Vertical's

Do They Really Work?

BY KEVAN NASON
N4XL

References

- Low Band DXing, ON4UN, Fifth Edition
- ARRL Antenna Book, Various
- Elevation and Pseudo-Brewster Angle Formation of Ground-Mounted Vertical Antennas, Robert J. Zavrel Jr., QEX Mar/April 2016
- DXpedition Antennas- Vertical vs. Yagi, N6PSE https://n6pse.wordpress.com/2014/02/21/dxpedition-antennas-vertical-vs-yagi/

Walter* once told me:

"They radiate equally badly in all directions. I wouldn't own one. Save your money and build a dipole."

* Not his real name

A Dxpedition member once said:

"When we were motoring to Rotuma Island for the 3D2R DXpedition in 2011, I experienced just how wonderful a vertical at/in salt water could be."

https://n6pse.wordpress.com/2014/02/21/dxpedition-antennas-vertical-vs-yagi/

So the question is not
"Do they work?"

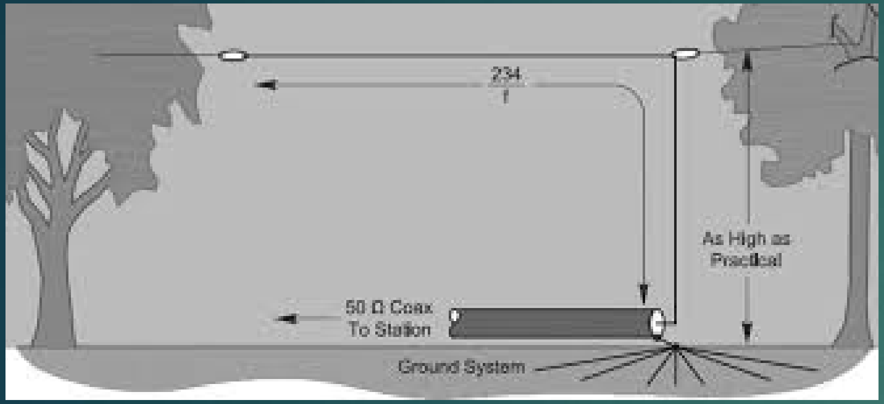
It is really:
"How can I make it work and is it worth the trouble?"

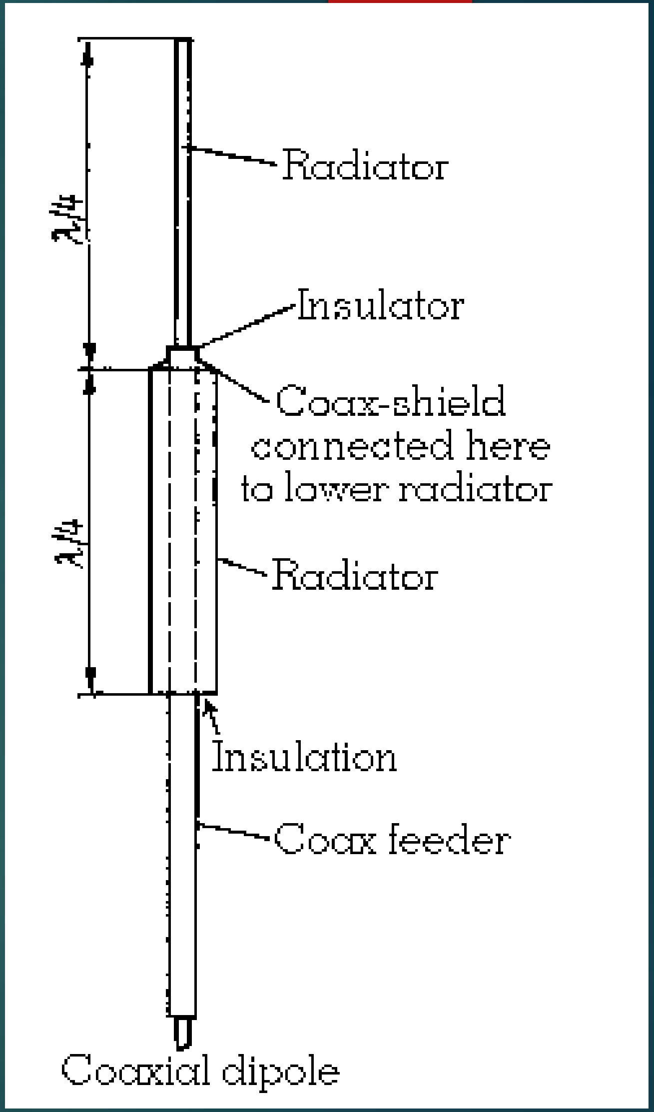
Types of Verticals

Who agrees with Walter and would never own or recommend a vertical?

