[End-fed Zepp]

[End fed longwire or random wire antenna]

[ground plane Vertical]

[End-fed half wave]

[IMAX 2000]

Understanding Gain differences

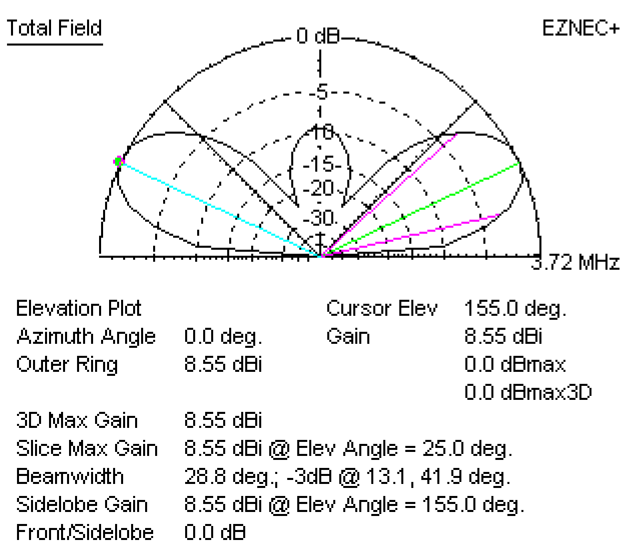
In order to understand gain differences between antennas, we have to understand the signal from a good basic antenna like the dipole. A dipole is the normal reference for comparing antennas.

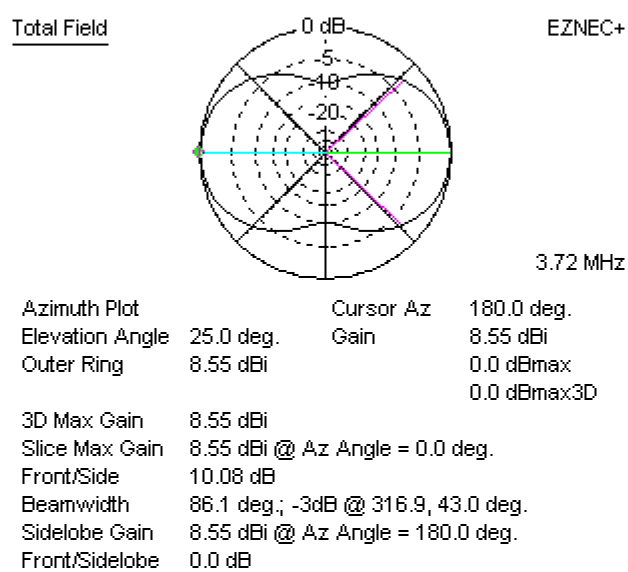
The dipole is also a basic building block of many antennas. Let's dispel a common gain misconception about dipoles and isotropic radiators.

A dipole does NOT have 2.2dB gain over an isotropic radiator when the dipole is placed over earth. At optimum heights, a common 1/2 wave dipole actually has about 8.5 dB gain over an isotropic radiator! Always remember that when you see antenna models over earth that tell you an antenna's gain in dBi.

If a model *over earth* shows a "gain" of about 8.5 dBi, the model effectively has the same gain as a dipole at optimum height over typical earth! We cannot add 2.15 dB to the isotropic gain to get the dBi gain unless ALL of the antennas are in free-space! The instant the earth is involved in a model or measurement the 2.15 dB rule flies out the window.

The plots below are for a 145-foot high copper wire dipole modeled with high accuracy ground over medium real earth on EZNEC:





You can see the gain is 8.5 dBi and it is just a simple dipole just over 1/2 wave high. Any antenna we model should be compared to a standard like a dipole over real earth (unless we intend to install the antenna in outer space)!

J-pole Antenna

Because the J-pole and Zepp are electrically identical in function, and are similar to all other end-fed antennas in problems, pages on J-poles, Zepps, and end-fed verticals overlap.

The J-pole and other end-fed Hertz antennas are prime examples of antenna that ***can*** have severe feed line common mode current problems. The coax shield has to be at zero volts potential and have exactly equal and opposite currents to those flowing into and out of the center conductor at the load and source, otherwise the feed line radiates.

When we allow the feed line shield to be part of the radiating system, due to poor feed system design or construction, the system can be unstable. With improper feed line and mast decoupling, feed line and mast length and grounding can affect SWR. Weather changes can affect feed line moisture between the outer jacket and the support for the feed line, and this can change SWR with rain or snow. Even if SWR does not change, pattern can change significantly. For example, just reversing the shield and center on a J-pole feed point can change low angle field strength several dB, without affecting SWR!

Potentially severe common-mode feed line problems of end-fed 1/2 wave antennas vary with feed line length and feed line routing. This is why some people swear by end-fed antennas, while other people swear at end-fed antennas.

The J-pole is a good example of a poorly implemented feed system, because it mixes balanced and unbalanced systems. In the J-pole, an unbalanced end-fed half wave radiator is fed by a balanced 1/4 wave stub. The balanced stub is fed by unbalanced coaxial cable. This creates two improperly treated balanced-to-unbalanced junctions. Additionally, a metal support is often connected to the J-pole antenna, adding a third variable.

Here is a zoom of the feed point in a ***correct model*** of a bottom-fed J-pole. Notice the model includes the coaxial feed line and/or mast attached to the "grounded point" of the J-pole.

Wire 2 is the long vertical element

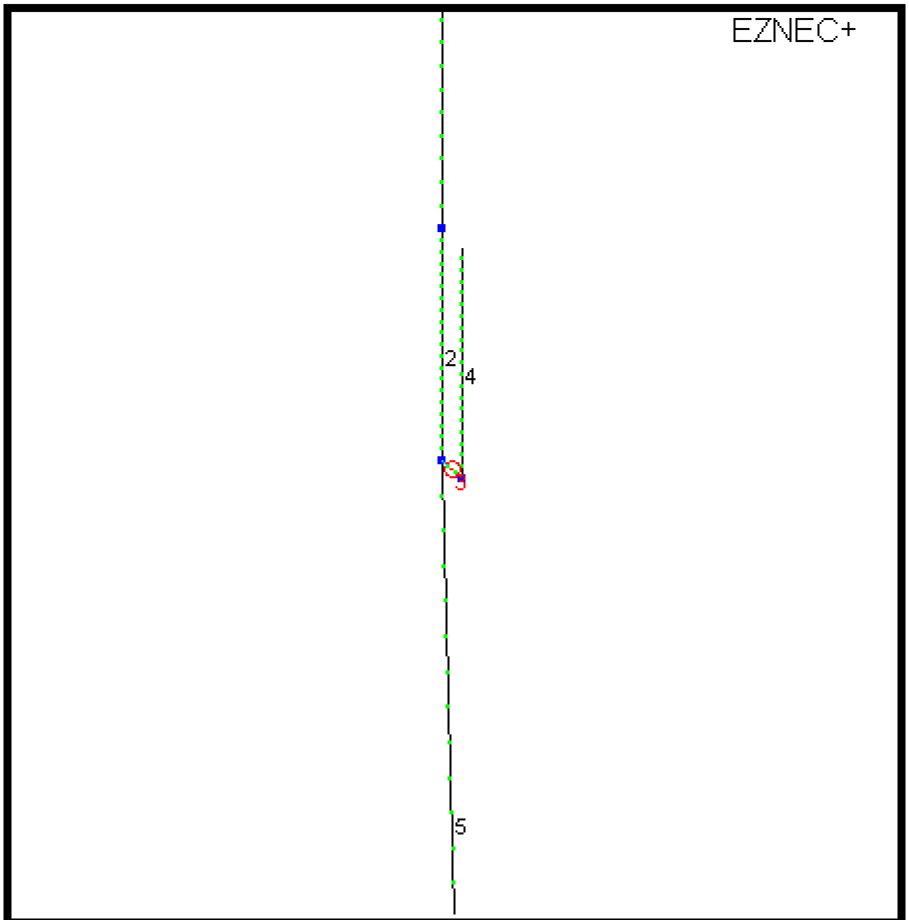
Wire 4 is the short vertical element

Wire 3 (obscured) is the horizontal bend (red circle the source)

