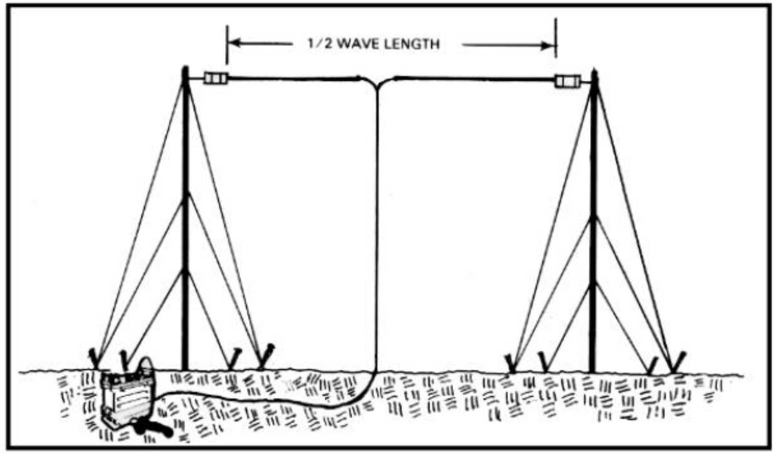

NVIS Antenna Theory & Practice

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W5IFQ

7 SEP 2021

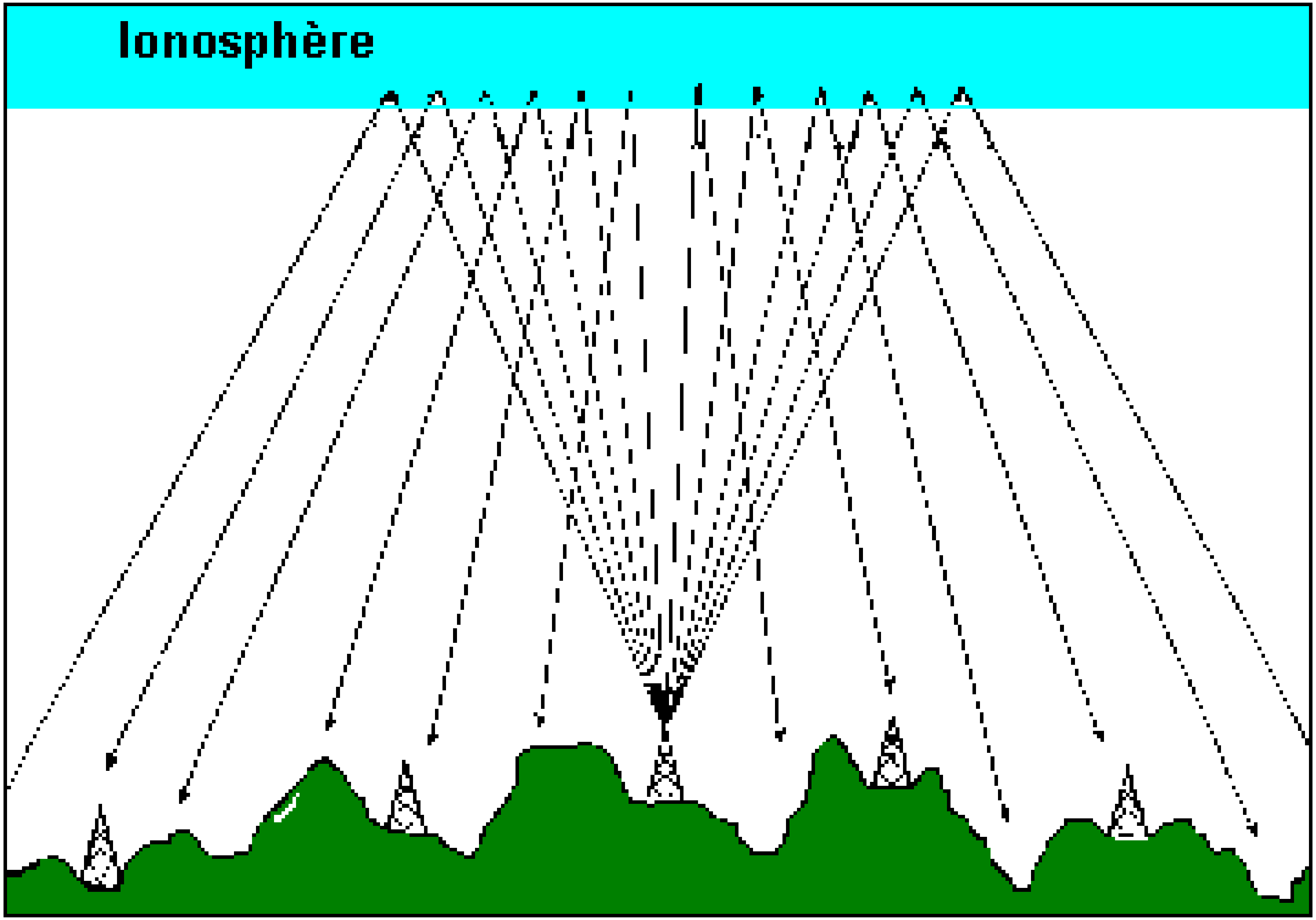
Objectives

- Define Near Vertical Incidence Skywave (NVIS) Propagation.
- Learn how to produce an efficient NVIS directivity pattern.
- Learn how to maximize the transfer of RF power to the antenna.

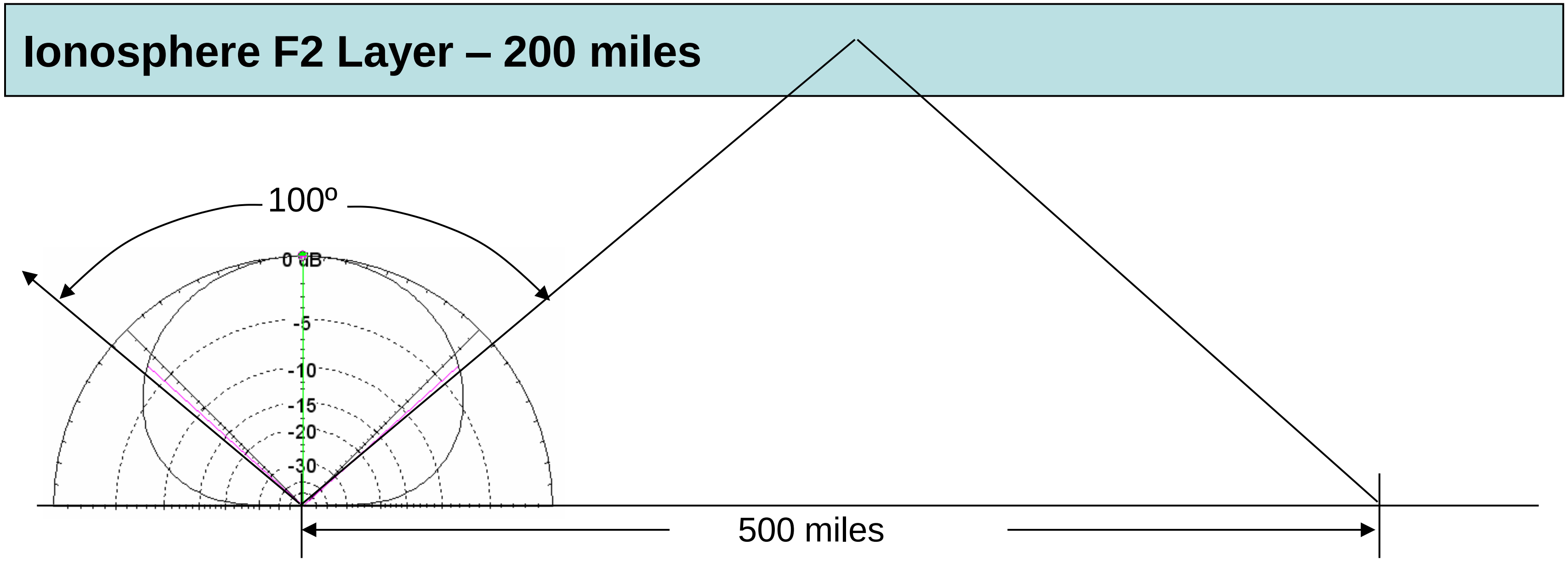
HF Propagation Modes

- Free Space – Line of site
- Ground Wave – Follows Earth's curvature
- Ionospheric Skip
  - Long Distance with a "dead or skip zone"
  - NVIS (Near Vertical Incidence Sky Wave)