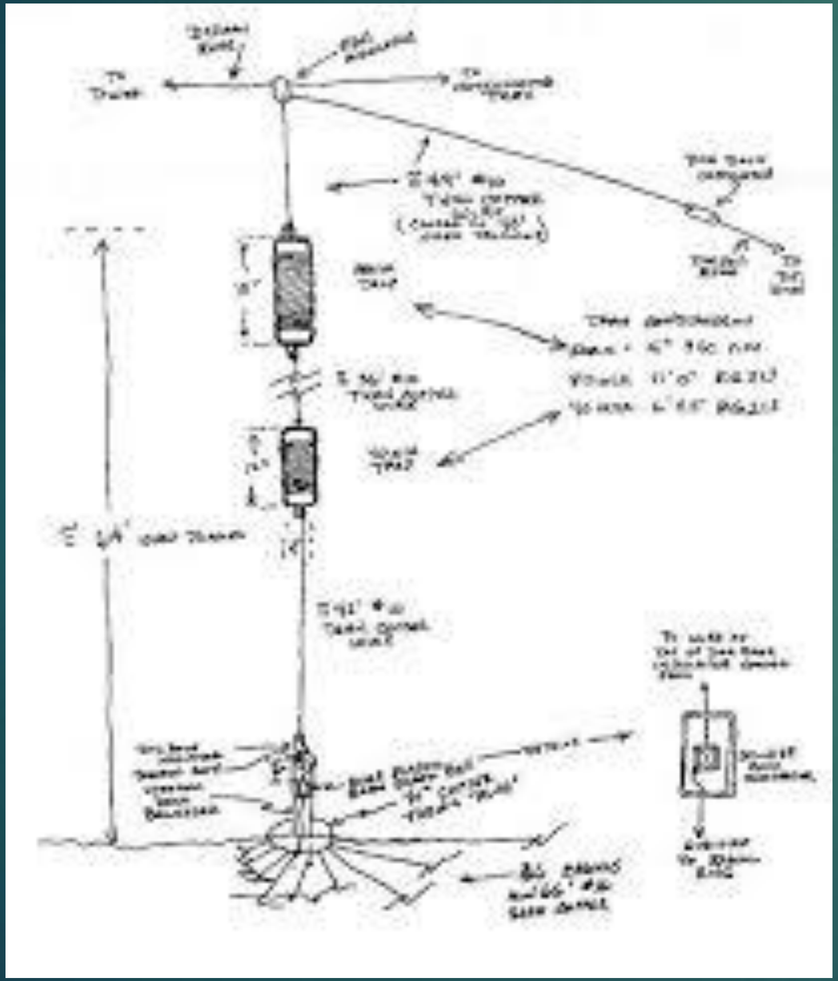
Types of Verticals

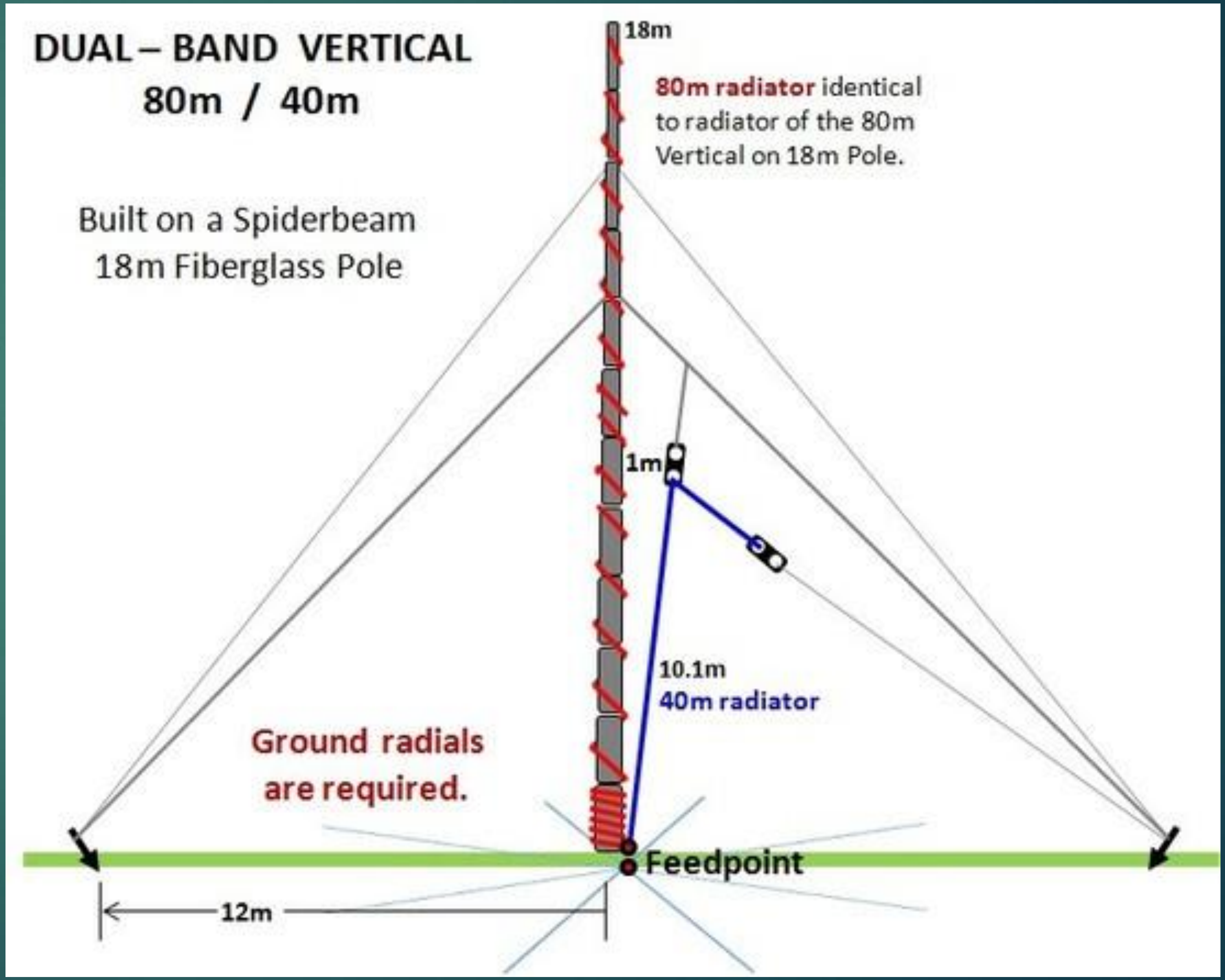
Types of Verticals



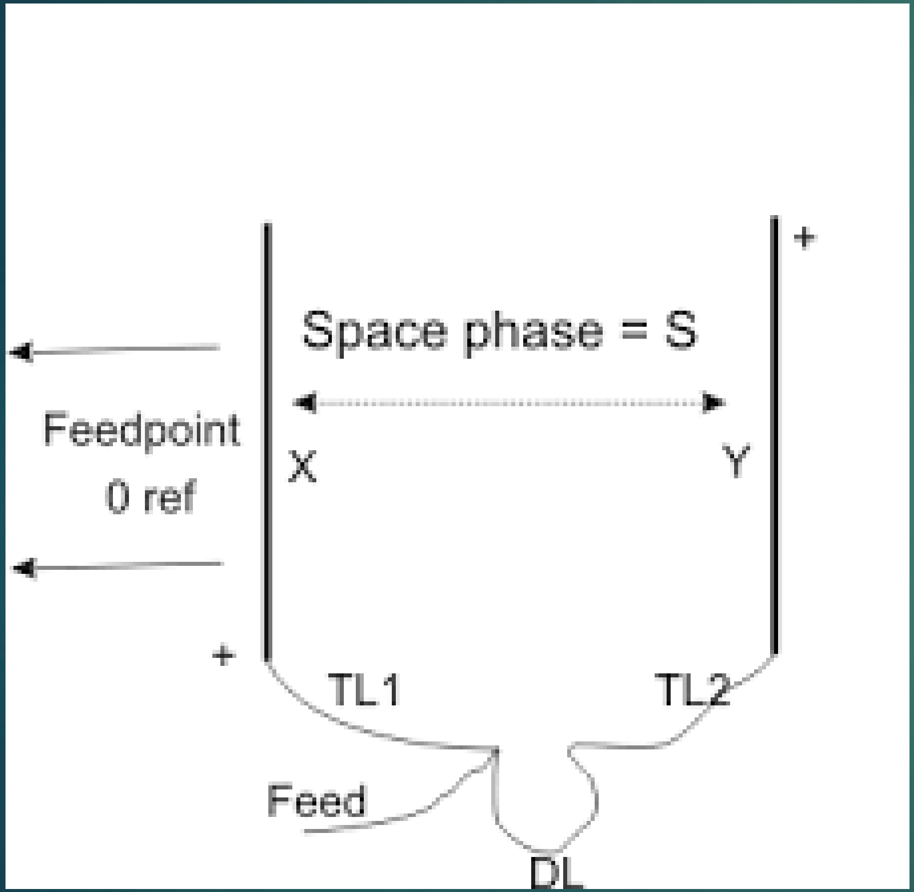


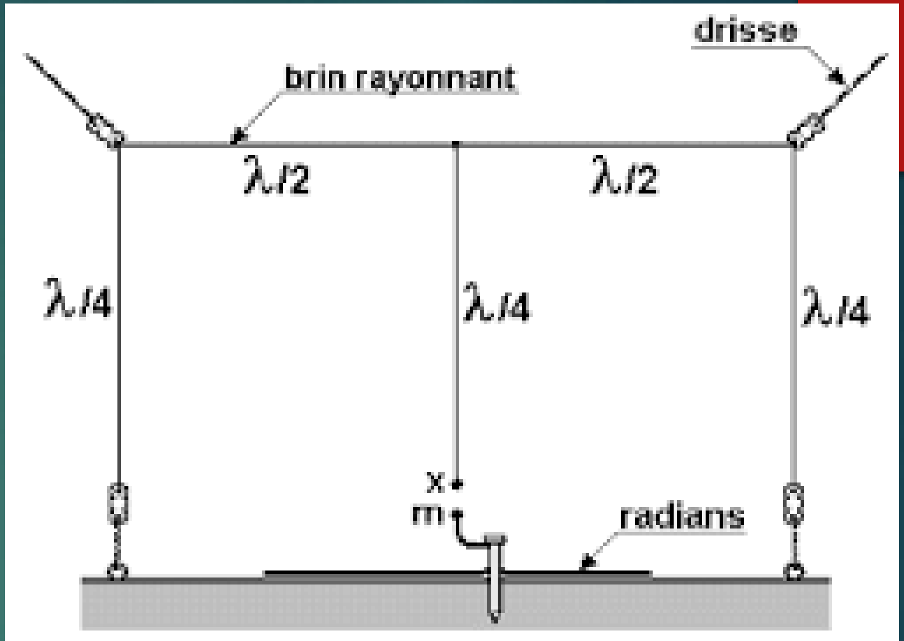
Types of Verticals

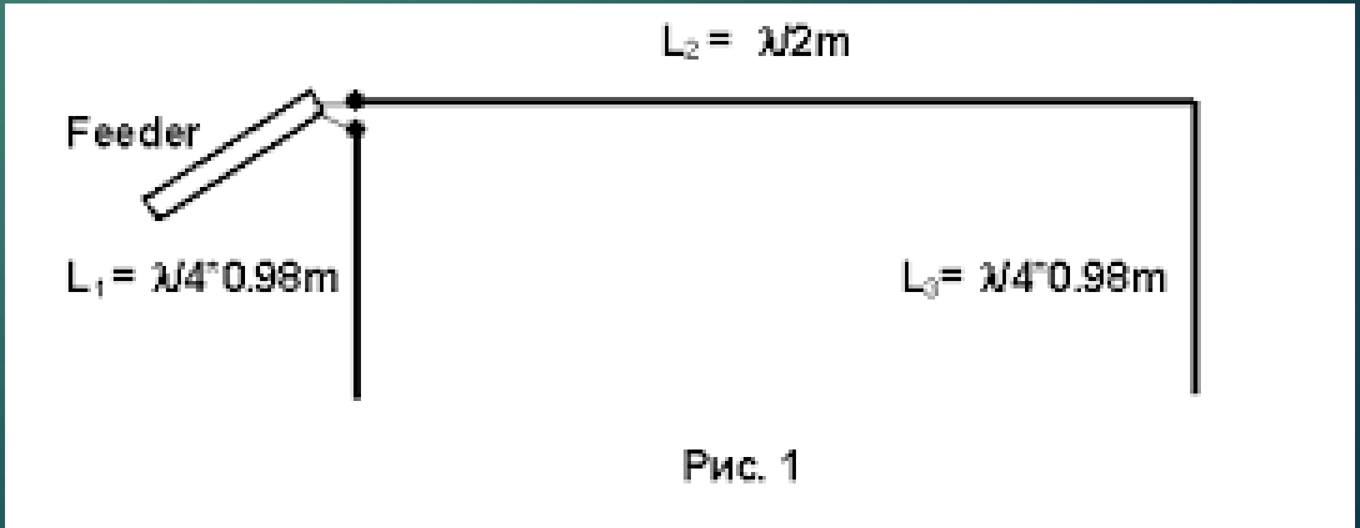




Types of Verticals







Why Use a Vertical?

- Want to work DX but can’t put up a high tower (particularly on low bands)
- No trees to hang dipoles from
- Want omnidirectional coverage, but existing trees would only allow a low dipole.
- More pleasing to the eye than a tower (at least for some!)
- Second hand verticals are fairly inexpensive. Easy to build your own with just wire

Why Use a Vertical?

Take off angles and antenna gain

Why Use a Vertical?

40 and 80 meter take off angles

