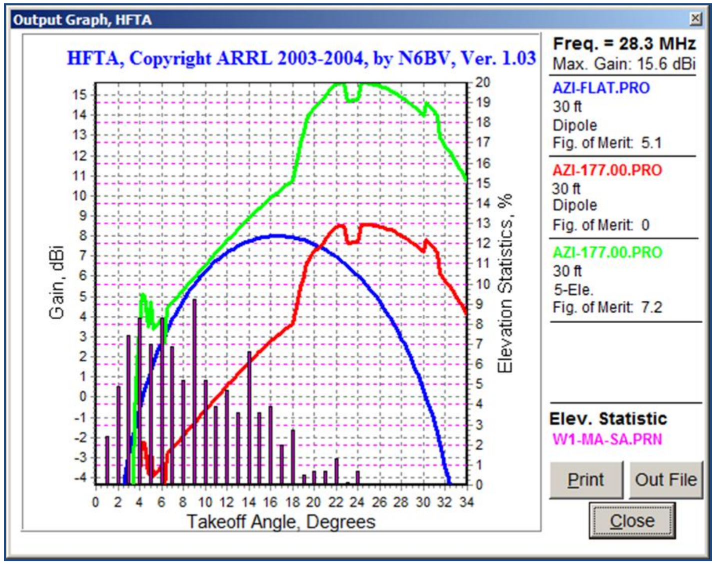
HFTA– HB 5 el 10M Yagi @ 33 BBHR

Example: How to improve my 10M yagi to South America

Increase antenna height: 30’ → 90’

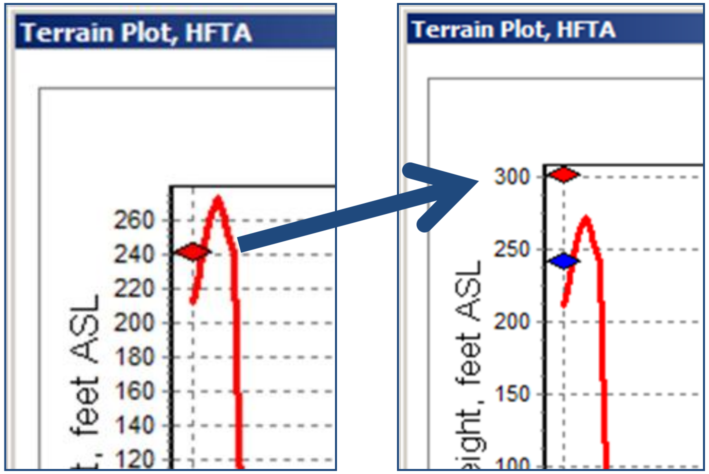


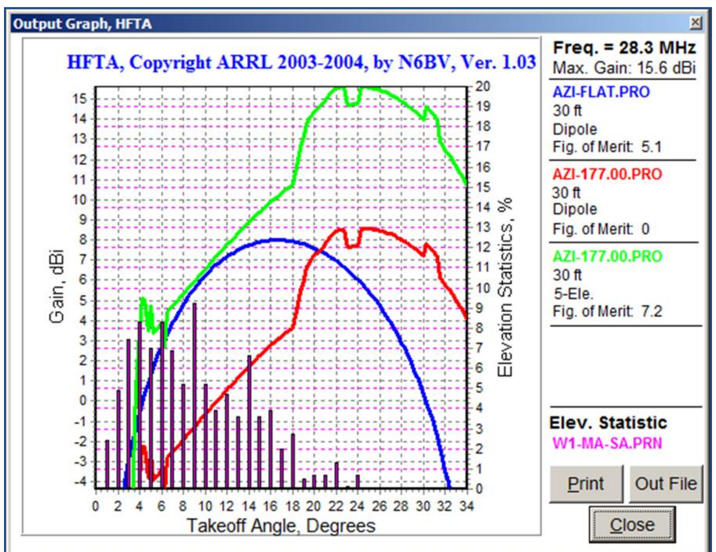




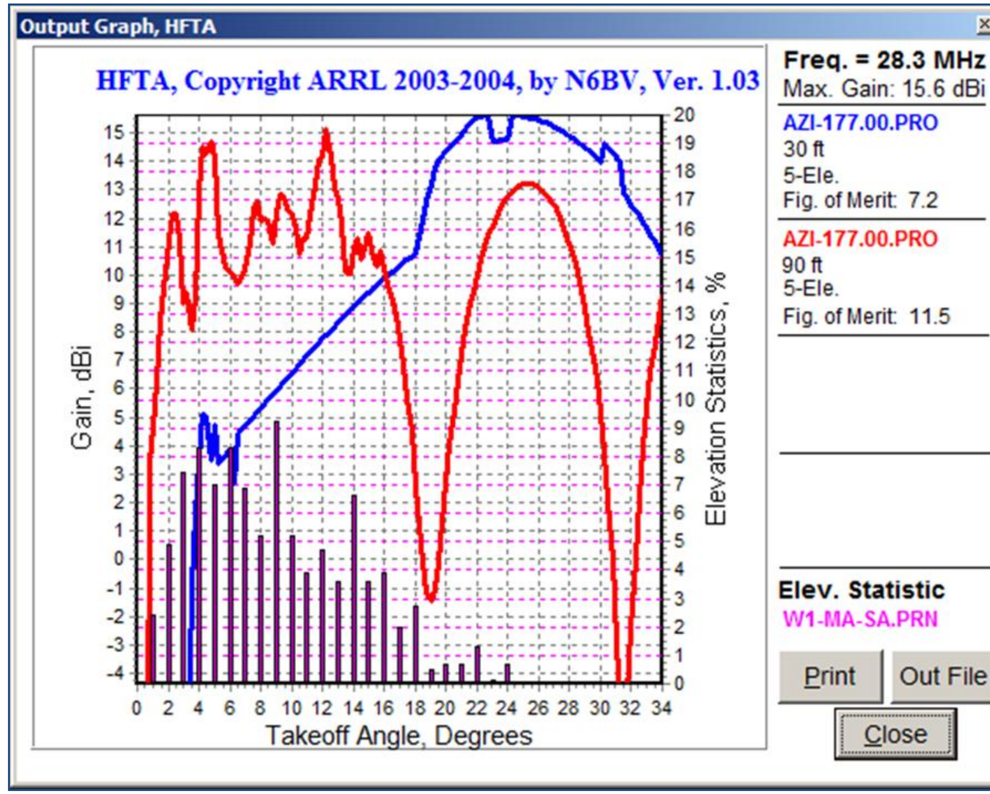
HFTA– HB 5 el 10M Yagi @ 33 BBHR

Example: How to improve my 10M yagi to South America



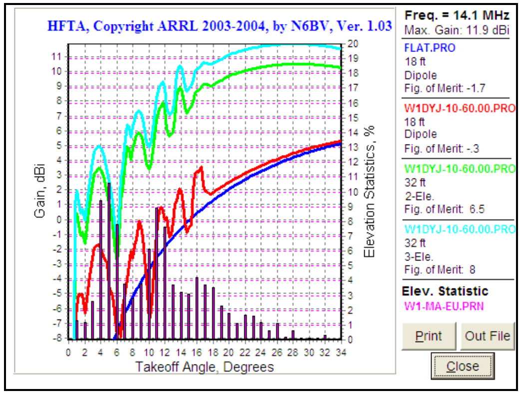


Increase antenna height: 30’ → 90’



HFTA – High Frequency Terrain Assessment

Lots of steps. Uses standard Yagis. Helps you understand your local terrain's effects to plan/assess your antenna system.



