ANTENNAS – Wires, Verticals and Arrays

Presented by

Pete Rimmel N8PR

Tonight we are going to talk about antennas.

Anything that will conduct electricity can be made to radiate RF can be called an antenna. People are experimenting with columns of salt water as antennas.

Kurt N. Sterba, in his articles in Worldradio Magazine, used to write about making bedspring antennas.

I worked another ham on 40 Meter CW with a 6 ft. piece of wire leading to a 100 watt light bulb!

But what is important is how to build an EFFECTIVE ANTENNA that hopefully will put your signal to some place on the globe where you want it to go.

The starting point is to decide where you want your signal to go, and then see if you can put up an antenna at your QTH that will accomplish that goal.

What affects where your signal goes?

1. Height above ground – affects take off angle
   -- low for close in work, high for DX (H-pol)
2. Polarization of the antenna – verticals are
   omni-directional, horizontal antennas usually are not.
   (always vertical for repeaters)
3. Gain or directivity of the antenna
   – puts more power in the desired direction

Antenna types:

Wire antennas

-- Dipoles
-- G5RV
-- Zepp
-- Off center fed

Horizontal arrays

+Yagi
+Quad
+Wires
+Commercial

Verticals

-¼ wave
-Arrays
-Commercial

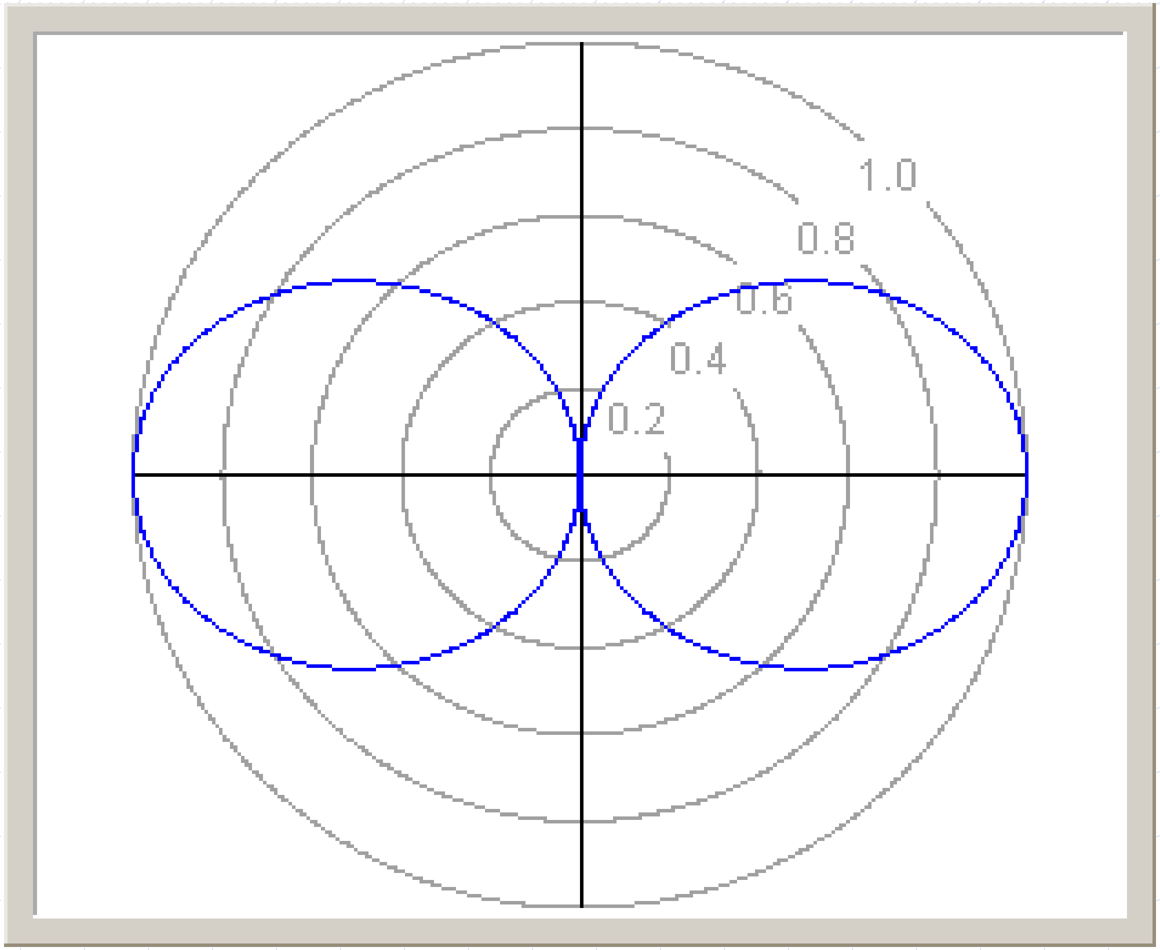
<u>DIPOLES</u>

Almost all antennas are based on a variation of a <u>Half Wave Dipole</u>. Most antennas are compared to the radiation characteristics of a half wave dipole.

A half wave dipole – ½ λ Dipole – has a radiation pattern like a figure 8.

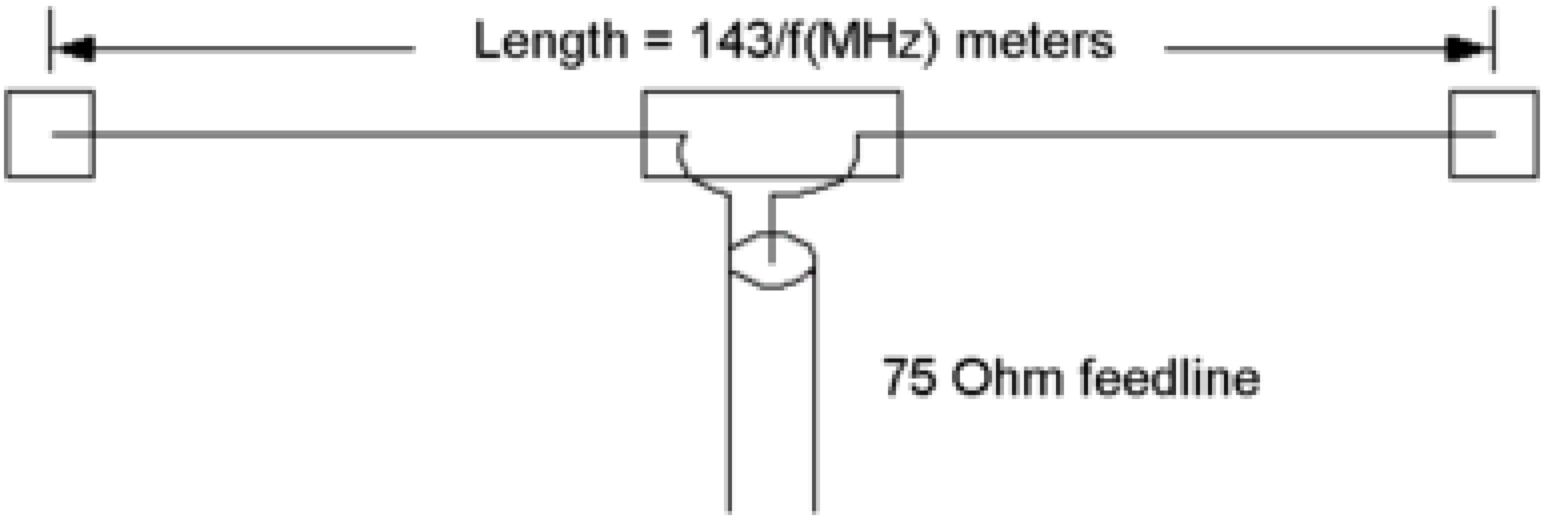
This is simple physics…

In this figure the dipole is in the vertical axis and we are looking down on the wire from above. Radiation is maximal in the plane of the wire, and minimal off the ends of the antenna



Calculating the length of a Half Wave Dipole (**bare wire**)

(for insulated wire deduct 2-3% for Vf [velocity factor])



For a λ/2 Dipole:

$$\text{Length (ft.)} = \frac{468}{f(\text{MHz})}$$

EXTRA ! How to tune the length of an antenna using an MFJ Antenna analyzer

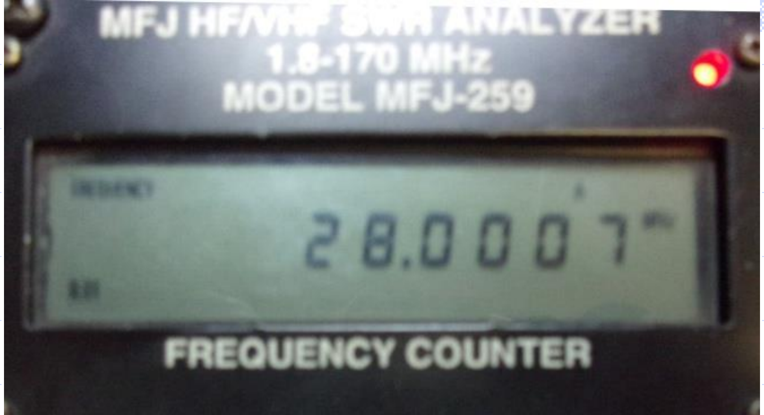
Let's build a 10 Meter Dipole

We know the formula for a ½ wave dipole:

468/f (MHz) = Length (ft)

What if we use this formula, cut it to length and find that the antenna is not resonant on the frequency that we specified ?

How do we decide how much to cut off, assuming we were smart enough to make the antenna a bit long?



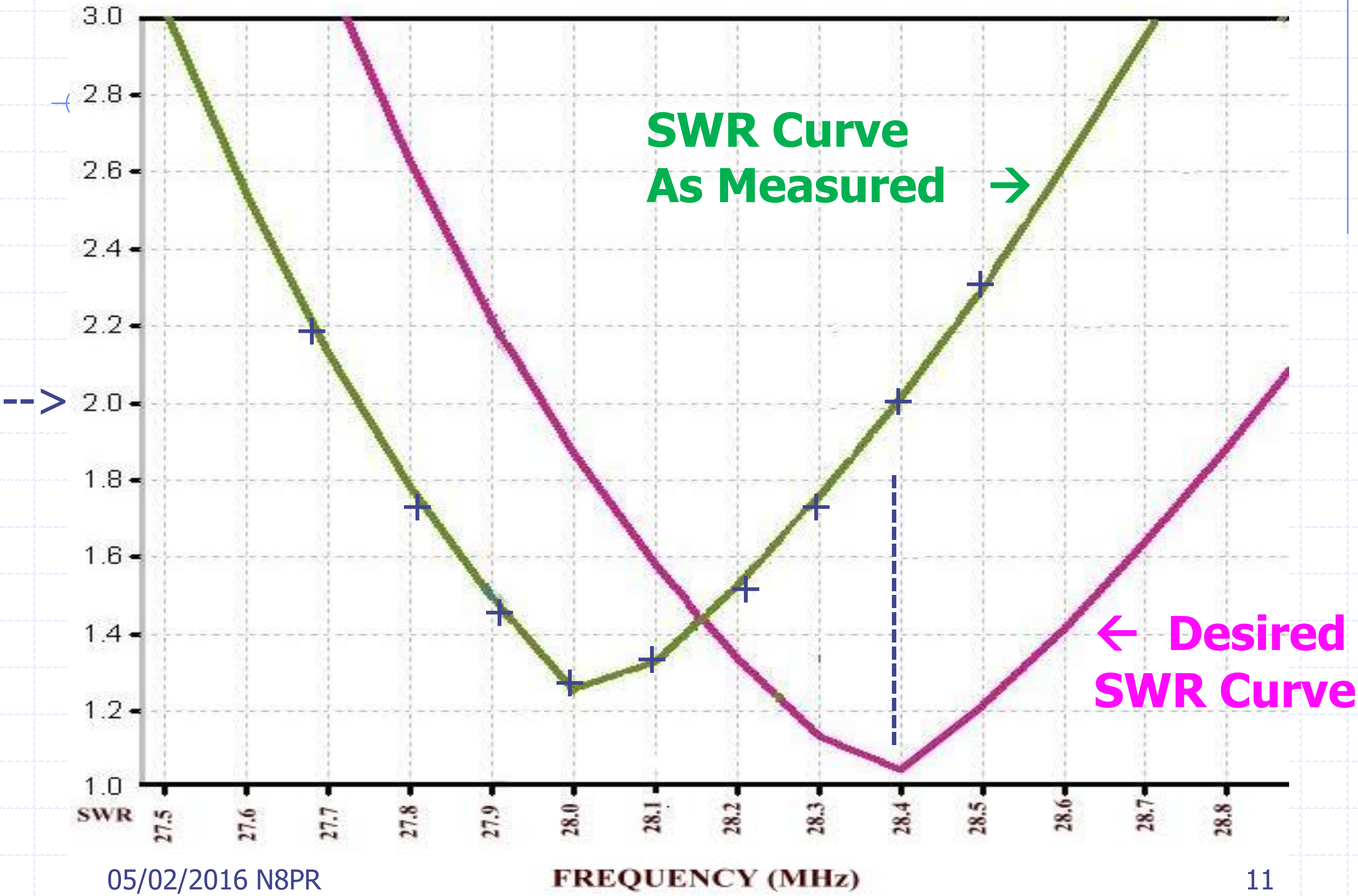
Let's say that we decided to cut the 10 meter dipole for SSB and used 28.400 MHz for our center frequency.

468/28.4 = 16.47 feet

We cut the antenna and run 75 ohm coax to it. By using the MFJ analyzer, we find that the minimum SWR dip in the antenna is at 28.0 MHz.

We call this the resonant frequency.

We can plot the readings from the MFJ meter:



Remember, we cut the antenna to 16.47 Ft…

Because the resonant frequency is lower than the design frequency, the antenna is TOO LONG!
How much should we cut off?

Let's use the formula at the frequency where we found the best SWR dip: (resonance)
468/28.0 = 16.71 feet

Take 16.71 – 16.47 = 0.24 ft x12 = 2.88 Inches

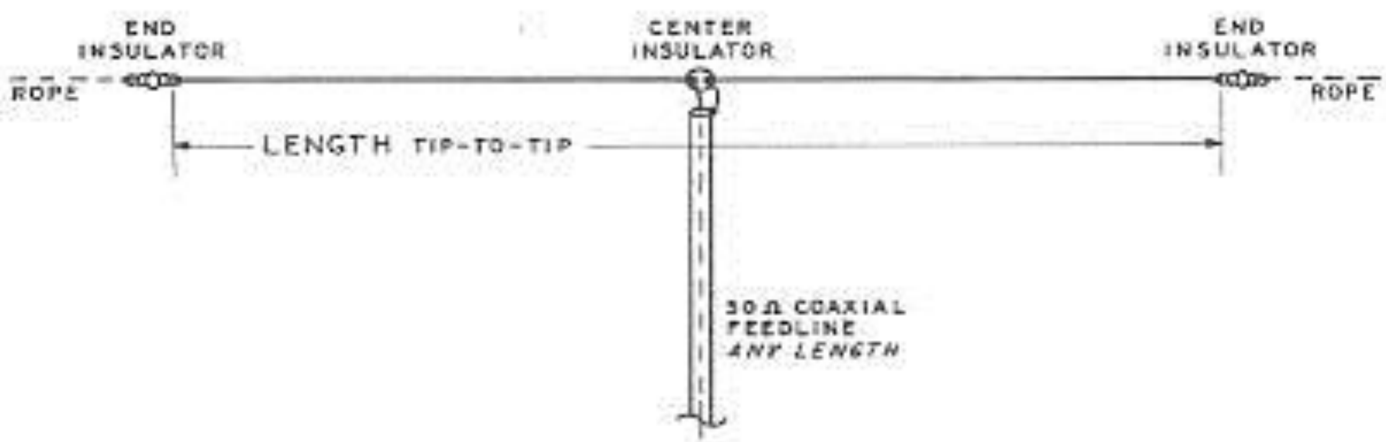
We must shorten the antenna 2 - 7/8"
to make it resonant at 28.4 MHz !

NOTE: You can use the SWR meter on your rig to take the same measurements !

WHAT COULD HAVE AFFECTED THE RESONANT FREUQENCY?

1. Was it bare or insulated wire?
2. What was the diameter of the wire? Tubing? (VHF) (Thicker Dia.= Shorter element)
3. How long was the coax lead to the antenna between the braid and where the coax and braid was attached to the elements?
4. How high was the antenna above ground?
5. Were there nearby objects that could have coupled with the antenna?
6. How did we attach the ends and center to insulators?