Table 5-1

Range of Radiation Angles for 40 and 80 Meters for Various Paths

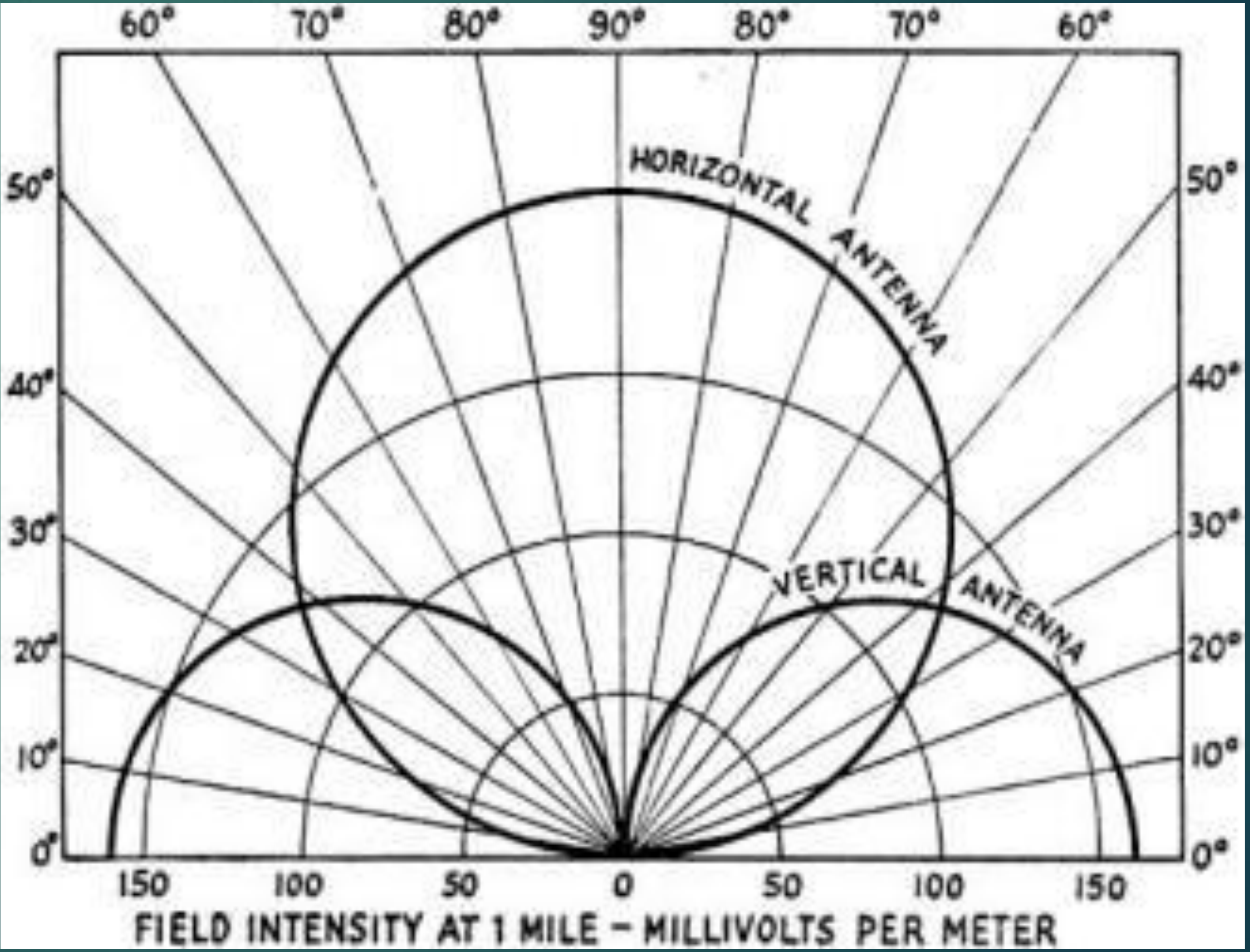
The values are averages across the complete sunspot cycle and across the seasons. The value between parentheses is the most common radiation angle (peak value in the distribution).

From	*Path to*	*40 Meters*	*80 Meters*
W. Europe (Belgium)	Southern Africa	1-18 (5)	1-17 (5)
	Japan	1-19 (3)	2-17 (3)
	Oceania	1-4 (1)	No Data
	South Asia	1-17 (4)	3-5 (4)
	USA (W1-W6)	2-33 (5)	1-35 (4)
	South America	1-17 (1)	1-12 (1)
USA East Coast	Southern Africa	1-16 (3)	3-4 (4)
	Japan	1-15 (1)	1-12 (5)
	Oceania	1-9 (1)	No Data
	South Asia	1-9 (1)	No Data
	South America	1-23 (5)	1-21 (10)
	Europe	1-38 (6)	1-31 (13)

Why Use a Vertical?