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Conclusions

- **You Can't Beat Physics**

➢ Understanding antennas
→understanding ANTENNA SYSTEMS
→all three of these programs will help

  - HOW YOU WANT TO USE YOUR ANTENNA
  - EFFECTS OF TRANSMISSION LINES
  - LOCAL TERRAIN
  - GROUND CHARACTERISTICS

- All antennas are COMPROMISES
- All models are SIMPLE EXAMPLES of reality
- Your real antenna WILL NOT MATCH your model

Summary

We’ve looked at:

TLW – Transmission Lines

YW – Simple Yagis

HFTA – Effects of Terrain

We’ve seen how these software programs can be used to plan your antenna systems

Questions???

> ***“All models are wrong. Some are useful”***
>
> **British Statistician *George Box*, 1976**

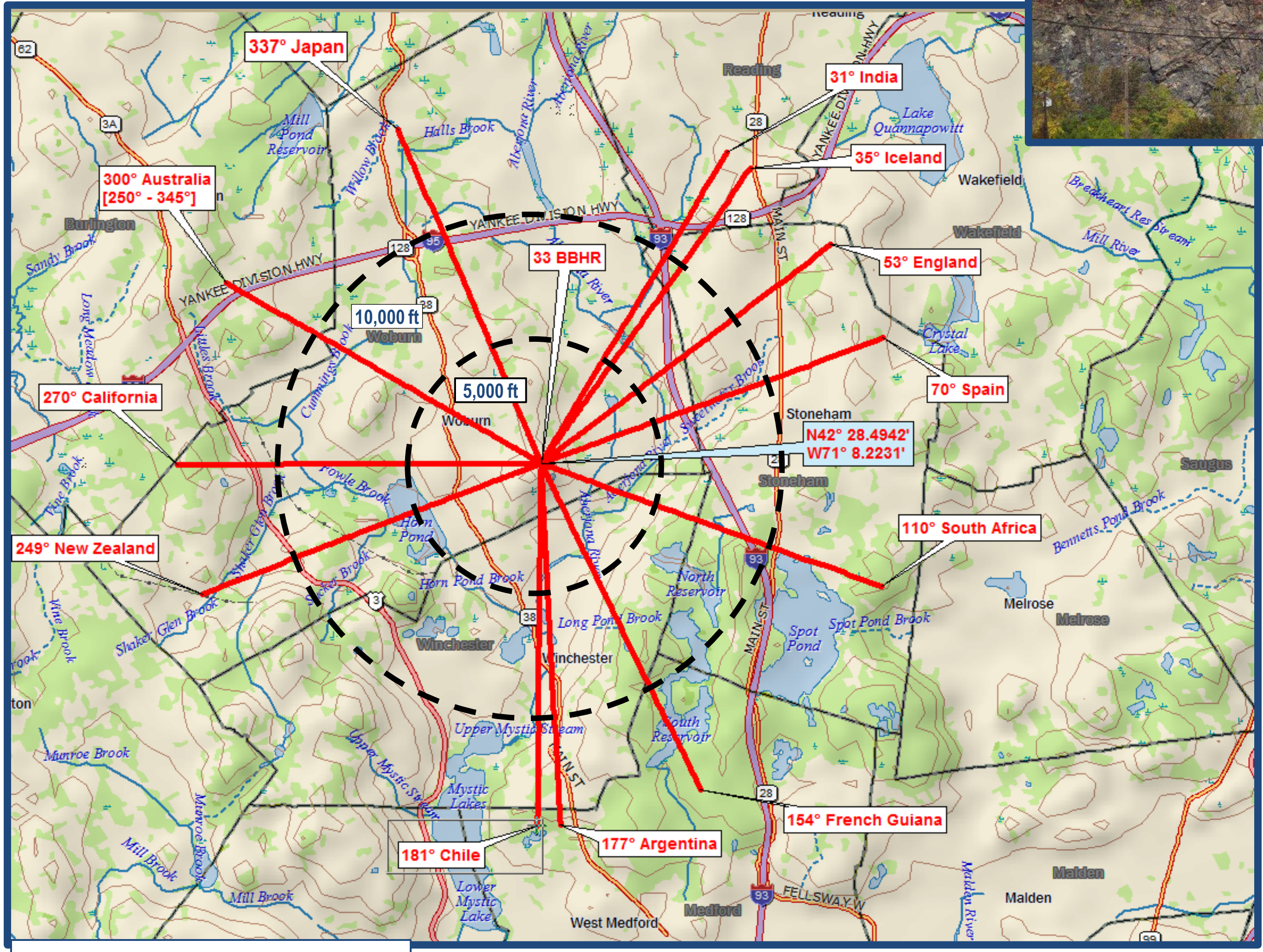
Appendix

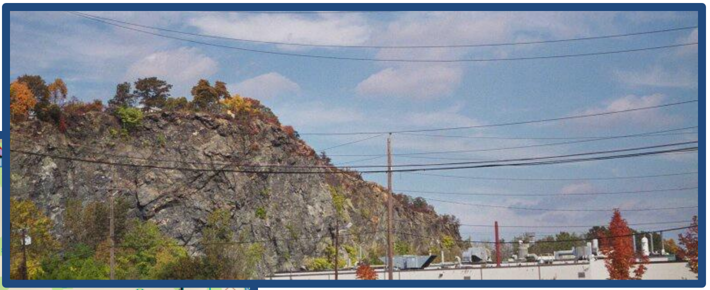
- W1DYJ Antennas in Woburn MA
- W1DYJ Antennas in Harpswell ME
- ARRL Handbook SW
- ON4UN's Low Band Dxing SW
- Additional ARRL Antenna Book SW
- Abstract / Bio