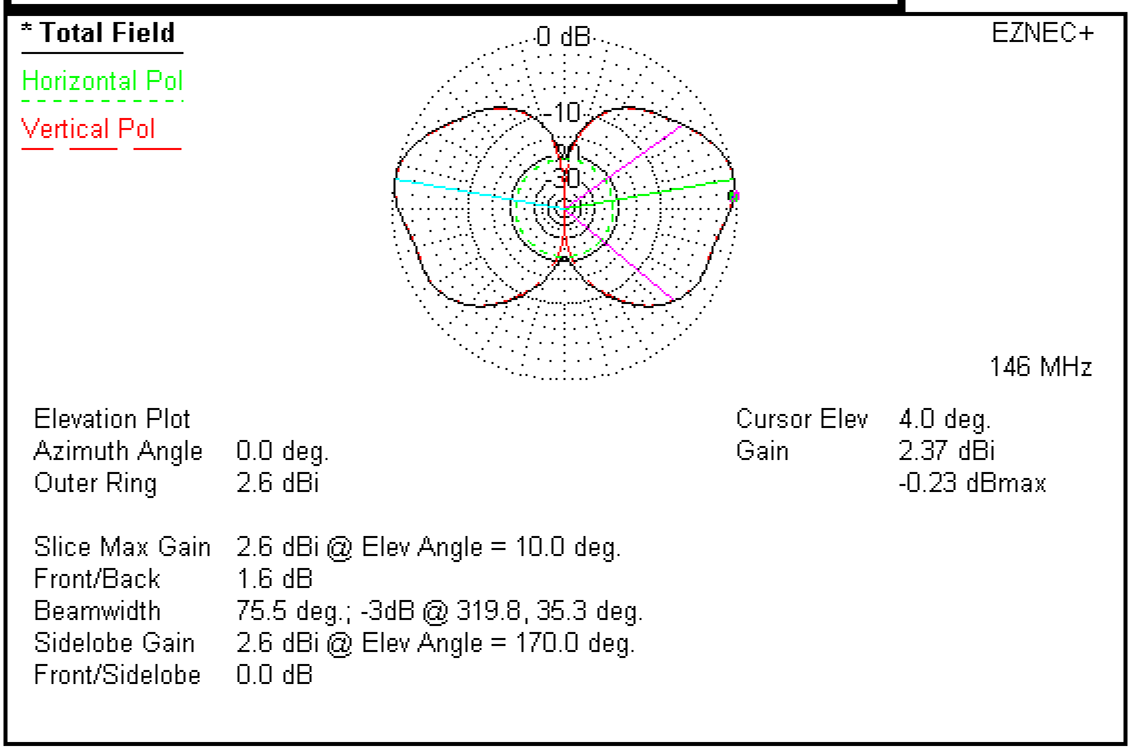
Wire 5 is the mast and coax shield

You'll see the feed line or mast grounds directly to what everyone assumes is a "zero voltage" point. This is the electrical equivalent of any J-pole with the coax connected in series at the feed point, and the longer J-pole leg connected to the shield. The shield can be connected to any supporting mast with much change in system performance. The feed line in this case is relatively cold.

Wire 5 can be moved to either side of the base. The side where wire five attaches represents the side the mast and shield connects to.



Here is the resulting pattern of the shield (wire 5) to short leg wire 4. This is with a split base feed, NOT with the coax tapped up on the "J" :

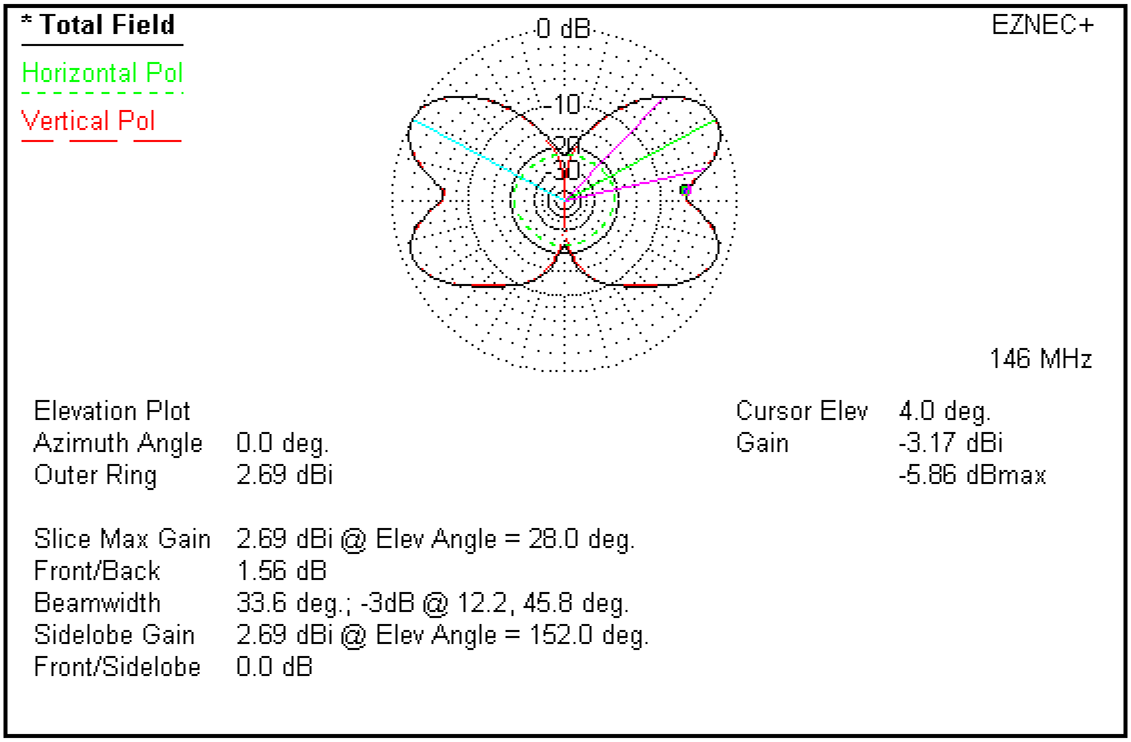


The gain is 2.37 dBi at 4 degrees elevation (compared this to 2.69 dBi for a 1/4wl ground plane). This is actually the best feed system for the J-pole! The shield is connected to the bottom of the short element of the J-pole, with the center conductor connected to the bottom of the longer element of the J-pole.

This antenna model is in freespace, so earth reflection gain is not a factor. It is essentially equal to a vertical dipole in the same environment.

There is some distortion of pattern cause by the imperfect feed, even though it is the best feed.

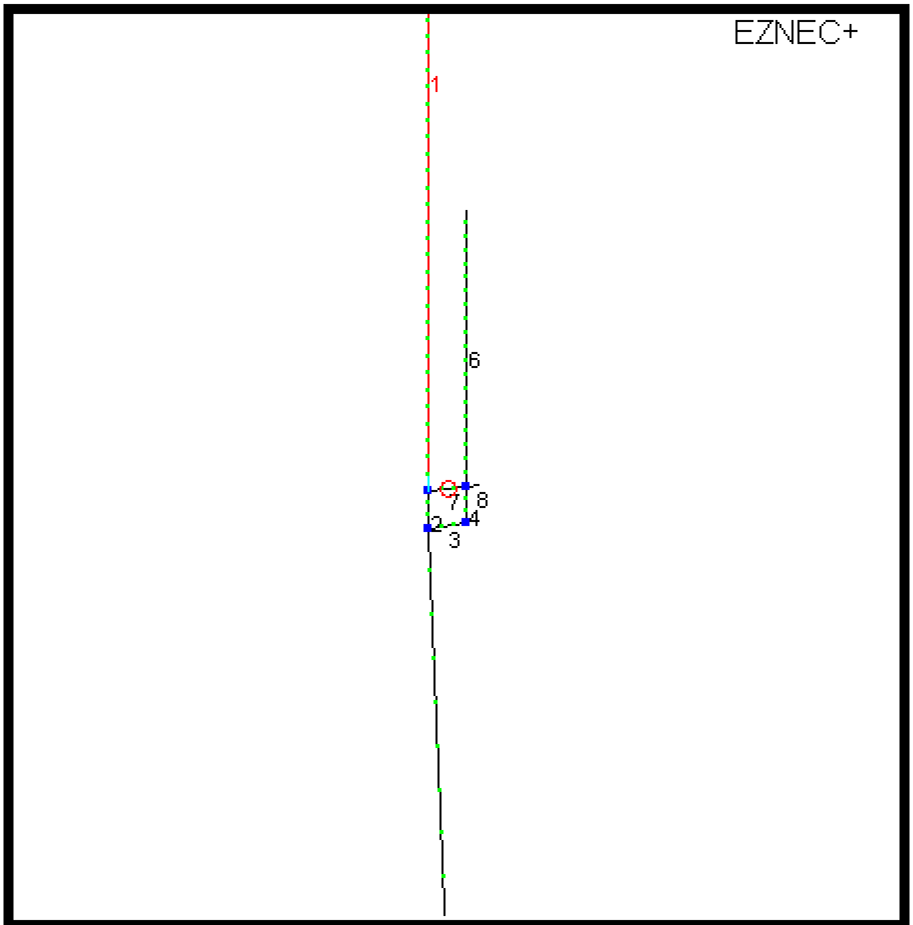
Here is the pattern with the feed point connections reversed. The shield is connected to the longer element (wire 2 in my model) and the center conductor to the short element (wire 4):



Low-angle gain dropped about 5dB with just a simple reversal of feed line connections! If the model did not include the feed line, the model would never show this problem. In both cases, the SWR stayed near 1:1, yet low angle gain was reduced 5dB by reversing the shield and center conductor positions on the antenna!