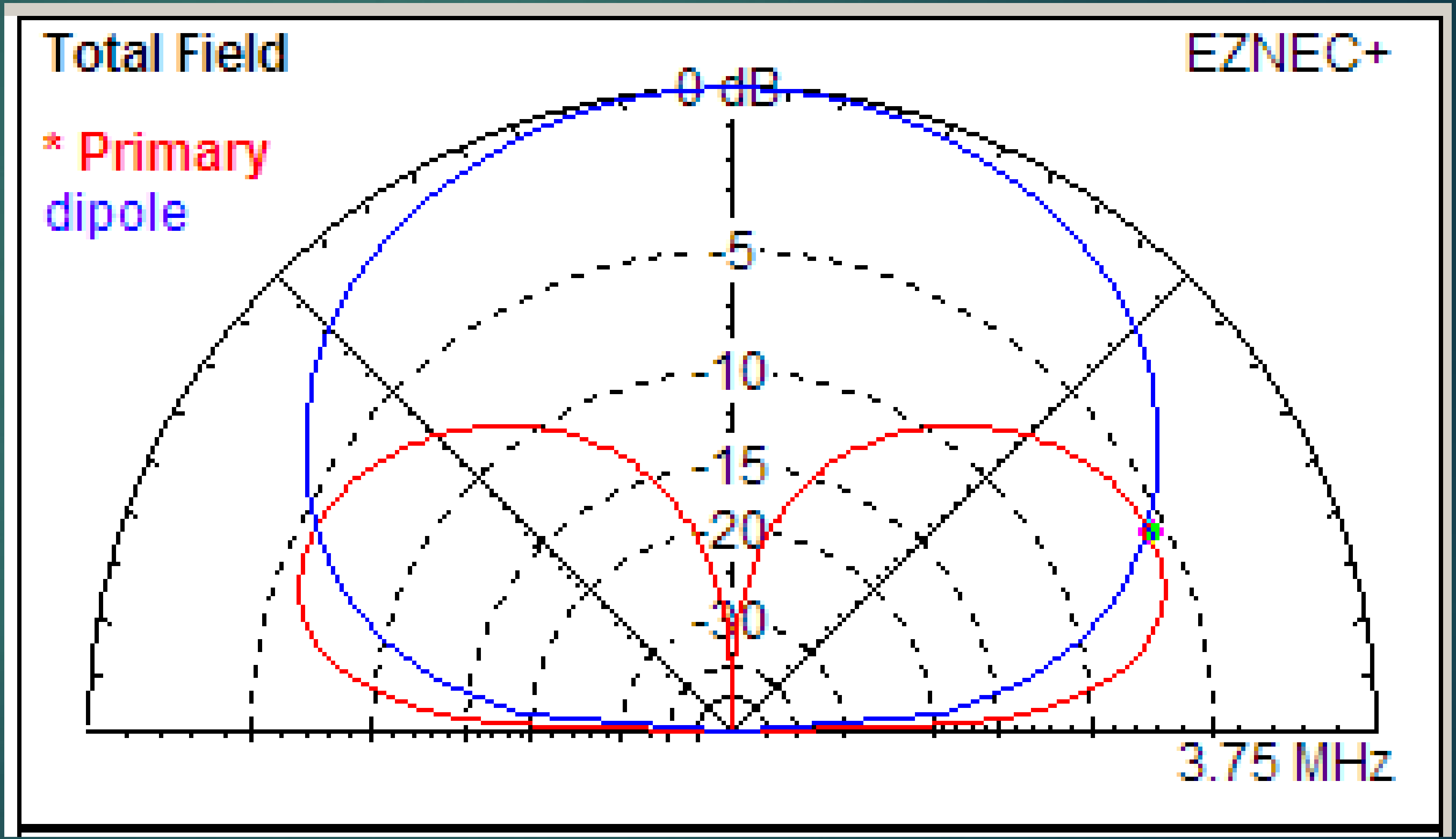
From 1952 QST Article

These would be nice patterns to have in the real world

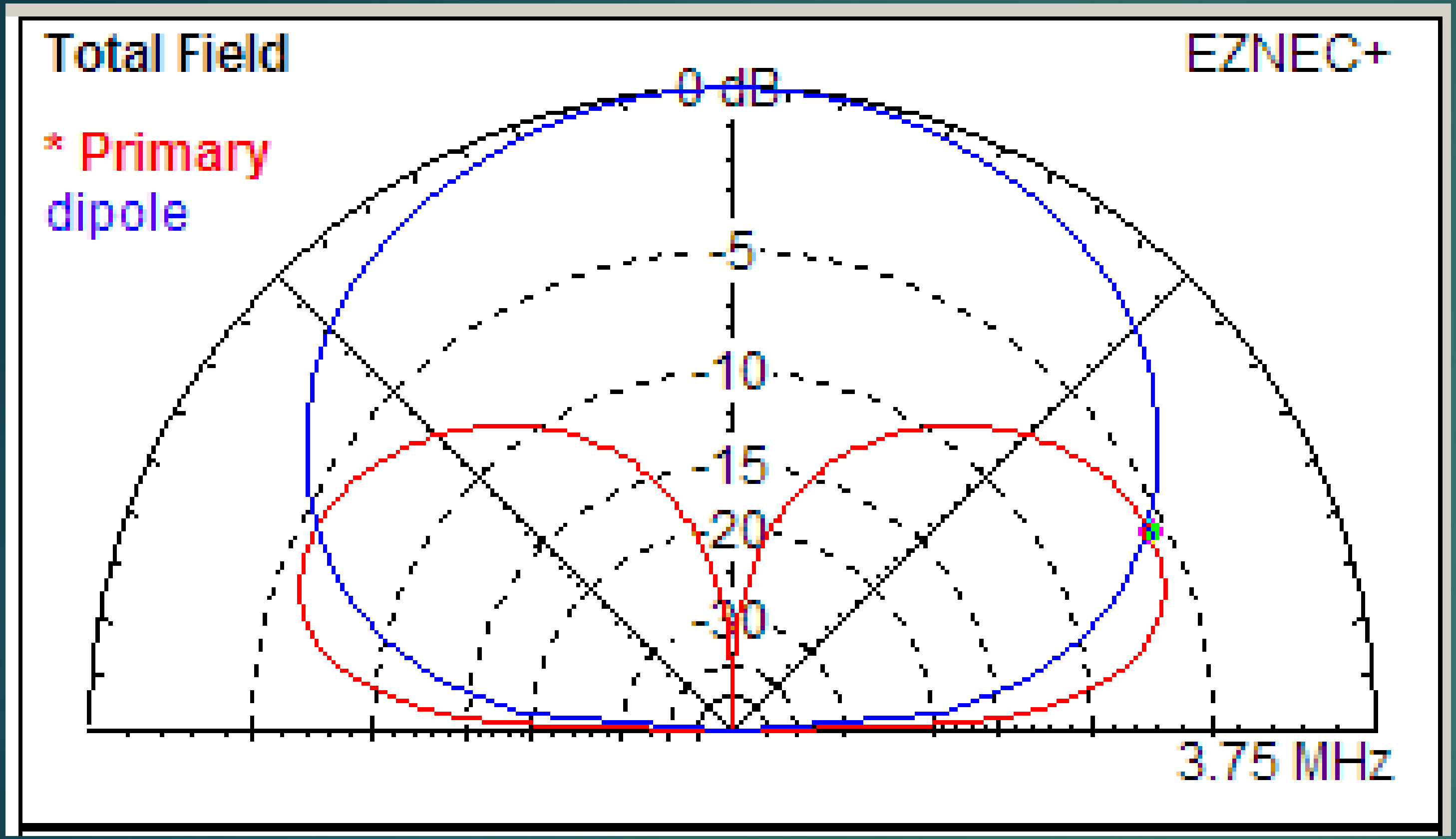


Why Use a Vertical?