https://www.qsl.net/w1dyj/

33 Blueberry Hill Rd – Woburn Antennas

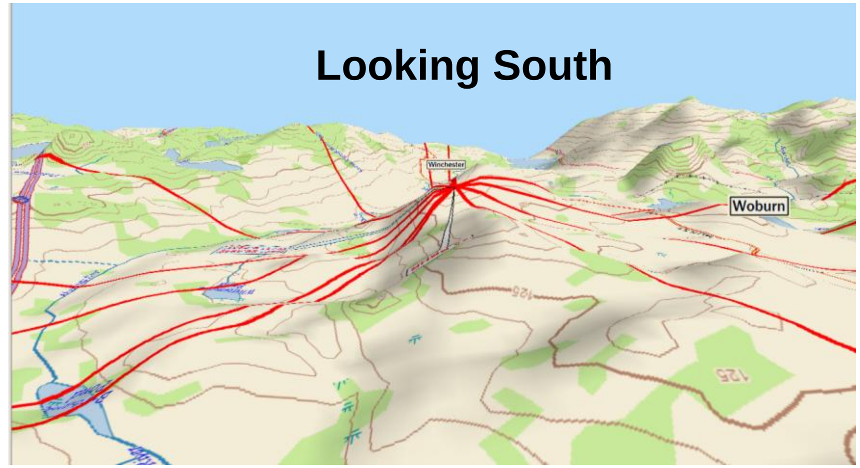
DX Azimuths @ 33 BBHR

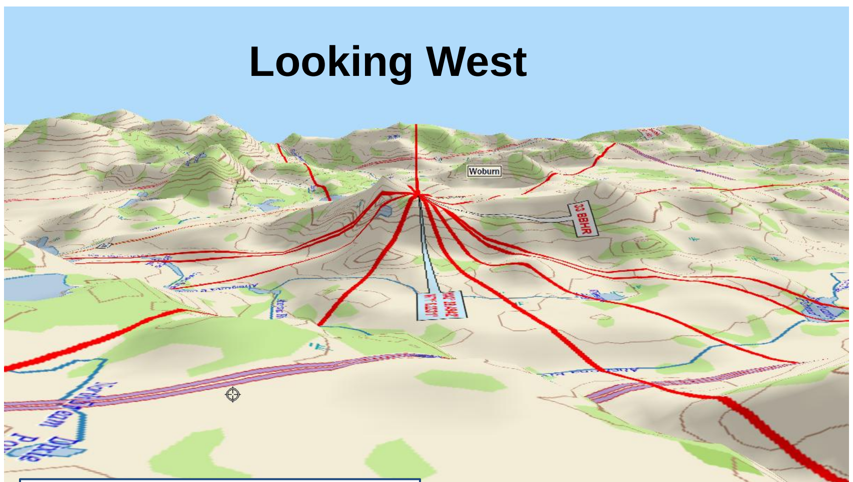


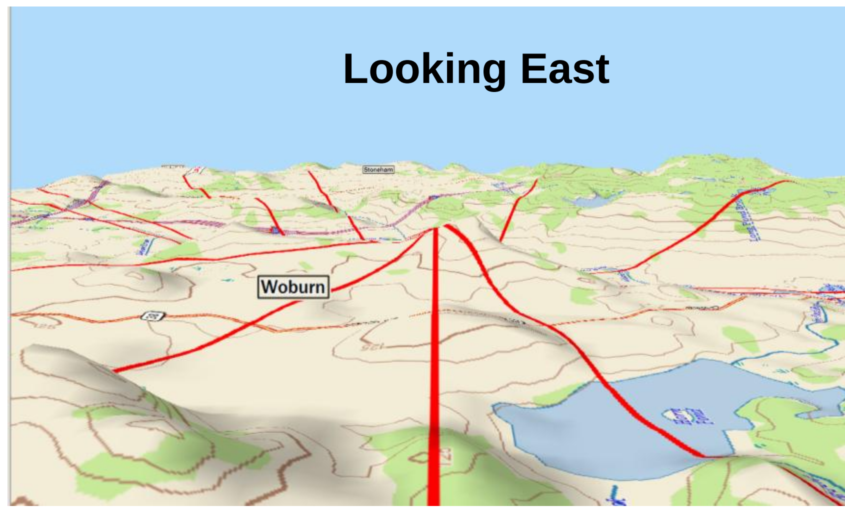


Delorme Topo USA 7.0

33 BBHR 3D Maps





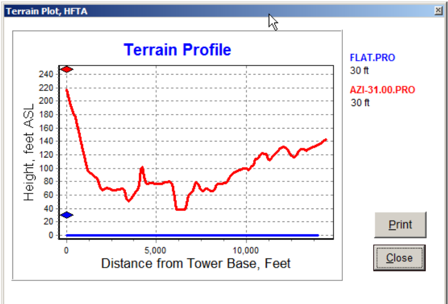


Delorme Topo USA

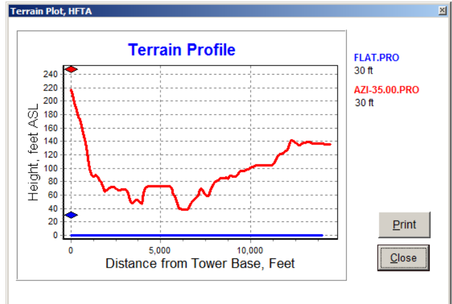
Note: Vertical dimensions are enhanced by a factor of 8