THE DIPOLE ANTENNA

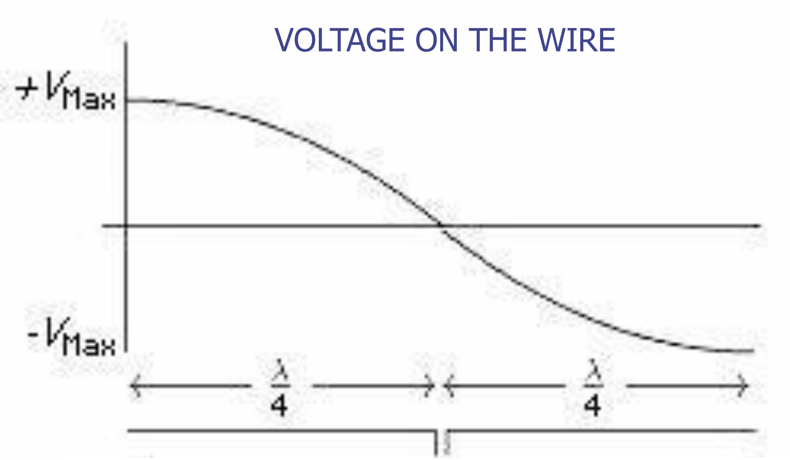


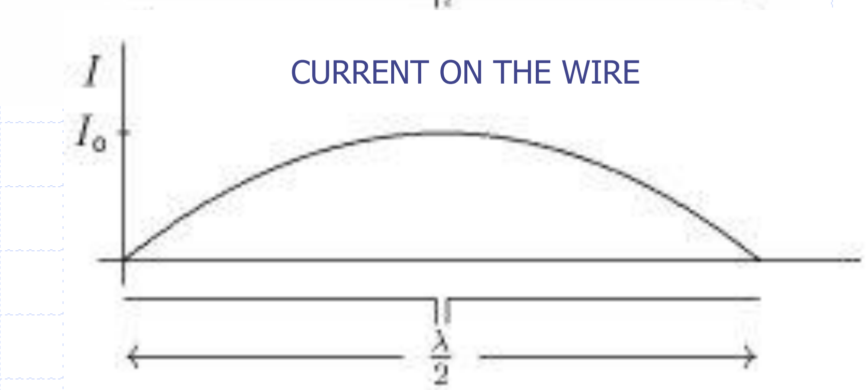
BAND	CENTER FREQ. (MHz)	LENGTH TIP-TO-TIP	METRIC LENGTH
160	1.85	253' 0"	77.10
160	1.95	240' 0"	73.15
80	3.60	130' 0"	39.62
80	3.80	123' 2"	37.54
40	7.15	65' 6"	19.98
30	10.12	46' 3"	14.10
20	14.15	33' 1"	10.10
17	18.12	25' 10"	7.87
15	21.20	22' 1"	6.73
12	24.93	18' 9"	5.72
10	28.60	16' 5"	4.98
5	50.20	9' 2"	2.80

$$\text{LENGTH (FT)} = \frac{468}{\text{F (MHz)}}$$

Length In feet

253′0″
240′
130′
123′2″
65′6″
46′3″
33′1″
25′10″
22′1″
18′9″
16′3″
9′2″

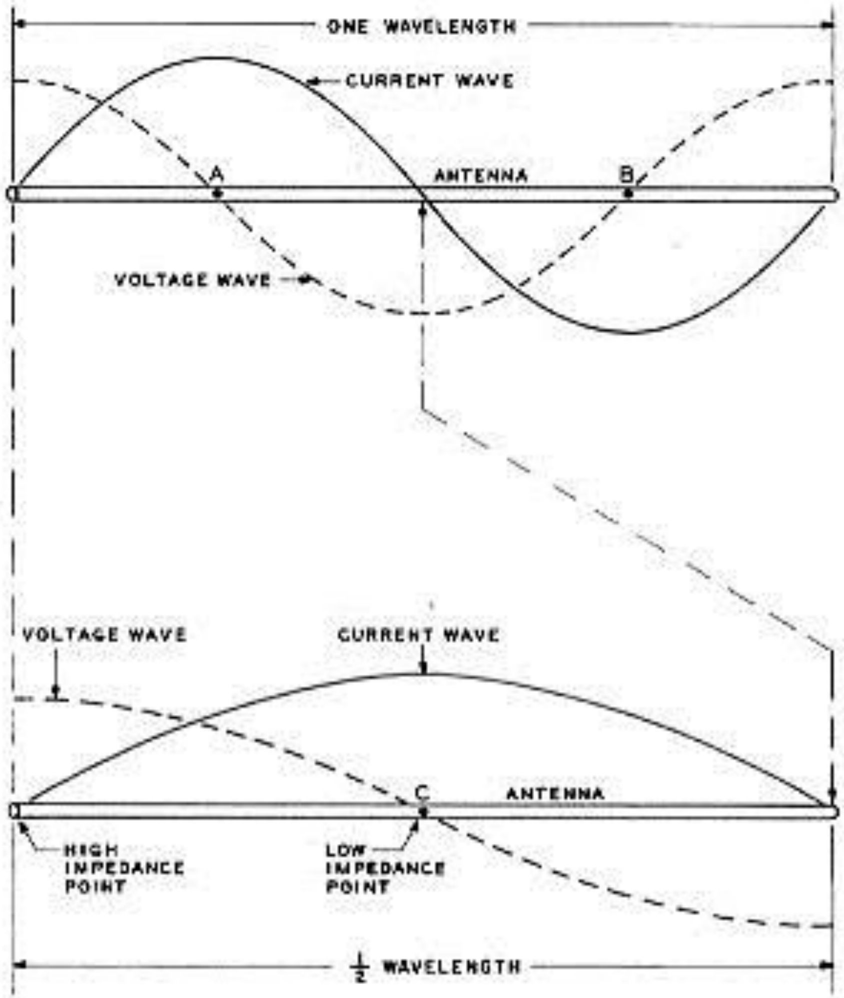




On a center fed Half Wave Dipole the voltage at the feed point is at a minimum. at the ends of the wire is at highest voltage.

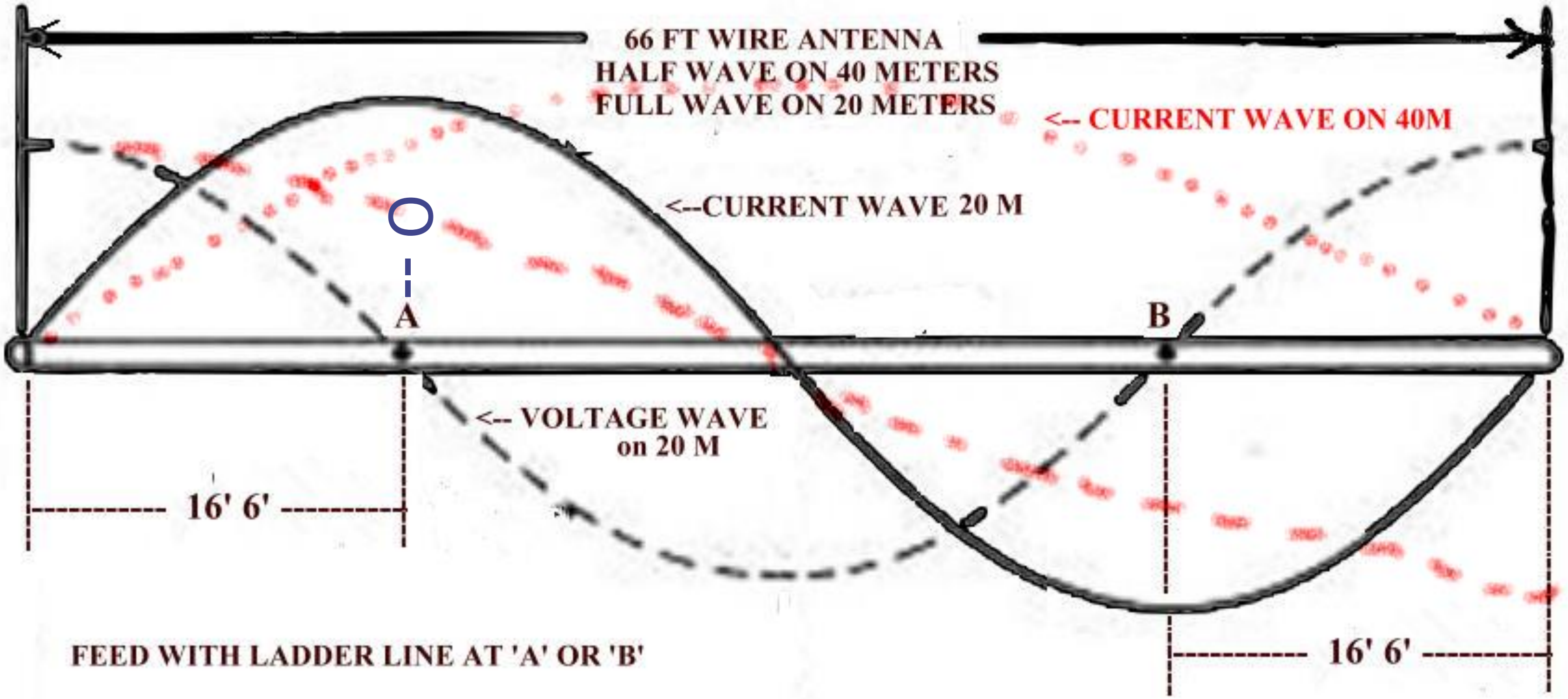
On the same wire, the current is at a maximum at the feed point and a minimum at the ends.

We always want the high current point as high as possible above ground



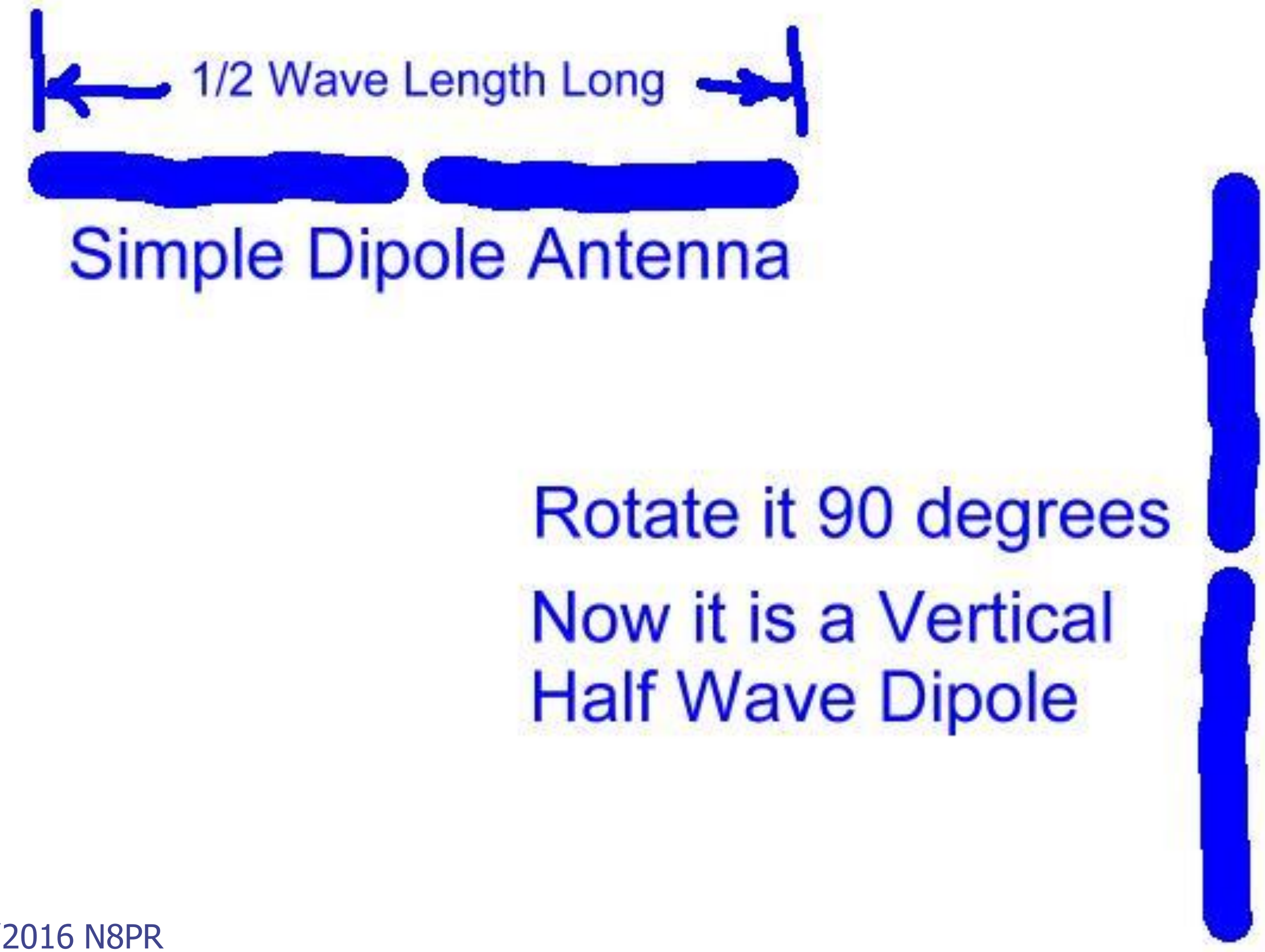
Here is why it is best not to feed full wave antennas at the middle, or half wave verticals at the bottom.

We cannot feed an antenna (generally) at a high voltage point. We must feed it at a voltage null which is also a high current point A or B in the top part of the drawing.



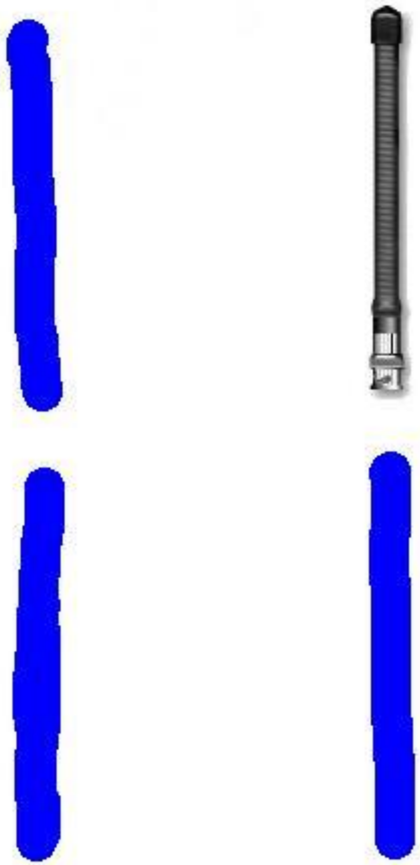
You can feed a full wave wire at the low voltage points with ladder line and use an antenna tuner to match it to the output of your transmitter.

VERTICALS:


1/2 Wave Length Long
Simple Dipole Antenna
Rotate it 90 degrees
Now it is a Vertical
Half Wave Dipole

Extra !

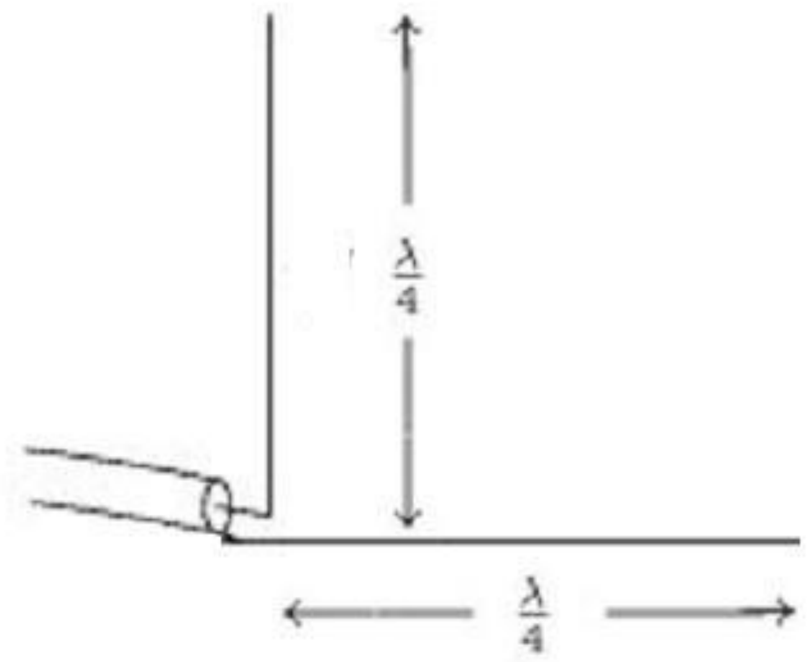
Your Rubber Duckie can be Half of the Dipole… just clip on a ¼ wave long wire to the ground side of the BNC and you have a more effective antenna !

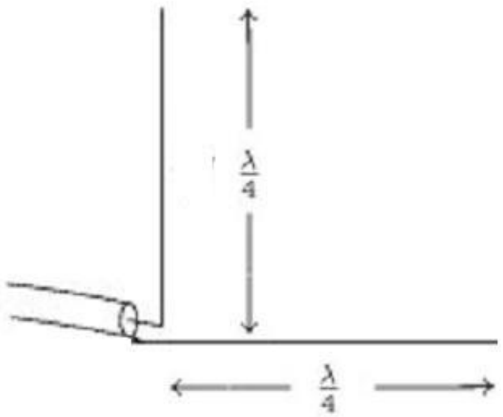


For 2 meters this wire is about 19 ½ inches long.

That will work for 440 as well – or clip on a 6” wire as on the right.

Let’s take that dipole and turn one of the horizontal wires 90 degrees and make it into a vertical element.