80 mtr
Dipole vs.
Vertical



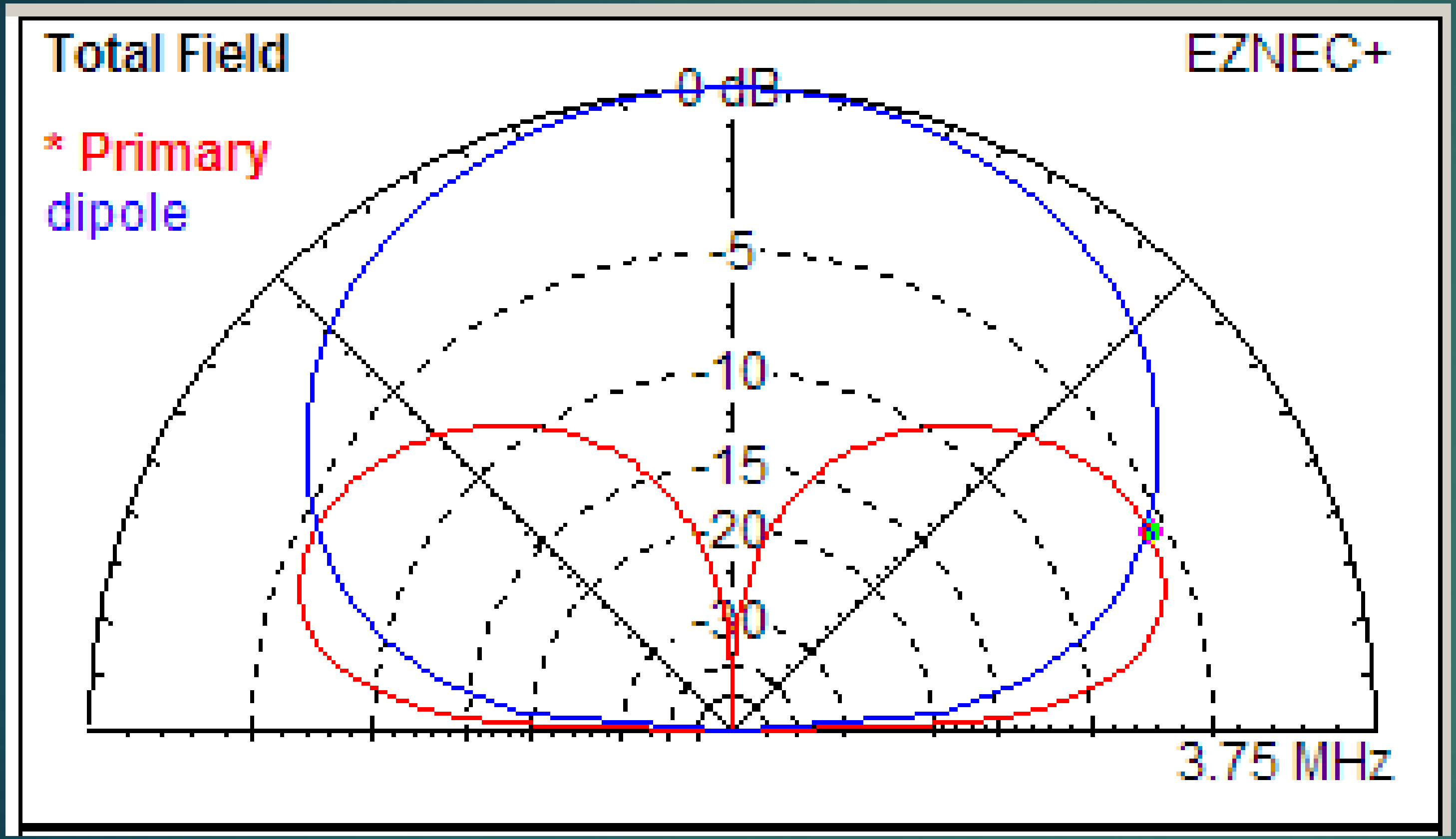
Comparison



Low Dipole vs Vertical over average ground

- Vert pattern has less gain over real earth
- Gain can be significant at low angles – i.e.: DX
- Vertical suppresses interference from stronger and closer stations – you can “hear” DX better

Comparison



Low Dipole vs Vertical over average ground

In many cases a low dipole is a better choice than a vertical

Make a Vertical work best by improving that low angle gain

Antenna efficiency

The type of ground around a vertical is very important

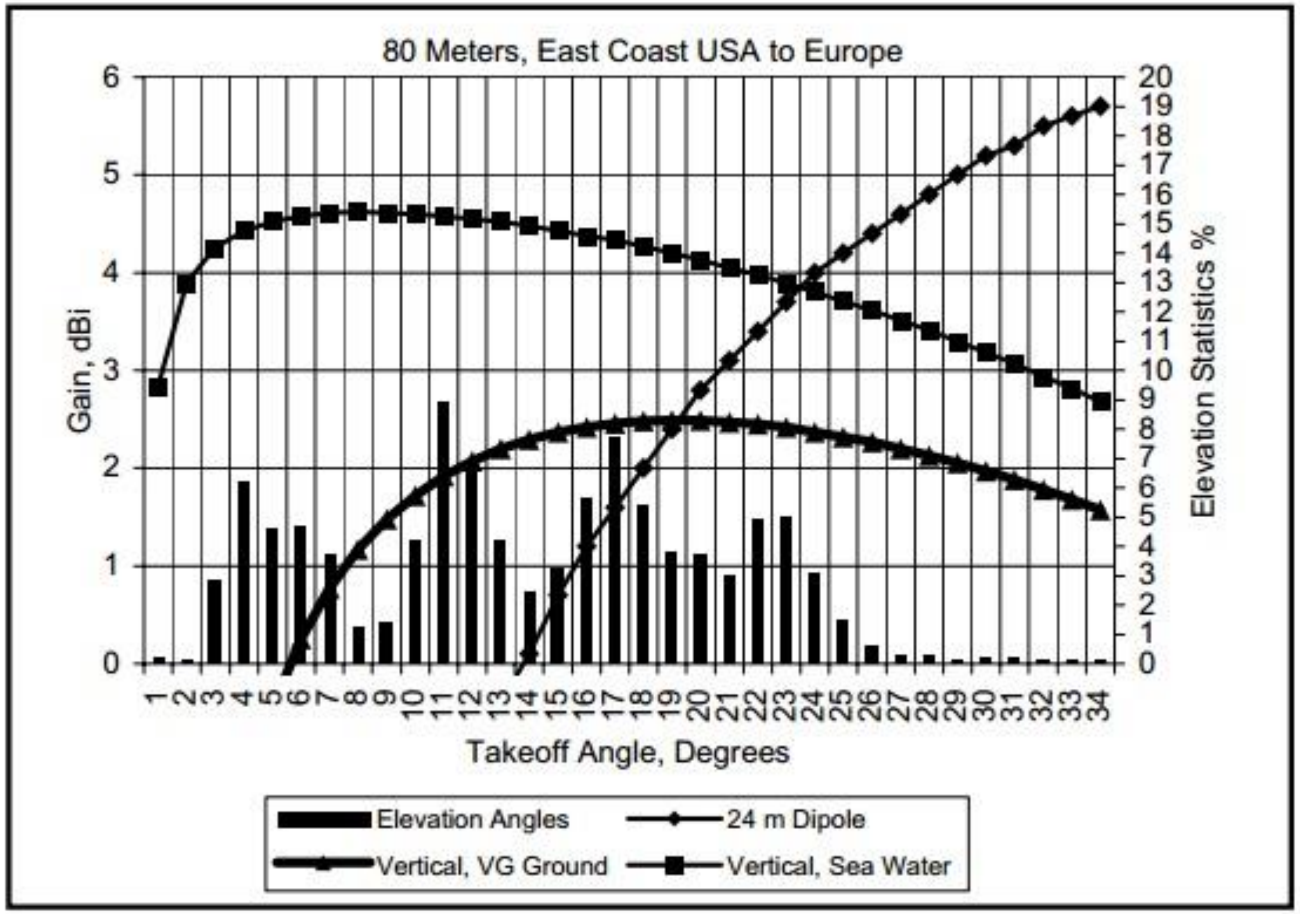


Fig 5-6 — A comparison of horizontal and vertical antennas on 80 meters from the US East Coast to Europe. A quarter-wave vertical over saltwater is virtually unbeatable for angles lower than about 20°.