J-pole With Coax Tapped up on Stub

This is the model without coaxial feed line. The feed line shield would attach to the open end of wire 8.



Wires

Wire Create Edit Other

☐ Coord Entry Mode ☐ Preserve Connections ☐ Show Wire

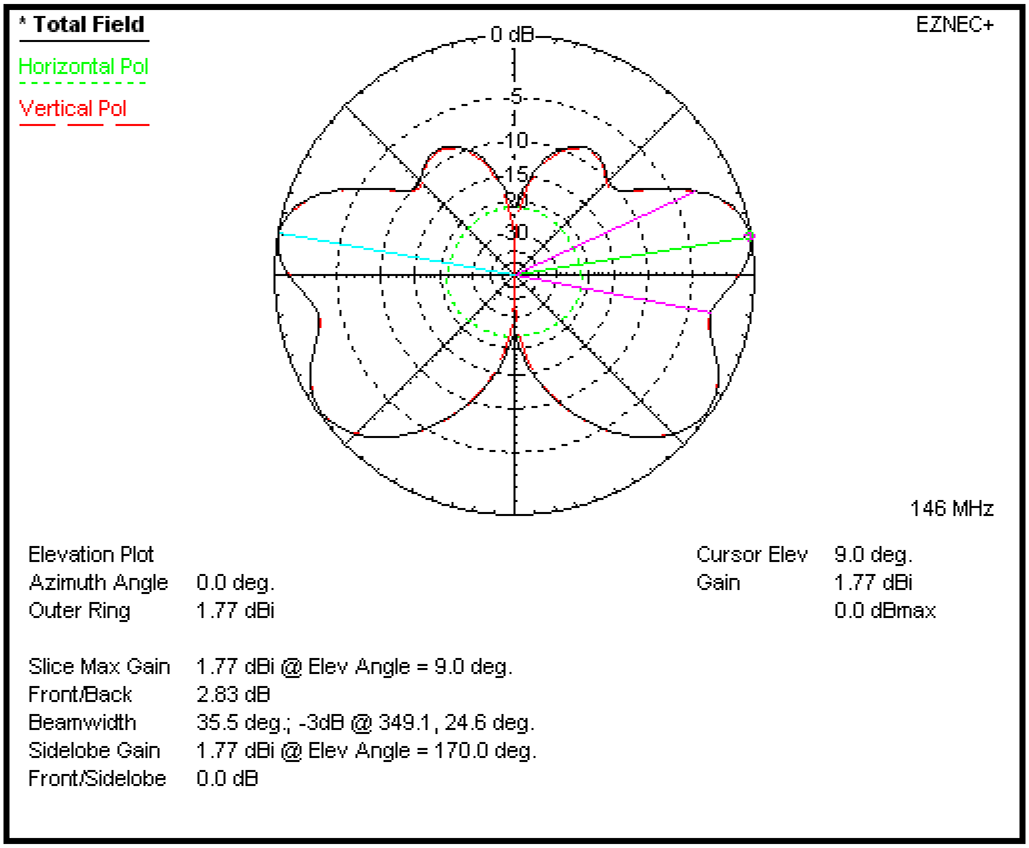
Wires

No.	End 1				End 2				Diameter	Segs
	X (in)	Y (in)	Z (in)	Conn	X (in)	Y (in)	Z (in)	Conn	(in)	
1	0	0	162.5	W2E2	0	0	220		0.1	50
2	0	0	160	W3E1	0	0	162.5	W7E1	0.1	3
3	0	0	160	W5E2	0	1.2	160	W4E1	0.1	3
4	0	1.2	160	W3E2	0	1.2	162.5	W6E1	0.1	3
5	0	1.2	100		0	0	160	W2E1	0.1	20
6	0	1.2	162.5	W7E2	0	1.2	181.5		0.1	20
7	0	0	162.5	W1E1	0	1.2	162.5	W8E1	0.1	3
8	0	1.2	162.5	W4E2	0	1.6	162.5		0.1	1

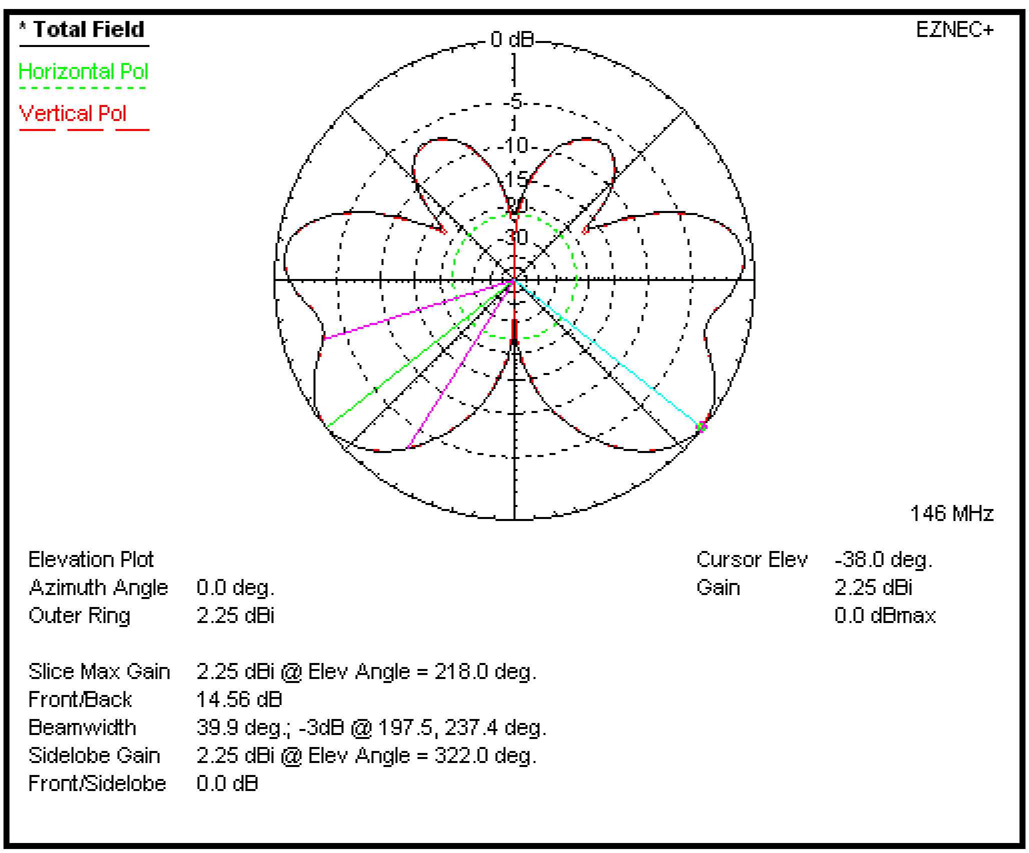
1 is the 3/4 wave element (1/4 wave plus 1/2 wave element)