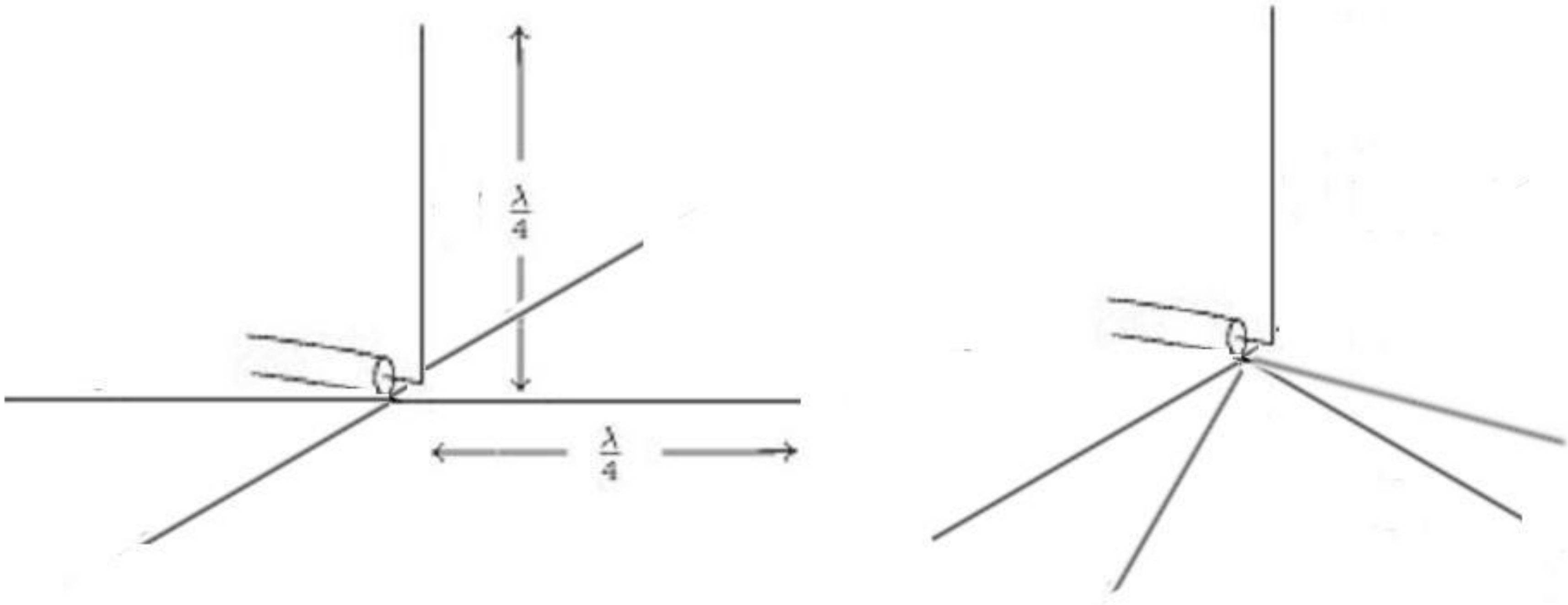


We still have a half wave antenna, but one element is in the vertical plane, and the other one is in the horizontal plane.

This is a basic $\lambda/4$ vertical.

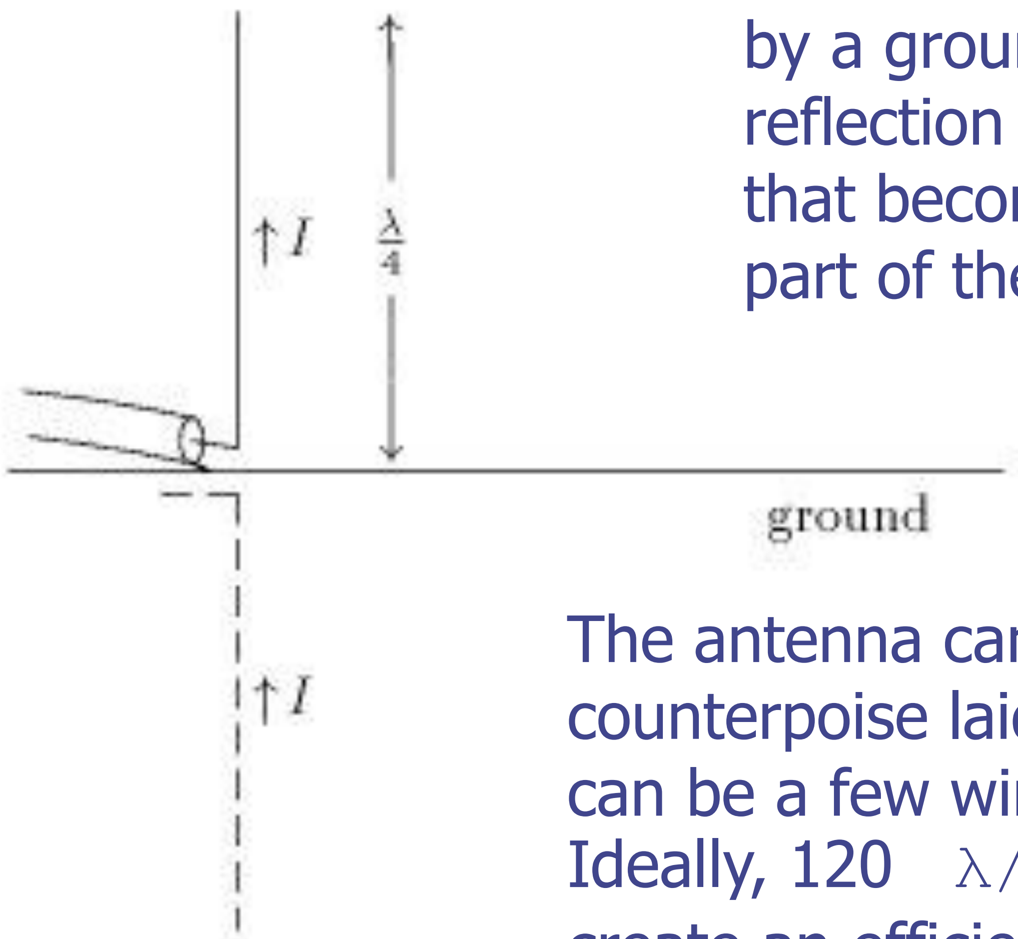
Currents and voltages are the same as they are in a half wave dipole.

Now we can replace the horizontal element with A counterpoise, radial system or ground.



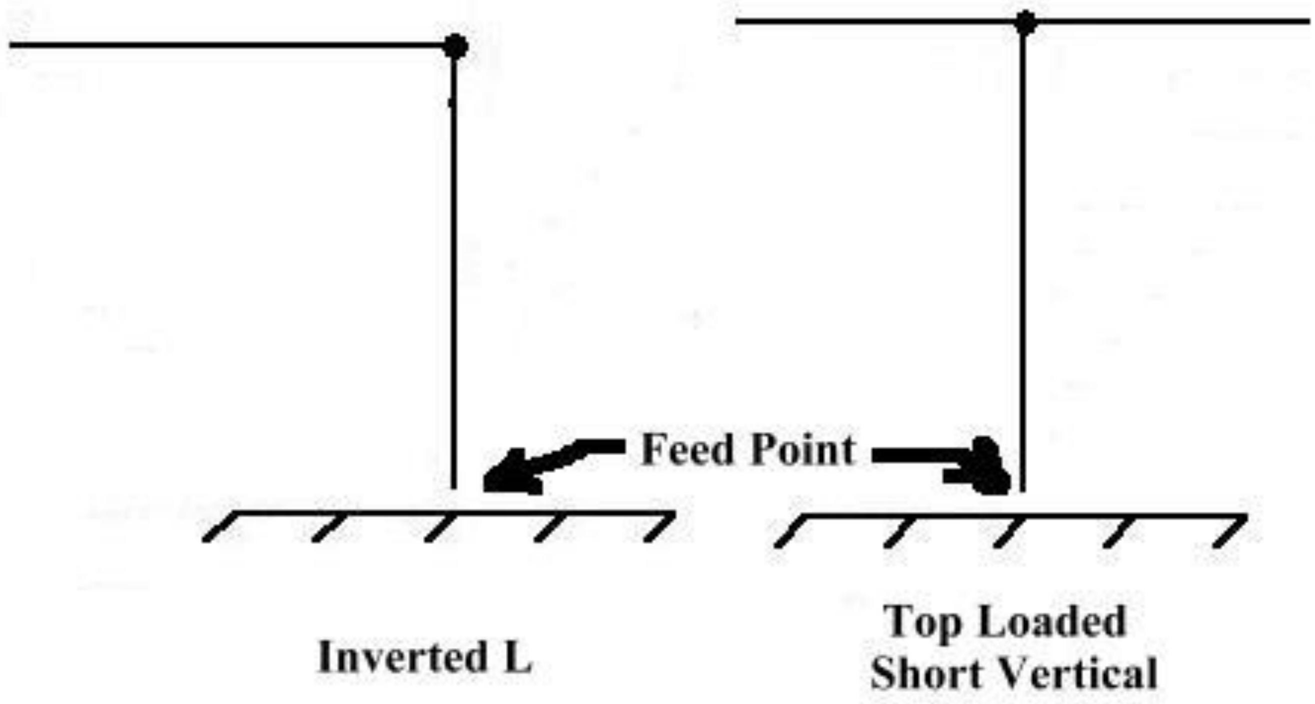
Add three more λ/4 radials and you have made a ground plane antenna. It can be a few feet above the ground or elevated high above ground.

The feed point impedance of this antenna is approximately 37 Ohms. By tipping the four radials down about 45 degrees you can get a good 50 Ohm match to coax cable



Here the $\lambda/4$ radials of the antenna have been replaced by a ground. The ground reflection creates an image that becomes the other part of the half wave antenna.

The antenna can be fed against a counterpoise laid on the ground. This can be a few wires of random length. Ideally, 120 $\lambda/4$ to $\lambda/2$ radials will create an efficient counterpoise


Feed Point
Inverted L
Top Loaded
Short Vertical

HALF WAVE END FED VERTICAL (AND HORIZONTAL) ANTENNAS

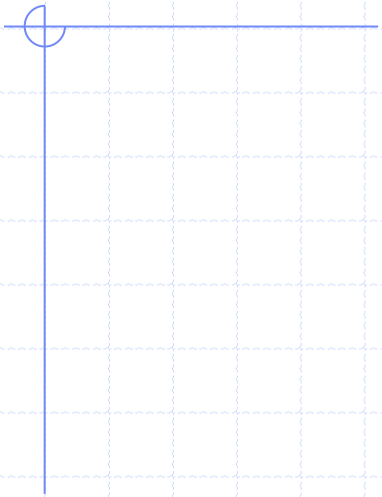
Many of you have built or seen end fed wire antennas that are ½ wavelength long. These are a special case where a choke /transformer takes the 50 Ohm Coax impedance and transforms it into a high impedance that will feed an end fed half wave antenna.

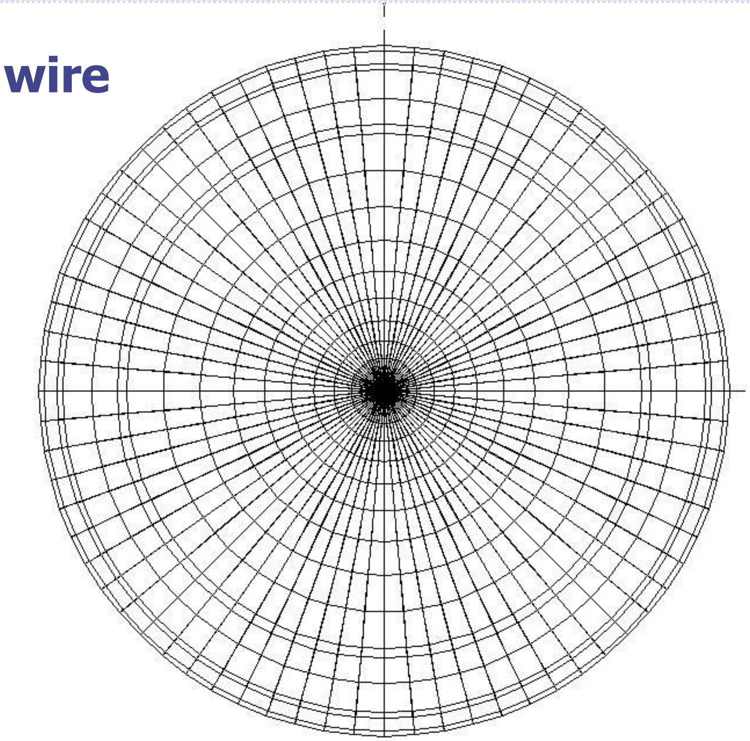
These antennas usually are only used on the band for which they are designed since the matching circuit will not work well on another band AND usually fed with LOW power.

These antennas can be used as a horizontal, sloping or vertical antenna. Patterns will be similar to a dipole or vertical. Sloping patterns depend on the angle. As you approach 45 degrees from vertical, they start to radiate more broadside 90 degrees each side of the angle where they slope away from vertical.

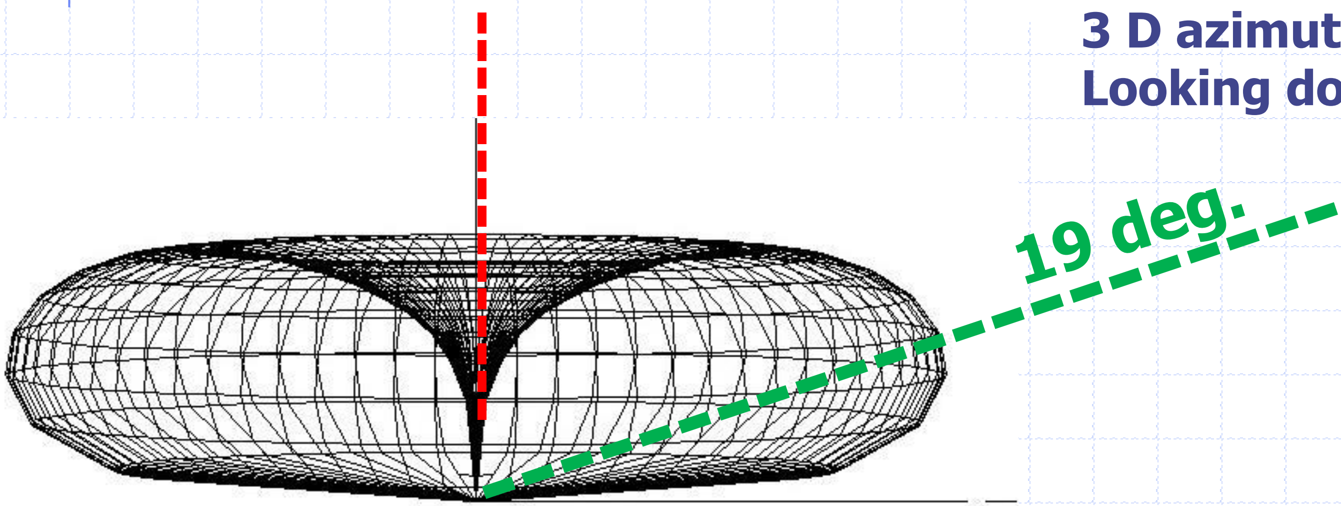
This is a ½ wave 20 Meter vertical end fed wire

Notice the symmetrical pattern.





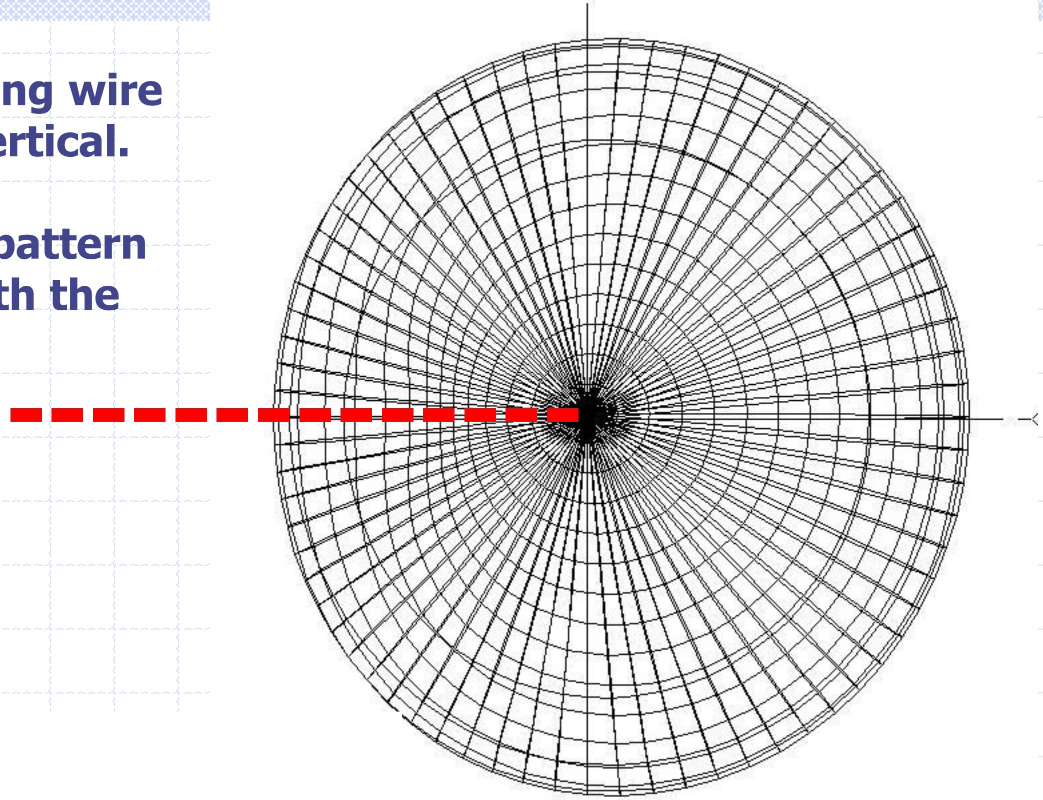
3 D azimuth plot of antenna
Looking down from the top



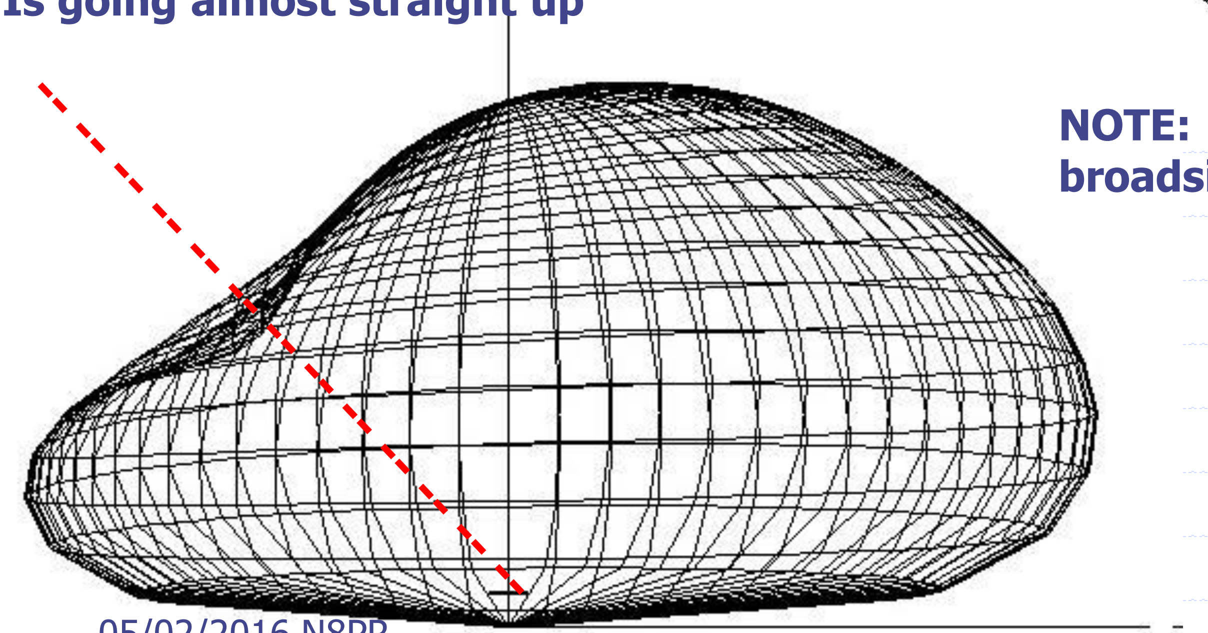
Side view of antenna – 3D elevation plot

This is the ½ wave 20 meter sloping wire with the wire 45 degrees from vertical.