Antenna efficiency

Radiation Resistance

- Your transmitter generates 100 watts. Where does it go?
- Some, hopefully most, is radiated as a signal
- Radiation resistance (referred to a certain point in an antenna system) is the resistance, which if inserted at that point, would dissipate the same energy as is actually radiated from the antenna

Antenna efficiency

Antenna efficiency

- The antenna efficiency of an antenna is simply the ratio of power radiated from that antenna to the power applied to it.
- Any energy that is not radiated will be converted into heat in the lossy parts of the antenna. Something in the antenna must consume the power.

Antenna efficiency

The efficiency of an antenna is expressed as follows:

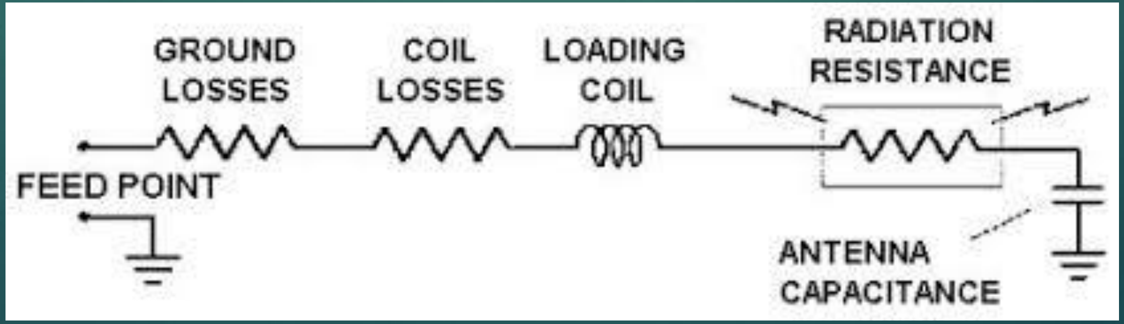
$$\text{Efficiency} = \frac{R_{\text{rad}}}{R_{\text{rad(B)}} + R_{\text{loss}}}$$

Where Rrad (B) is the radiation resistance of the antenna and Rloss is the total equivalent loss resistance of all elements of the antenna (resistance losses, dielectric losses, loading coils, etc).

Antenna efficiency

$$\text{Efficiency} = \frac{R_{rad}}{R_{rad(B)} + R_{loss}}$$

To make a vertical more efficient you must either increase radiation resistance or decrease loss resistance

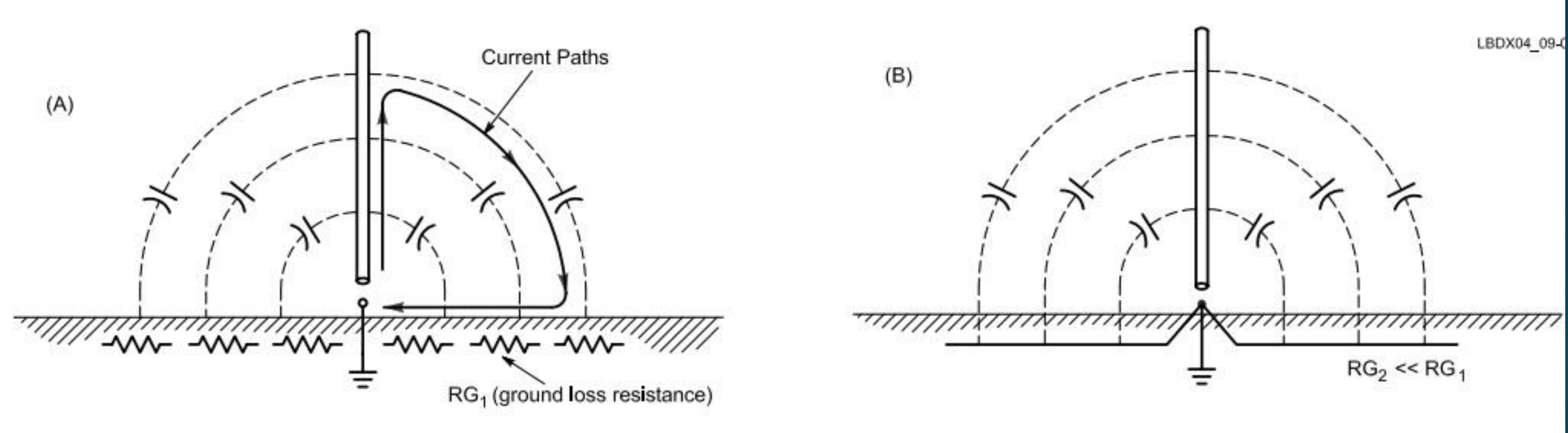


Antenna efficiency

How lower loss resistance?

- Use aluminum or copper instead of steel
- Avoid traps if possible and/or use good coils
- Repair or replace loose or corroded parts
- **REDUCE GROUND LOSSES**

Antenna efficiency



Antenna efficiency

- Radiation occurs most where current is strongest
- Current is strongest at the base of a ¼ wave vertical
- A lot of the radio wave is dissipated into the ground