NVIS Propagation

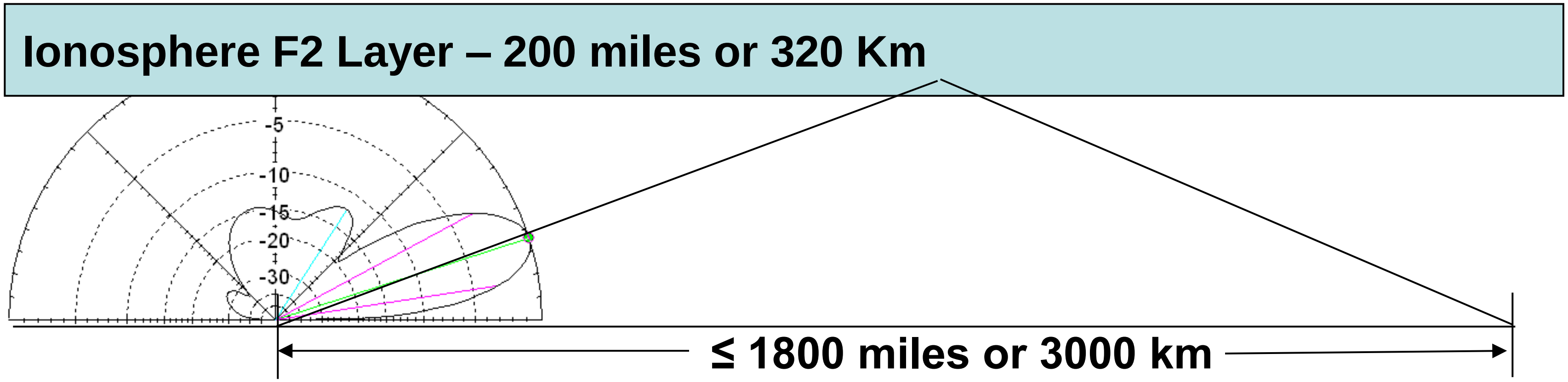


Required NVIS Antenna Pattern



- Want to optimize take-off angles from 50º to 90º
- Elevation Beam width = 100º
- Centered on the vertical axis.

TYPICAL LONG-RANGE PROPAGATION



Both F2 & E layers propagation can be involved in multiple reflection circuits.

NVIS PARAMETERS

- Antenna design
  - Correct directivity pattern
  - Provide usable impedance to RF transmitter

Frequency versus Wavelength

- When designing antennas, the length and height in wavelengths determines the antenna characteristics. It is easier to work in wavelengths and then convert to actual dimensions at the design frequency(s):

  λ (wavelength, ft.) = 983.6/f (frequency, MHz)

- A convenient lookup table follows.

Frequency to Wavelength Chart

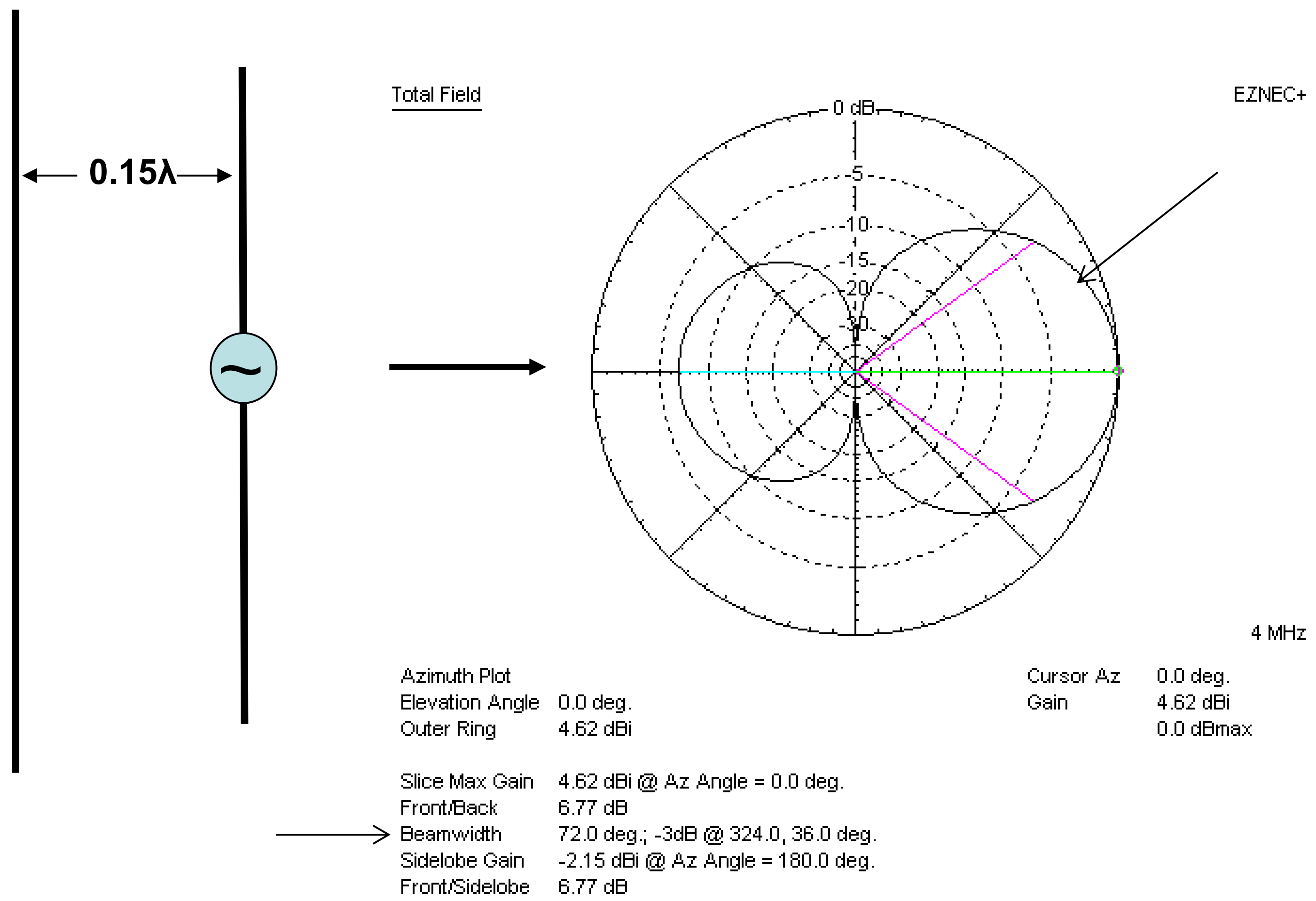
Frequency (kHz)		Wavelength (Meters)		Wavelength (Feet)		1/2 Wavelength (Feet)		1/4 Wavelength (Feet)		1/3 Wavelength (Feet)		1/10 Wavelength (Feet)	
2,194.00	2,495.00	136.7	120.2	448.6	394.5	224.3	197.2	112.2	98.6	149.5	131.5	44.9	39.4
2,505.00	2,850.00	119.8	105.3	392.9	345.3	196.5	172.7	98.2	86.3	131.0	115.1	39.3	34.5
3,155.00	3,400.00	95.1	88.2	312.0	289.5	156.0	144.7	78.0	72.4	104.0	96.5	31.2	28.9
4,000.00	4,063.00	75.0	73.8	246.1	242.2	123.0	121.1	61.5	60.6	82.0	80.7	24.6	24.2
4,438.00	4,650.00	67.6	64.5	221.8	211.7	110.9	105.8	55.4	52.9	73.9	70.6	22.2	21.2
4,750.00	4,995.00	63.2	60.1	207.2	197.0	103.6	98.5	51.8	49.3	69.1	65.7	20.7	19.7
5,005.00	5,450.00	59.9	55.0	196.7	180.6	98.3	90.3	49.2	45.1	65.6	60.2	19.7	18.1
5,730.00	5,950.00	52.4	50.4	171.8	165.4	85.9	82.7	42.9	41.4	57.3	55.1	17.2	16.5
6,765.00	7,000.00	44.3	42.9	145.5	140.6	72.7	70.3	36.4	35.2	48.5	46.9	14.5	14.1
7,300.00	8,195.00	41.1	36.6	134.8	120.1	67.4	60.1	33.7	30.0	44.9	40.0	13.5	12.0
9,040.00	9,500.00	33.2	31.6	108.9	103.6	54.4	51.8	27.2	25.9				
9,900.00	9,995.00	30.3	30.0	99.4	98.5	49.7	49.2	24.9	24.6				
10,150.00	11,175.00	29.6	26.8	97.0	88.1	48.5	44.0	24.2	22.0				
11,400.00	11,650.00	26.3	25.8	86.3	84.5	43.2	42.2	21.6	21.1				
12,050.00	12,230.00	24.9	24.5	81.7	80.5	40.8	40.2	20.4	20.1				
13,410.00	13,600.00	22.4	22.1	73.4	72.4	36.7	36.2	18.3	18.1				
13,800.00	14,000.00	21.7	21.4	71.3	70.3	35.7	35.2	17.8	17.6				
14,350.00	14,990.00	20.9	20.0	68.6	65.7	34.3	32.8	17.1	16.4				
15,600.00	16,360.00	19.2	18.3	63.1	60.2	31.5	30.1	15.8	15.0				
17,410.00	17,550.00	17.2	17.1	56.5	56.1	28.3	28.0	14.1	14.0				
18,030.00	18,068.00	16.6	16.6	54.6	54.5	27.3	27.2	13.6	13.6				
18,168.00	18,780.00	16.5	16.0	54.2	52.4	27.1	26.2	13.5	13.1				
18,900.00	19,660.00	15.9	15.3	52.1	50.1	26.0	25.0	13.0	12.5				
19,800.00	19,990.00	15.2	15.0	49.7	49.2	24.9	24.6	12.4	12.3				
20,010.00	21,000.00	15.0	14.3	49.2	46.9	24.6	23.4	12.3	11.7				
21,855.00	23,200.00	13.7	12.9	45.0	42.4	22.5	21.2	11.3	10.6				
23,350.00	24,890.00	12.8	12.1	42.2	39.5	21.1	19.8	10.5	9.9				
25,330.00	25,550.00	11.8	11.7	38.9	38.5	19.4	19.3	9.7	9.6				
26,480.00	28,000.00	11.3	10.7	37.2	35.2	18.6	17.6	9.3	8.8				
29,800.00	30,000.00	10.1	10.0	33.0	32.8	16.5	16.4	8.3	8.2				