HFTA – Local Terrain @ 33 BBHR

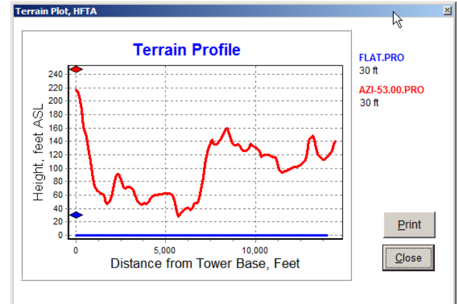
31° India



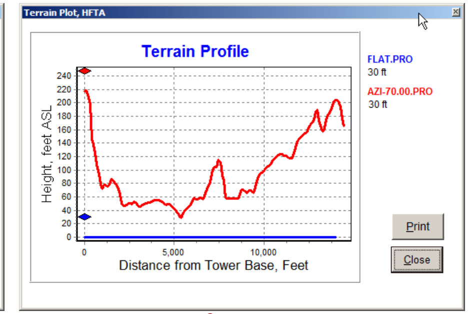
35° Iceland / EurRussia



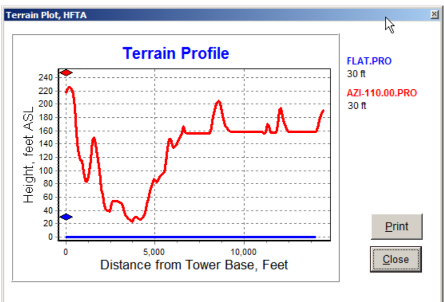
53° England



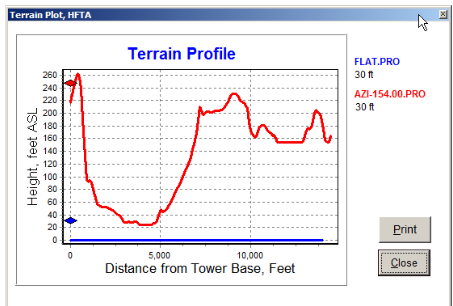
70° Spain



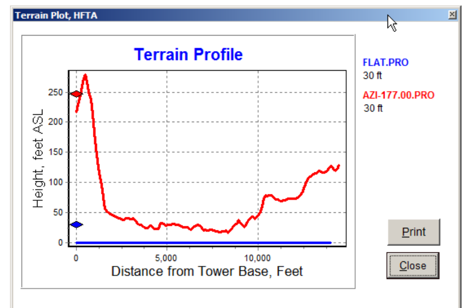
110° South Africa



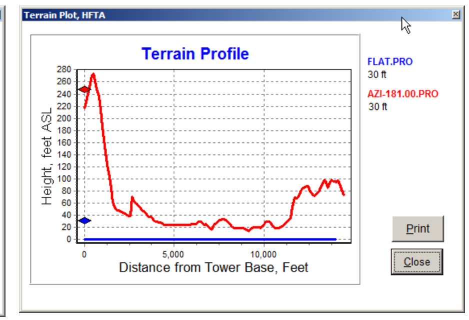
154° French Guiana



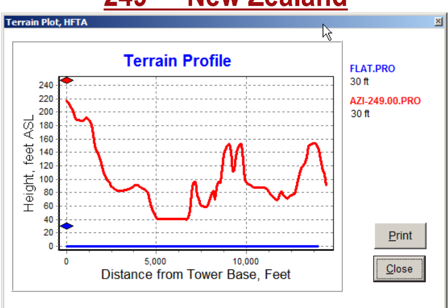
177° Argentina



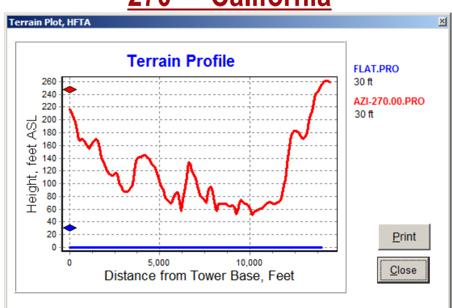
181° Chile



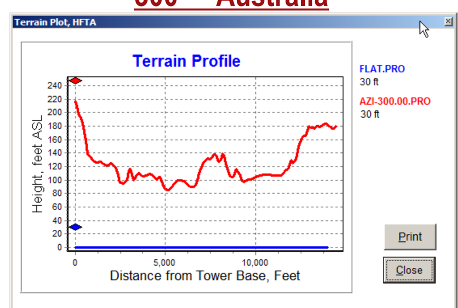
249° New Zealand



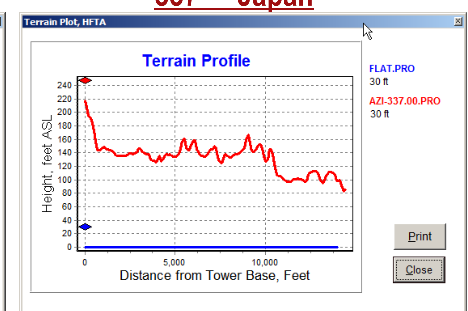
270° California