6 is the stub

7 is the feed tap



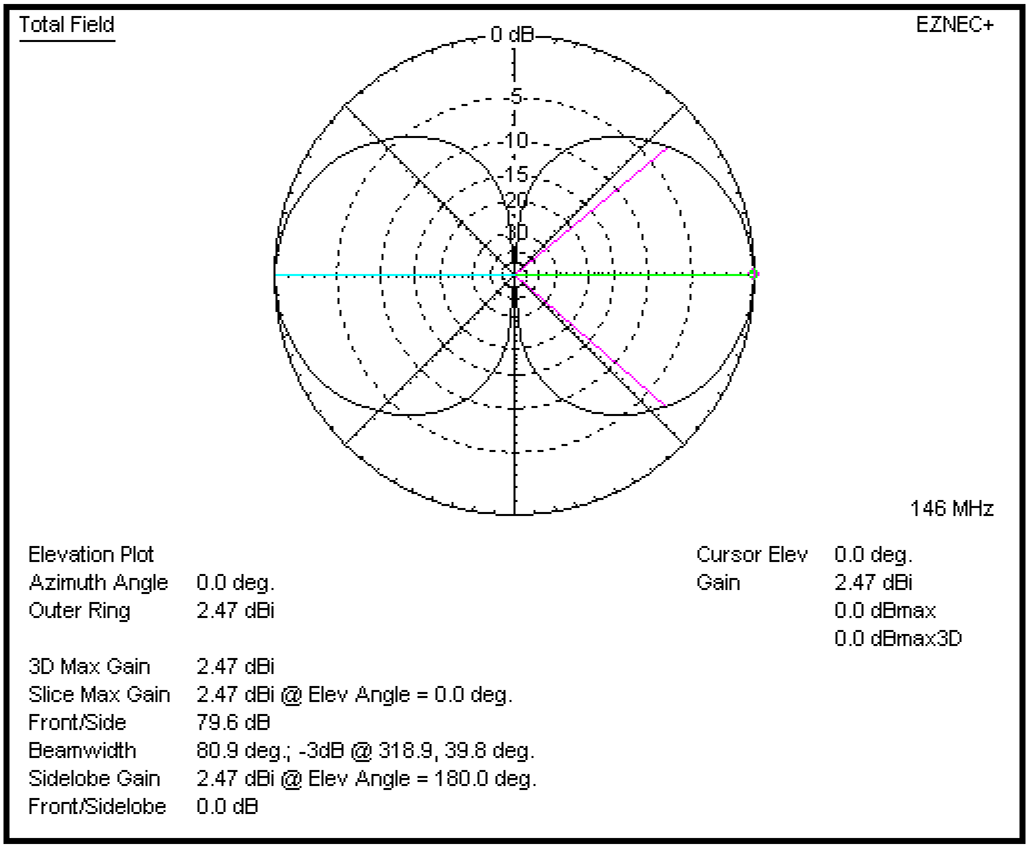
With feed line of poor length choice:



Peak gain is now below the horizon.

None of this means the J-pole won't work, have a low SWR, and make contacts. It simply shows the pattern is unpredictable because the feed line, mast, and grounding significantly affects performance.

In contrast, a properly decoupled 1/4-wave ground plane pattern:



This antenna is significantly shorter in height, has more gain along the horizon, a smoother pattern, and is less sensitive to mast and feed line changes.

This is why commercial two-way radio manufacturers avoid J-poles. For hobbyists, in particular with portable antennas, the J-pole is considerably easier to build and it works OK.

Things Affecting J-pole Pattern and Gain

Affecting J-pole gain and pattern, but not included in models, are:

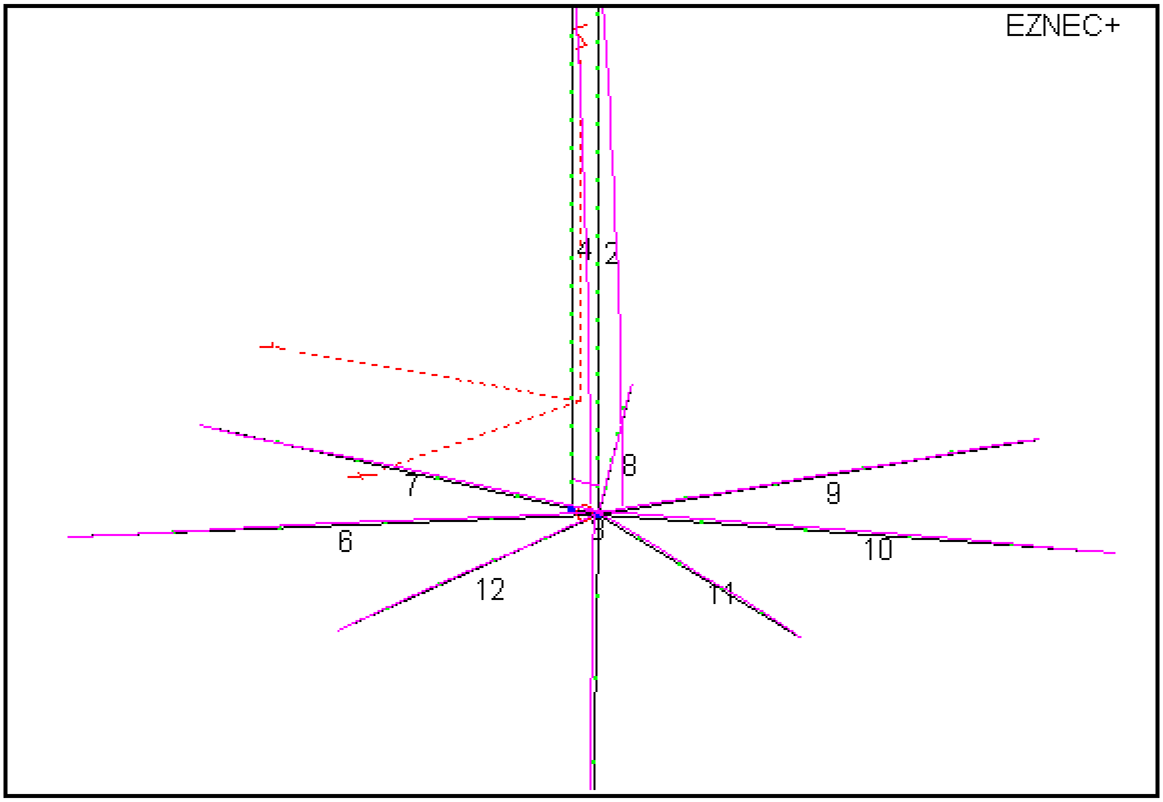
> 1.) Tapping the coax up on the J-pole can result in even worse problems. This elevates the shield even higher in voltage.
>
> 2.) Diameter, length, and area of the structure or mast the J-pole is mounted on
>
> 3.) feed line routing and connections
>
> 4.) feed line and mast length, diameter, and grounding
>
> 5.) Diameter and spacing of J-pole elements

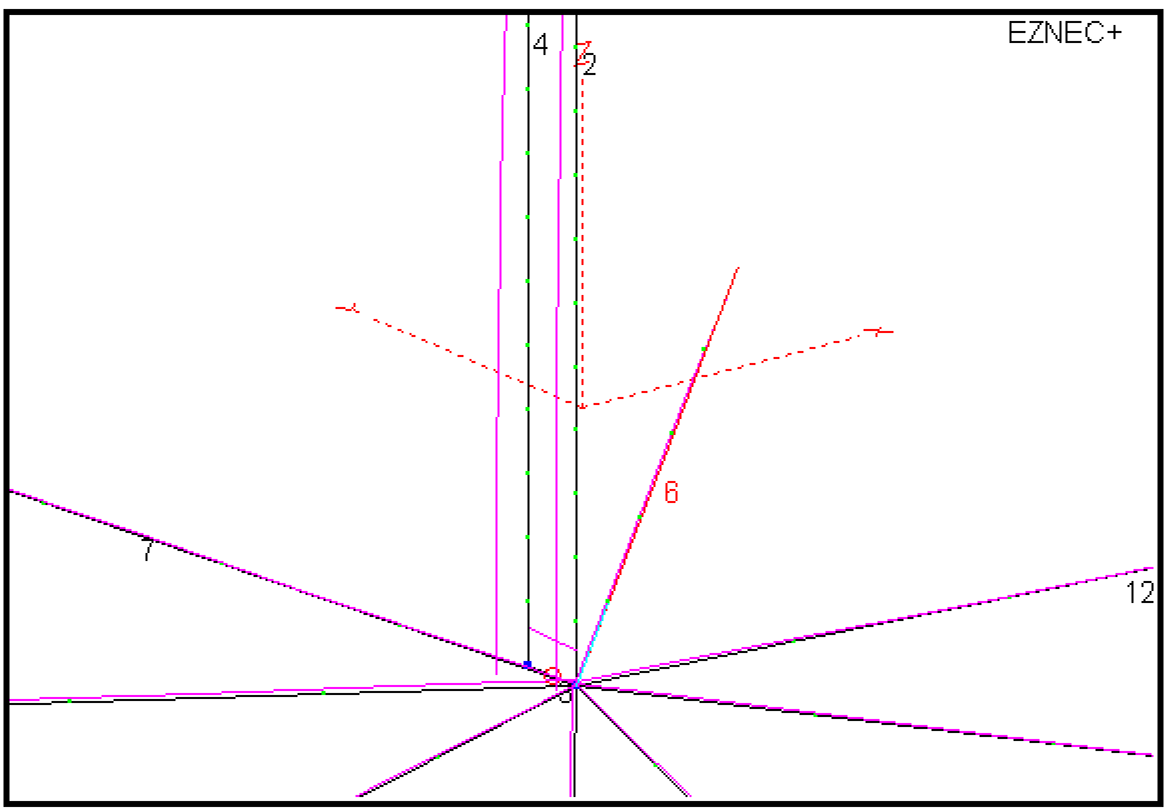
Correcting the J-Pole Common Mode Problem

The J-pole cannot be fixed with a choke balun, or any common type of balun. Let's look at a few reliable cures for common mode.

