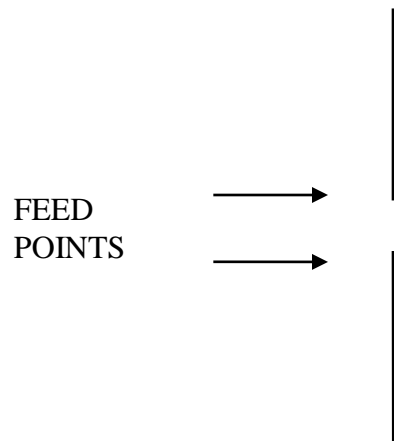


ANTENNAS

An antenna is a mechanical structure by which electromagnetic waves are sent out or received.

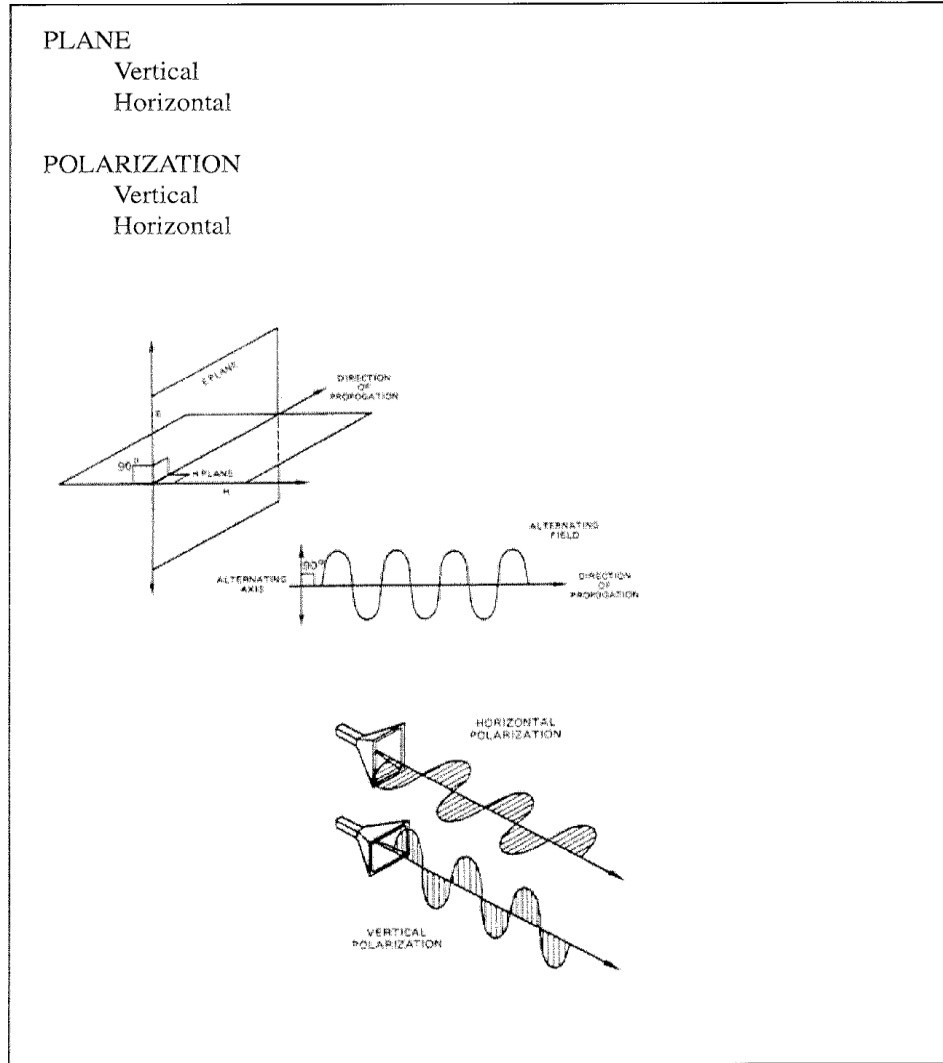
An antenna accomplishes this by being made so that its structure will be resonant at the frequency or frequencies of interest. At the heart of most common antennas is what is known as a dipole. In the simplest form this can be two metal rods, typically one pointed up and the other pointed down with the feed point being between them.



As the name implies there are two poles as seen above. The length of the dipole determines the frequency at which it is resonant. Dipoles are also called “Half Wave Dipoles” by many. This is because when the dipole is approximately one half wave length long in total it will be “Resonant” with the frequency of interest. When a signal is applied to the antenna by a radio it transmits the energy into the air. If the antenna is subjected to a radio wave from another source it converts that energy to an electrical current and that then travels through the feed line to a radio as a received signal. The antenna will perform this for transmission or reception equally.

When the dipole is oriented vertically as above it produces or receives signals that are termed vertically polarized. The transmitted radio wave that leaves the dipole is a wave that oscillates up and down. If the dipole was in the horizontal plane the signal would oscillate side to side and would be termed horizontally polarized.

The graphic below shows this clearly.



If a vertically polarized antenna has a horizontally polarized signal arrive from another antenna it will not receive the signal at a sufficient strength for the receive radio to be able to use it. And the reverse is also true that a vertically polarized transmitted signal from our system would not be useable to a horizontal remote receiving system.

Frequency

Looking at the graphic above we see a depiction of what is called a Sine Wave. This is the basis of all radio waves. We see that the signal starts out going up, peaks and then goes down, peaks again and then it rises to the center line where it started. This is one cycle; from zero to plus, then to minus and back to zero. This can vary in length of course, and this length and the time it takes to make one cycle we use to determine the frequency. The frequency of the most common radio systems is measured in Mega Hertz (MHz) which is millions of cycles per second. Radio waves travel through free space (air) virtually at the speed of light, so we can then determine the Wave Length. For instance, a 150 MHz signal will have a WL of 78.7 inches. A 450 MHz signal will have a WL of 26.2 inches.

Antenna designers use these numbers when designing antennas to make sure the antenna will be resonant at the frequency of interest. As we see above, the lower frequency has a longer WL and the higher frequency has a shorter WL. Hence the antenna of a lower frequency will be larger than an antenna for the higher frequency. A common dipole used to operate at 150 MHz should be about one half a WL tall, so we would expect it to be 39 inches tall and a 450 MHz dipole would be approximately 13 inches tall.