Note the null off the end and the pattern better broadside than in line with the antenna.



NOTE much of the signal Is going almost straight up

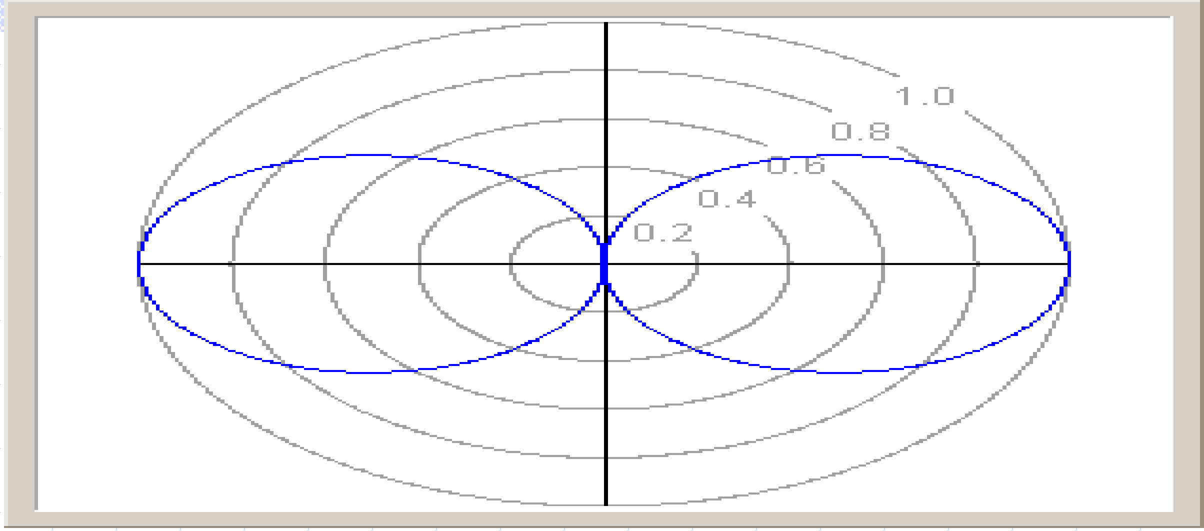


NOTE: Pattern is becoming more broadside than symmetrical

Loop antennas

Loop antennas share one common factor. The ends of a dipole antenna are connected together to form a closed antenna. This antenna has more gain broadside to it than a dipole, if in the vertical plane. It is usually 1λ +5% long on the desired band.

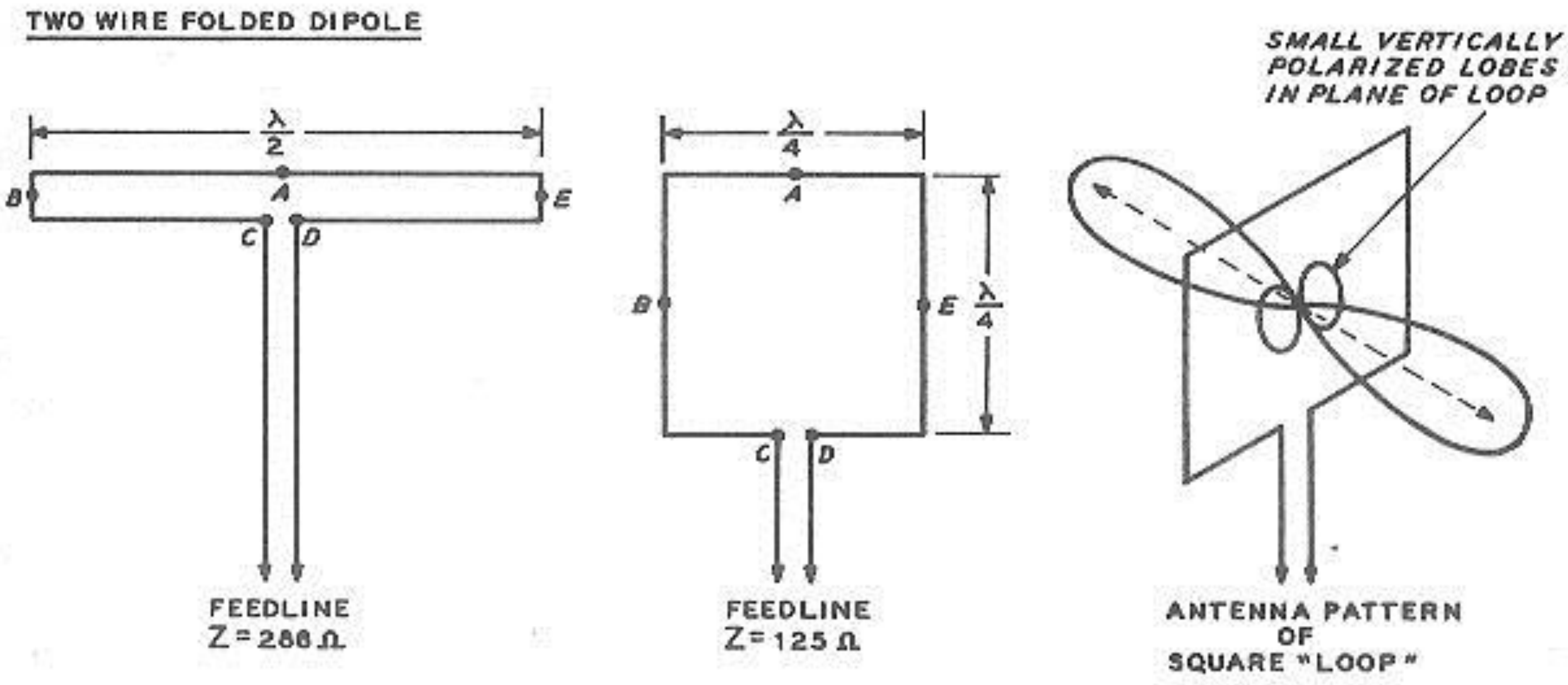
Loop antennas are usually quieter than long wire Antennas when receiving. ie. They are less susceptible to man made noise and static.



The large vertical loop antenna is similar to a dipole, except that the ends of the dipole are connected to form a circle, triangle or square. Typically such a loop is some multiple of a half or full wavelength in circumference. Good results can be had with a 1λ loop.

A loop has a pattern similar to a dipole with the maximum radiation broadside to the plane of the loop. The minimum is in the plane of the loop.

A single full wave loop has about 3 dB gain over a dipole

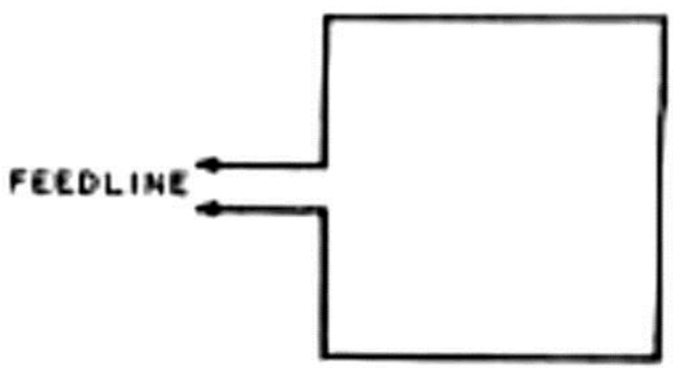


The Folded Dipole is a special case of a closed loop antenna. It is 1/2λ long and only a few inches high.

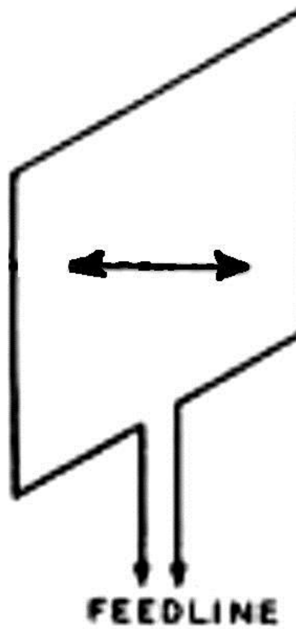
1/4 Wave length of 75 OHM coax as a transformer will match a 50 OHM coax cable

A round or square loop that is fed at the top or center of the bottom leg will be horizontally polarized.

A round or square loop that is fed in the middle of the side will be vertically polarized.

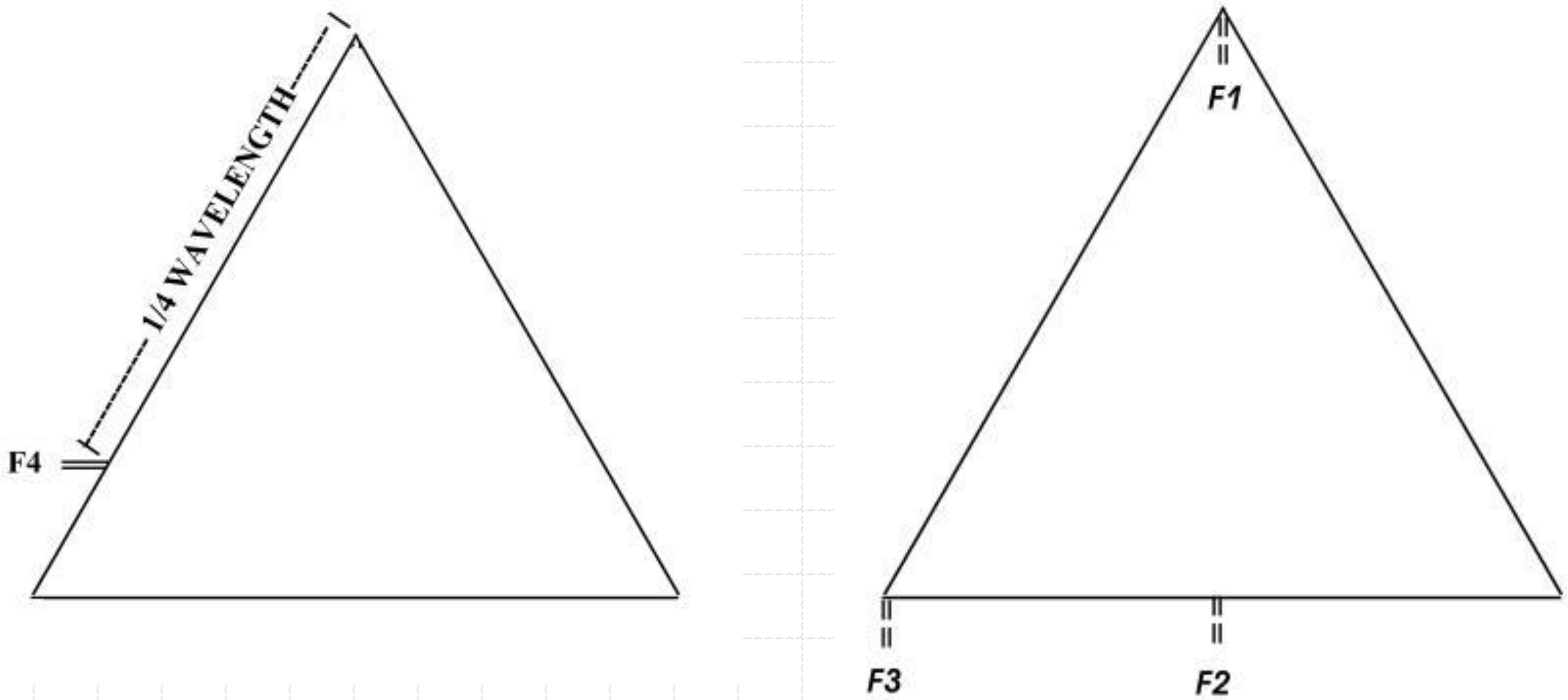


VERTICALLY POLARIZED
QUAD LOOP



**HORIZONTALLY POLARIZED
QUAD LOOP**

A delta loop that is fed 1/4 wave down from the top will be vertically polarized. If it is fed at the top or the middle of the bottom, or bottom corner, it will be horizontally polarized



Why would you want horizontal or vertical polarization?

As you design your antenna, you must decide <u>where</u> you want your signal to go.

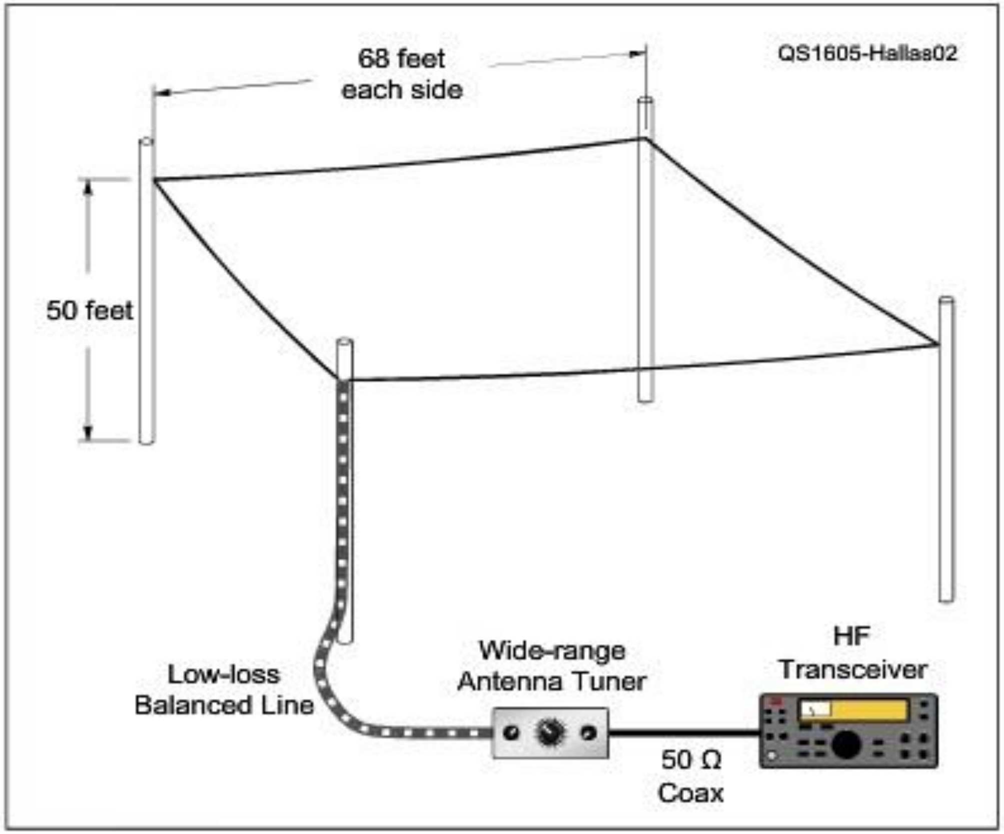
Short skip, cloud warmer antennas are good for working close in – stateside and the Caribbean… use horizontal polarization.

If you can get the antenna 1-2 wavelengths above ground, a horizontal antenna may be good for DX

OR

FOR DX to Europe, Asia, South America or half way around the world… use a vertical antenna for lower take-off angle and longer skips.

A **horizontal loop** held up equally high at 4 corners and fed with ladder line or a balun will perform well on a number of bands.