300° Australia



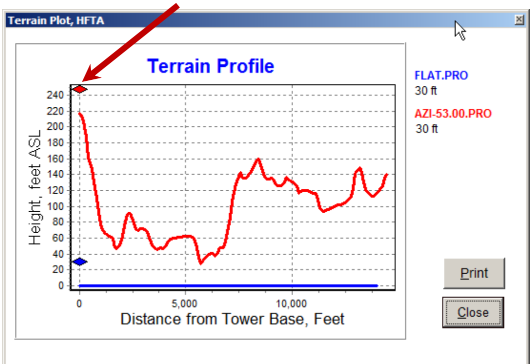
337° Japan

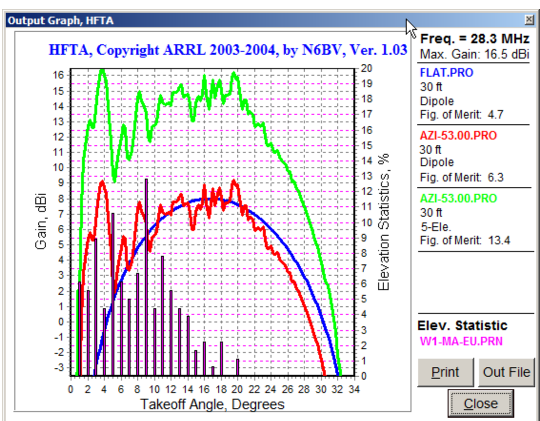


HFTA– HB 5 el 10M Yagi @ 33 BBHR

53° England

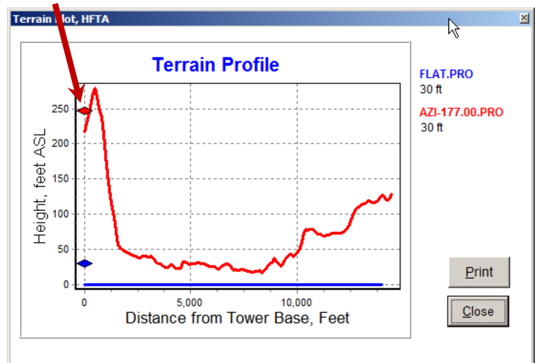
Note: Antennas are IN FRONT of Hill

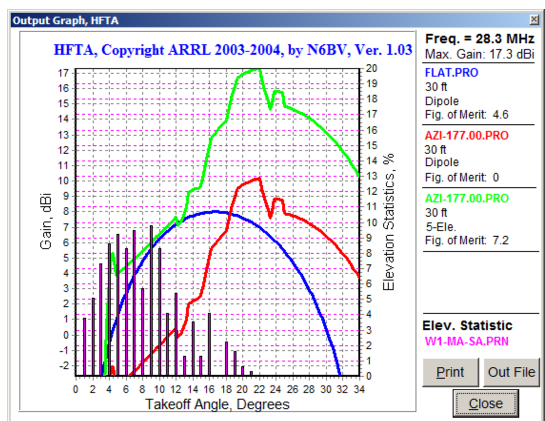




177° Argentina

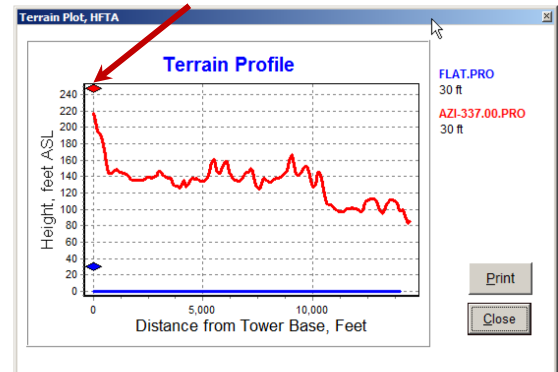
Note: Antennas are BEHIND Hill

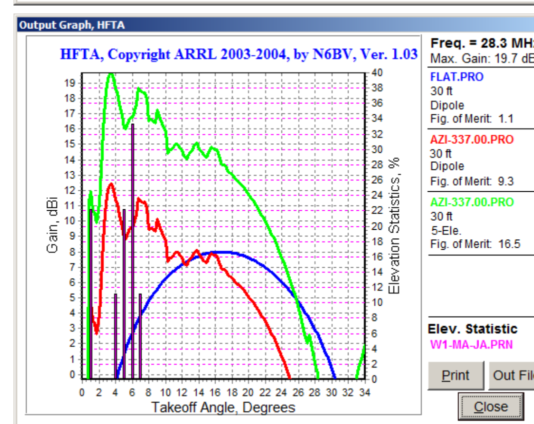




337° Japan

Note: Antennas are IN FRONT of Hill





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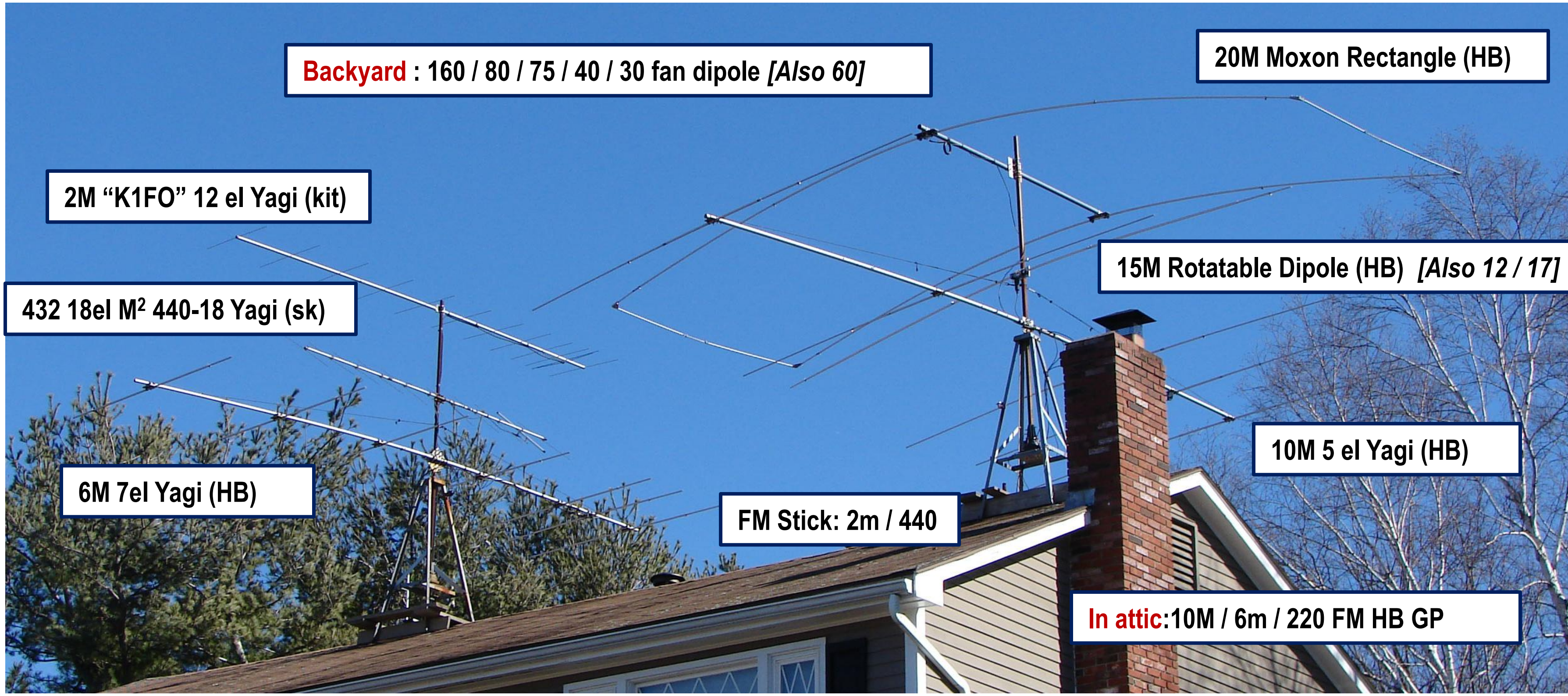
33 Blueberry Hill Rd – Woburn Antennas