It is important to note that a 150 MHz antenna will not be affected by signals at 800 MHz as it is not resonant at the higher frequency.

You may have seen a demonstration where a soprano sings a particular note and is able to cause a crystal glass to shatter. This happens because the note and the glass are resonant. The audible waves cause the glass to vibrate to the point of destruction.

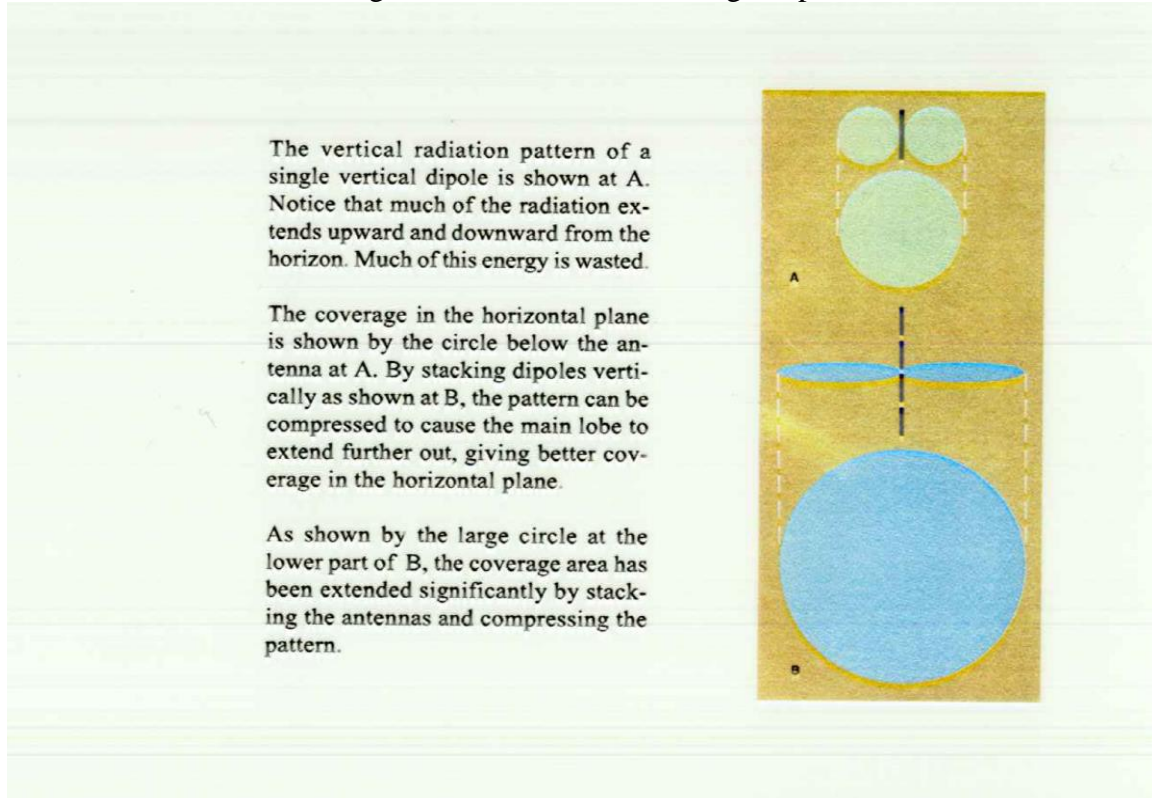
Antenna Types

There are many types of antennas. The basic reason for the many different types is that they produce different shapes of signals called patterns. The basic dipole produces a signal as seen below at A.

The depiction is what we would see if we could see radio waves being transmitted. The upper portion at A is what the pattern would look like if we were standing off to the side and we could see the energy in cross section. Below that still at A the circle is what it would look like if we were directly above the dipole looking down.

What happens when we make an antenna that has several dipoles arranged one above the others in what is called an array, is seen at B below. We see that the cross section has become flattened and that the view from above shows the circle has gotten larger in diameter. So, standing several dipoles up one above the other changes both the Vertical (as seen from the side) and the Horizontal (as seen from above) patterns. The larger

diameter of the circle at B is intended to demonstrate that it will be able to transmit and receive at a greater distance than the single dipole would.



The above shows that we can change the way antennas distribute the energy that they send out into the air.

This leads us to an unfortunate term that is widely used when discussing antennas and that term is GAIN. The word implies that we are going to get more of something. The truth is that we do not get more. The total amount of energy radiated by the single dipole is the same as that radiated by the four bay array if they are fed equal signals. The energy in the four bay dipole array has been distributed differently is all that has happened. The vertical pattern has been compressed and because of this the signal level that we would measure at the horizon from the single dipole would be found to be the same for the four bay array at a much further distance. Yes, we have been able to get the four bay dipole array to communicate to a further distance than the single dipole, but there is still the same amount of total energy emitted by both antennas. So, Gain really isn't Gain in power, it is just compressing the signal in ways that provide a pattern that suits our needs better.

The various types of antennas are all based on the simple dipole, and it is the basis of all common antennas. Depending upon what we want the pattern to do suggests the type of antenna that we select. We need to consider where we need signal to be placed from a given location where the antenna is mounted.

When discussing antennas we often talk about Radio Frequency (RF) energy. This is measured in Deci Bells (dB), honoring Alexander Graham Bell. The term dB by itself is not a useable term. It has to be referenced to something. In antennas it is either dBd, where we compare a signal level to a dipole, or it is dBi when referencing a signal level to an isotropic radiator. An isotropic radiator is an impossible antenna to make as it is defined a single point in space that radiates equally in all directions. This dBi is useful in some engineering efforts but isn't much help with real antenna measurements. The difference is that one dBd is equal to 2.14 dBi and is a mathematically calculated value.

Discussing antenna patterns usually involves a reference to the antennas beam width. This can be measured for both the vertical and the horizontal beams unless the subject happens to be a collinear antenna where the horizontal beam is circular. We'll come back to that antenna later.

The beam width is defined as the included angle between the points where the power level has dropped to one half of the peak gain value. The increase of signal level to a value of double is 3 dB, and if it is half it would be -3dB. So, you may hear the term half power points in reference to describing the beam width that an antenna produces.

In the example below, which is an example of the vertical, or E-Plane pattern of a Yagi type antenna you can see the half power points marked on the pattern with a dash.