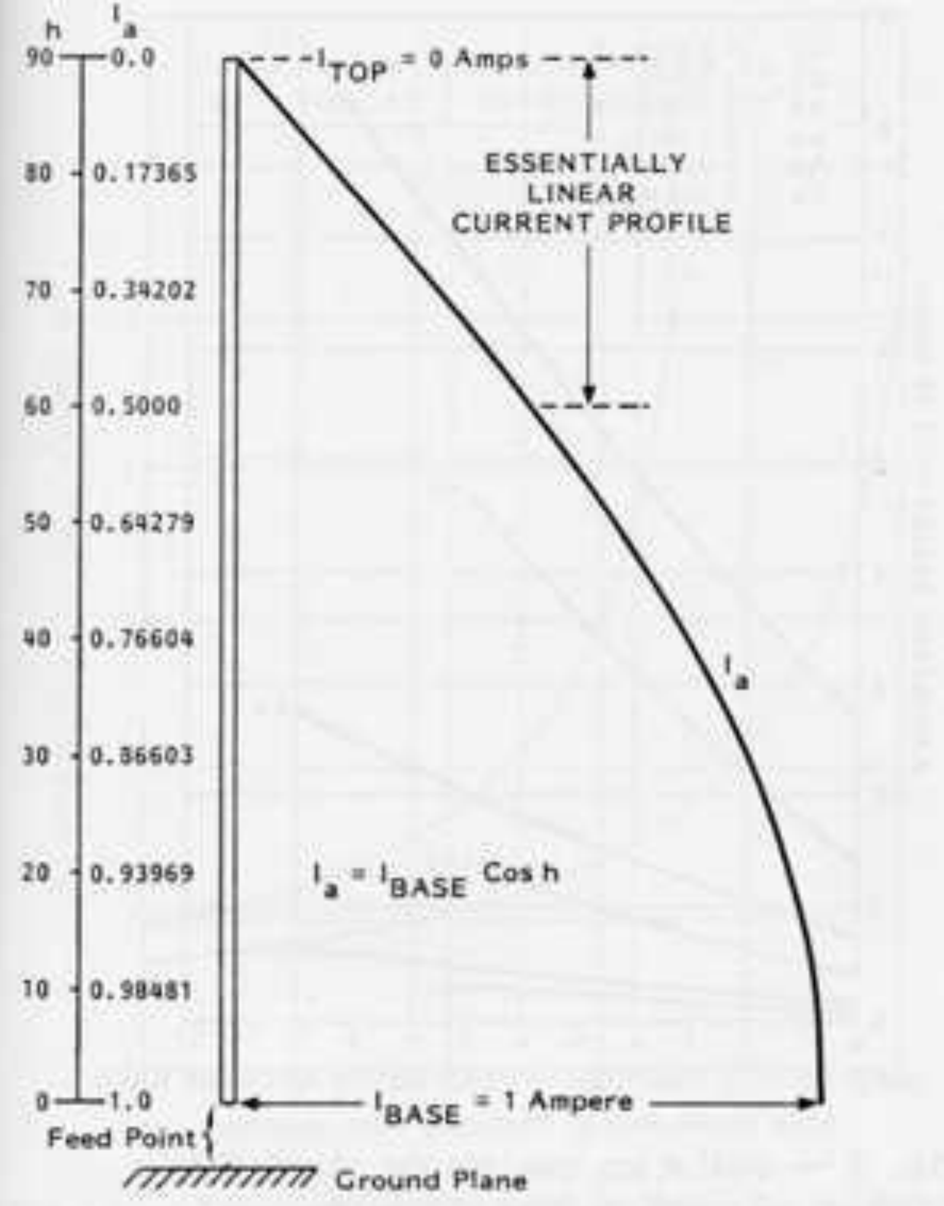


Fig. 1 — Relative current profile in a vertical antenna of height h equal to 90 electrical degrees.

Antenna efficiency

Using radials to minimize ground loss

- Use low resistance radials to return the signal current to the base of the antenna instead of trying to use the high resistance earth
- The more radials there are the less signal heats the earth so the lower the ground loss.

How many radials do you need?

Antenna efficiency

- Conventional wisdom says 120 half wave radials
- Hams who measured these things say 32 are good. 64 is better. >64 gives less and less improvement
- Wire size of radials not important. 18 gage is good
- Insulated or not doesn't matter
- Use copper. Other metals dissolve fairly quickly in acidic earth
- ¼ wave good, but length not critically important. Put out whatever number and length wires you can afford

Antenna efficiency

Table 9-1

Equivalent Resistances of Buried Radial Systems

Radial Length (λ)	*Number of Radials* 2	15	30	60	120
0.15	28.6	15.3	14.8	11.6	11.6
0.20	28.4	15.3	13.4	9.1	9.1
0.25	28.1	15.1	12.2	7.9	6.9
0.30	27.7	14.5	10.7	6.6	5.2
0.35	27.5	13.9	9.8	5.6	2.8
0.40	27.0	13.1	7.2	5.2	0.1

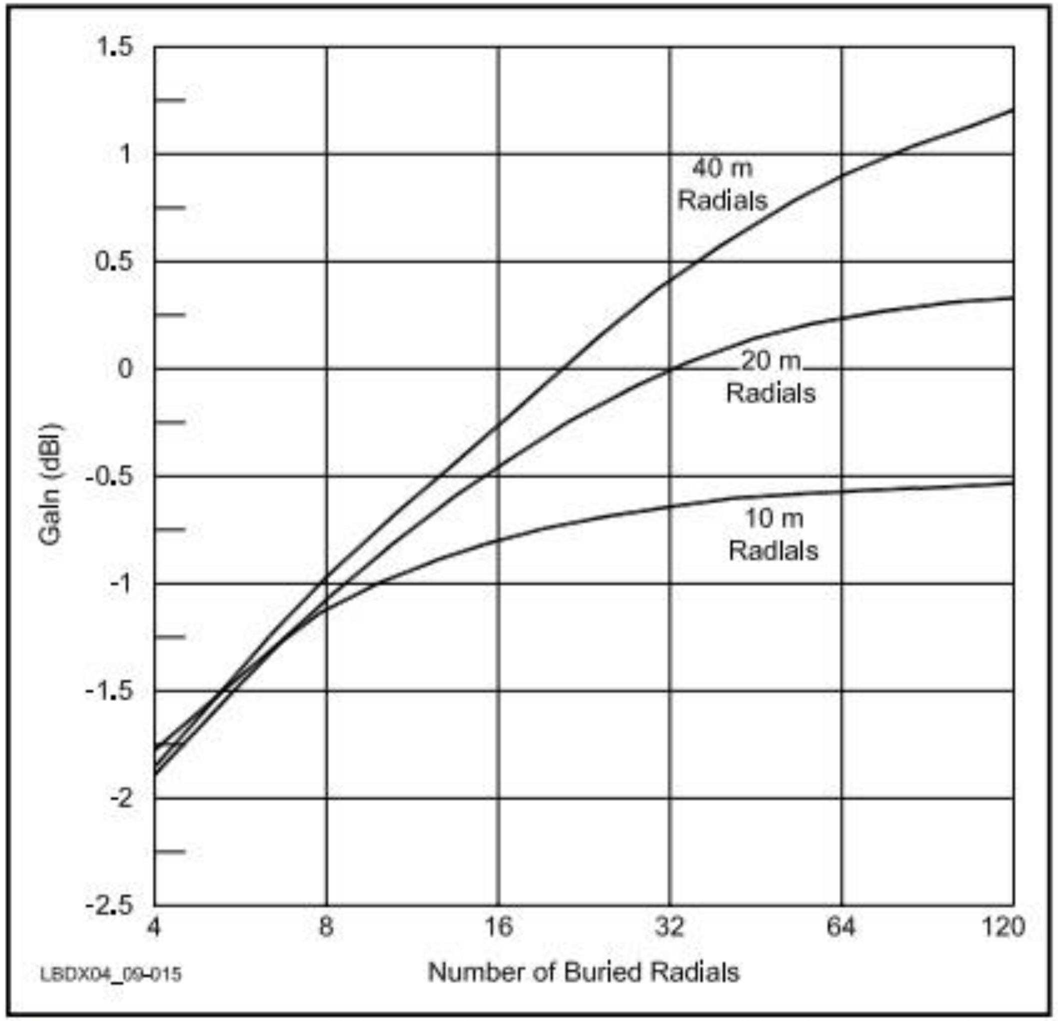


Fig 9-15 — Gain of a λ/4 80-meter vertical over average ground, as a function of radial length and number of radials. Note that for 10-meter long radials there is practically no gain beyond about 52 radials. For quarter wave radials there is little to be gained beyond 104 radials, and the difference between 26 λ/4 radials and 104 λ/4 radials is only 0.5 dB. These are exactly the same number N7CL came up with by experiment (see Section 2.1.3).

Antenna efficiency

2.1.3.2. Some Observations

- For short radials (0.137 λ), there is negligible benefit in having more than 15 radials.
- For radial lengths of 0.274 λ and greater, continuous improvement is seen up to 60 radials. Note that doubling the number and doubling the length of radials from the above case (15 short radials of 0.137 λ) only gains 1 dB greater field strength, with four times the total amount of wire.
- Lengthening radials 50% from 0.274 λ to 0.411 λ and keeping the same number hardly represents an improvement (0.24 dB). Raising the number to 113 radials represents a gain of 0.66 dB over the second case, but uses nearly three times as much wire.

From these almost 70-year-old studies, we can conclude that 60 quarter-wave long radials is a cost-effective optimal solution for amateur purposes.