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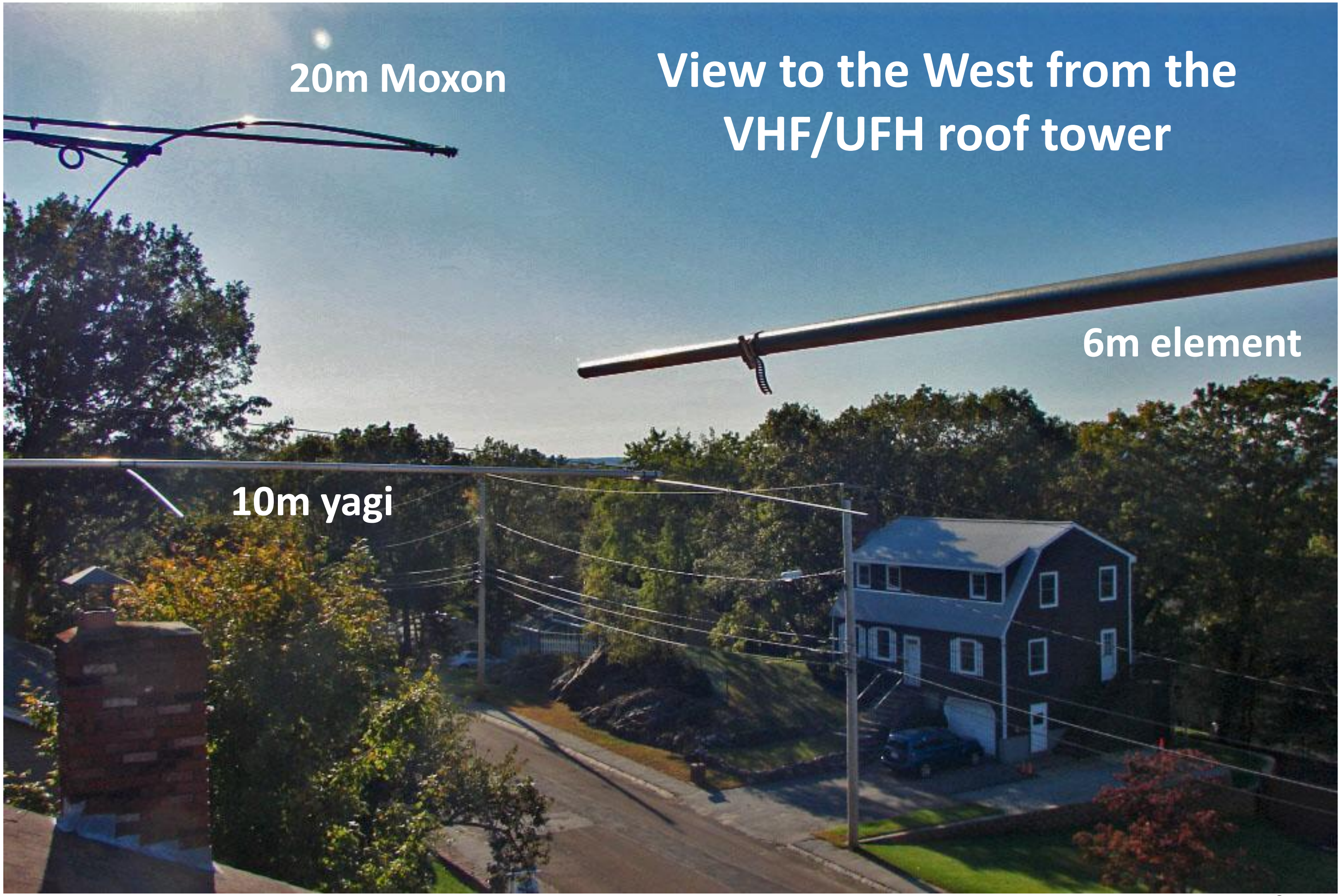
33 Blueberry Hill Rd -- Woburn



W1DYJ Antennas in Woburn MA

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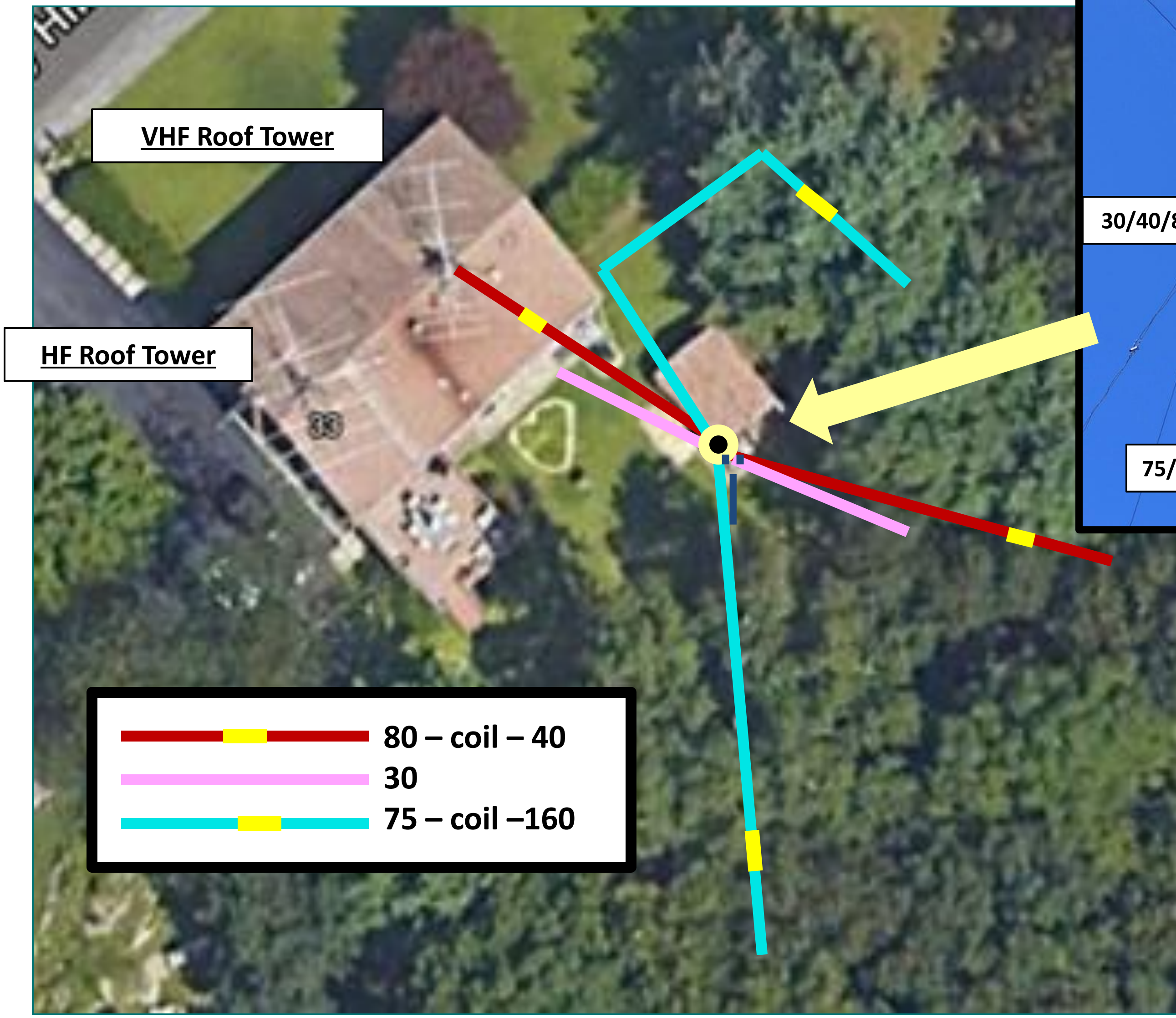
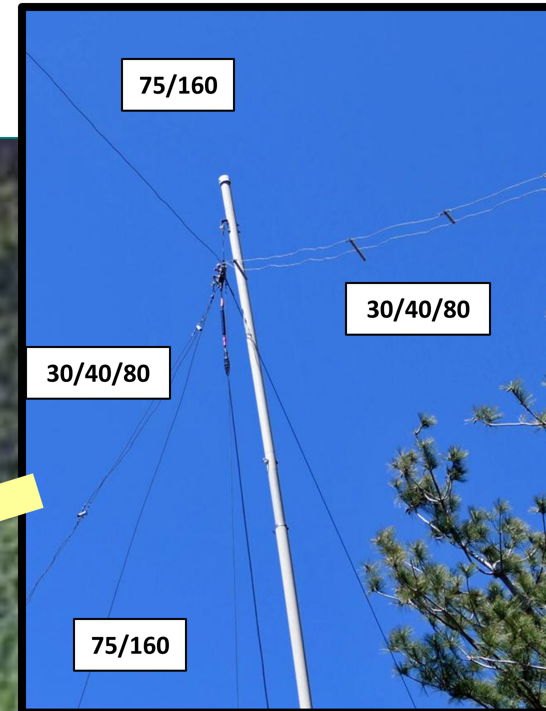
W1DYJ Antennas in Woburn MA