Minimum NVIS Height

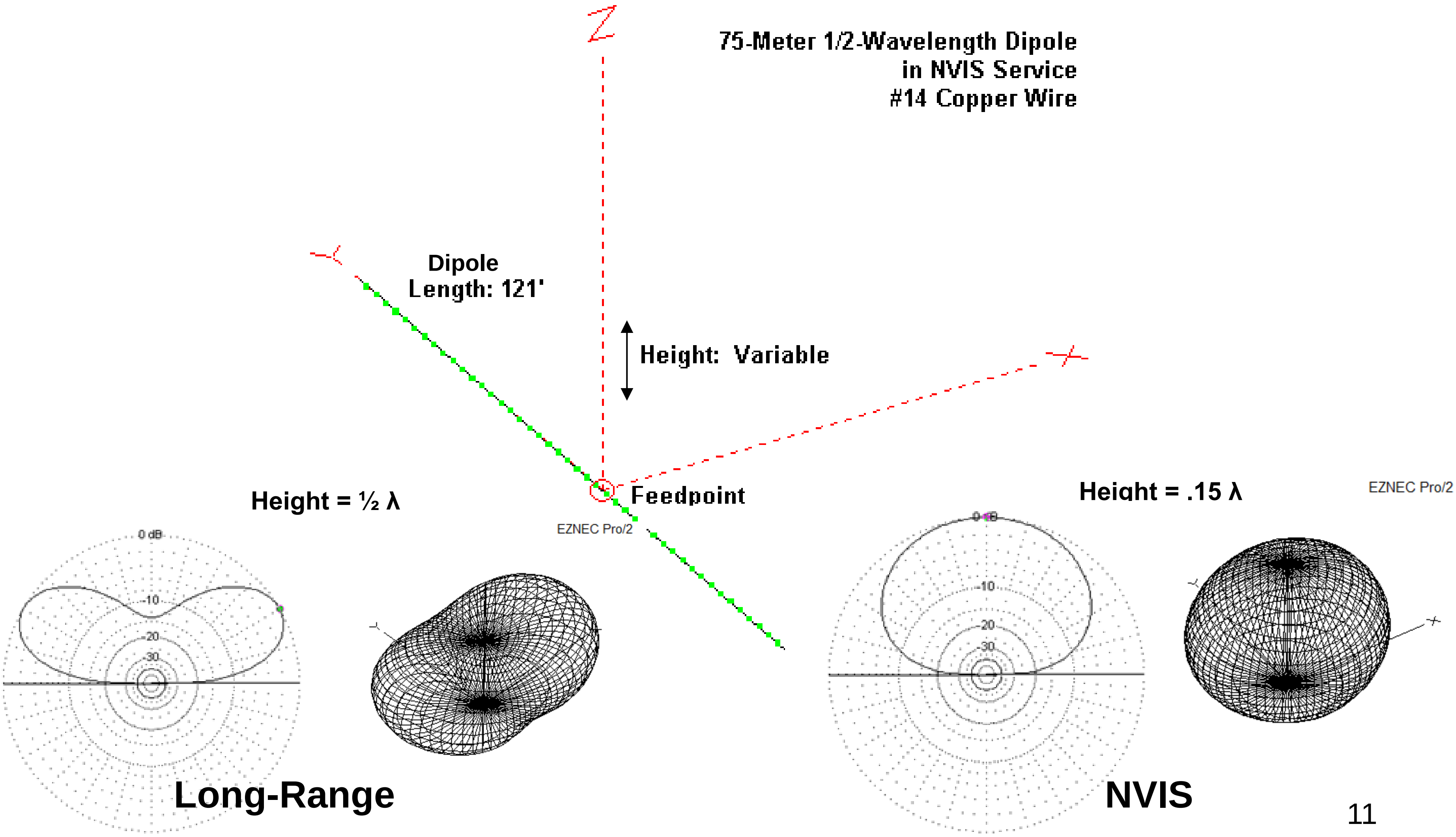
Maximum NVIS Height

Long-Range Height

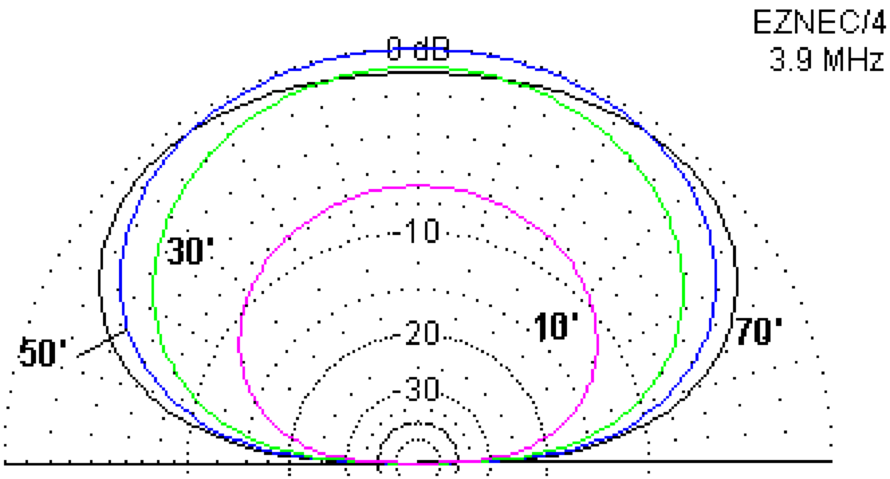
TWO-ELEMENT YAGI
(Free Space)



Dipole Directivity versus Height
(1/2 Wavelength Dipole)

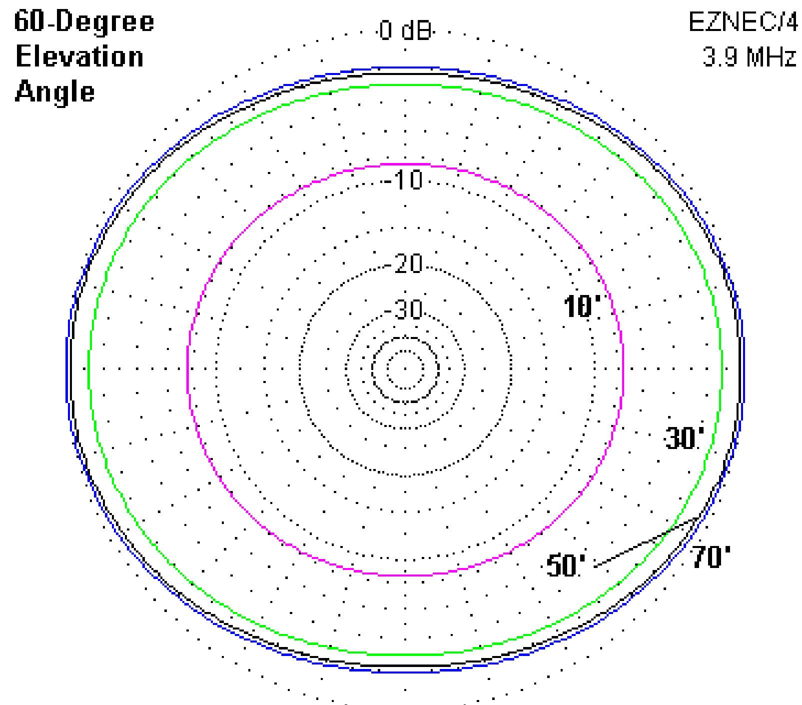


NVIS Dipole Patterns Versus Height – 3.9 MHz



Elevation Patterns of a 75-Meter Dipole for NVIS Service at 10, 30, 50, and 70 Feet Above Average Soil