Its height above ground will determine its vertical takeoff pattern. Usually, on the low bands, it is used as a cloud warmer to talk to near in stations. It is also omni-directional (almost)

It can be 1λ or longer on desired bands. It must be at least 1λ long on the lowest band used. (80M antenna in figure above)

Before we talk about parasitic antennas and arrays, lets talk about various wire antennas that we can build and some general characteristics of some antennas:

Dipoles-- flat, sloping, inverted Vee

G5RV– a special multiband dipole

Zepp– end fed wire

Windom – off center fed wire

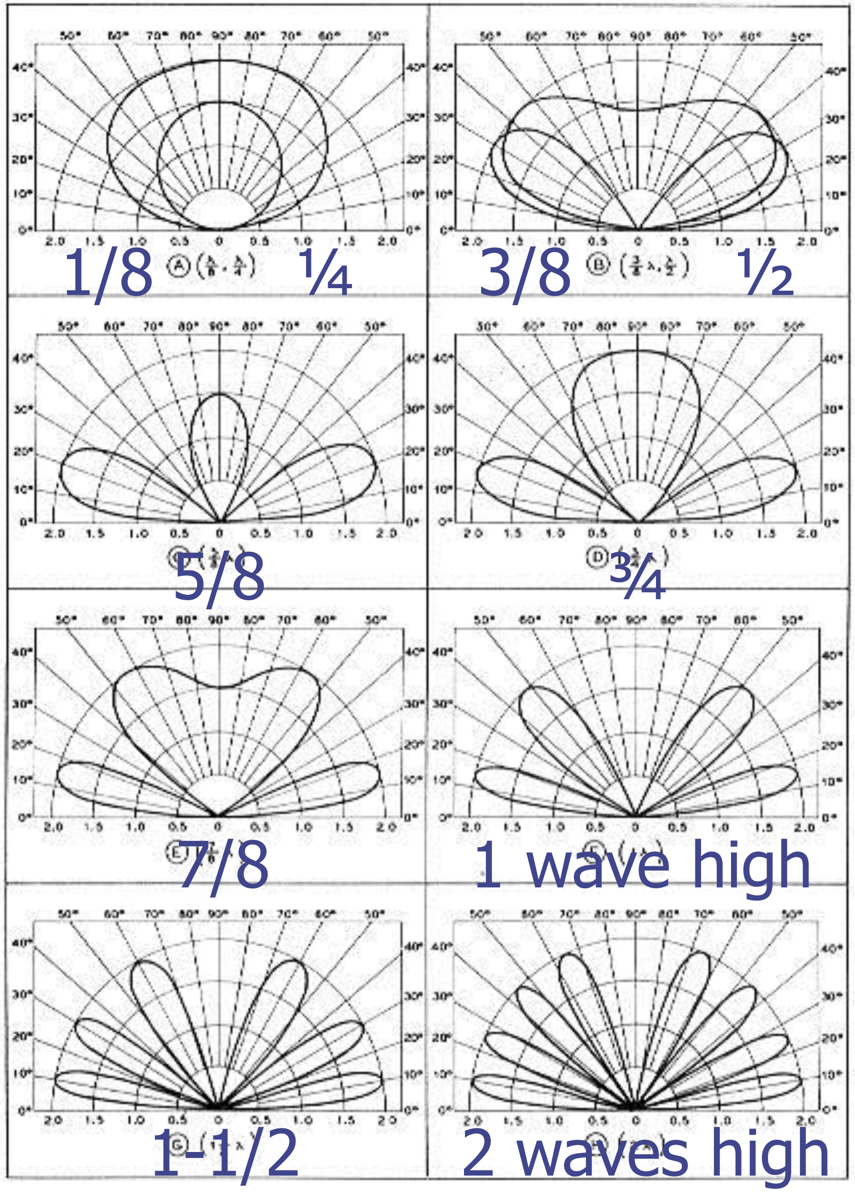
Loops – Square, Delta, Rectangle

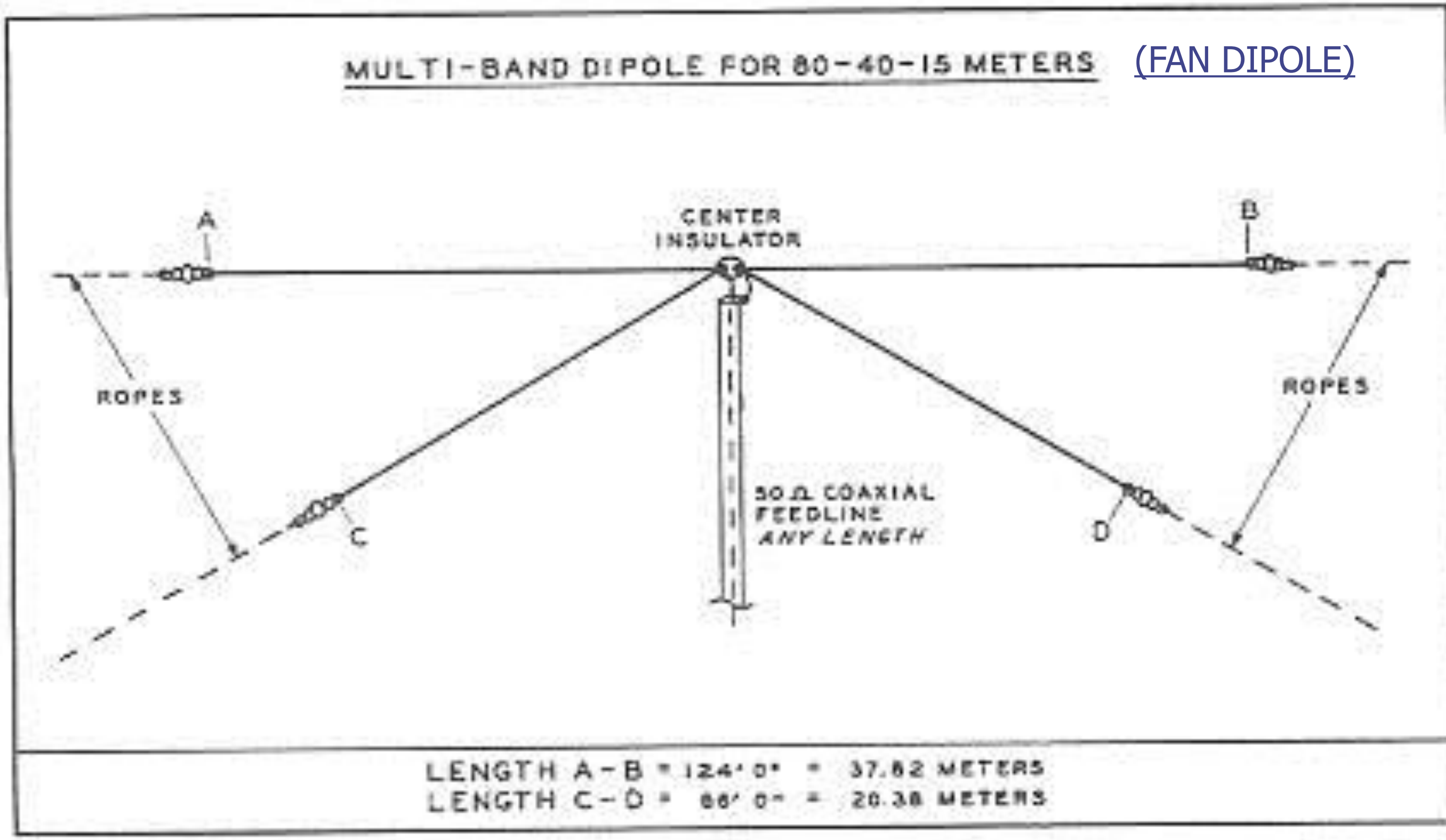
Dipole antennas work best when horizontal. They also work well when operated on odd multiples of a half wavelength.   (40M -> 15 M; 80M -> 30M)

The take off angle of a dipole or any horizontal antenna is dependent on its height above ground.

To the right are patterns of a half wave dipole from 1/8 wave above ground to 2 wavelengths above ground. This holds for all HF Frequencies.

These patterns occur and vary due to the ground reinforcement and reflection of the RF.

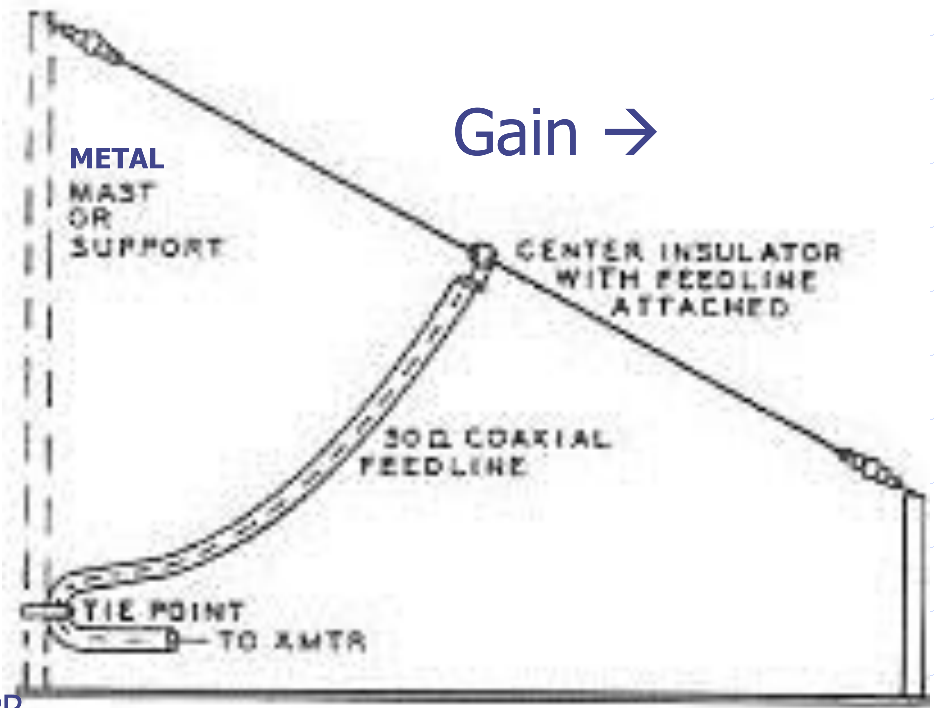




You can feed more than one dipole with the same feed line, but you must keep the wires somewhat separated to be effective, otherwise they interact and detune each other and nothing works.

Sloping Dipoles must be resonant, and can be held up by supporting one end higher than the other.

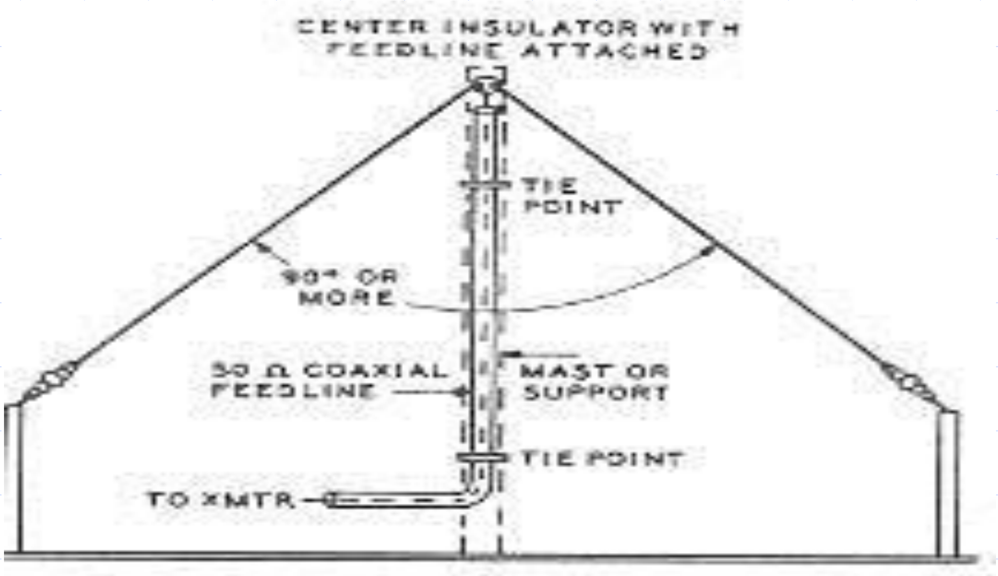
The feed line should be led away at right angles to the wires. It will show a small gain in the direction that the wire slopes.



Inverted Vee antennas are easy to erect because they can be held up by only one support.

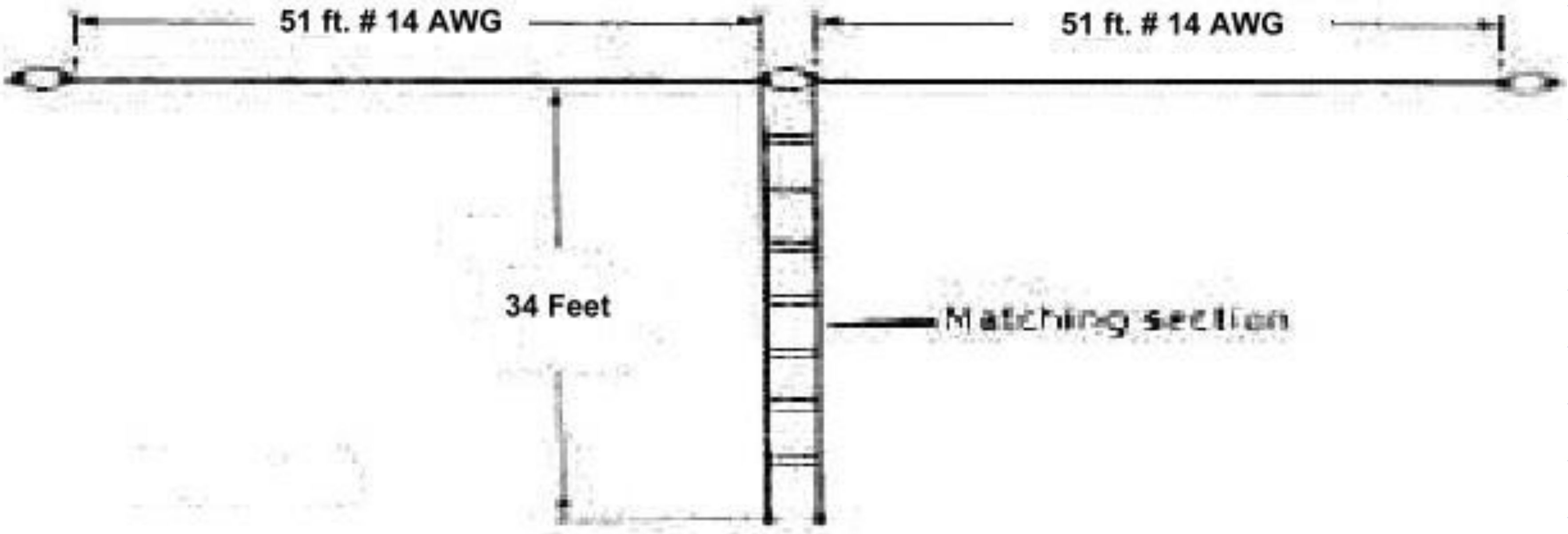
It is imperative that the included angle between the two wires is greater than 90 degrees, otherwise canceling will occur and the antenna will not radiate. ~120^{o} angle = 50 Ohm feed impedance.

The inverted vee has horizontal polarization broadside to the antenna and vertical components off the ends.



The G5RV antenna is a special dipole that by design (or accident of properties) allows a dipole that is fed with a special length of ladder line, a balun and coax cable to radiate fairly well on the HF bands.

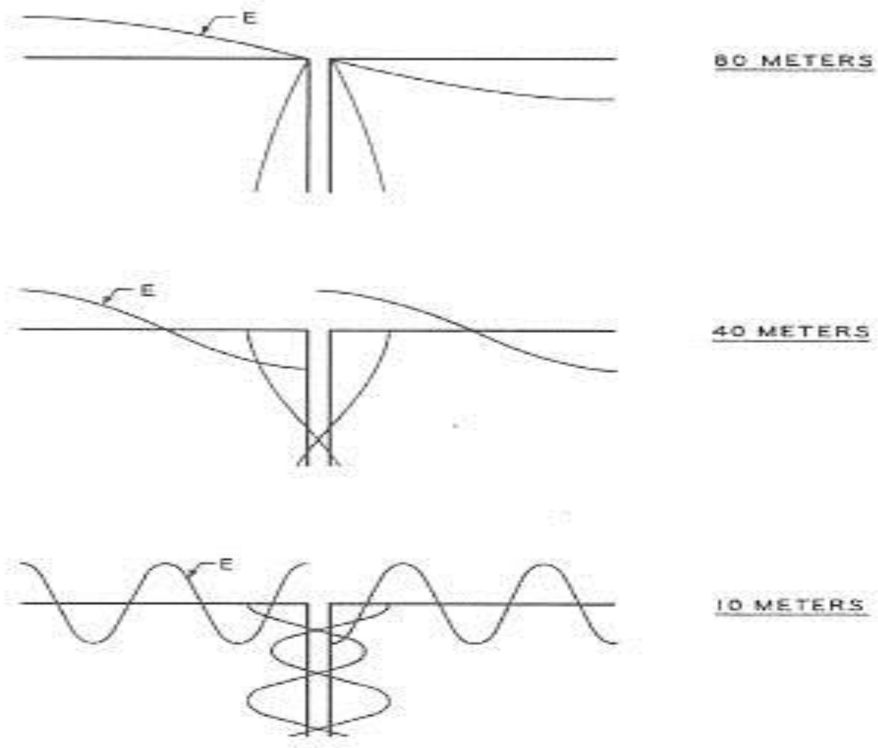
This antenna is usually 102 feet long. The ladder line to it is 34 feet long. The two lengths added together in one instance create two ~λ/4 wires on 80 Meters, and other resonant lengths for the higher bands from 40 through 10 meters. It must be fed with a Balun, to match a coax feed line.