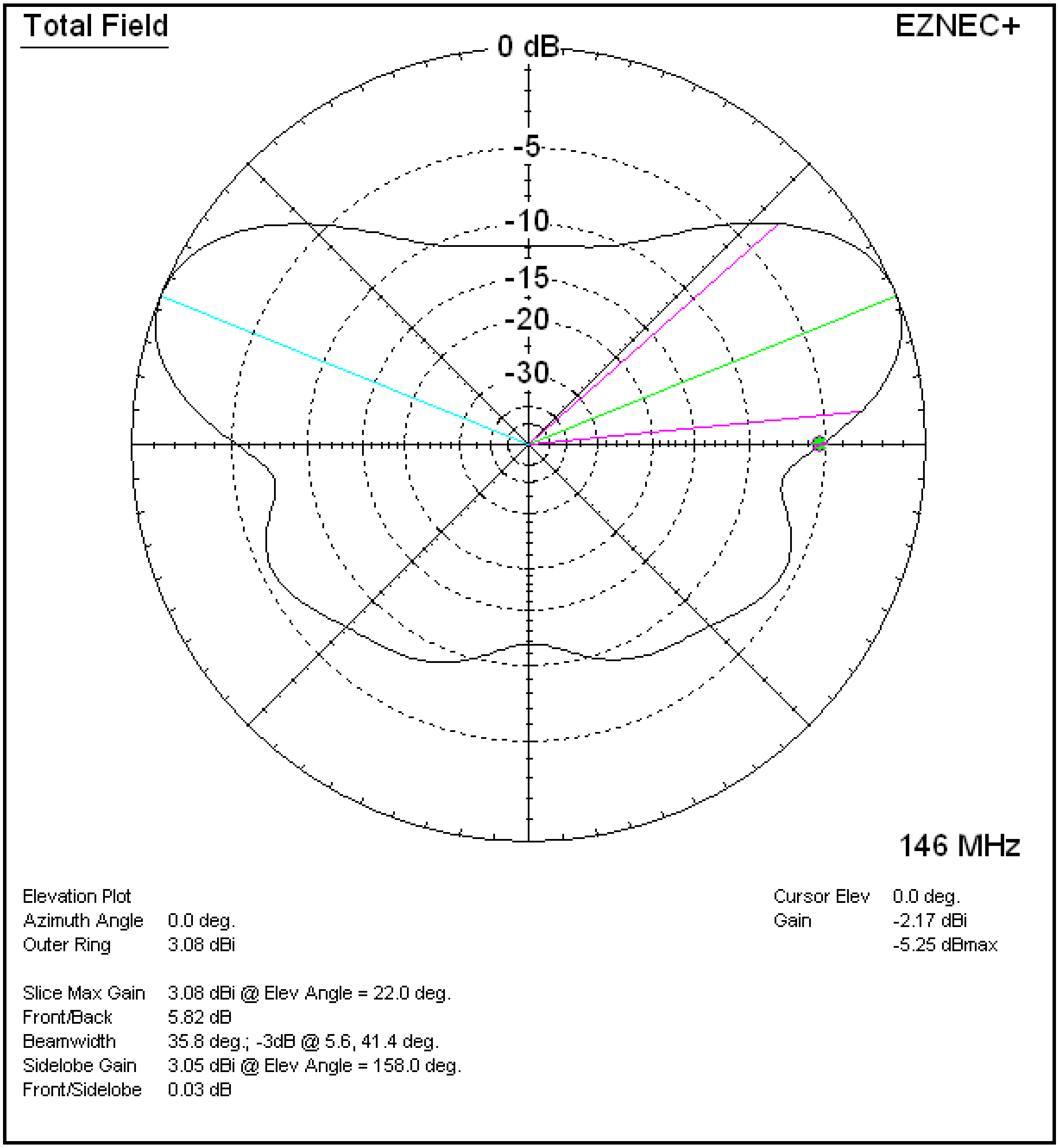
Radials

Adding 4-8 radials helps a great deal, if we do it correctly. Here is a model including coax and mast with 7 radials (wires 6 through 12).



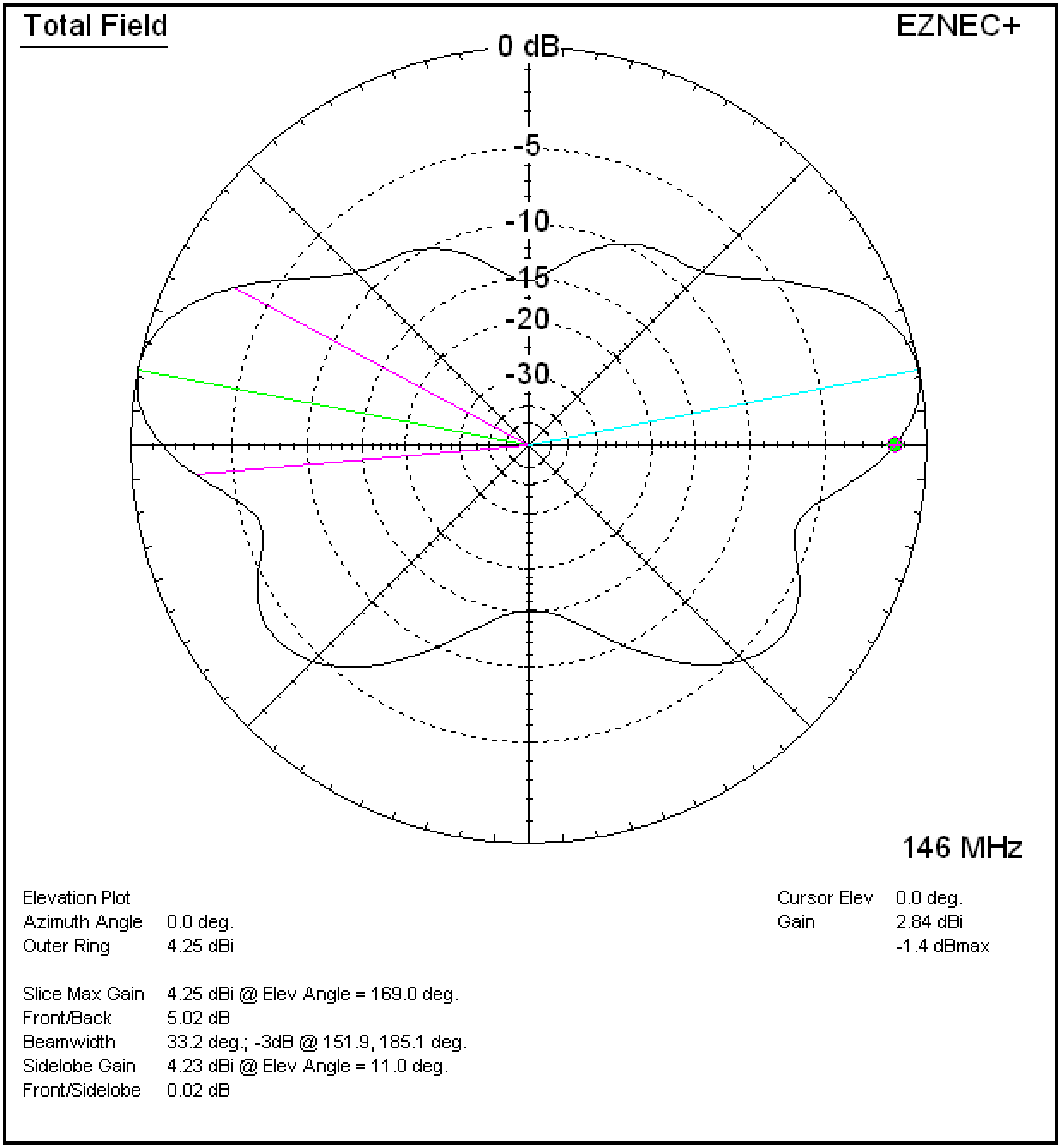


J-pole feed point close up.



This elevation pattern is with the long element grounded.

This pattern is with the short element grounded, and the long element to the coax center.