That particular antenna produced 10.52 dBd of gain, so the half power points would measure 7.52 dBd, and the included angle between the dashes is about 44 degrees.

A Yagi antenna looks like this one below.

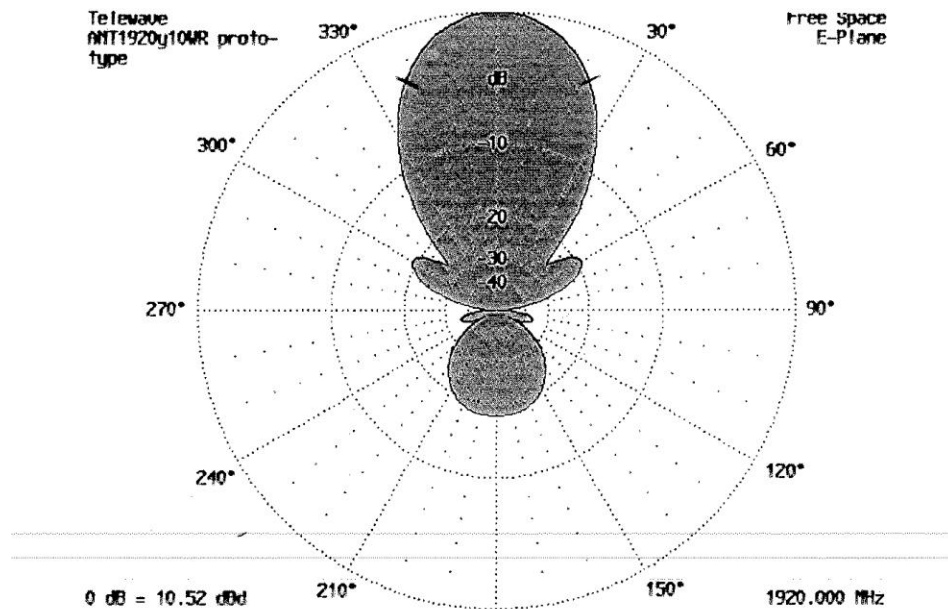


It provides compression in both the vertical and horizontal planes.

ANTENNA BEAM WIDTH

THE ANGLE BETWEEN THE 1/2 POWER
POINTS OF THE RADIATION PATTERN

- -3dB POWER POINTS
- VERTICAL POLARIZATION
- HORIZONTAL POLARIZATION
- RELATIVE TO GAIN

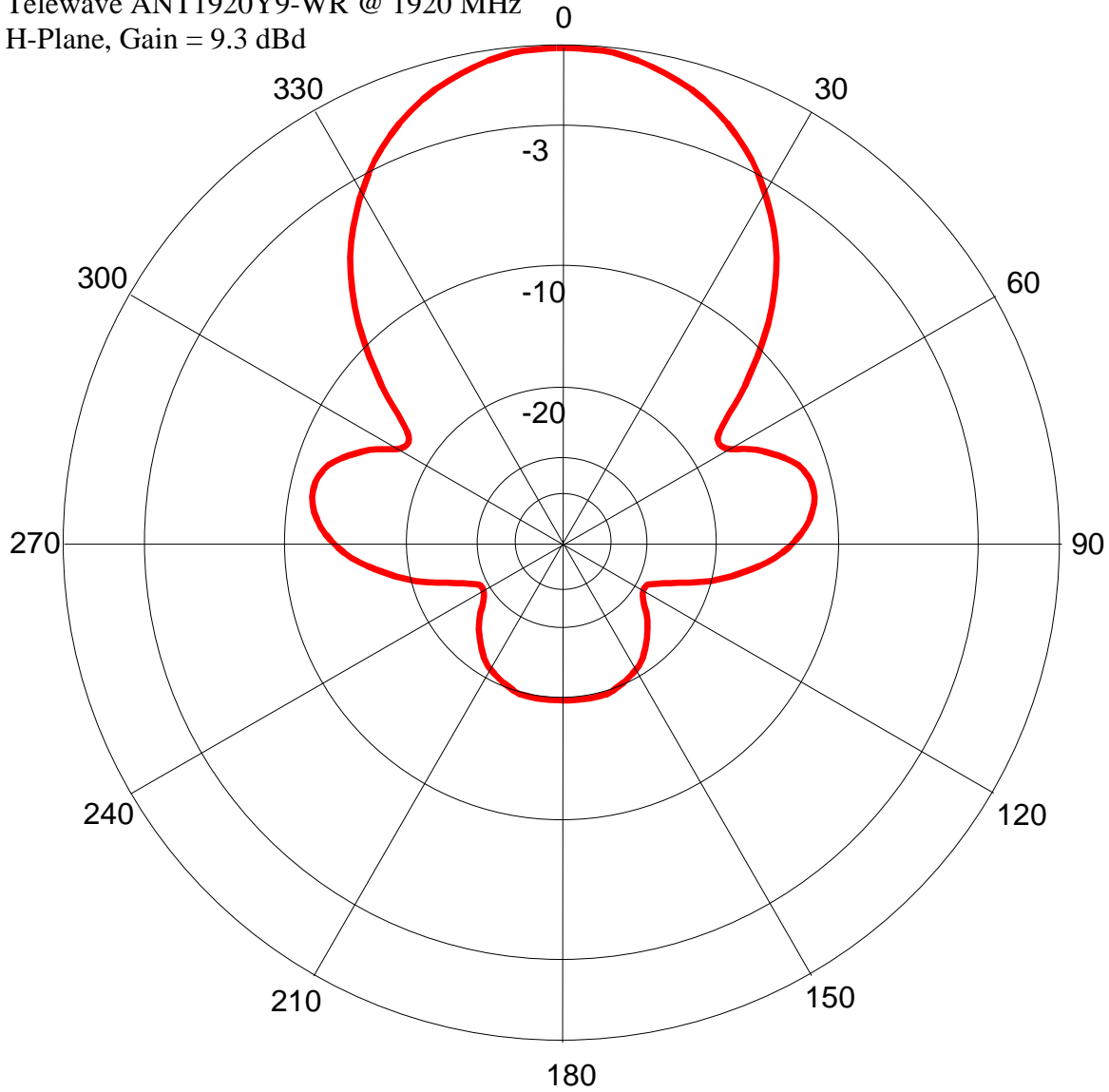


Now we are ready to examine some basic antenna type and the patterns that they produce.