50 ft. = 0.2λ
30 ft. = 0.12λ

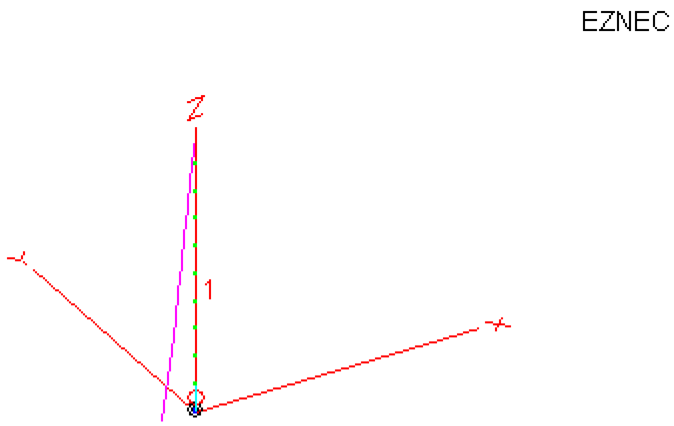


Azimuth Patterns of a 75-Meter Dipole for NVIS Service at 10, 30, 50, and 70 Feet Above Average Soil

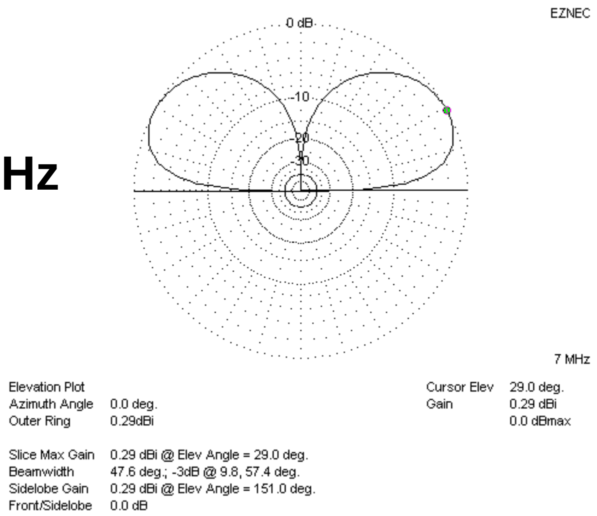
NVIS Antenna Rules

- Excellent antenna is a resonant ½ λ horizontal dipole at 0.15 λ height.
- Good performance from 0.1λ to 0.25λ
- Inverted-V is some 2-3 dB worst than dipole, but has more uniform horizontal pattern.
- 75m resonant loop is poor performer for 40m.
- Vertical antennas do not generate a NVIS pattern.

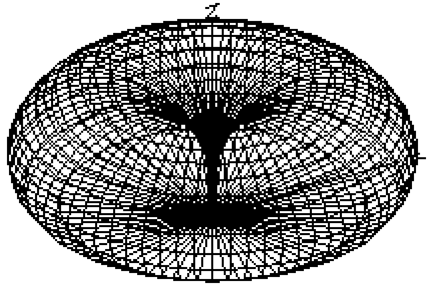
VERTICAL ANTENNAS



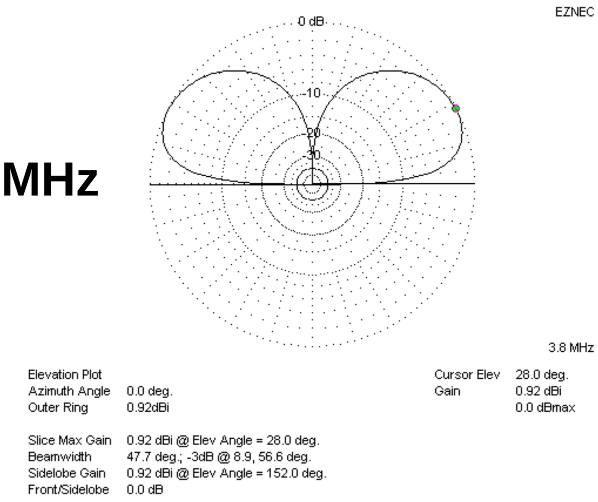
7 MHz



Height = 1.8 m (6 ft)



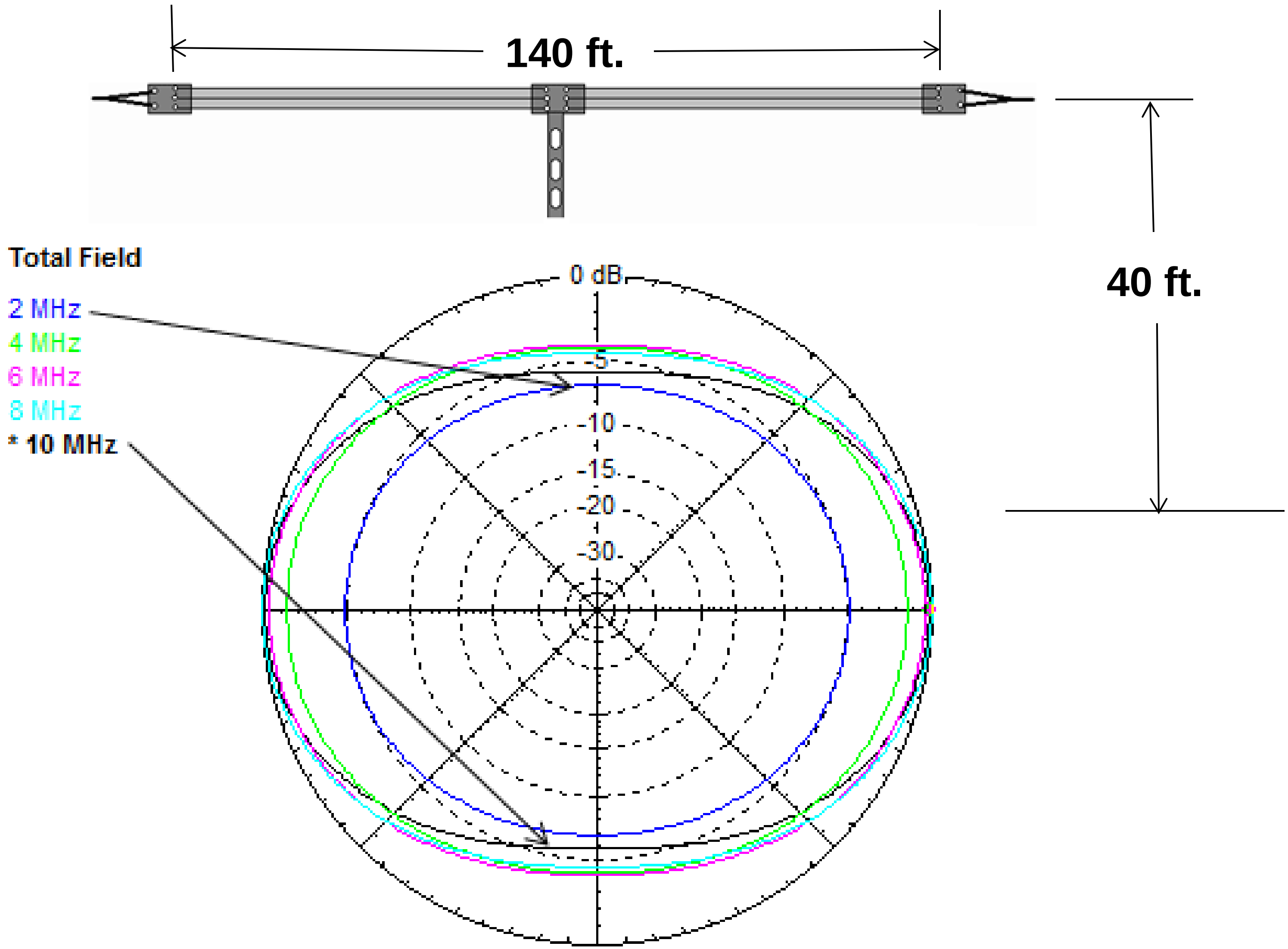
3.8 MHz



Wide-Band NVIS Antenna Directivity Problem

- MARS operators must operate over a range of frequencies in the NVIS mode.
- When the length of the antenna exceeds ½ λ, the azimuthal directivity pattern becoming increasingly more asymmetric.