←Connect 4:1 Balun and Coax from
Here to the Shack
OR run ladder line all the way

G5RV Multiband Antenna
And the "New"
Davie "Windom" Antenna by Sandy KK4OXM
(Like the antenna hanging from the crane last Field Day)

Voltage on the G5RV on Various Bands

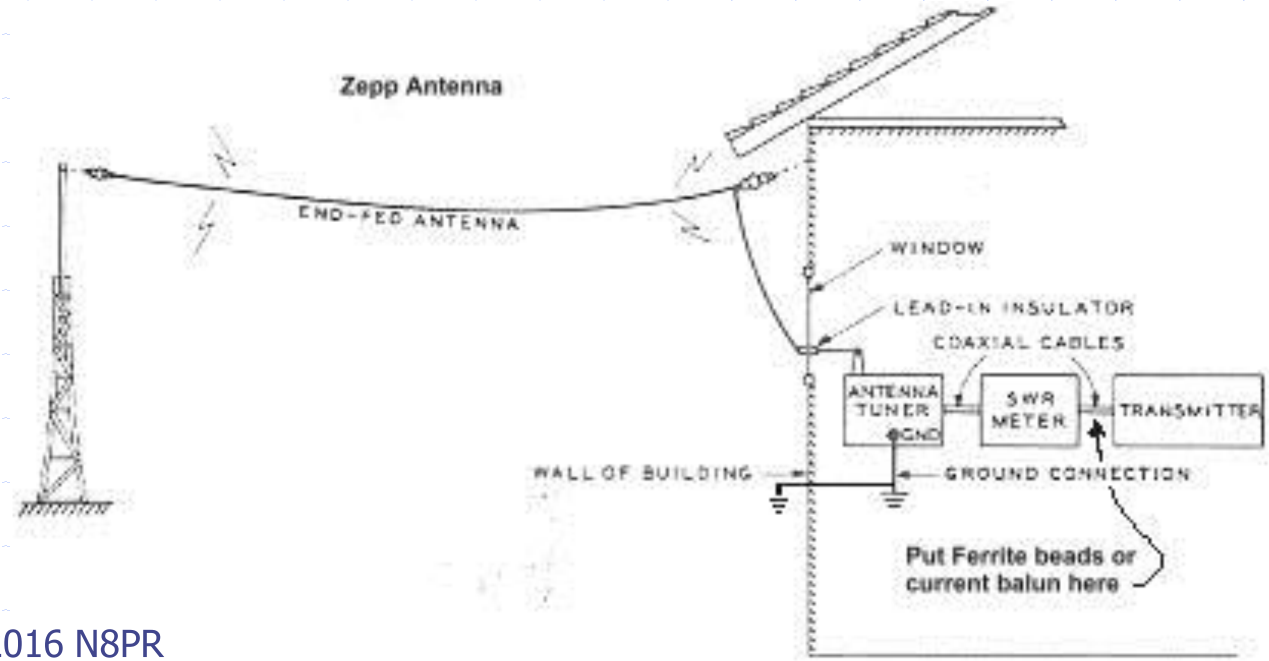


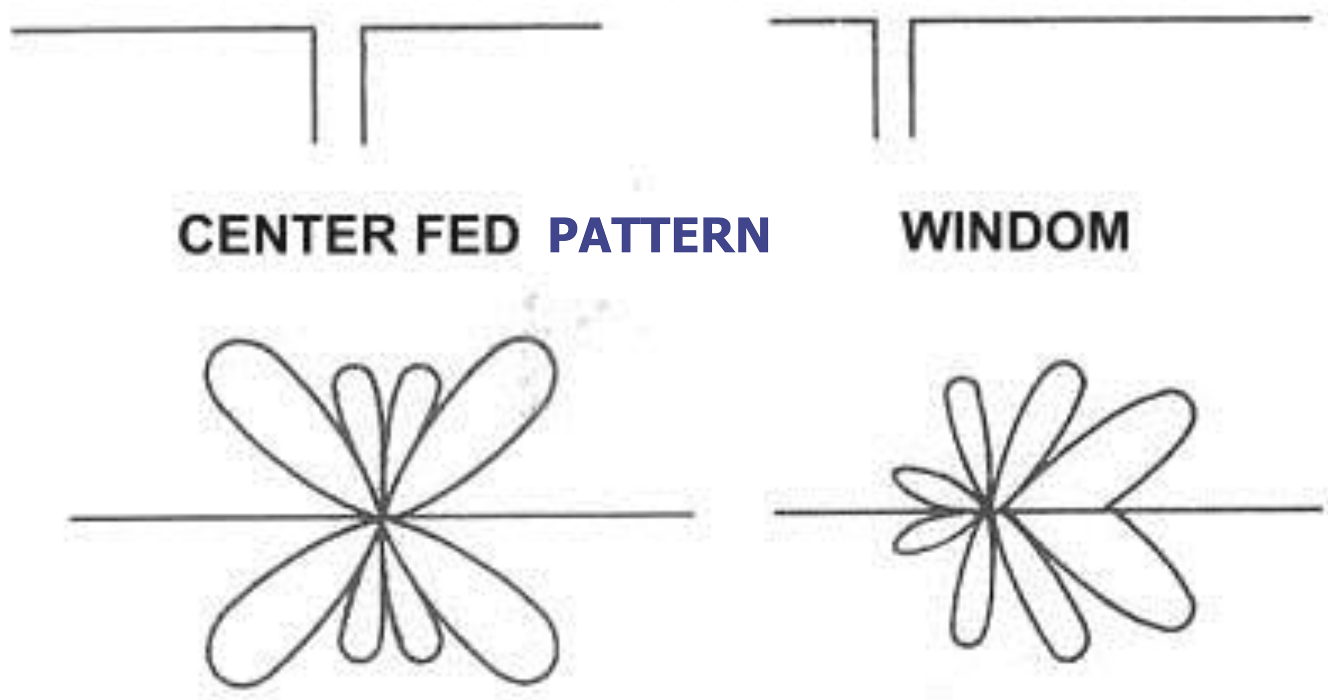
A variant of this antenna can be fed with ladder line all the way to a tuner in the ham shack.

It is best that this antenna be as horizontal as possible, but sloping the ends down a bit will not affect the antenna radiation patterns too much.

The Zepp antenna derives from the end fed wires that trailed the zeppelin airship. It was end fed, and unless it is an odd multiple of half wavelengths on the band desired, it will be difficult to feed.

The longer this antenna is in wavelengths, the more the pattern is skewed away from broadside radiation toward a more end fire pattern.





A Windom antenna is a wire antenna that should be cut to resonance. It is off center fed, which allows multi-band operation if fed with ladder line. Ideally, the feed point is placed at a $\lambda/4$ away from one end on the favorite band to be used. Hopefully, the other bands will still find an acceptable match relative to that feed point. It can be fed with ladder line or a single wire feed.

Question:

How do you use an antenna tuner to tune an antenna?

?   ?   ?

Question:

How do you use an antenna tuner to tune an antenna?

Answer: <u>You don't tune the antenna with a tuner</u>.

You create a match between the transmitter and the transmission line with a tuner. This allows the transmitter to put out it's maximum power. If there is a poor match, the protection circuits for the solid state finals will cut back on the output power of your rig.

NOTE: A pi-network final in a tube rig is a "built in" tuner.

<u>Only by altering the antenna do you "tune" it or make it resonant</u>.

Using an antenna tuner in line with an antenna creates a <u>resonant system</u>, where the transmitter sees a “perfect” 50-75 Ohm load for which it was designed. This might not be a resonant antenna because the tuner can match any random length or it could be a proper ½ wave antenna with the feed line to the tuner.

A “<u>Resonant Antenna</u>” is an antenna or antenna plus matching system (L-C network) which presents a 50-75 Ohm load to a piece of coax which then is led to the output of the transmitter.

The L-C network could be a gamma match (yagi), phasing line (vertical), torroid/capacitor network (1/2 wave end feed) or other similar network that matches the impedance of the antenna to 50 Ohm coaxial cable that can then be led inside directly to the transmitter.

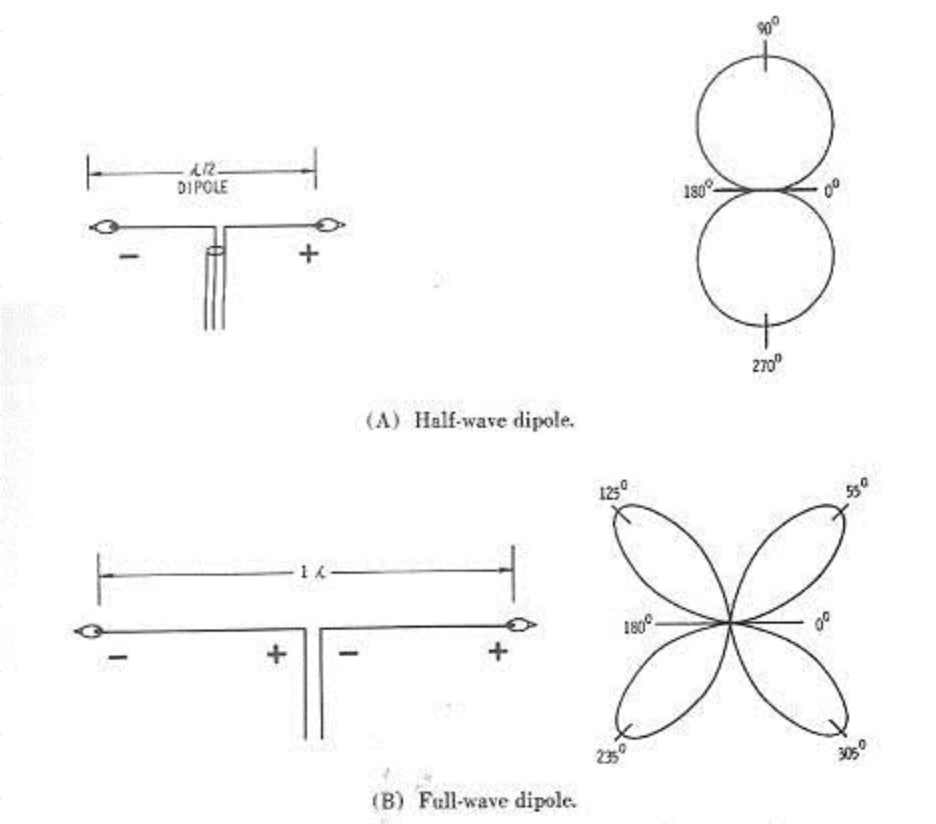
A resonant antenna could be:

A dipole or inverted vee cut to ½ wavelength fed with coax
A ¼ wave ground plane fed with coaxial cable.
A G5RV antenna with the proper balun feeding the coax
A 5/8 wave vertical with a proper tuned circuit to the coax
A Yagi antenna or Quad antenna with proper matching to coax
A set of phased verticals or Yagis with proper matching network
An end fed wire ½ wave with the proper match to coaxial cable
And many more…

Unless they have traps (tribander, multiband vertical, trap or fan dipole) they usually are only resonant on one band. (SteppIR antennas change lengths to be resonant)

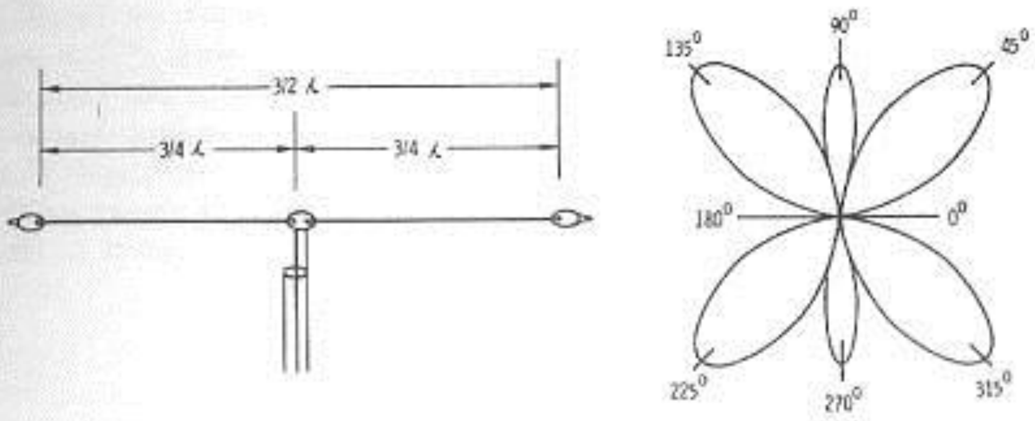
Basically any antenna which shows a 1:1 SWR at the coax when plugged into the transmitter, not needing a tuner to match it.

Harmonically fed dipole antenna patterns



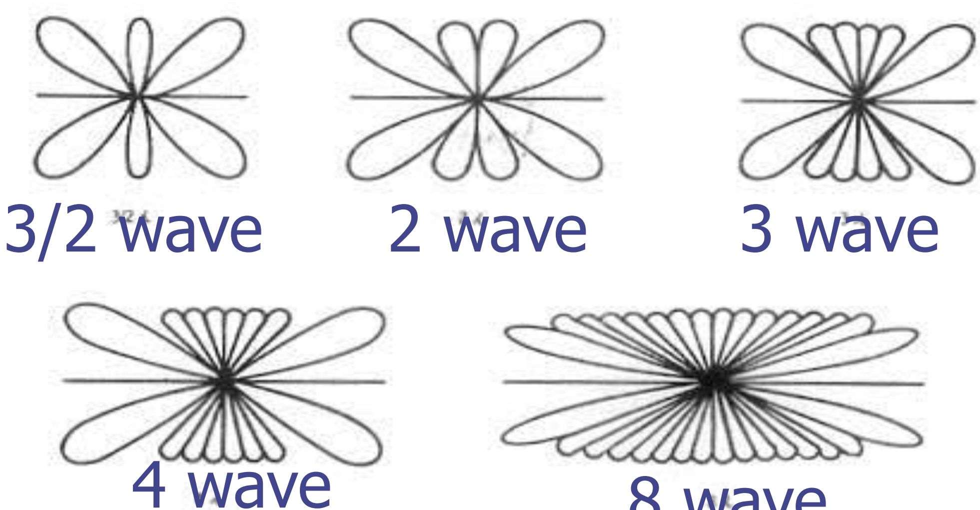
We know the typical pattern of a half wave dipole… a figure 8

Here is the radiation pattern when that same wire is fed as a full wave antenna… the pattern is now like a 4 leaf clover



(A) Basic construction. (B) Radiation pattern.

At Left is a 3/2λ Antenna



Influence of long-wire length on horizontal pattern.

These are higher multiple patterns.

You can see how the patterns skew toward the ends as the wire gets longer.

DIRECTIONAL ARRAYS

Take the antennas we have just discussed and we can create arrays of them to force the RF to be focused in one or two directions. This creates gain in those antennas relative to a dipole, loop or vertical antenna.

These antennas are Yagis, Quads and phased vertical arrays. The more elements, the more gain in a given direction. This can be good and bad.

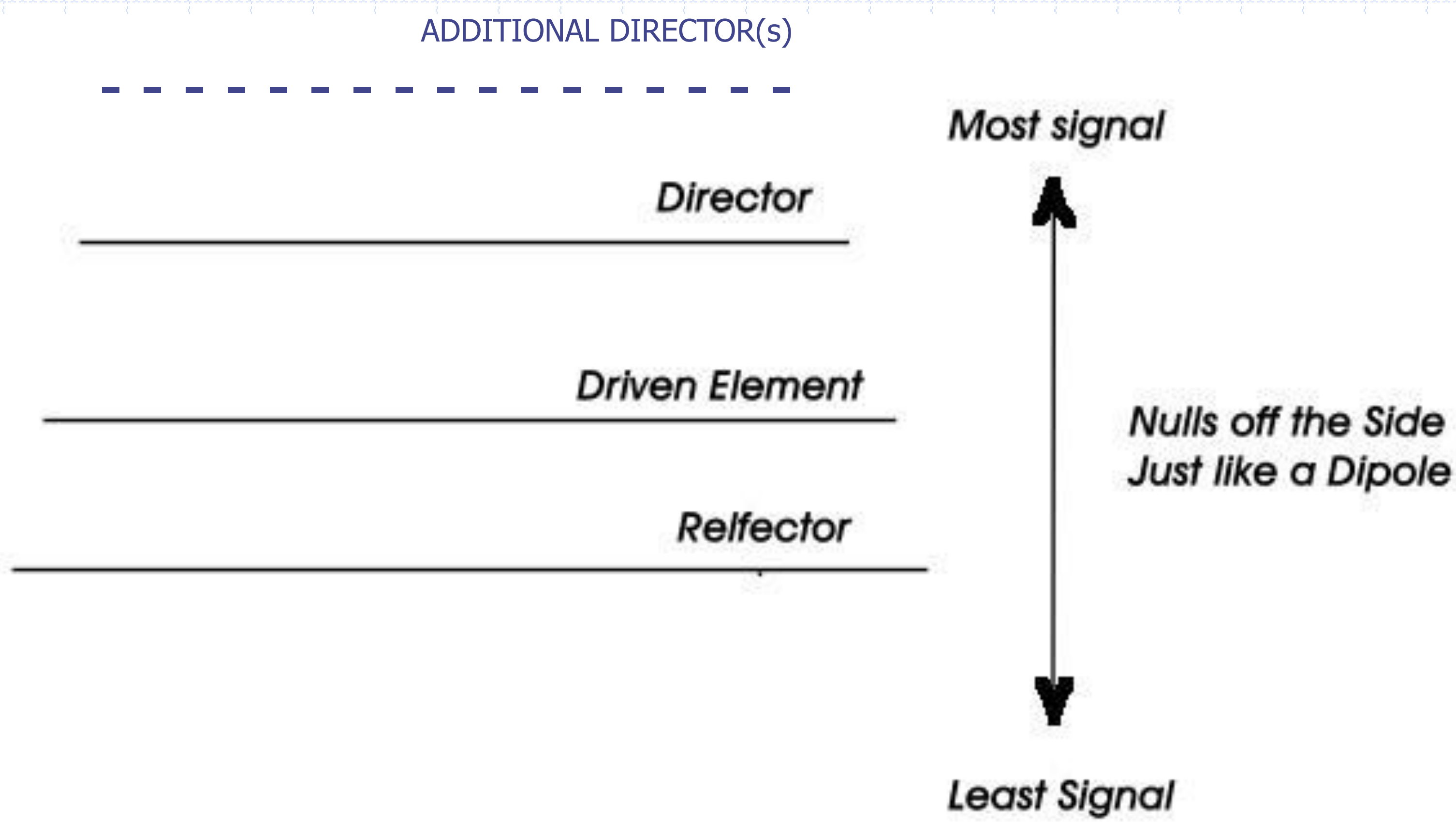
Good: We have more ERP in a given direction.
Bad: We can't hear or be heard as well in other directions.