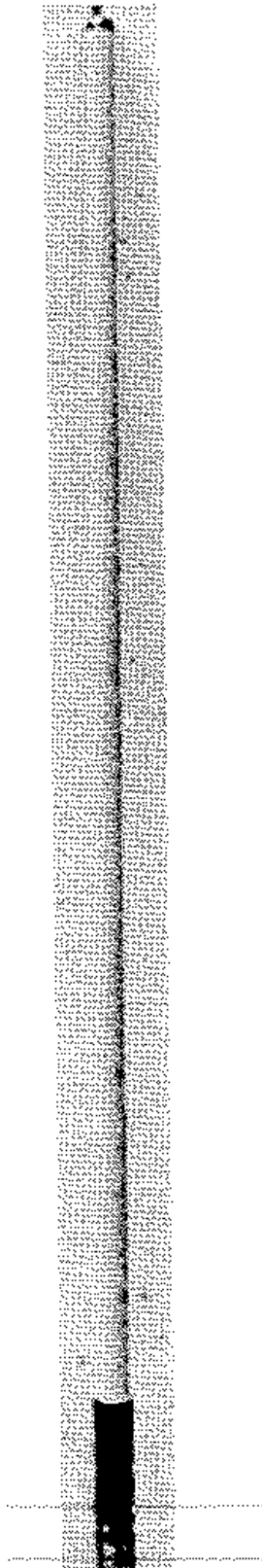
This is the horizontal pattern for the same ANT1920Y12-WR as the above E-plane image.

Note that the half power points are wider in this H-Plane pattern than the E-Plane pattern above.

Telewave ANT1920Y9-WR @ 1920 MHz
H-Plane, Gain = 9.3 dBd

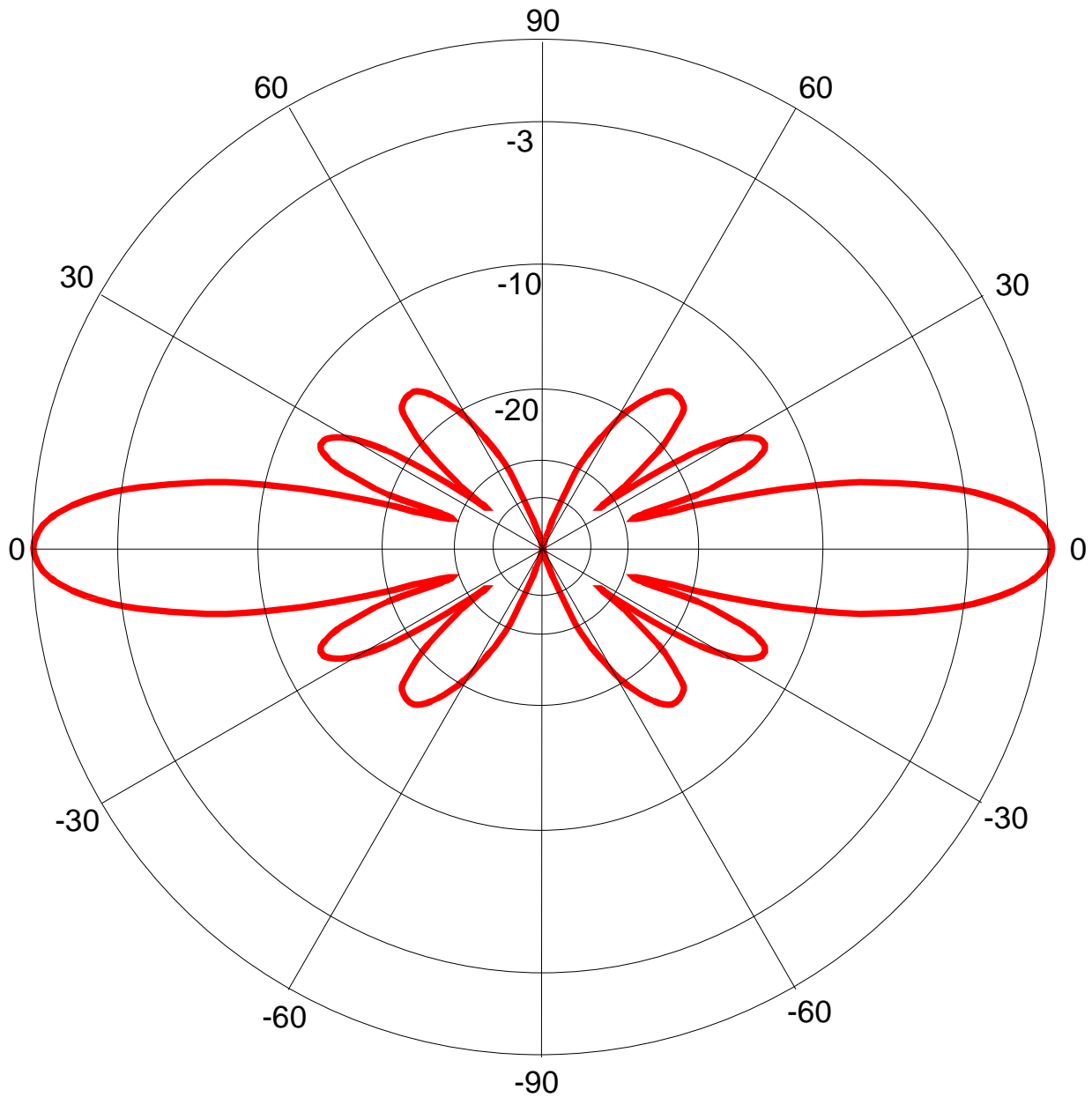


Yagi type antennas are commonly used for point to point or point to multipoint needs.