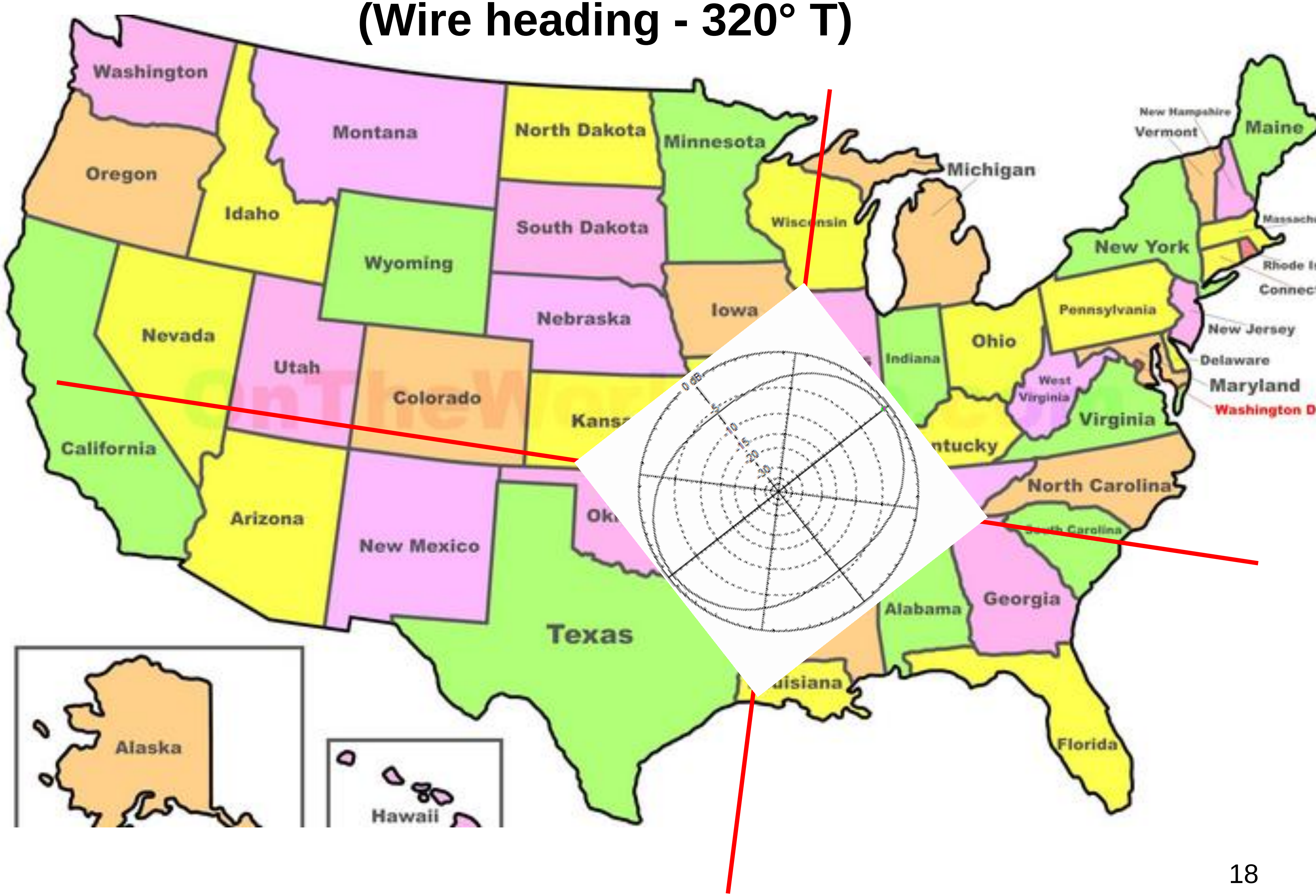
Cobra Senior Example



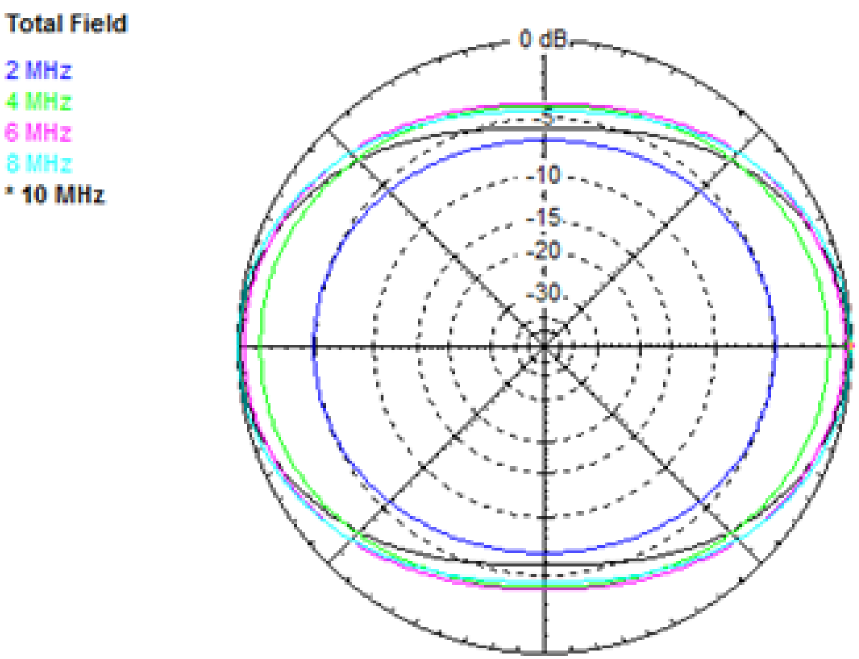
Dipole Directivity Problem Solutions

- Point antenna broadside to destination stations.

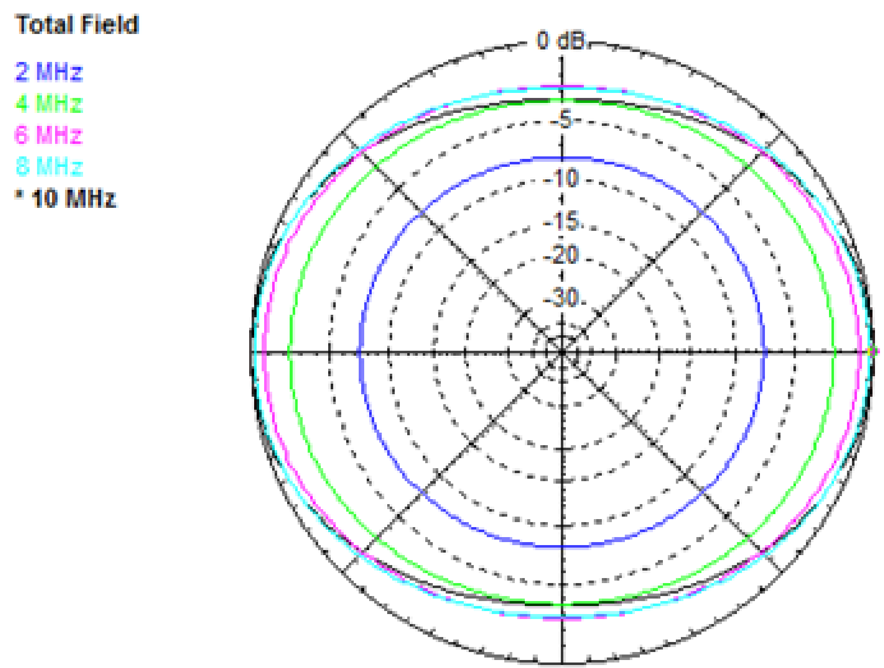
Azimuth Coverage – Cobra Senior at 5.202 MHz (Wire heading - 320° T)



Inverted-V Solution
(Cobra Senior - 45° Inverted-V)



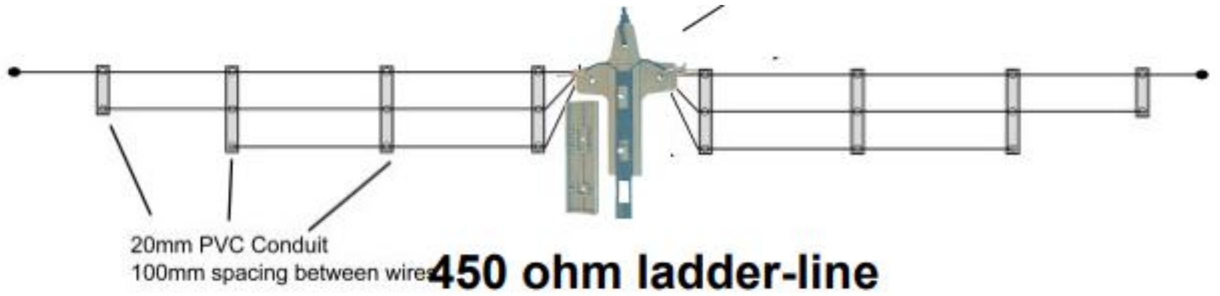
Horizontal Dipole



45° Inverted-V

Other Dipole Directivity Solutions

- Fan Dipole – Shorter legs dominate radiation pattern as frequency increases. Requires careful design including modeling.