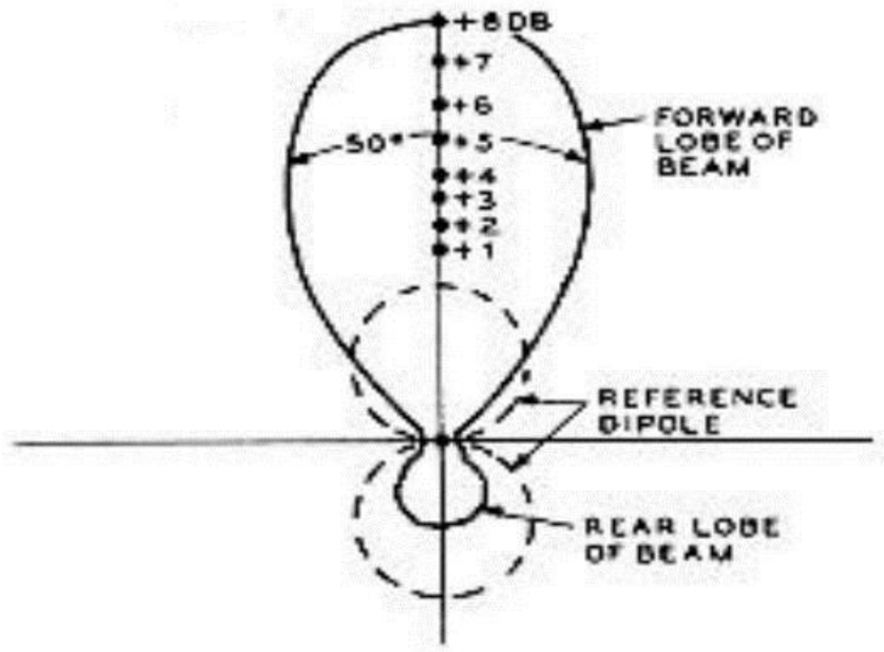
The Yagi – Uda Antenna

The Yagi antenna consists of two or more elements.

The driven element is a dipole and the directors and reflector are called parasitic elements.
They are resonant elements and will cause the RF to be reflected or directed in a specific direction giving the antenna gain in that direction.

The yagi antenna

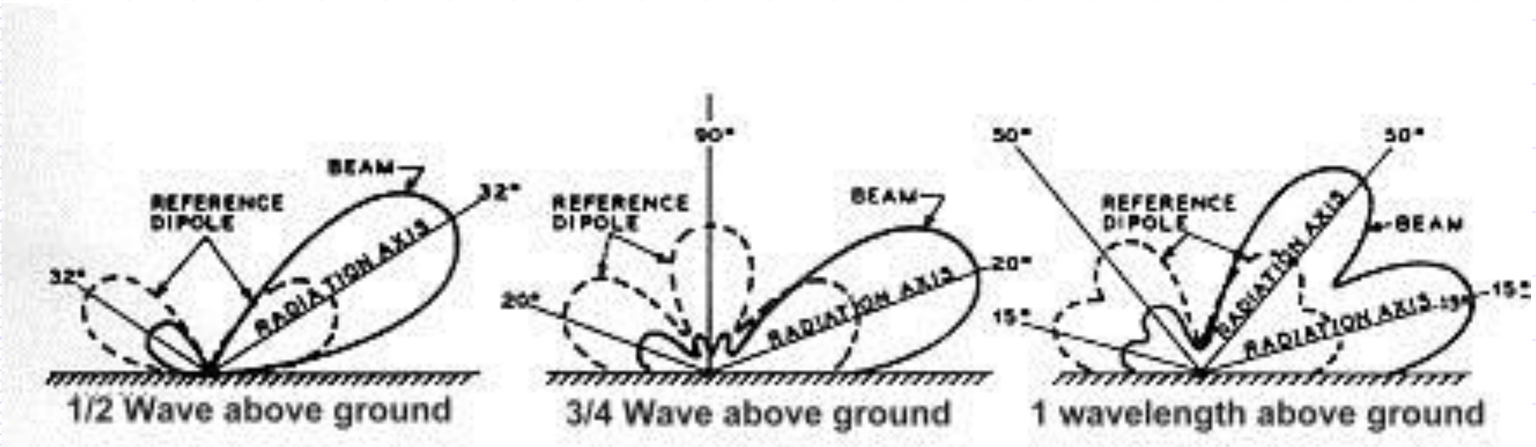




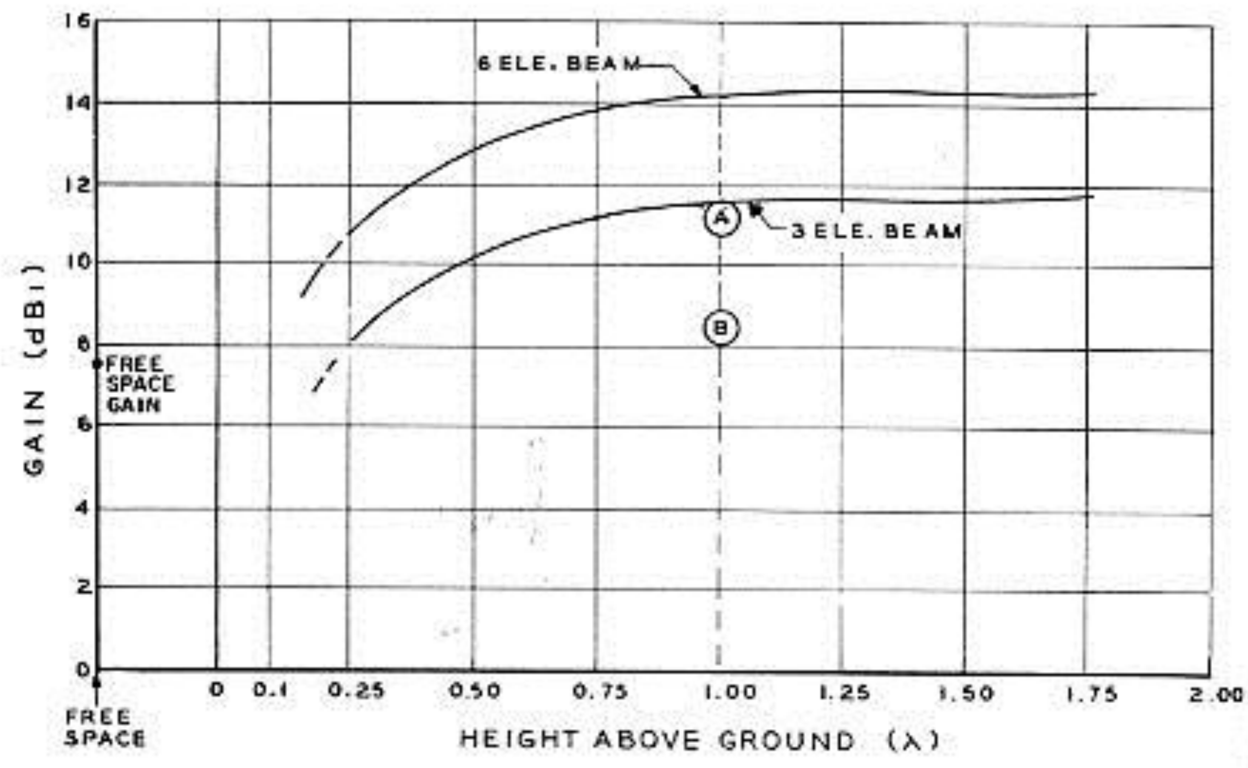
A 4 element Yagi polar plot shows that the Half Power Beamwidth (3 dB down points) is about 50 degrees.

The antenna has about 8 dB gain over a dipole (dotted line) and a front-to-back ratio of about 18 dB.

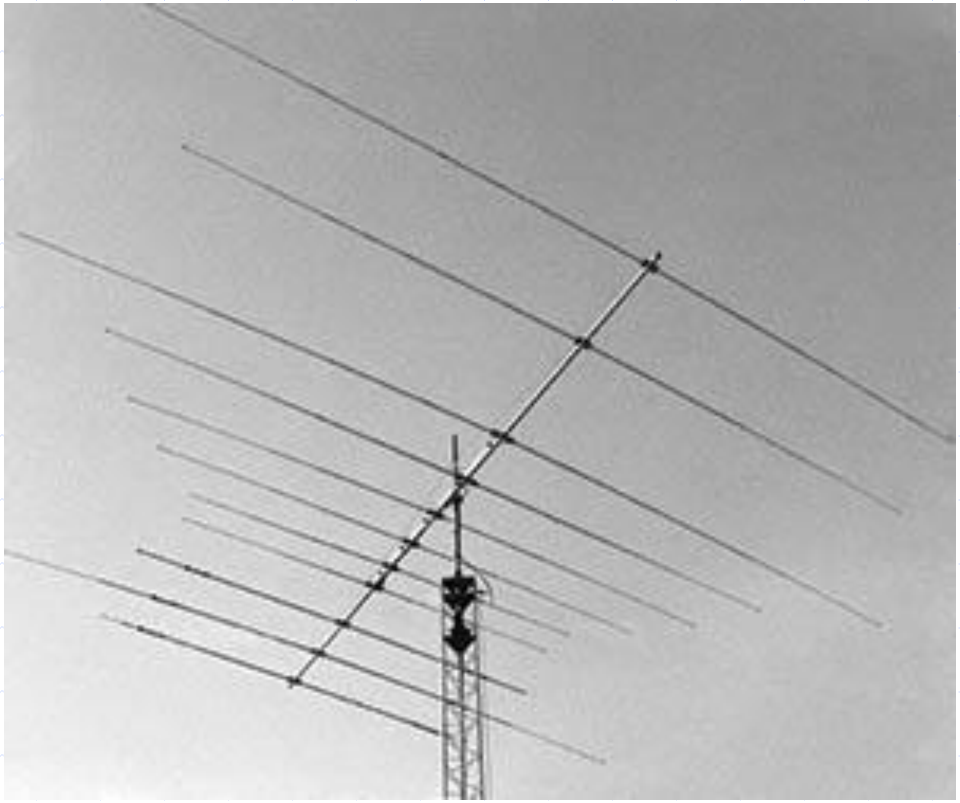
Since the pattern is broad, precise aiming is not necessary.



A 3 element Yagi, at various heights is compared to a dipole at similar heights. The same amount of radiated energy is seen by the area of both curves being equal. Only the Yagi concentrates the energy more in one direction.



As the number of elements increase, so does the forward gain of the Yagi. Once it is 1 λ above ground, the ground effects are lessened and the antenna gain is as if it were in free space. Subtract 2.3 dB for reference to a dipole antenna.



The Hy Gain TH-11 covers 20, 17, 15, 12, and 10 Meters
With good results. It weighs 88 pounds. Forward gain is in
The area of 7.5 to 9.2 dBi depending on the band.
$1112.00

The Force 12 XR-5 antenna covers 5 bands 10/20M
It weighs 56 # and has gain figures approximately
4.5 dBd (6.7 dBi) on each band.   It has two
active elements on each band. $1659.00

Mosely makes a nice 3 element tribander with an add on WARC Dipole for 12 & 17 Gain is typically 7-8 dB on 10-15-20 and unity on 12-17.   Wt 35 Lbs/54 $612/$916 for classic Jr./Classic (KW+)

The Cushcraft MA5B 5 band trap yagi shows gain in the 3.5 to 5 dBd range for 10, 15, and 20M and unity with the resonant dipoles on 12 and 17 M. It weighs 26 # and will handle 1200 W PEP. $499.95

There are many “tribanders” that are 2 to 6 element trapped antennas. They cover the 10-15-20 Meter bands but usually not the WARC bands 12 & 17 M.

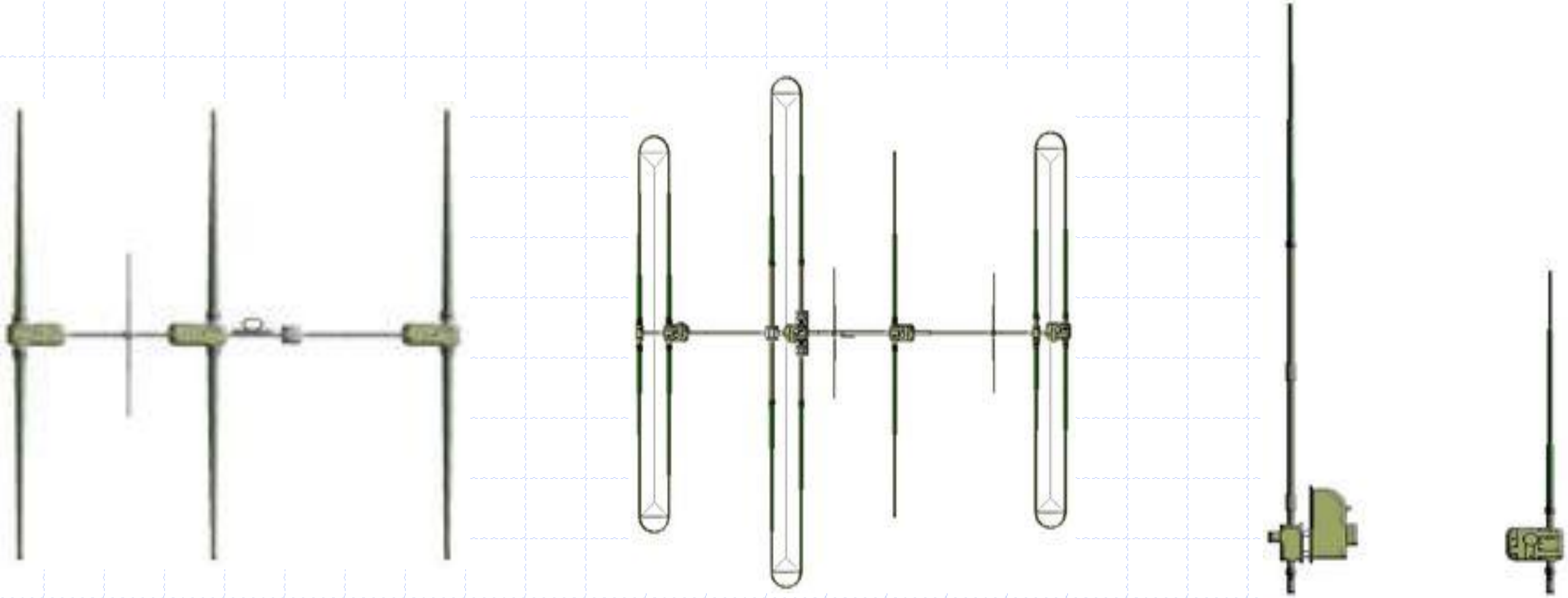
The reason that there are so many is that they have been around much longer, since they were designed before the WARC bands were created.

Also, they are in demand by contesters where only the non-WARC bands are used.

To compliment them, there are duo-band trap yagis available for 12 & 17 meters that can be added to a stack.

Also, Single band yagi antennas are available for those who prefer only one band, or want to stack them in a “Christmas tree” array, or on several different towers.

Cushcraft also makes a D3W Dipole for 12/17/30 Meters. It can be mounted above a tribander and rotated with the other yagis

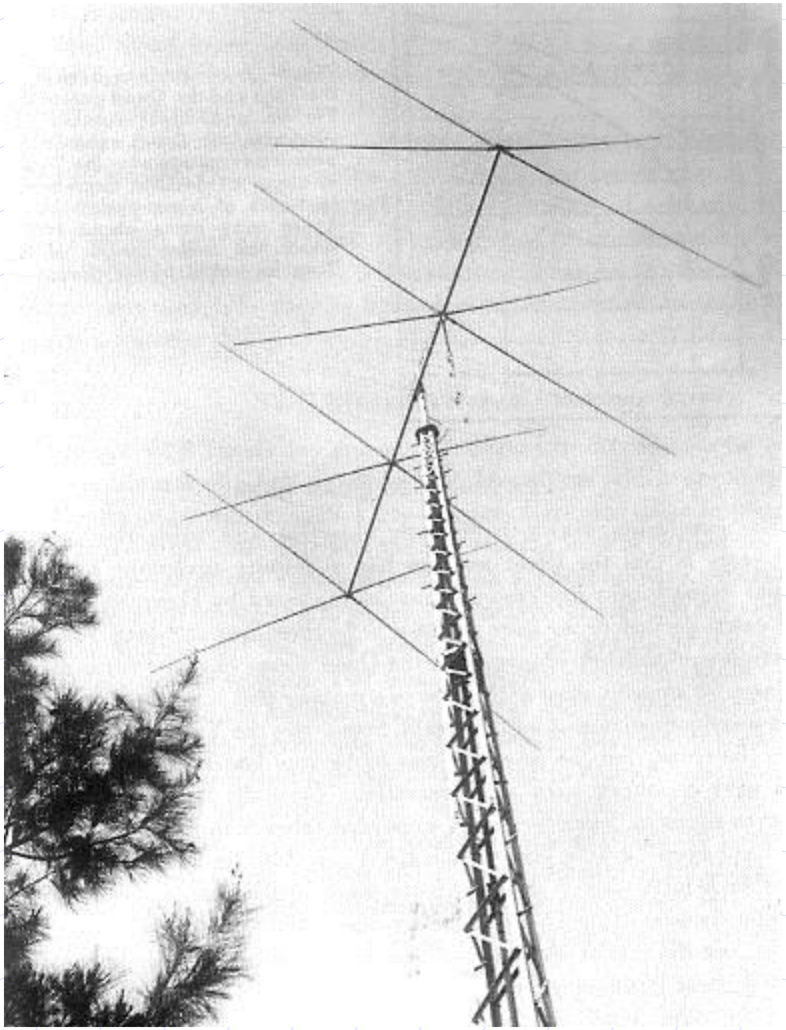


The SteppIR series of antennas are the new generation of technology. Each element in the Yagi or vertical antenna slides inside a hollow fiberglass housing. Each element length is continuously adjustable using a stepper motor (thus the name) to make each element the proper length for the operating frequency chosen. The adjustments can be made manually or automatically. You can have your rig or logging program tell the antenna the frequency.