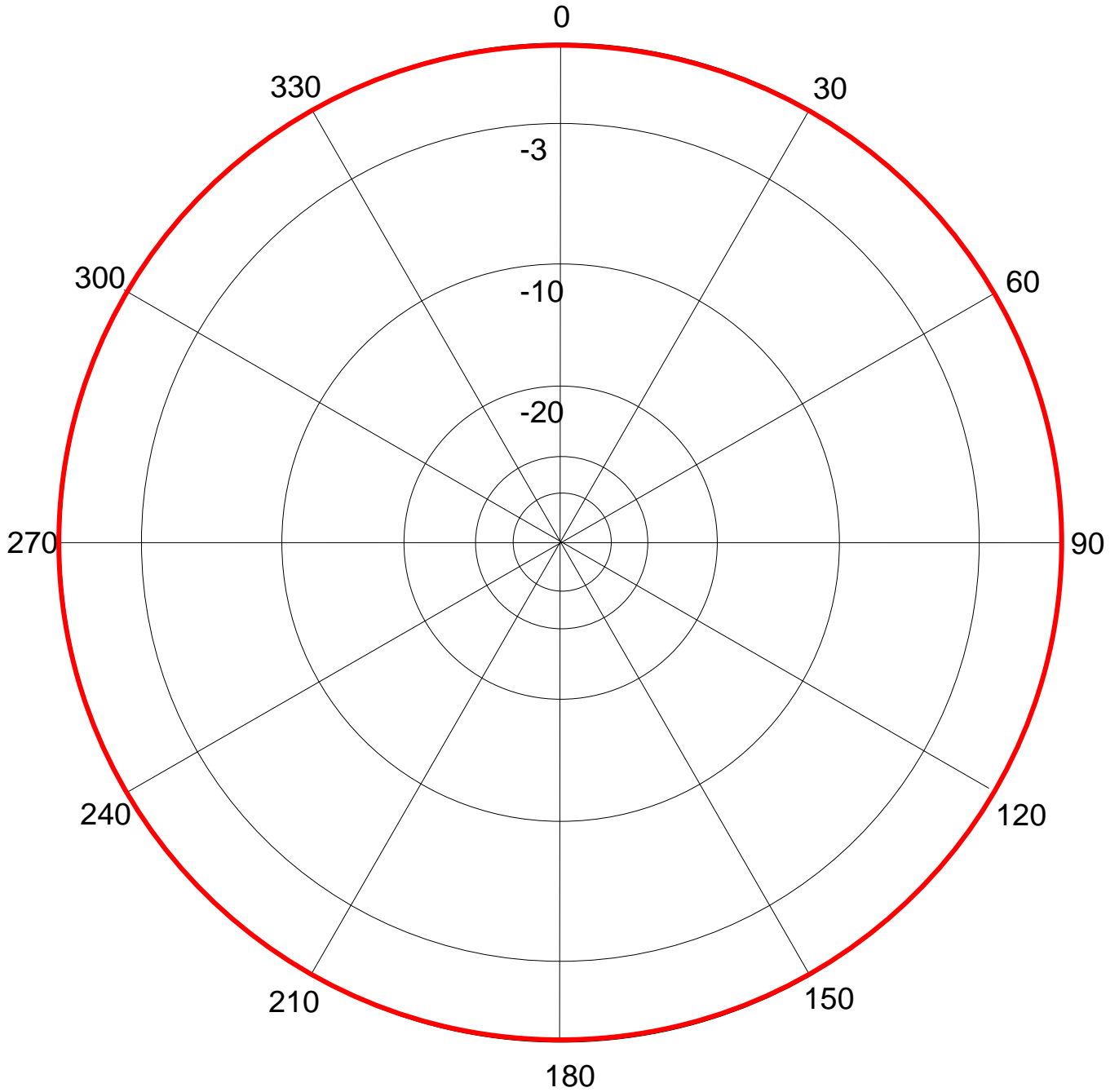
The above is what a Collinear antenna looks like. It derives its name from the fact that multiple dipoles are stacked up vertically inside the fiberglass enclosure which is called a radome. These type antennas are used when we need to cover an area all around where the antenna is placed or in every direction across the horizon equally. All of the compression in this type of antenna is done in the vertical plane.

Telewave ANT150F6-3
E-Plane, peak gain = 6.07 dBd



Telewave ANT150F6

H-Plane, Gain = 6.08 dBd



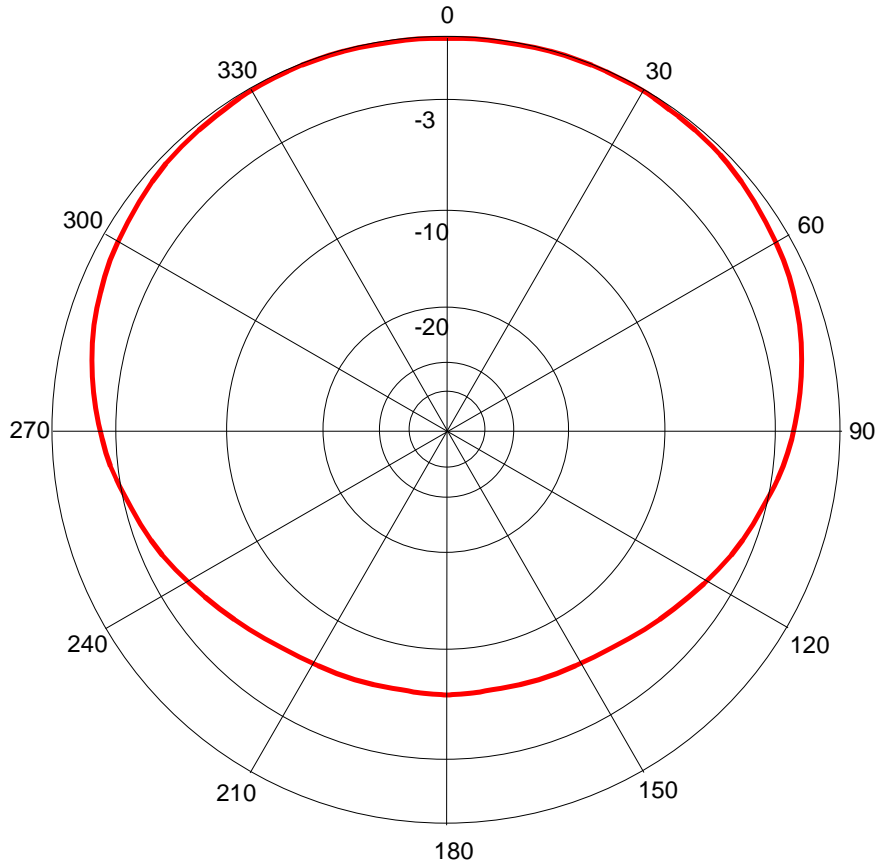
And here we see that the collinear antenna provide equal signal strength in all horizontal directions.