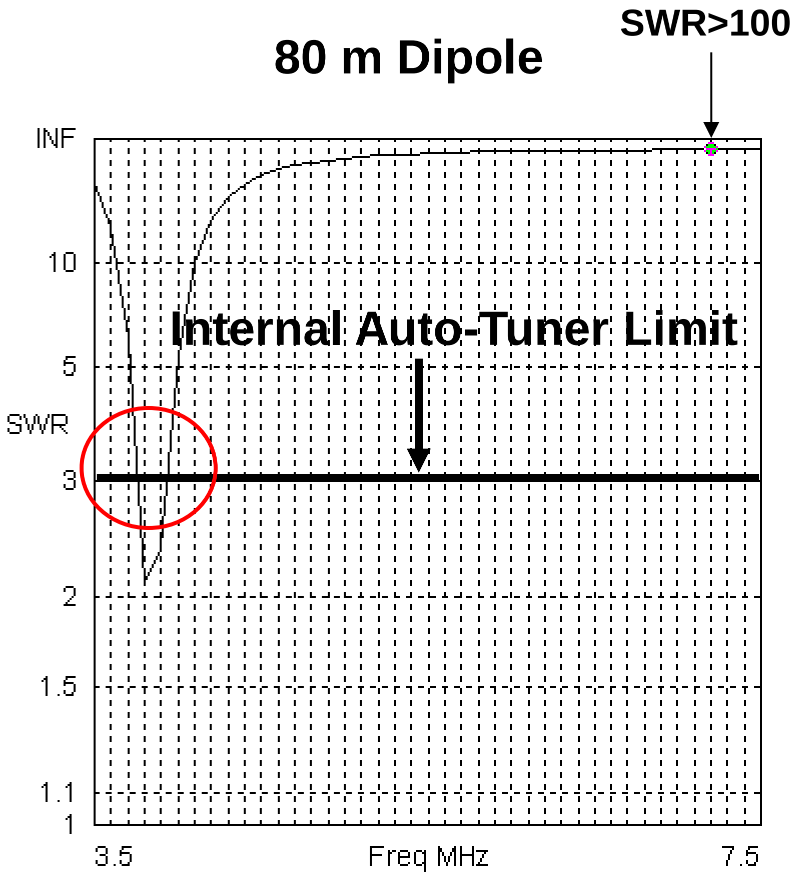


- Traps – Shortens antenna length as frequency increases. Can be lossy and difficult to tune.

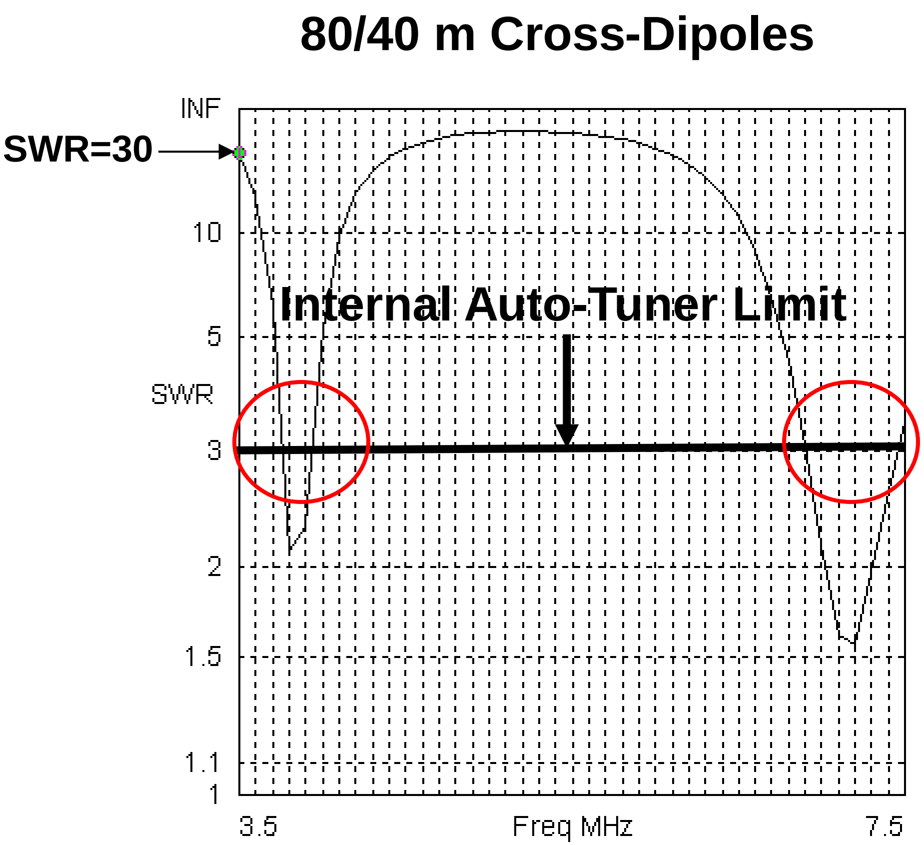
NVIS PARAMETERS

- Antenna design
  - Correct directivity pattern
  - Provide usable impedance to RF transmitter (i.e.,Low VSWR)
    - All modern HF transceivers will start “folding-back” the transmit power when VSWR exceed 1.5:1 and will typically shut off power at 3:1.
    - Some transceivers have built-in tuners but they are limited to 3:1 VSWR.

Internal Auto-Tuner Limitations



Freq 7.2 MHz
SWR > 100
Z 4589 + j 2444 ohms
Refl Coeff 0.9832 at 0.52 deg.
Source # 1
Z0 50 ohms



Freq 3.5 MHz
SWR 30.3
Z 15.27 - j 143 ohms
Refl Coeff 0.9362 at -38.18 deg.
Source # 1
Z0 50 ohms

Antenna Tuning Options

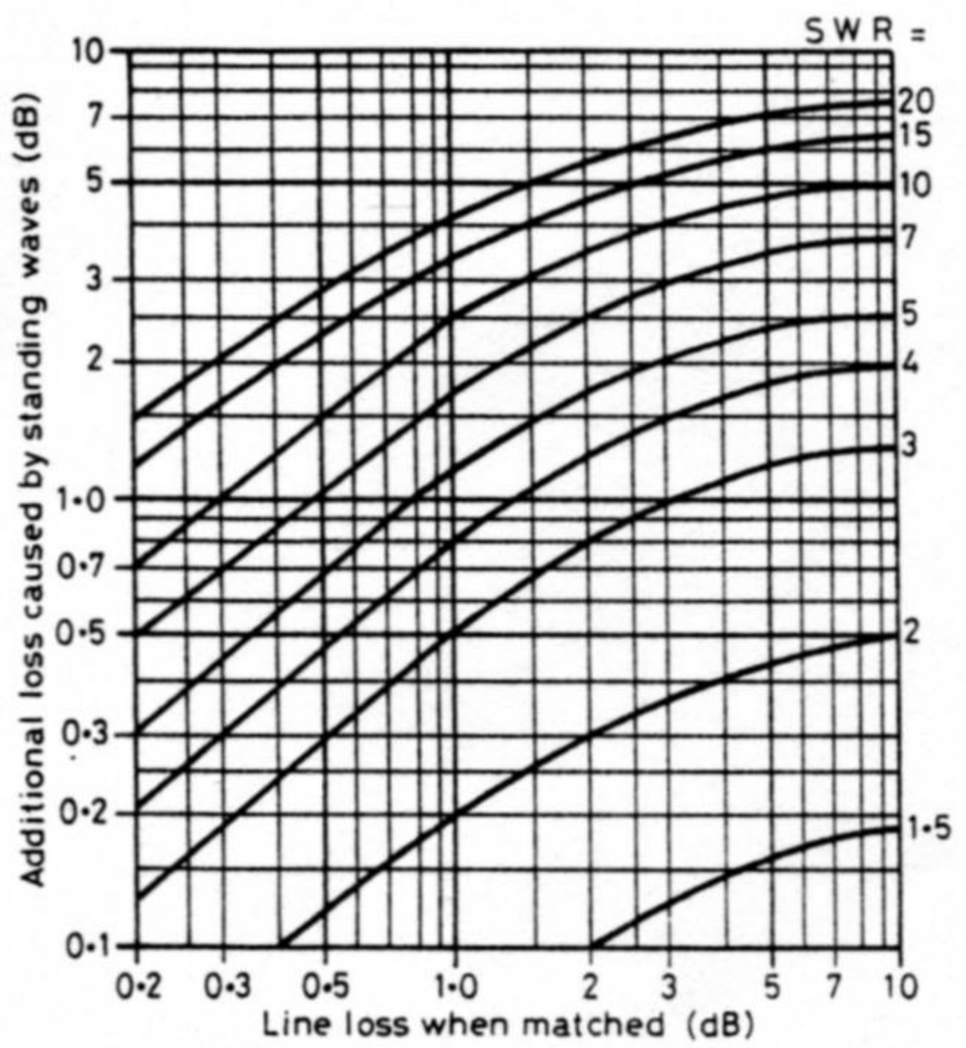
- Modern Amateur Transceivers with auto-tuners require VSWR < 3:1, so are of little value.
- Options for matching:
  - “Magic” antennas (dummy loads!)
  - Exact ½ wavelength antennas for each frequency
  - Wide-Band Terminated Folded Dipole
  - Automatic Antenna Tuner at or near antenna
  - Manual or automatic tuner at rig

When is VSWR A Concern?

- When using Coaxial Cable at high VSWR.
- Air has no dielectric loss at HF frequencies. This is why ladder is very low loss even at very high VSWR's.