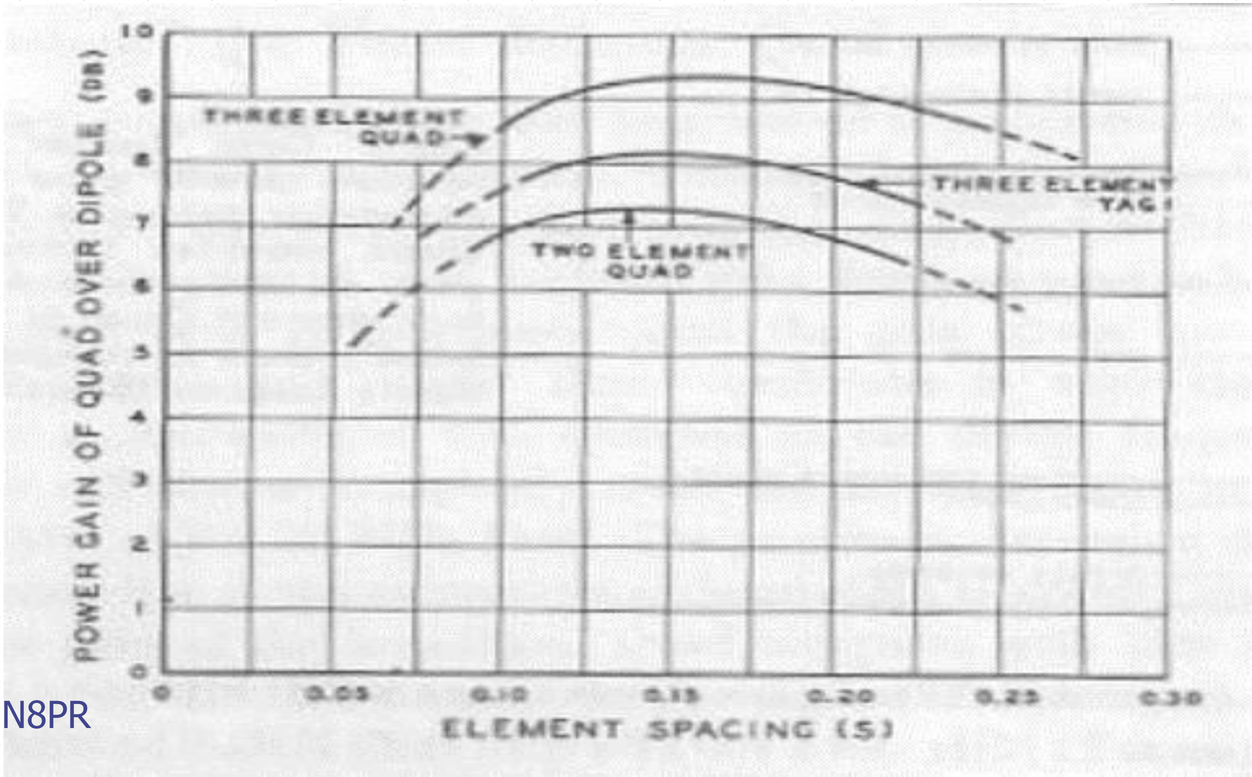
Quad antennas

Quad antennas are similar to the Yagi antenna in that they use a driven element and a reflector and/or directors to focus the RF in a desired direction.

The only difference is that the elements are loops and not dipoles or linear elements

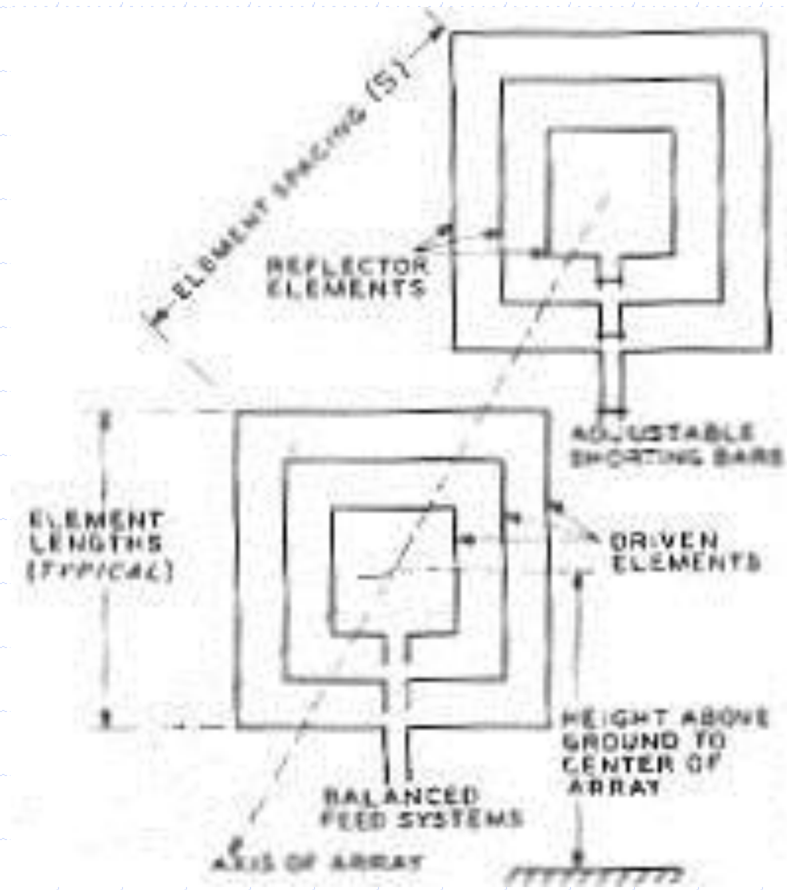


Being a loop antenna, the quad is a quieter receive antenna. It has a gain figure per element a bit higher than a Yagi. Remember– a full wave loop has a gain figure of 3 dB over a dipole to start with.



The quad is easily placed on multiple bands by interlacing resonant elements on each set of spreaders. The driven elements can be driven in parallel or individually.

Sometimes smaller spreaders are used to mount intermediate elements for the higher frequencies. This creates a better spacing between those elements and adds gain.



Vertical Arrays

Just like Yagi or Quad arrays of elements, the vertical antenna is suited to creating gain in a given direction. By arranging the elements in a specific orientation and phasing how the RF is delivered to the antennas, all elements are usually active and radiating.

When the signals from the various elements meet, they reinforce or cancel similar to waves in a pond when several stones are thrown into it simultaneously or in succession.

The radiation patterns are determined by element spacing and phase lag or lead of the RF

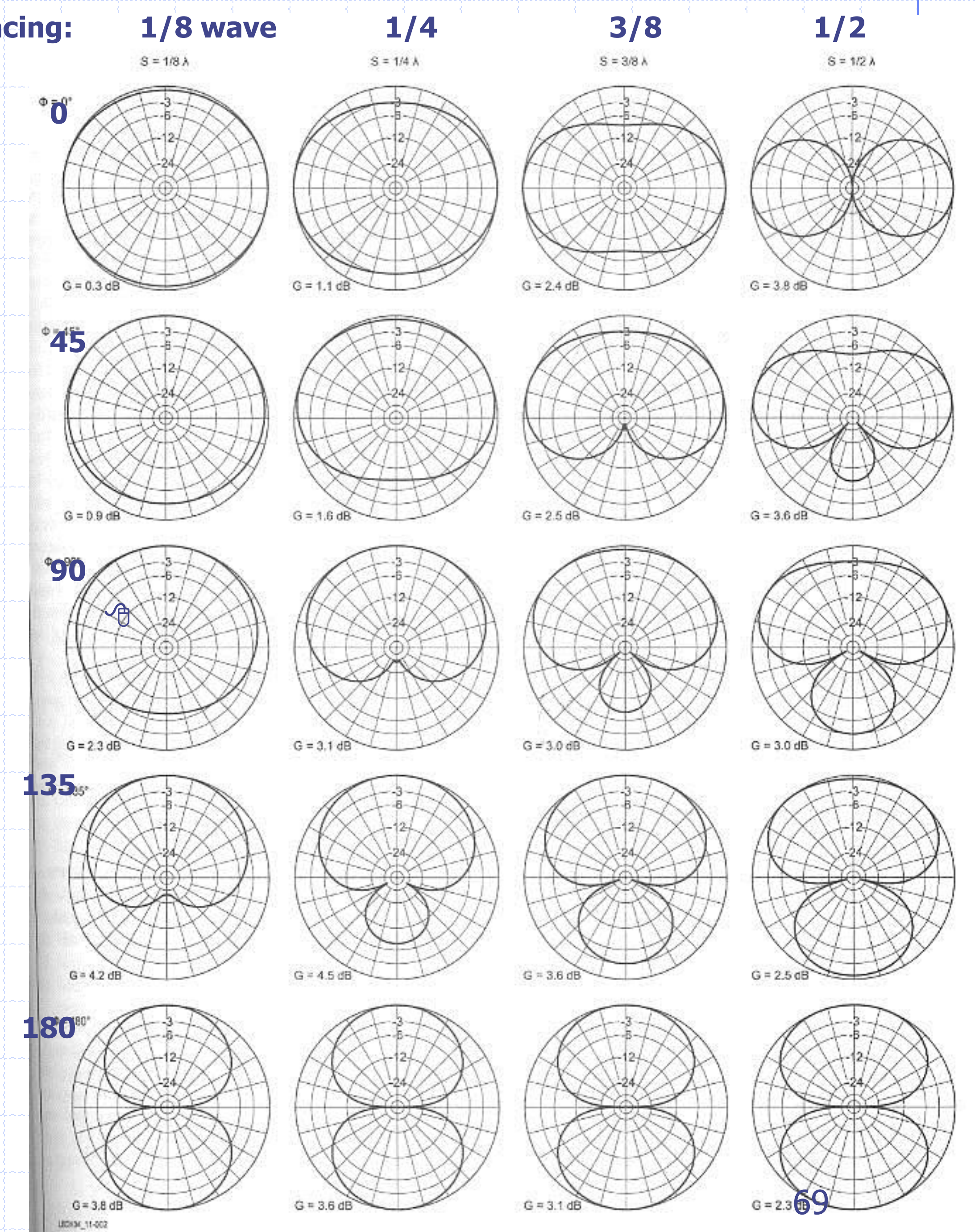
Except for the ground plane verticals discussed earlier, vertical antennas are usually best suited for the low bands, 160, 80 and sometimes 40 Meters.

They can be $\lambda/4$ tall or trap/coil loaded to shorten them.

If you have a large area, the verticals can be put up in various configurations to give gain, just like Yagi antennas.

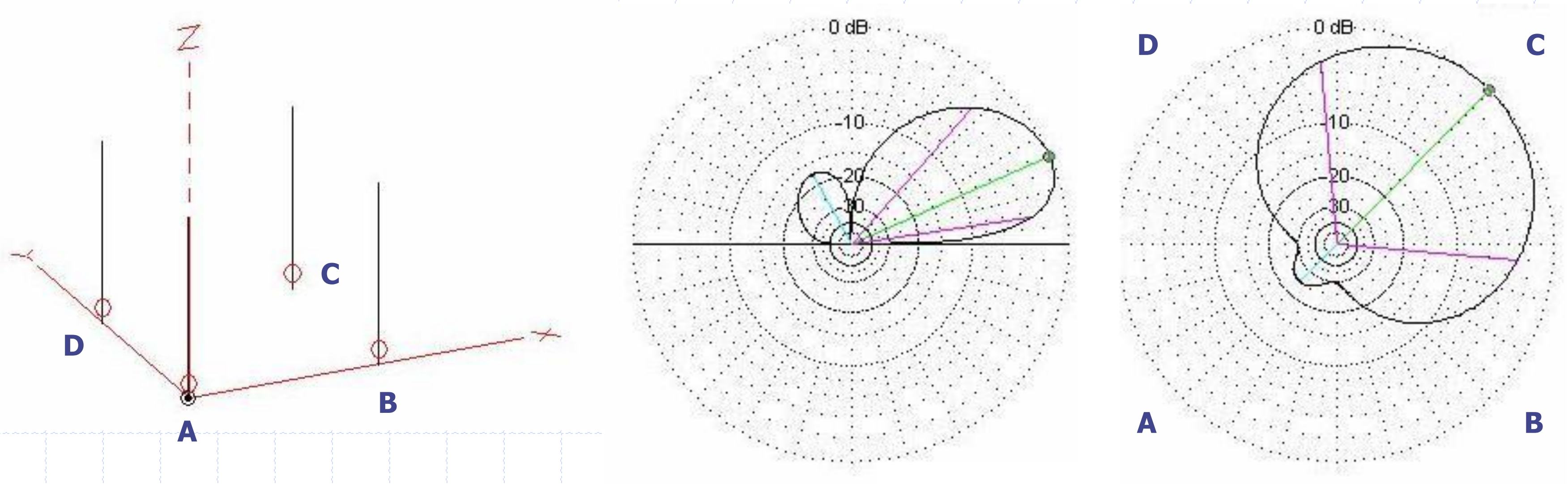
2, 3, 4 or more verticals can be fed in or partially out of phase to produce gain in a desired direction. This is a topic that could consume several nights.

The plots shown here are for a <u>pair of phased verticals</u> fed with equal current each, with spacing and phase lag between the two verticals as shown.



Phasing can be done by using different lengths of coax to each vertical.

4 - ¼ wave verticals – phased:

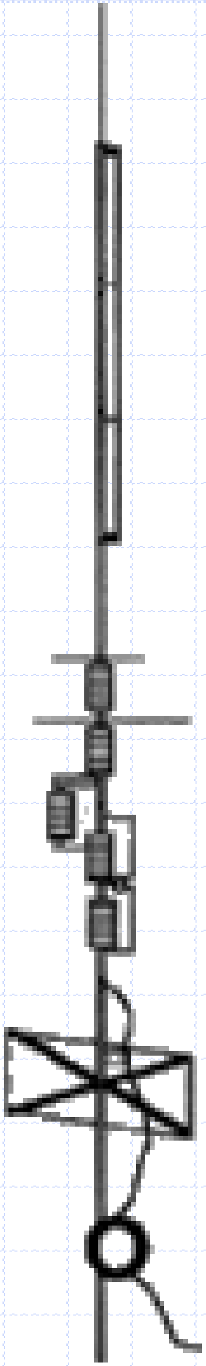


All 4 verticals are fed diagonally with two in phase and the leading and lagging corners fed 90 degrees leading or lagging to produce gain as shown above. A=+90deg.; B&D= 0deg.; C= -90 degrees phase.

Commercial, trapped verticals can be made to perform well on many of the HF bands. They must be fed against a counterpoise or ground system.

(Right) Butternut HF9V 80-6M

Vertical. $605.00



Exceptions to the need for radials or a counterpoise are the R5, R6, R8 and MFJ verticals.

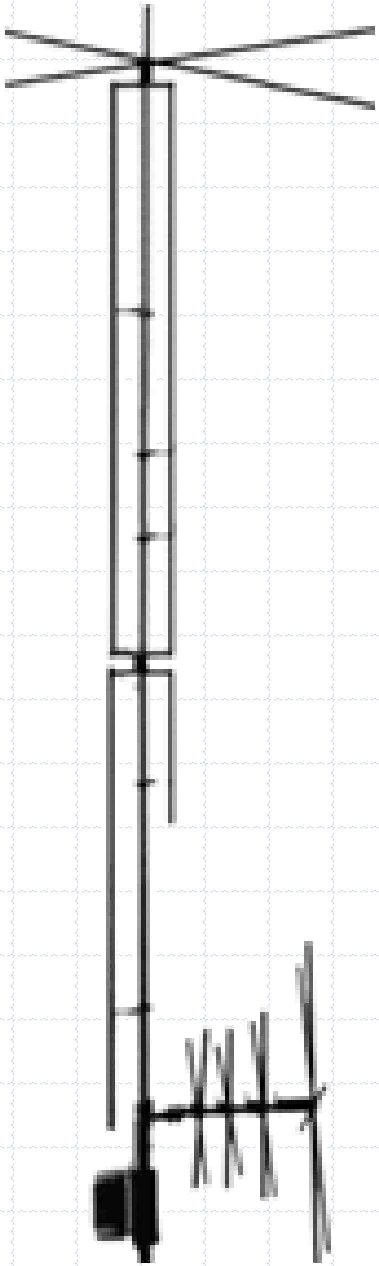
The R series are end fed half wave antennas with a high impedance matching system for a feed.

(Right) Cushcraft R8 40-6M Vertical $529.00

The MFJ is an off-center fed vertical dipole with the trapped lower resonant parts of the antenna rotated 90 degrees.

(Right) MFJ 1798 80-2M Vertical

$329.00



This extendable vertical can be used at home or on an RV or at field day.

It contains a flexible wire and extends to 32 feet. When nested it is 4 feet long.

Here an antenna tuner feeds the vertical against the chassis of the RV and other wires as a counterpoise.

Under $100.00

Sold as Eagle 1

Also see "Jackkite" 32 ft. poles

Thank you for your attention

Any Questions???