This is what a four bay dipole array looks like. Note that the four elements are attached to a support pipe.

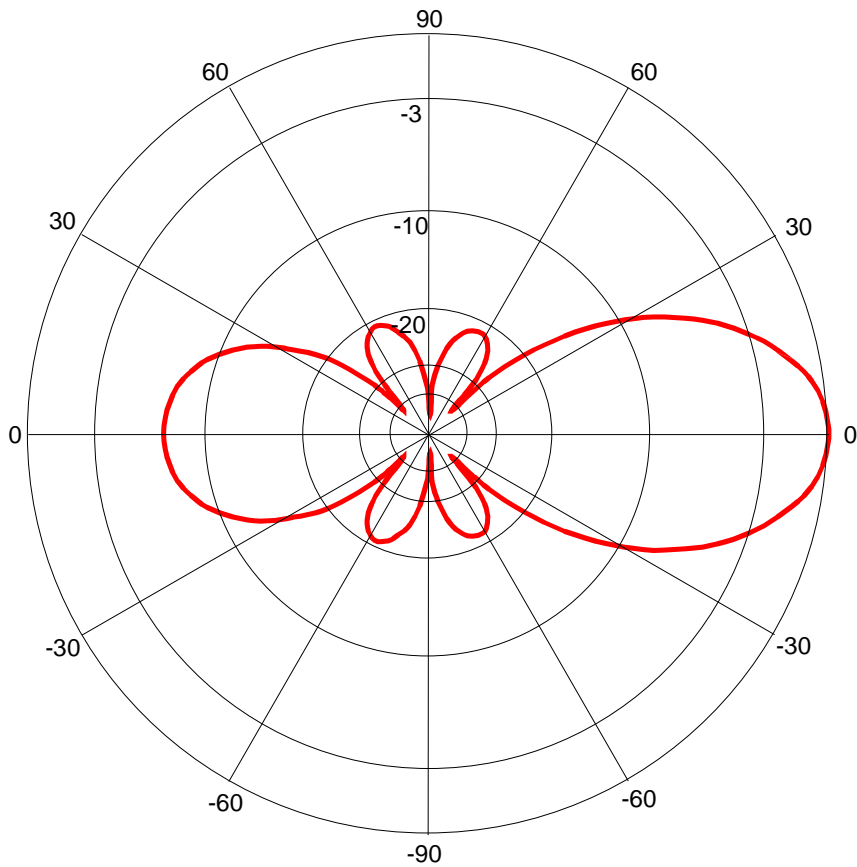


Because the support pipe is made of strong metal in order to support the antenna when it is installed on a tower the natural circular horizontal pattern that it produces in the horizontal plane is distorted because the pipe reflects the signal away from it. This can be very useful when the tower isn't in the center of what we want to cover. For instance if the tower is close to a coast line and we do not need to cover the ocean.

Telewave ANT150D3 @ 1/4 spacing
H-Plane, gain = 5.07 dBd peak

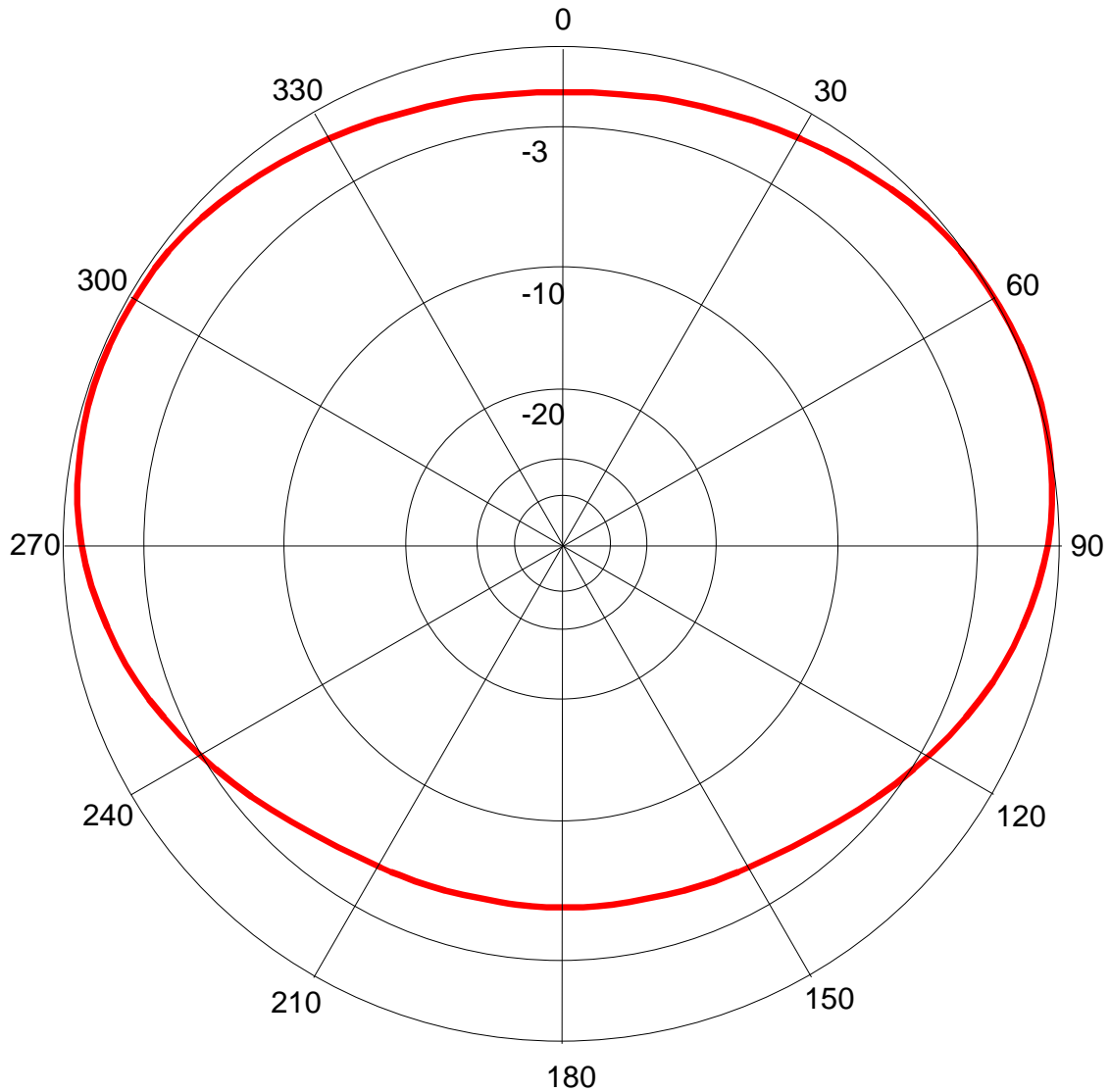


Telewave ANT150D3 @ 1/4 spacing
E-Plane, peak gain = 5.07 dBd



The above patterns depict what a two bay dipole array produces when the distance between the dipole elements and the support pipe is $\frac{1}{4}$ of a WL.