Coaxial Cable Loss

- Additional coaxial cable lose is caused by dielectric losses in the center insulator when cable is operated at high VSWR's**.**
- Example – If normal line loss is 1 dB and SWR is 20:1, the additional loss is 5 dB for a total loss of 5 dB. 100 watts in = 32 watts out!
- Ladder Line has an air dielectric so has very low losses even at high SWR.

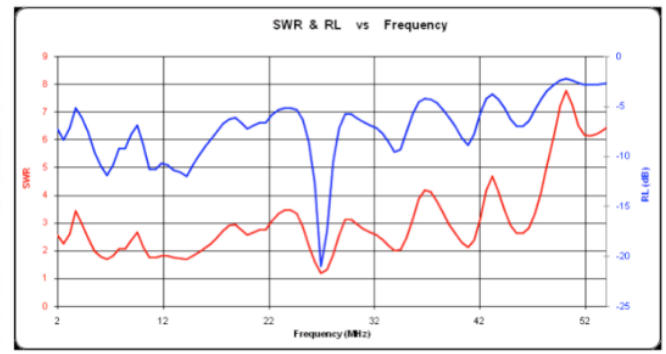


Low VSWR Antennas

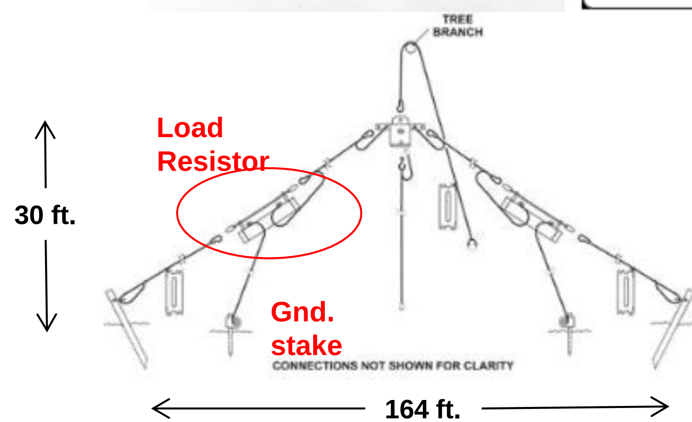
- Terminated or loosely coupled Antennas
- One-half wave-length Dipoles
- Special dimensioned wire antennas (for example - G5RV)
- Commercial antennas

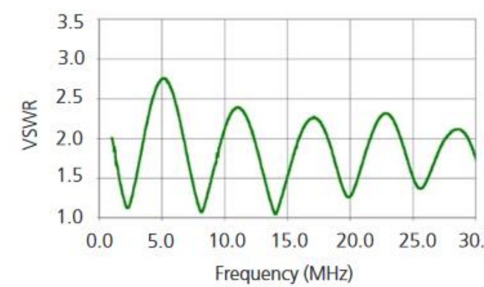
"Junk" Antennas at NVIS Frequencies (2-6 MHz)

Chameleon EMCOMMII
3.5 – 30 MHz
<2.5:1 SWR
$149.00



Harris RF-1944
1.6 – 30 MHz
<2.5:1 SWR
-15 dBi at 2 MHz
(20W in – 0.1 W out)
-2 dBi at 30 MHz
$2530.00

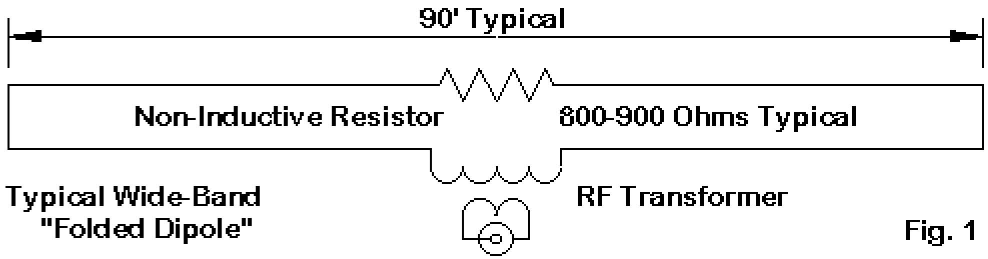


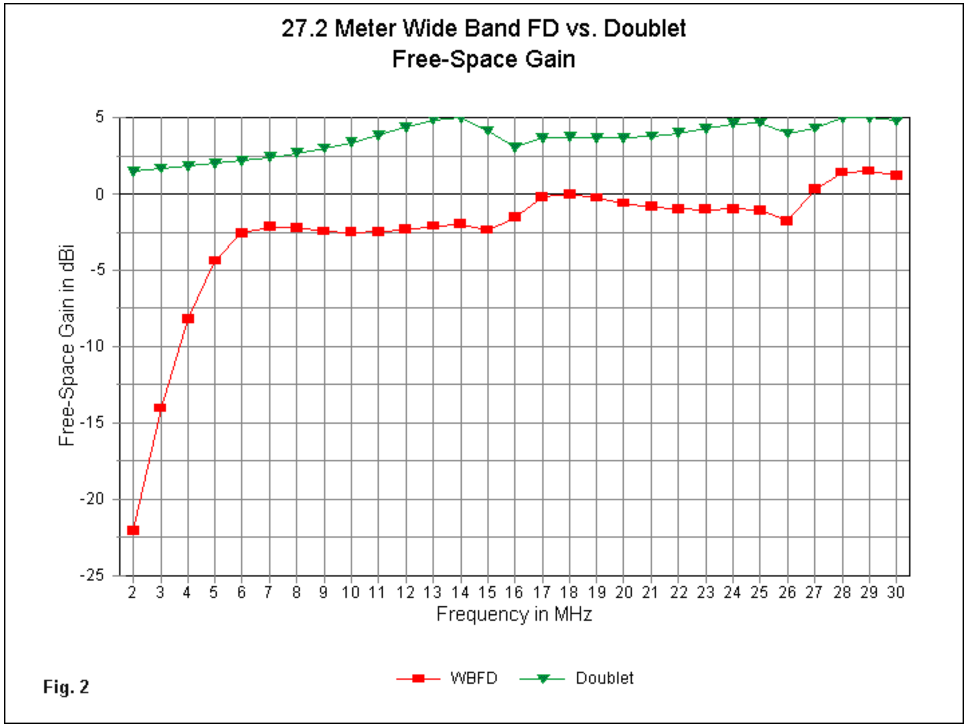


Any long-wire, vertical, or dipole claiming VSWR of <3:1 over the complete HF band has a very high loss matching network and will have a low transmit efficiency. Receiving requires only gain so will appear to work as a receiving antenna.

Terminated Folded Dipole (TFD) (B&W 90)