N

International DX Association

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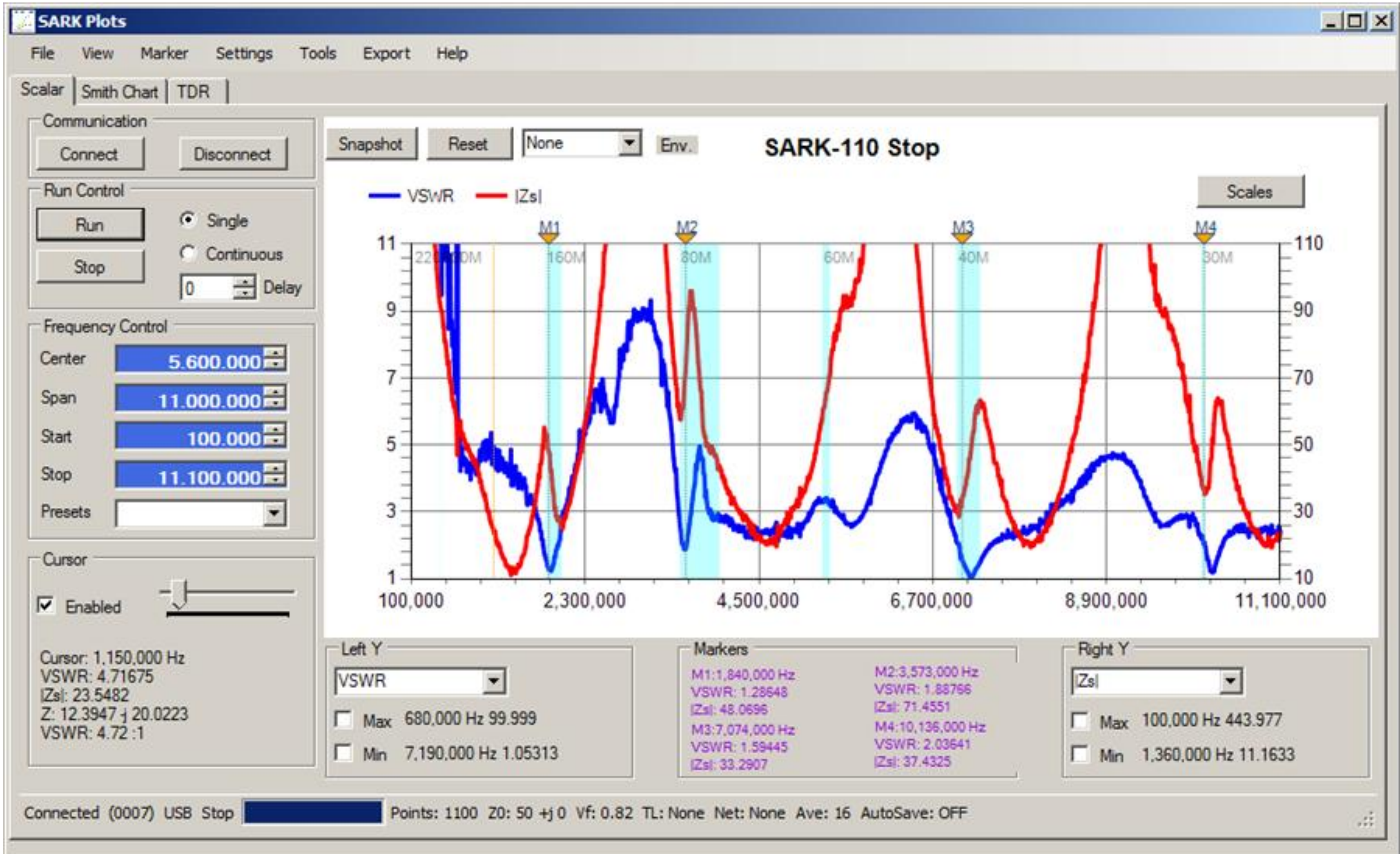
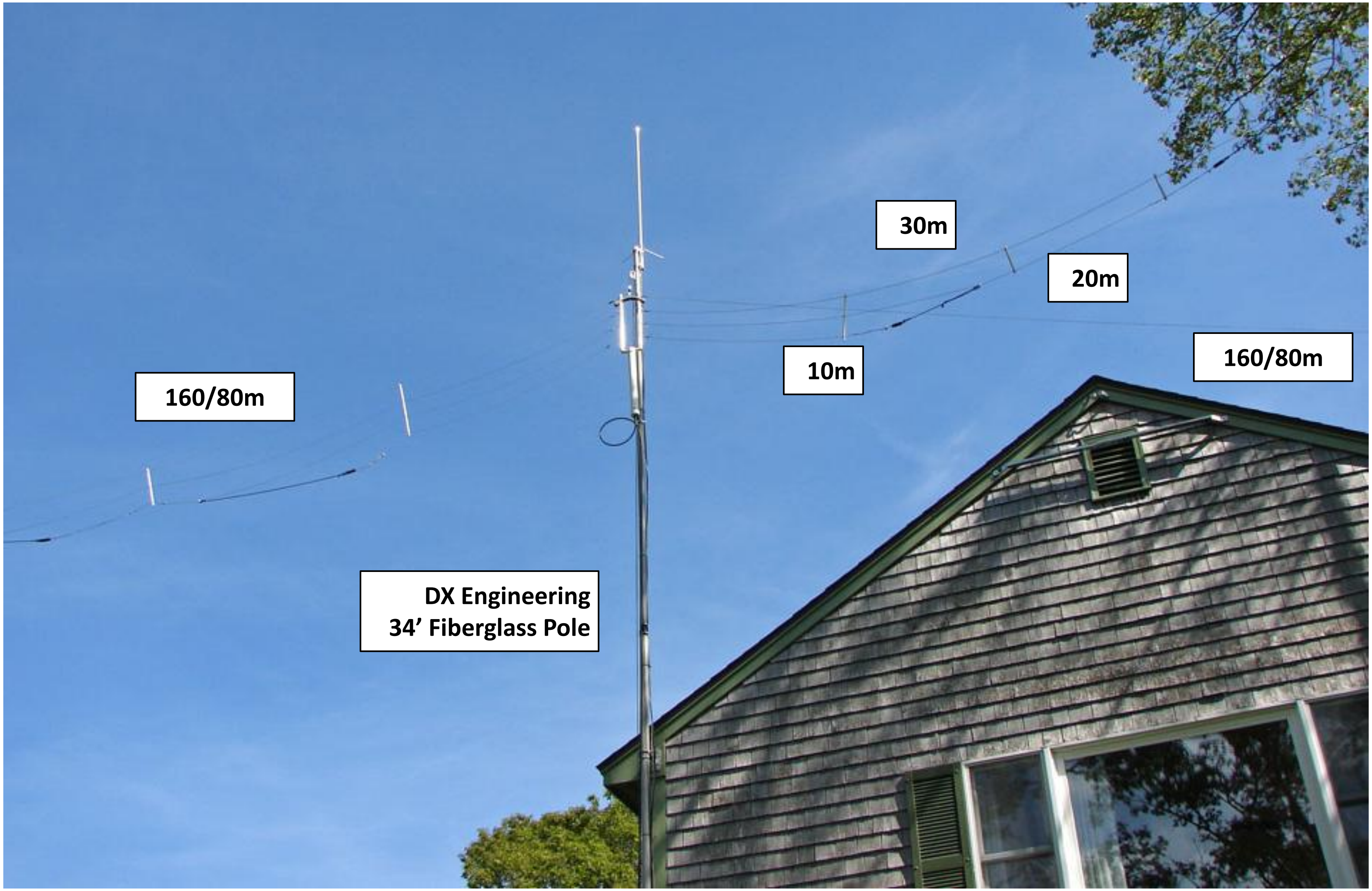
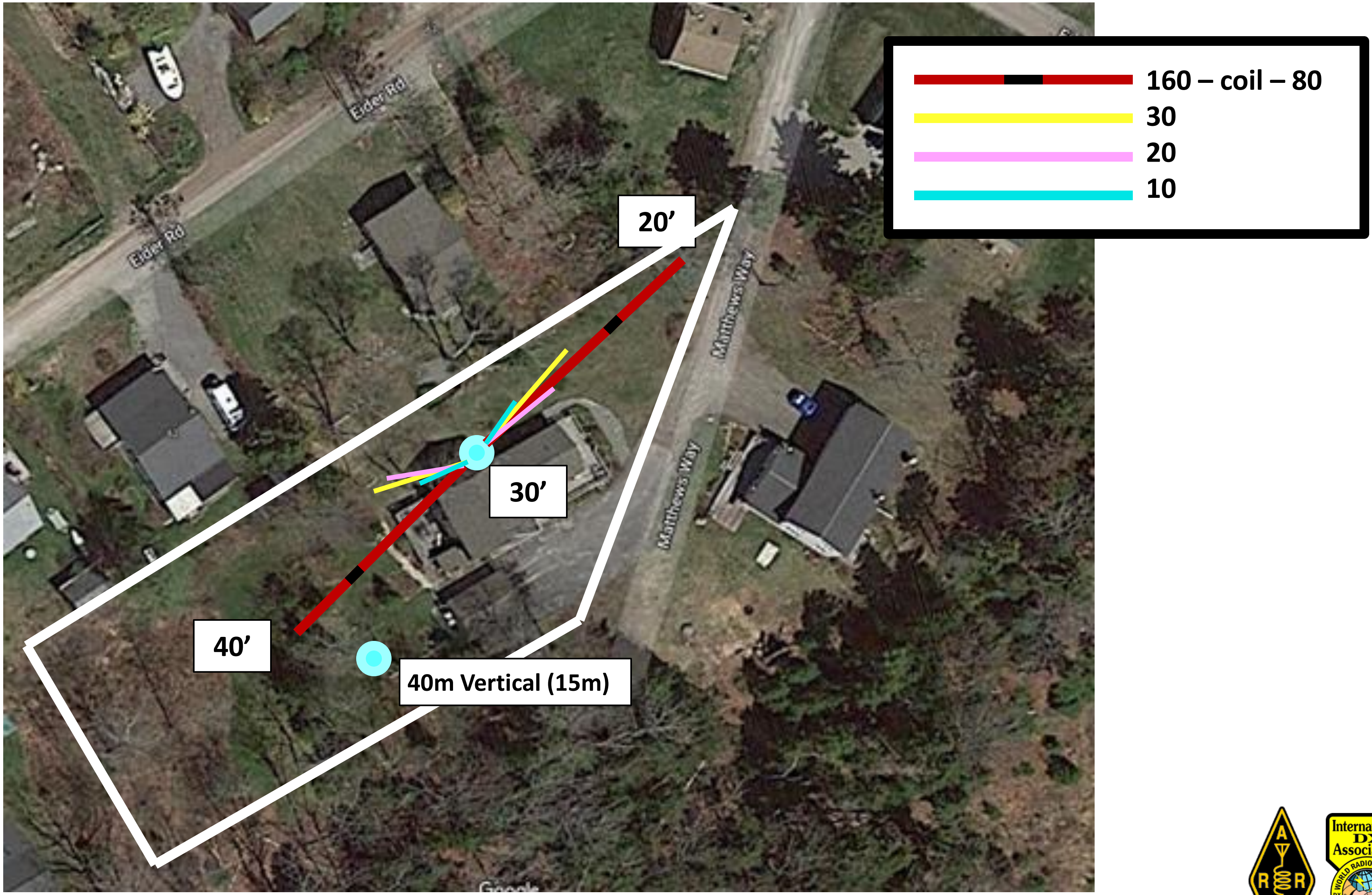
Woburn MA ~ Low HF SWR/|Zs| sweep