Telewave ANT150D3 @ $\frac{3}{8}$ spacing
H-Plane, Peak Gain = 4.43 dBd

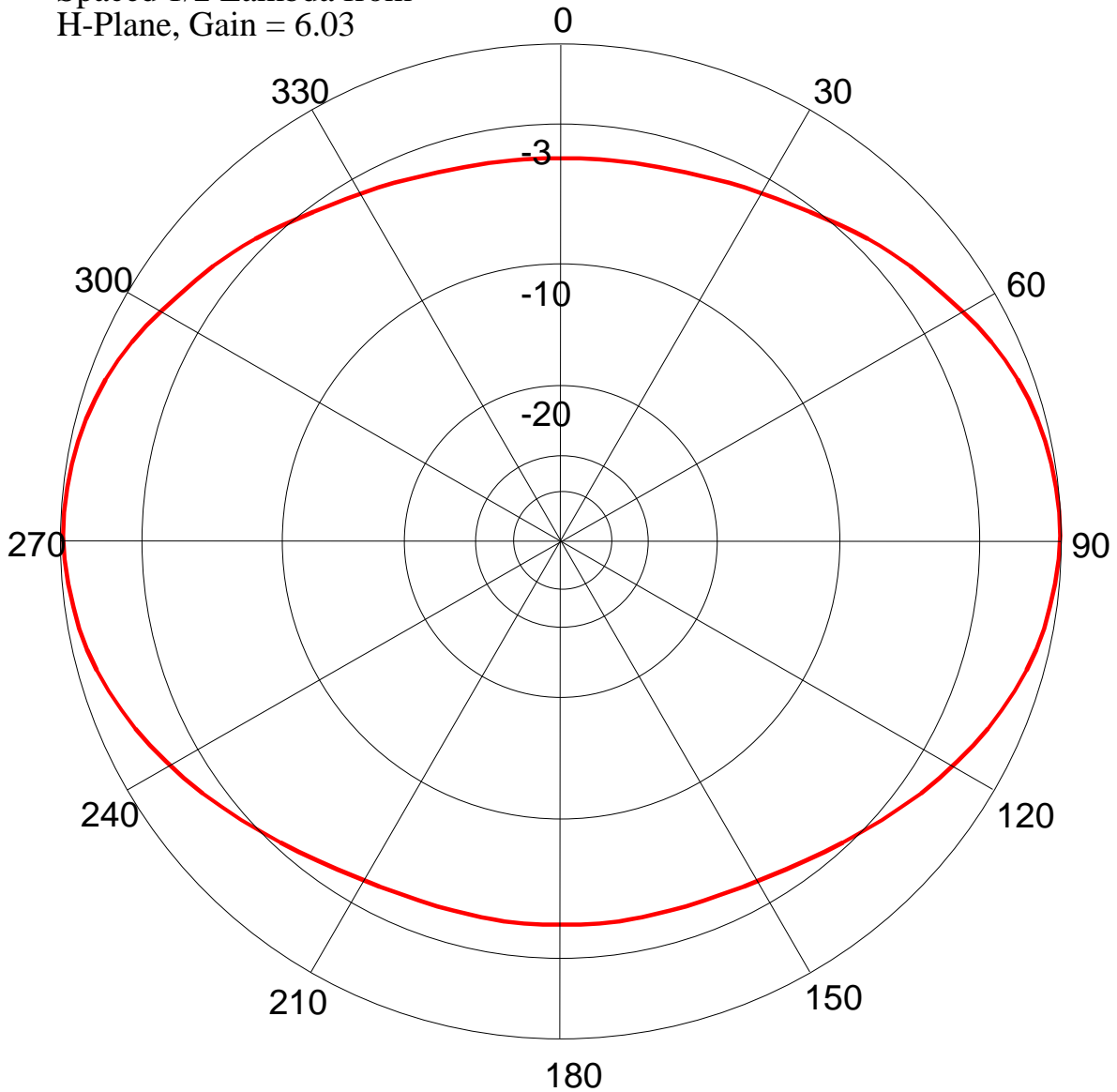


Above we see the change that occurs when we set the spacing to the support pipe to $\frac{3}{8}$ WL.

Depending upon what needs covered this is also a very useable pattern. Note that the peak gain value has changed from the $\frac{1}{4}$ WL spacing but not by a lot. We are radiating the same total amount of energy in both of the above situations, just the shape of the pattern changes due to the spacing and the difference in compression that the pipe causes.

Below is the resulting pattern when the dipole to support pipe distance is $\frac{1}{2} \text{WL}$.