From: http://on5au.be/content/a10/wire/wbfd.html

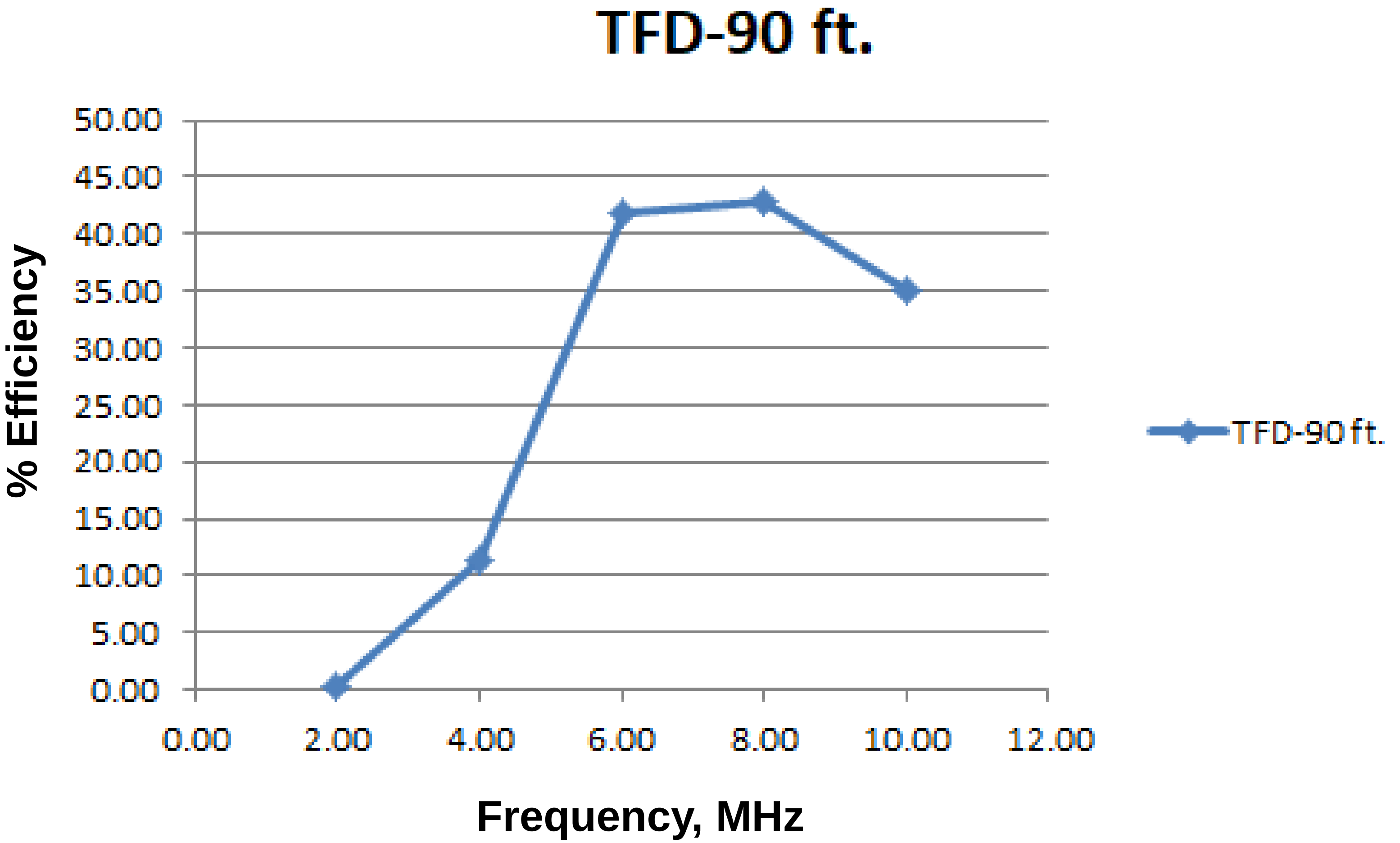




Rules:

1. **Length – ½ wavelength at lowest operating frequency**
   B&W 90 > 5 MHz
   B&W 180 > 3 MHz
2. **Accept losing ¾ of your transmit power, i.e., 100 watts in, 25 watts out!**
3. **Solution for ALE**

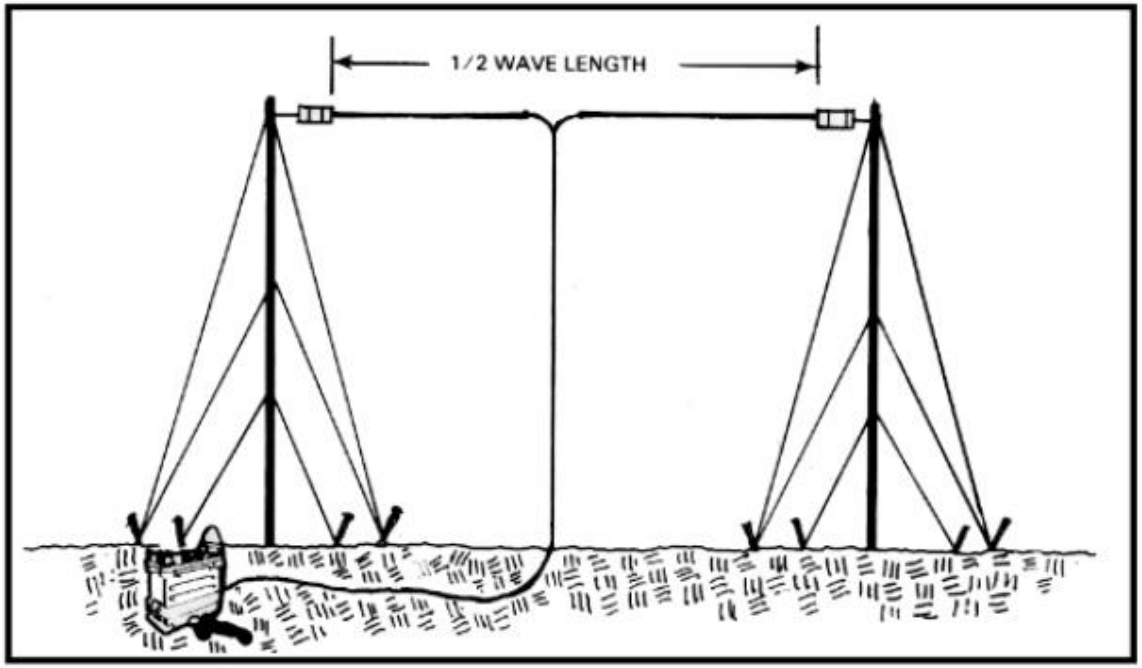
NVIS Antenna Efficiency

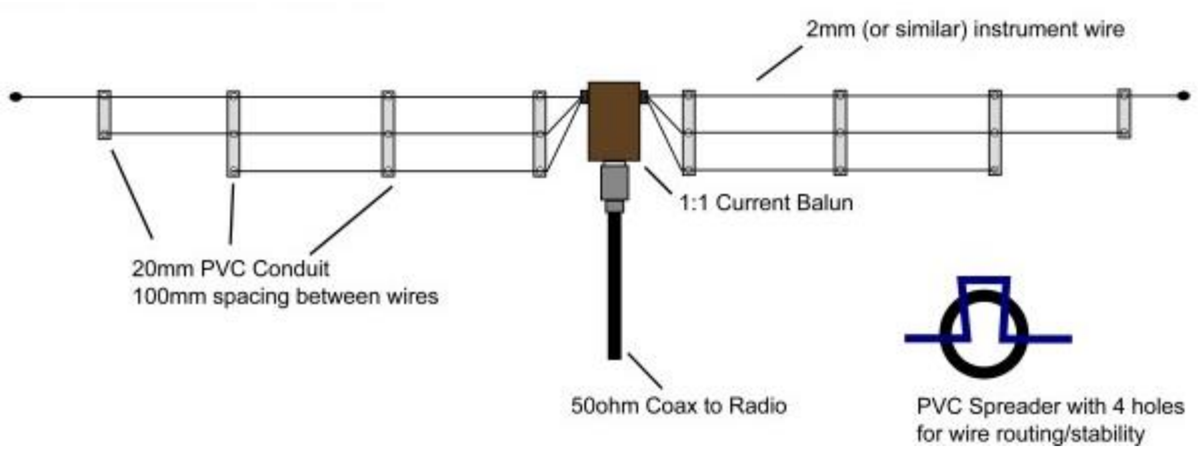


TFD Analyses

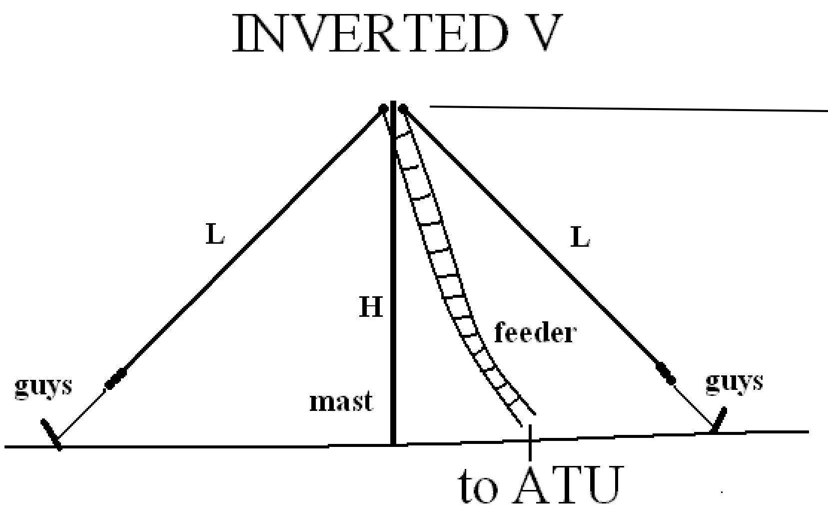
- Have EZNEC Pro files for the following:
  - B&W 90
  - B&W 180
  - Bushcomm BBA 27m (3-wire)
  - Bushcomm BBA 54m (3-wire)
- Only the B&W 180 and BBA 54m are applicable for low NVIS frequencies (3 – 5 MHz). But their length causes severe azimuthal asymmetry at higher frequencies.
- Their low transmit efficiencies also require a HF amplifier to compete with typical non-resonant dipole antennas.
- Only advantage is when a station must rapidly frequency scan, i.e. ALE (Automatic Link Establishment).

Resonant Dipole(s)





Generic Non-Resonant Dipole Driven by Tuner



WA1FFL Ladder-Loc

L = 65 ft. – 75 ft.
H = 30 – 50 ft.
Angle = As large as possible

Use 4:1 balun between ladder line and coaxial cable for rig Located tuners.

Summary

- To communicate around Texas and FEMA region 6 we must operate in the NVIS mode of HF propagation.
- The best way to generate the required NVIS directivity pattern is with a horizontal antenna at a height of less than 0.2 wavelengths.
- The efficiency of the NVIS antenna drops as the height is decreased below 0.2 wavelengths.
- Wide-bandwidth NVIS antennas can have horizontal (azimuth) directivity variance that can be mitigated in a number of ways.
- The SWR of a wide-bandwidth NVIS antenna must be addressed to minimize transmission line losses and maximize power transfer to the antenna.
- The second part of this series will address hardware approaches to maximizing the performance of a NVIS antenna. A number of members antennas will be shown as examples.