W1DYJ Antennas in Harpswell ME *[no longer there]*



W1DYJ Antennas in Harpswell ME *[no longer there]*



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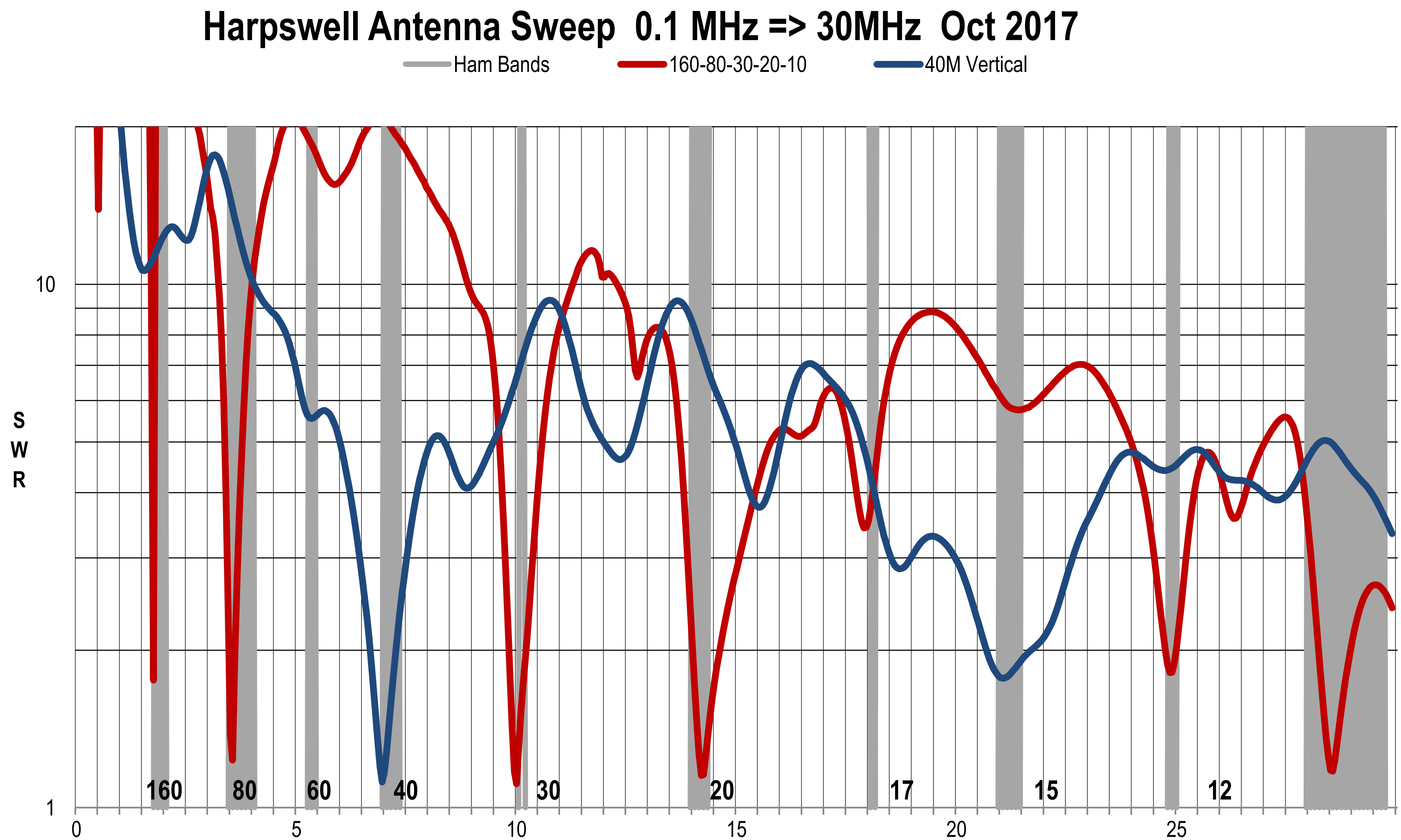
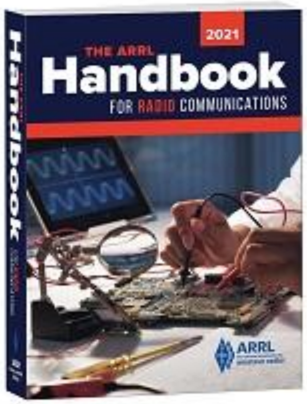
Harpswell ME ~ SWR sweep *[no longer there]*



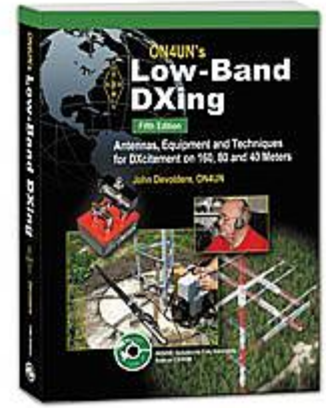
SW: ARRL Handbook



- **TubeCalculator** — Design tube-type High Power linears
- **ClassE** — Designs single-ended Class E RF amplifier
- **Diplexer** — Designs both high-pass/low-pass and band-pass/band-stop types of diplexers
- **Helical** — Designs and analyzes helical-resonator bandpass filters usually used in VHF and UHF
- **Elsie** — A lumped-element filter design and analysis program (the student edition)
- **MeterBasic** — Designs and prints professional-quality analog meter scales
- **OptLowpass** — Designs and analyzes transmitter output low-pass filters
- **PIEL** — Designs and analyzes pi-L networks for transmitter output
- **QuadNet** — Designs and analyzes active quadrature networks
- **SVCFilter** — Standard-value component routine to design low-pass and high-pass filters
- **Supplemental Files** — Additional discussion, additional projects, full-size PC board etching patterns, program examples and other useful information

W1DYJ's
1962
1968
1970
1996
2012
2023

SW: ARRL OH4UN's Low Band DXing



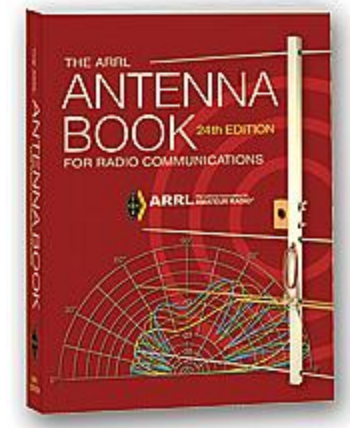
W1DYJ's
4th Edition
2005

- **Conversion Calculator** Excel spreadsheet that converts signal levels typically encountered at receiver inputs between µV, mV, dBµV, µW, etc
- **Receiver Levels** Excel spreadsheet tool shows you levels involved with radio signals from transmit power to received signal
- **RX noise figure and MDS calculation** Excel spreadsheet tool shows you the relation between receiver bandwidth, temperature and receiver MDS
- **ON4UN Low-Band DXing Software (DOS)**
  Propagation Software; Mutual Impedance and Driving Impedance; Coax Transformer/Smith Chart; Impedance, Current and Voltage Along Feed Lines; Two- and Four-Element Vertical Arrays; The L Network; Series/Shunt Input L-Network Iteration; Shunt/Series Impedance Network; Line Stretcher (Pi and T) Stub Matching; Parallel Impedances (T Junction); SWR Value and SWR Iteration; Radiation Angle for Horizontal Antennas; Coil Calculation; Gamma-Omega and Hairpin Matching; Element Taper
- **ON4UN-Yagi-Design (DOS)**
  The Analyze Module; Generic Dimensions; Element Strength; Element Taper; Mechanical Yagi Balance; Yagi Wind Area; Matching; Optimize Gamma/Omega; Feed-Line Analysis; Rotating Mast Calculation

OH4UN John Devoldere (SK)

Out of Print

SW: ARRL Antenna Book



- **TLW** — **Computes parameters for transmission lines and antenna-tuners**
- **YW** — **Computes parameters for Yagi-Uda antennas**
- **HFTA** — **Evaluates the effect of local terrain on the launch of HF signals**

→24th Edition: Software is available online

W1DYJ's
17th Ed. – 1994
23rd Ed. – 2015
24th Ed. – 2019

- **Many of the apps from previous editions are available at:** www.arrl.org/antenna-book

AAT	Automatically evaluates antenna tuner networks
Arrayfeed1	Computes parameters necessary for feeding 2-element and 4-element phased-arrays.
GAMMA	Computes the parameters for a gamma match
LPCAD30	For computing LPDA designs
MOBILE	Evaluating and designing mobile whip antennas and coils
Range-Bearing	Computes the range/bearing from one lat/lon point to another
SCALE	Scales Yagi designs to other frequencies

EZNEC 7 *Roy Lewallen W7EL (retired)*