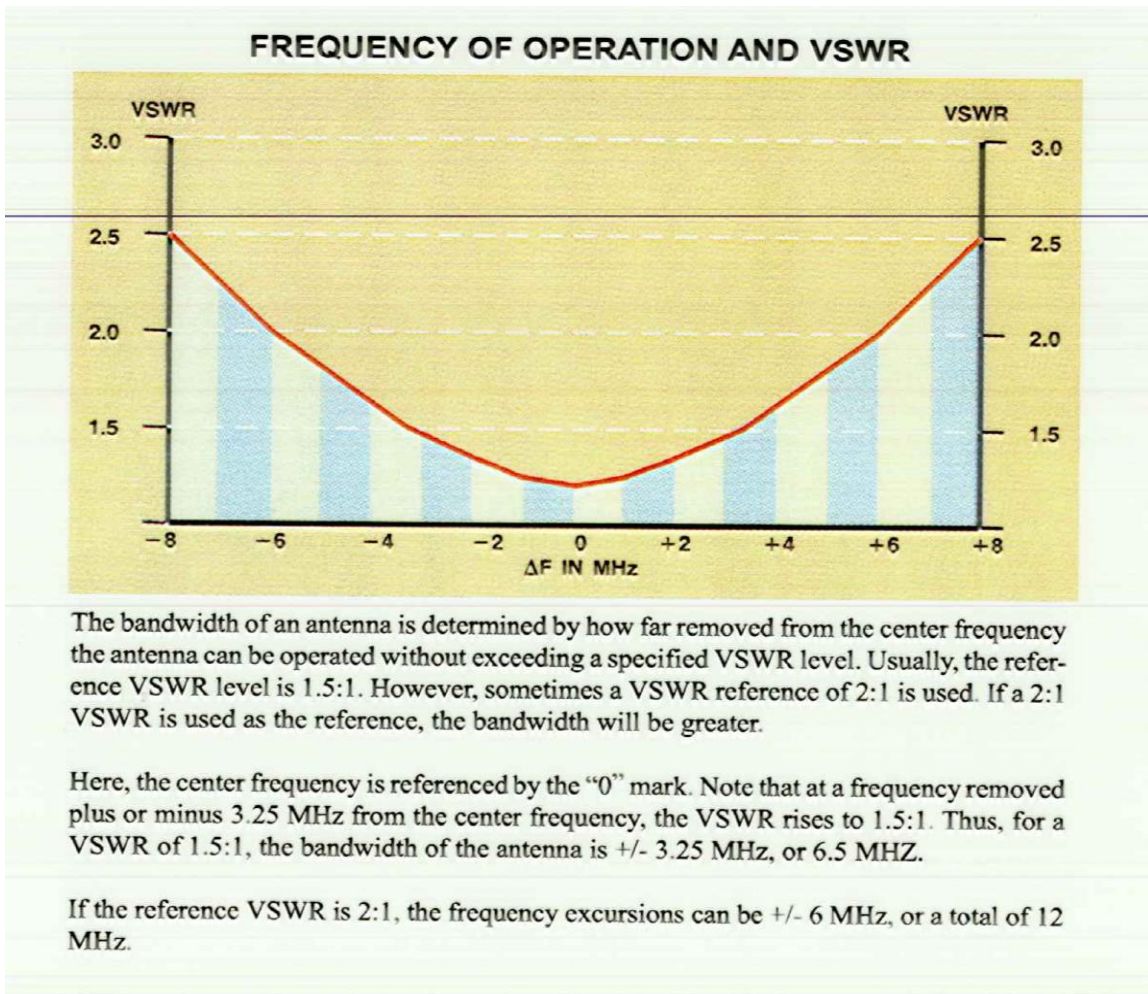
Telewave ANT150D3 @ 156
Spaced $\frac{1}{2}$ Lambda from
H-Plane, Gain = 6.03



This pattern is widely used when valleys are the target because we want a pattern that is long and narrow. Note that the gain is significant in this arrangement and will give good results up and down the valley.

Many rather odd patterns can be achieved by changing how dipoles and added reflectors are arranged.

Most communications systems require the ability to both Transmit (Tx.) and Receive (Rx.). Typically Tx. is on one frequency and Rx. is on a different frequency but both will be in the same band. Two of the most used bands are the VHF, 138 – 174 MHz and UHF which is 406 – 512 MHz. For these bands it is preferable to have antennas that will work properly across the entire band if possible. Dipole antennas can be designed and manufactured to do this but the collinear antennas cannot owing to construction limits and the physics involved. We need now to discuss VSWR and band width.



Vertical Standing Wave Ratio or VSWR, and Return Loss are directly related and these terms allow us to describe whether or not an antenna will perform properly and efficiently across some range of frequencies. As we vary the frequency away from the design center frequency the antenna begins to not transmit or receive at 100% and some of the power is reflected back to the radio. The commercial standard for acceptable VSRW is 1.5:1 as is illustrated above and this equals 96% efficient at the worst point above and below the design frequency. This determines the bandwidth for an antenna.

All of VSWR troubles are due to the resonance not being perfect across the bandwidth. The impedance of the antenna incorporates resistance, inductance and capacitance. The

industry standard impedance is 50 Ohms plus or minus j zero. J is the symbol for the inductive/capacitive components of the impedance. The wider the bandwidth the more difficult it becomes to obtain a good VSWR but with careful design effort the bandwidth can be optimized in many cases. As with many things of this nature there are tradeoffs that must be considered. An antenna with a very large bandwidth will have significant gain slope. The gain at the edges of the bandwidth will be less than what it will be near the center in most cases because the antenna is less resonant. All of this concern about bandwidth and VSWR is related to maintaining a good impedance match between the antenna and the rest of the system including the feed line, filters and the radios. It is more important for the Tx signals than it is for the received signals because the Tx is generally high power where the Rx signals are very low. An antenna will receive signal very well outside the normal bandwidth because they see the impressed voltage and pass it to the radios.

Mechanical Considerations

The design of any of the three basic antenna types must be evaluated for mechanical strength. Many of the locations where antennas are installed are on top of mountains where there is severe weather. They are exposed to wind, rain, snow and lightning. They may be installed near coast lines where there is salt spray and what is known as salt air.

They often are installed in oil fields where the burning off of stack gasses generates acidic or caustic atmospheres. All of these can cause the antenna to fail due to mechanical forces and chemical attack.

It has always been interesting to me to consider the collinear antenna in regards to how it is used and the strength required for it to survive. A 20Foot tall fiberglass radome enclosed antenna is subjected to 100 plus MPH winds routinely and survives for years because we do a great design and manufacturing job. These antennas can only produce their unique omni directional horizontal pattern if they are mounted above the top of the tower. When they are mounted that way they become a prime target for lightning and they cannot survive a lightning strike. So the one place that they can work properly puts them at the maximum risk.

System Cost Considerations

When we consider the risk of a system malfunctioning, the single component that is most at risk is the antenna, not the filters or radios because lightning arrestors protect them. Apart from lightning the antennas are subject to all the abuse mentioned above. During sever weather when most antenna failures occur is generally when the communications system it needed the most. It is therefore wise to use antennas that have a very robust design and are protected from the elements well.

As a percentage of the cost of a system the antenna is very small so buying an antenna that costs less and is not robust is a poor decision. Nearly always the cost to mount the antenna is many times the cost of the antenna.