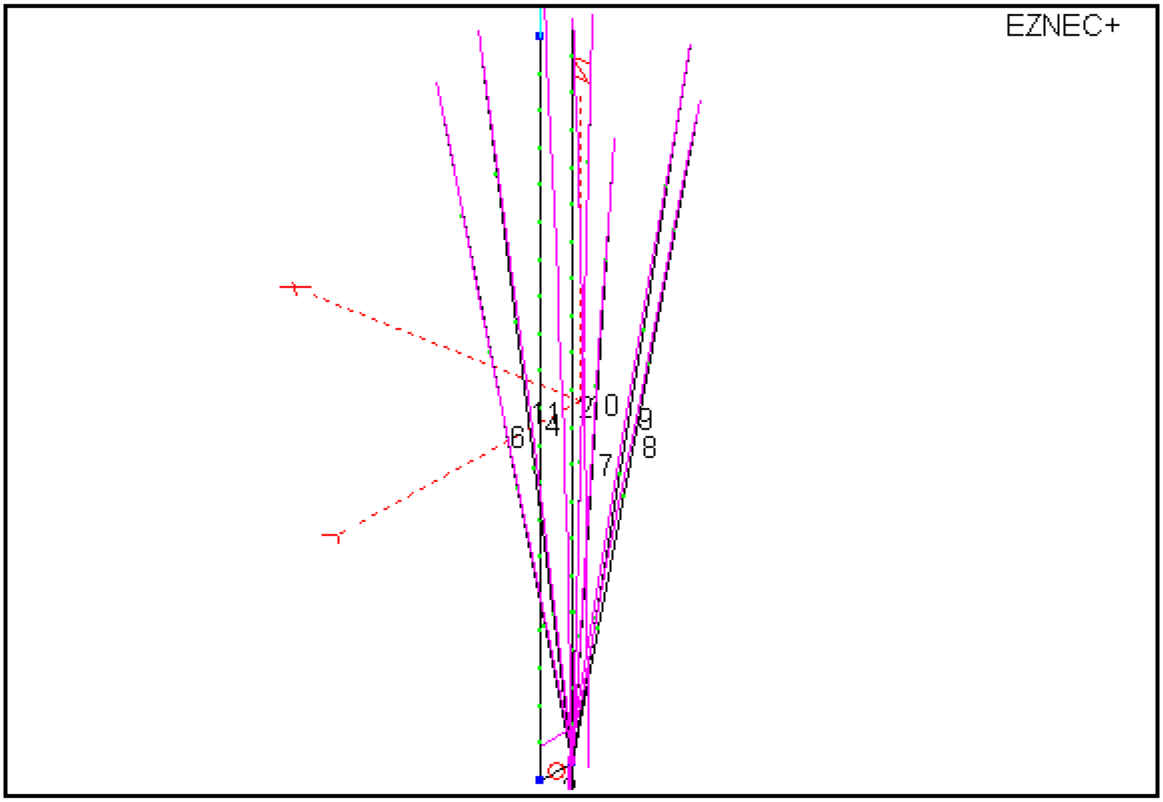


Cone or Sleeve

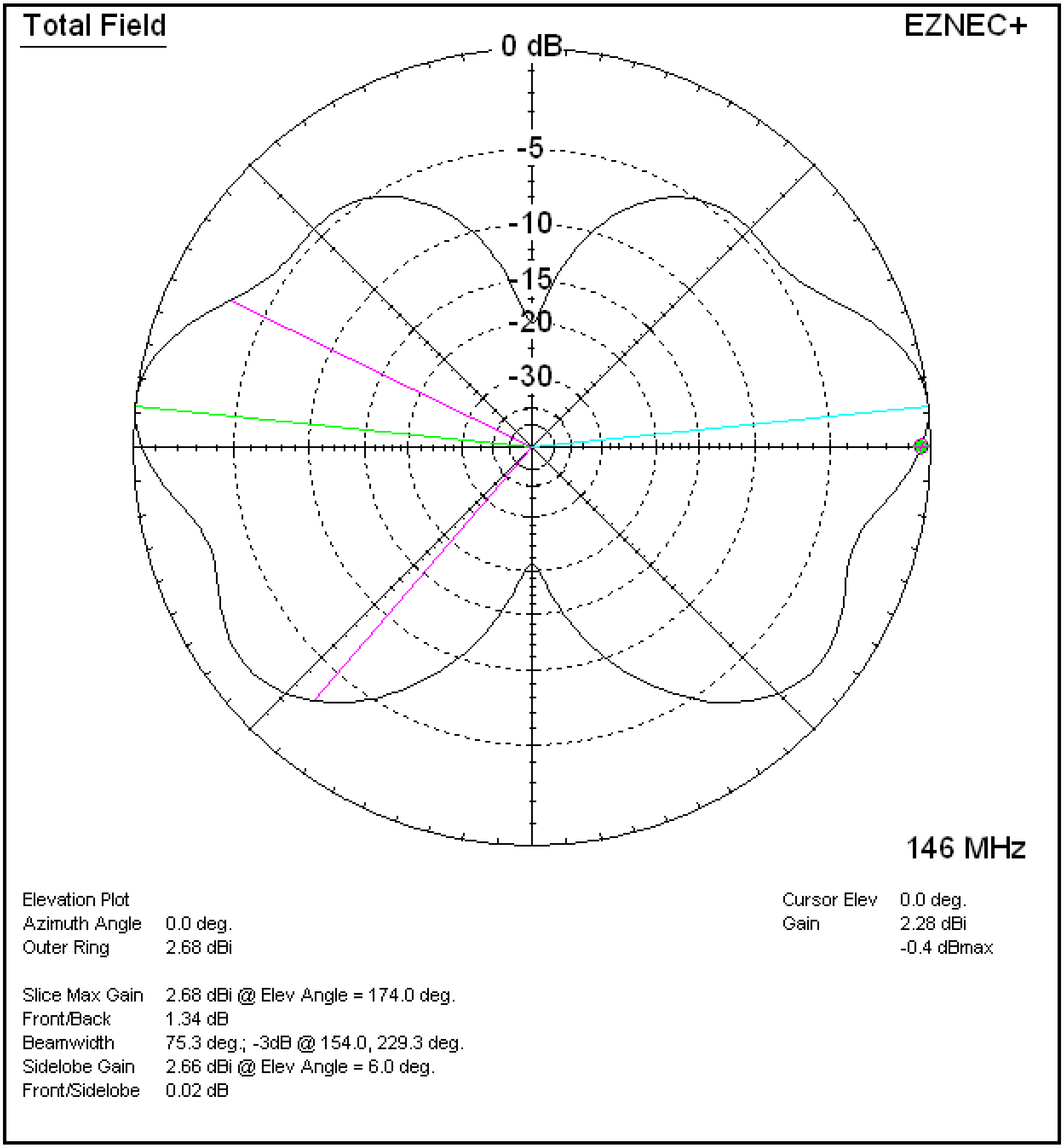
Decoupling

In this case a cone or sleeve if formed to decouple antenna common mode.

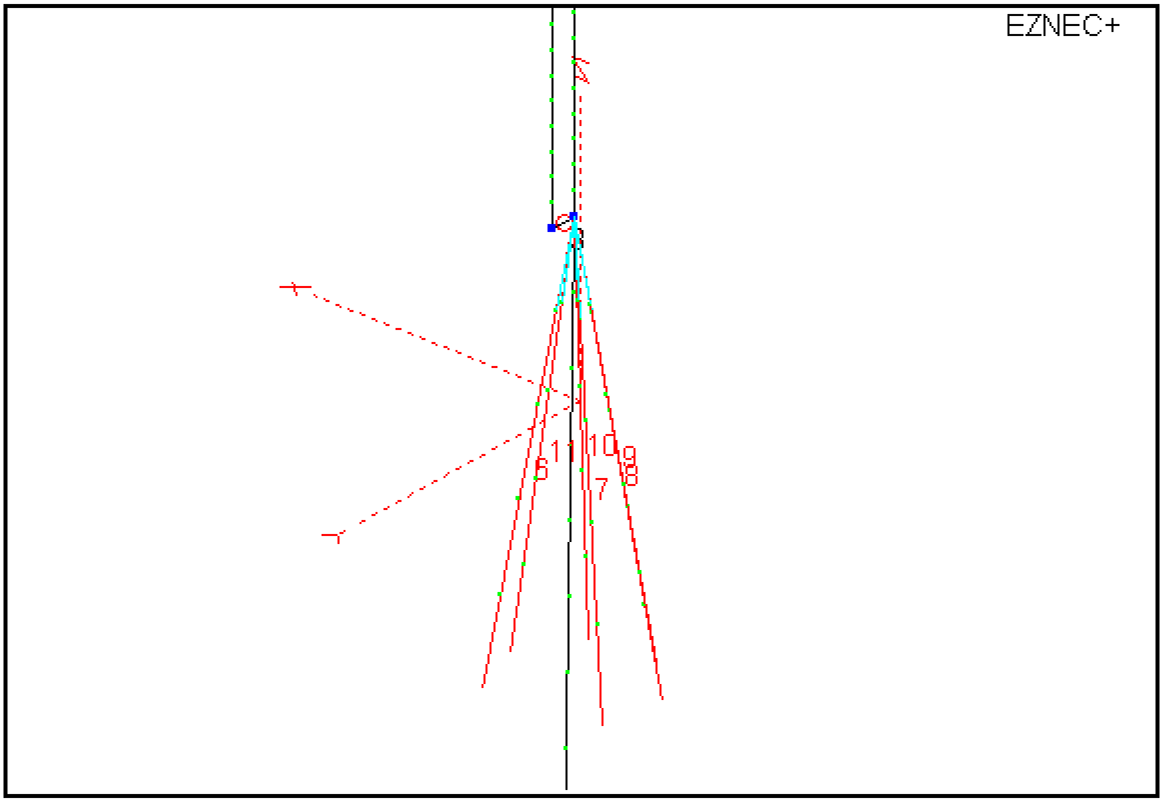
The radials are bent upwards to form a vertical sleeve or cone. This could be done with a hollow pipe, making the feed coaxial.



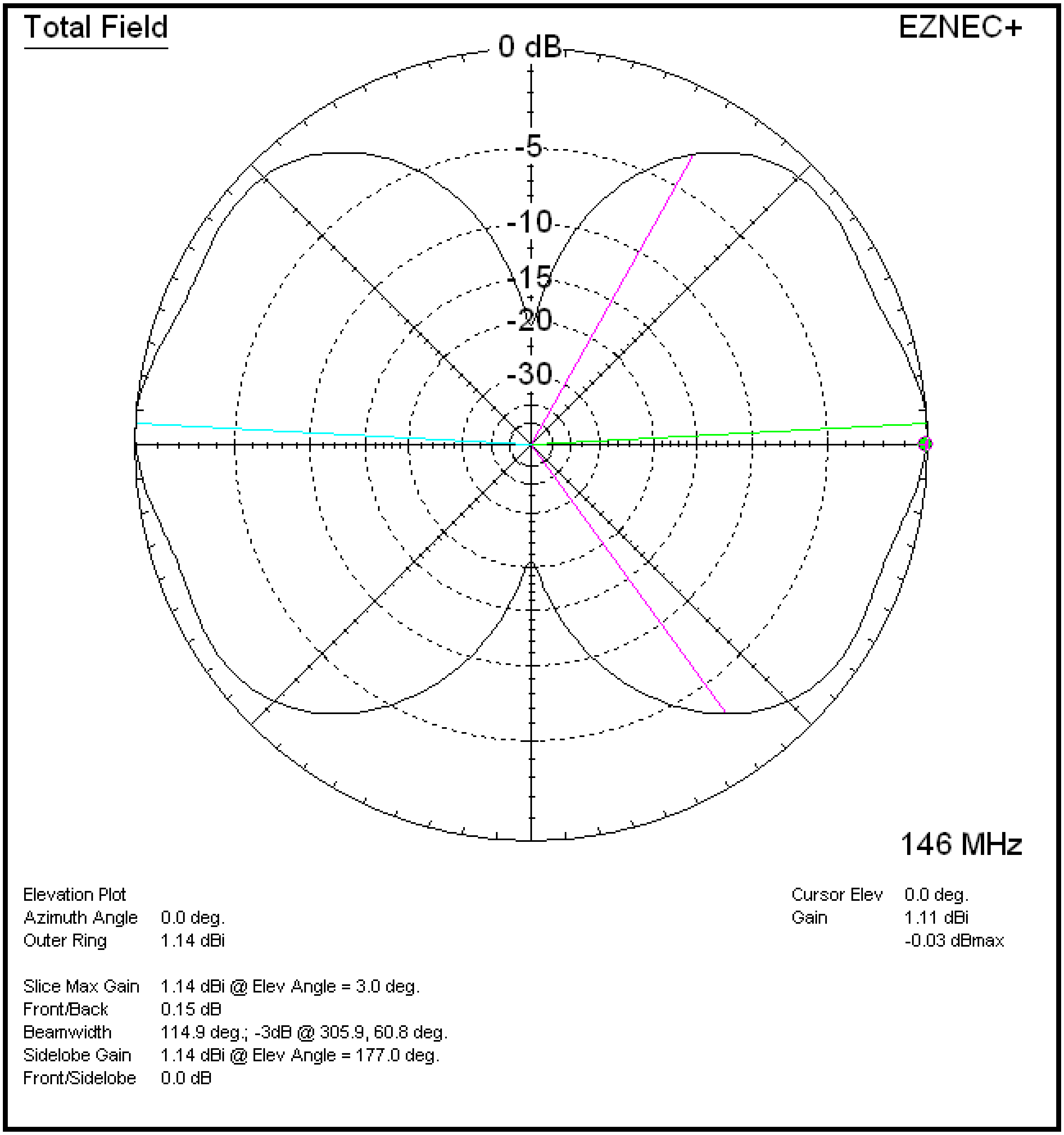
Elevation pattern



Drooping radial cone to isolate common mode



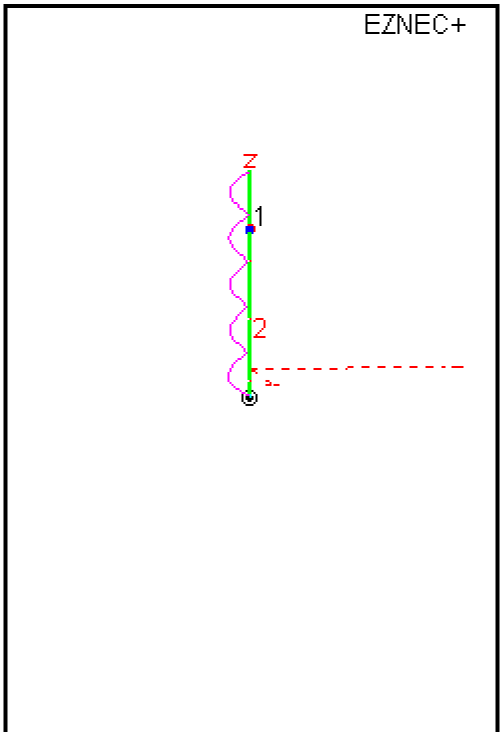
Pattern is clean but gain is reduced with drooped radial cone.



I-Max 2000 Solarcon A-99 Antenna

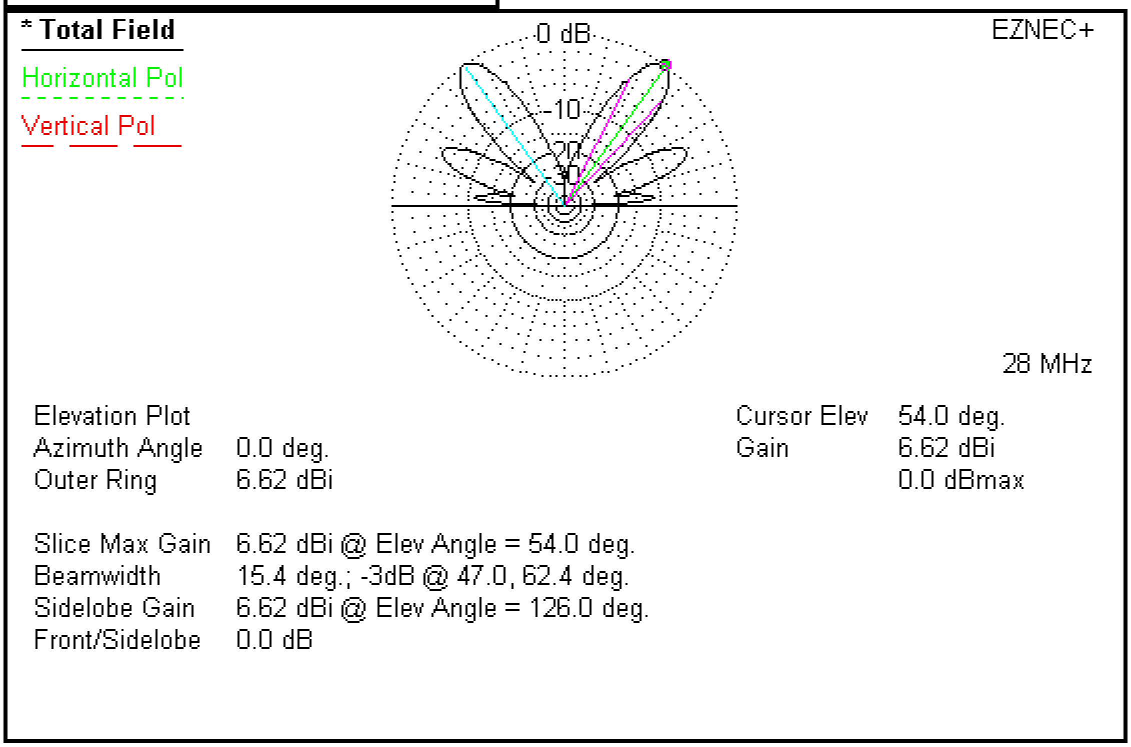
The following model is an I-Max 2000 5/8th wave vertical with a vertical feed line or mast connected to the antenna base, and no radials. In this case I picked one of many worse-case feed line or mast lengths:

feed line shield current is 100% of antenna current. This illustrates why some users complain about SWR problems and RF in the shack with end-fed verticals like the I-MAX 2000, while other people do not complain and seem to love the antenna. This is because some people pick a lucky mast height or feed line length, while others are not so lucky. Unlucky people happened to choose a mast height, feed line length, or grounding system length that enhanced common mode problems.



Here is the pattern of an antenna that copies the I-MAX dimensions and feed system:

Most of the radiation is up in the sky at a high angle. The angle is so high, it is even useless for skywave.

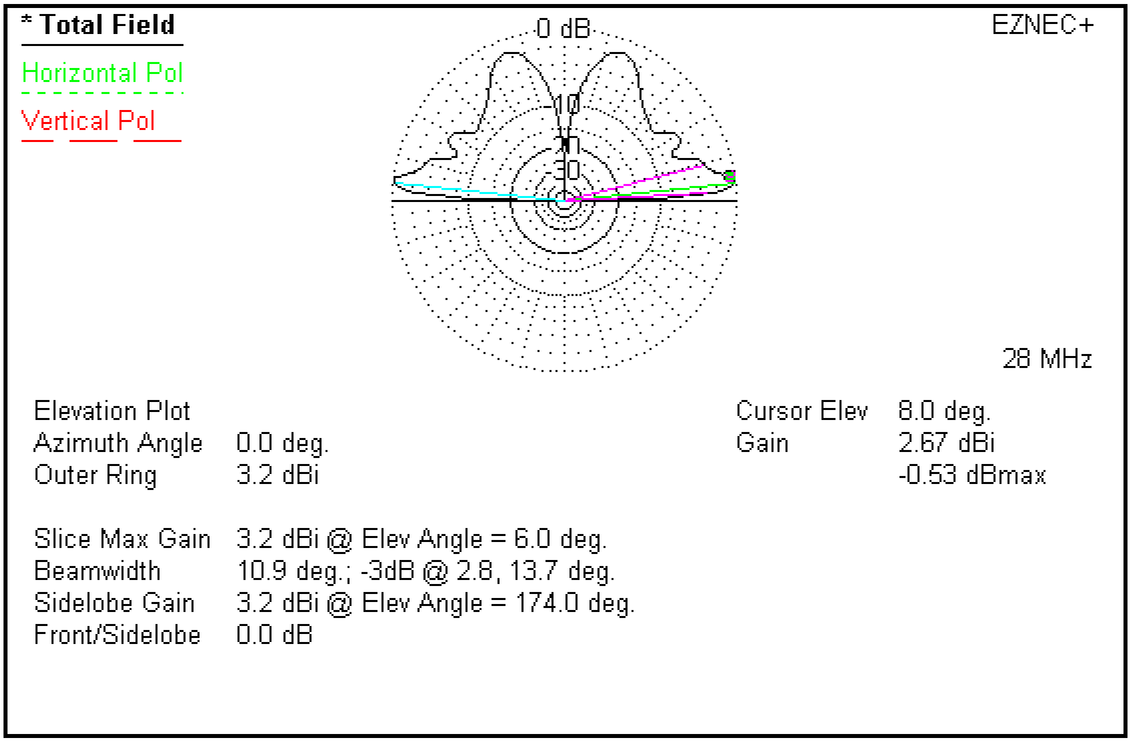


This is a NEGATIVE gain antenna at low angles. A 1/4wl ground plane would seriously outperform the I-MAX 2000 or any other 1/2 or 5/8th wl antenna that does not have a large ground plane.

This pattern is over real earth, where a conventional dipole has about 8 to 8.5 dBi gain. This antenna about -2 dBd gain maximum. It has negative gain over a dipole. The gain over a dipole at most **useful angles** for DX is about -10 dB....significant negative gain.

Optimum feed line length and antenna mast height:

Even if we use the optimum feed line and mast length, here is the very best the end-fed vertical antenna will do is this pattern.



In this case we now have 2.67 dBi at 8 degrees elevation. This is actually an amount that is unnoticeably less than a perfect 1/4wl ground plane will produce! These severe common-mode mast and feed line currents make "no-radial" verticals extremely sensitive to mounting height, mounting structure, feed line length, and grounding. CB'ers for example often talk about grounding coax or changing coax length to match an antenna. If changes in mast length or feed line length or grounding affect the antenna pattern or SWR, it is an antenna design problem.

The gain over a dipole is now a few db at some really low angles, so it can be better than a dipole. At slightly higher angles for shorter skip, the dipole takes over and can be several dB better than the vertical.

This change is entirely the result of altering height and feed line/mast length!!! No antenna changes were made!

Summary End-feds Without Grounds

ALL END-FED ANTENNAS REQUIRE A POPERLY DESIGNED ISOLATION METHOD OR METHODS, OR A VERY LARGE ground plane AT THE FEED, TO PREVENT feed line OR MAST COMMON MODE CURRENTS!

Even ignoring pattern problems, 5/8th waves, Zepp antennas, R7's, R5's, or even common J-poles do not have the stable SWR performance most of us might expect. While poor patterns caused by lack of a flat dense far field ground will remain, lack of a counterpoise or radial system at the base encourages harmful common mode feed line and mast currents. The lack of proper counterpoise systems make antennas dependent on mast length, mast grounding, feed line routing, and feed line grounding. End-feeding antennas is generally bad news unless we include a stable low impedance counterpoise or ground at the feed point.

A ground or ground plane without a supplemental feed line decoupling system improves a system, but is no guarantee the system will be immune to feed line or mast common mode currents. For example, a common directly fed 1/4wl ground plane with three or four radials will have common mode mast or feed line currents. When I designed a commercial 1/4 wave ground plane with four 1/4 wave long radials, I had to insulate the radials from the mast. I then needed to isolate the coax shield from the mast and radials with a 1/4 wave stub that formed a choke balun. Without the decoupling, I could change SWR simply by changing mast or feed line grounding. The antenna feed impedance (and pattern) was unstable without additional common mode decoupling.

While virtually no one looks at antenna patterns or gain, end users often notice SWR issues. A few manufacturers learned from SWR performance problems in the field. Cushcraft manufactured a series of end fed verticals called the "Ringo" and "Ringo Ranger". The Ringo series initially had a matching ring at the vertical element's base, but it lacked a ground plane or counterpoise. This made the antenna very sensitive to what it was mounted on, and sensitive to feed line lengths. People noticed that, at times being unable to obtain a low SWR with any amount of adjustment or tuning. Cushcraft eventually had no choice, they had to fix the problem. Cush Craft eventually added a separate additional ground plane a predetermined distance below the feed point to control the significant common-mode currents generated by the lack of a suitable counterpoise at the feed point. Even that solution is marginal, leaving some mast currents. At least the extremely bad cases, where feed line or masts were just perfectly wrong and the antenna could not ever be matched, were eliminated.

The Isopole antenna used multiple sleeve sections to decouple the feed line, and it probably was one of the best antennas available for immunity to feed line coupling problems. It employed sleeve decoupling.

Common mode current problems become worse when the element is not 1/2 wave long. If we make a 1/2 wave antenna 5/8th wave long, common mode significantly increases. Think of this when we read claims of "no-radial" CB antennas with "3dB gain" and a "low wave angle". No-radial antennas have negative gain at ground wave, or low (DX) angles, when compared to a properly constructed conventional 1/4-wave ground plane! Even when corrected and perfect, 5/8th wave antennas barely have gain over a ground plane antenna. Instead of focusing the signal at useful DX or ground wave angles, long end-fed antennas without radials concentrate the signal toward a neighbor's TV set or toward an airplane flying overhead. These unwanted common mode currents cause the antenna system to be critical for feed line grounding, routing and length and even allow moisture on the feed line jacket to change performance of the system!

To read more about end-fed antennas of various types, follow the end-of-page link:

Verticals, end fed antennas, and baluns