Antenna efficiency

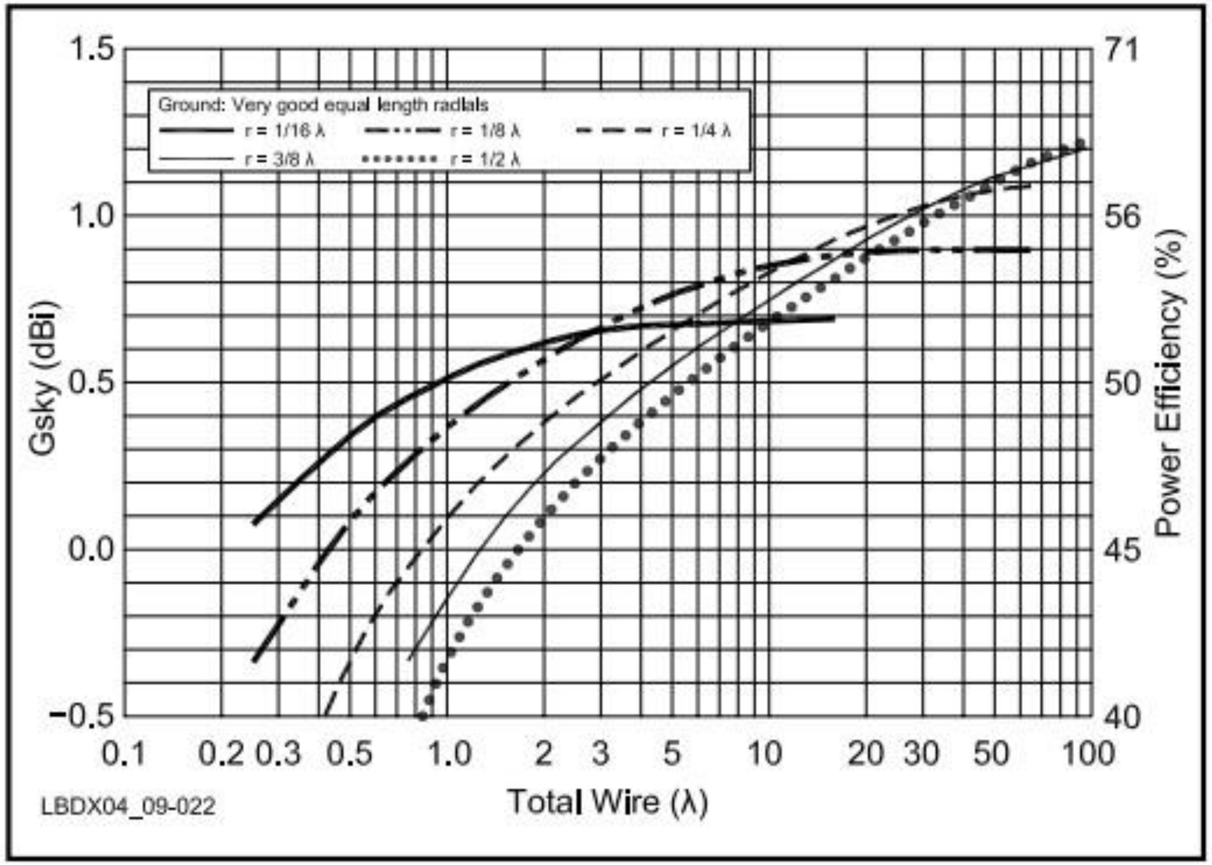


Fig 9-21 — Total sky-gain results over very good ground for various radials systems using standard radials, shaped like the spokes of a wheel. The graph shows clearly that with small amounts of wire, many short radials are the answer. It also tells us that 10 λ of radial wire used to make 80 λ/8 radials is only 0.2 dB down from 30 λ of radial wire used to make 120 λ/4 radials.

Antenna efficiency

Alternative to ground radials:

- Raise the whole antenna, radials and all, up in the air.
- The elevated radials will screen the earth so the antenna doesn't "see" it as well
- Length of radials is important – now critical part of the antenna and acts just like half of a dipole
- Height of antenna also plays a role

Antenna efficiency

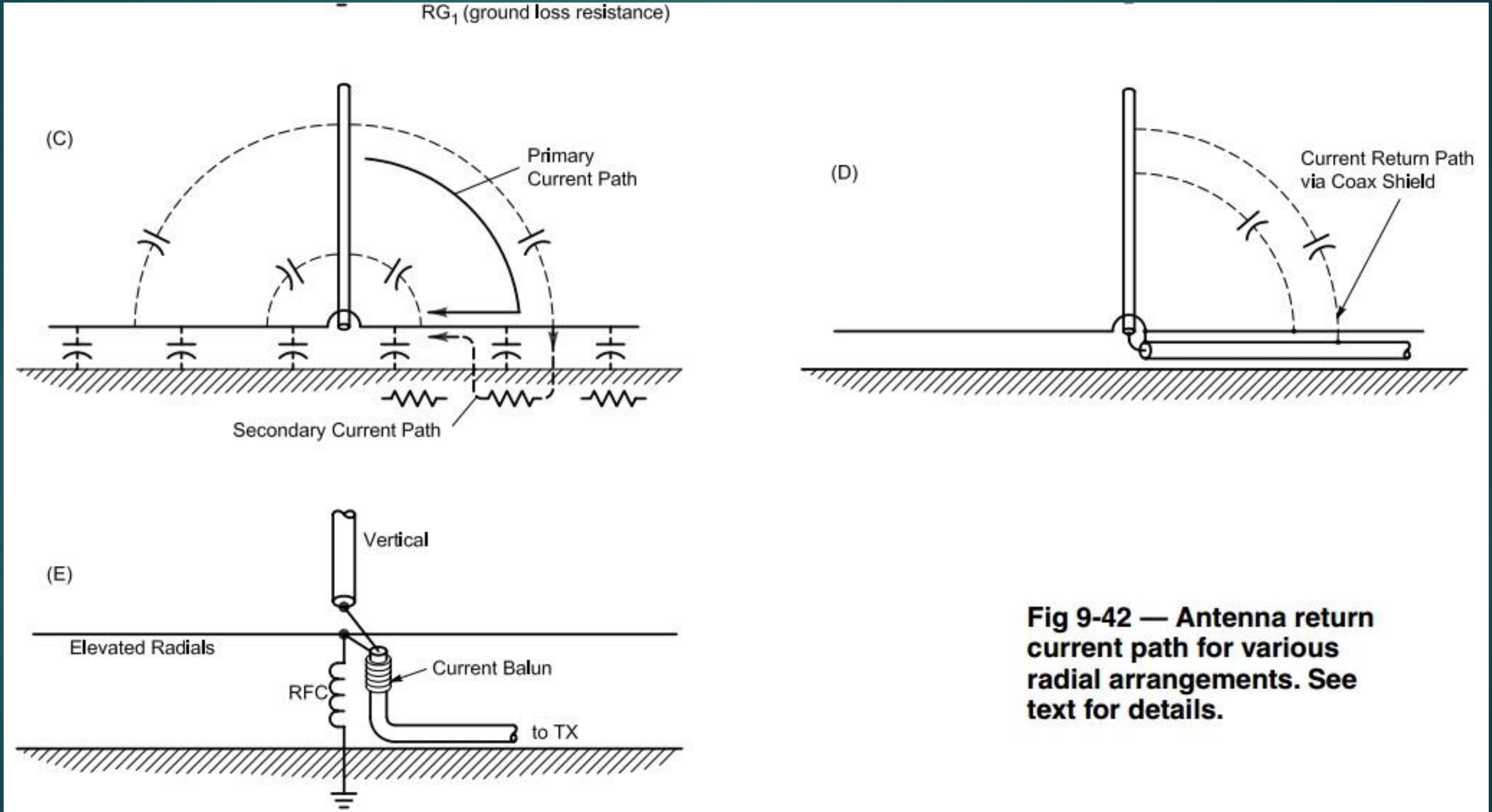


Fig 9-42 — Antenna return current path for various radial arrangements. See text for details.

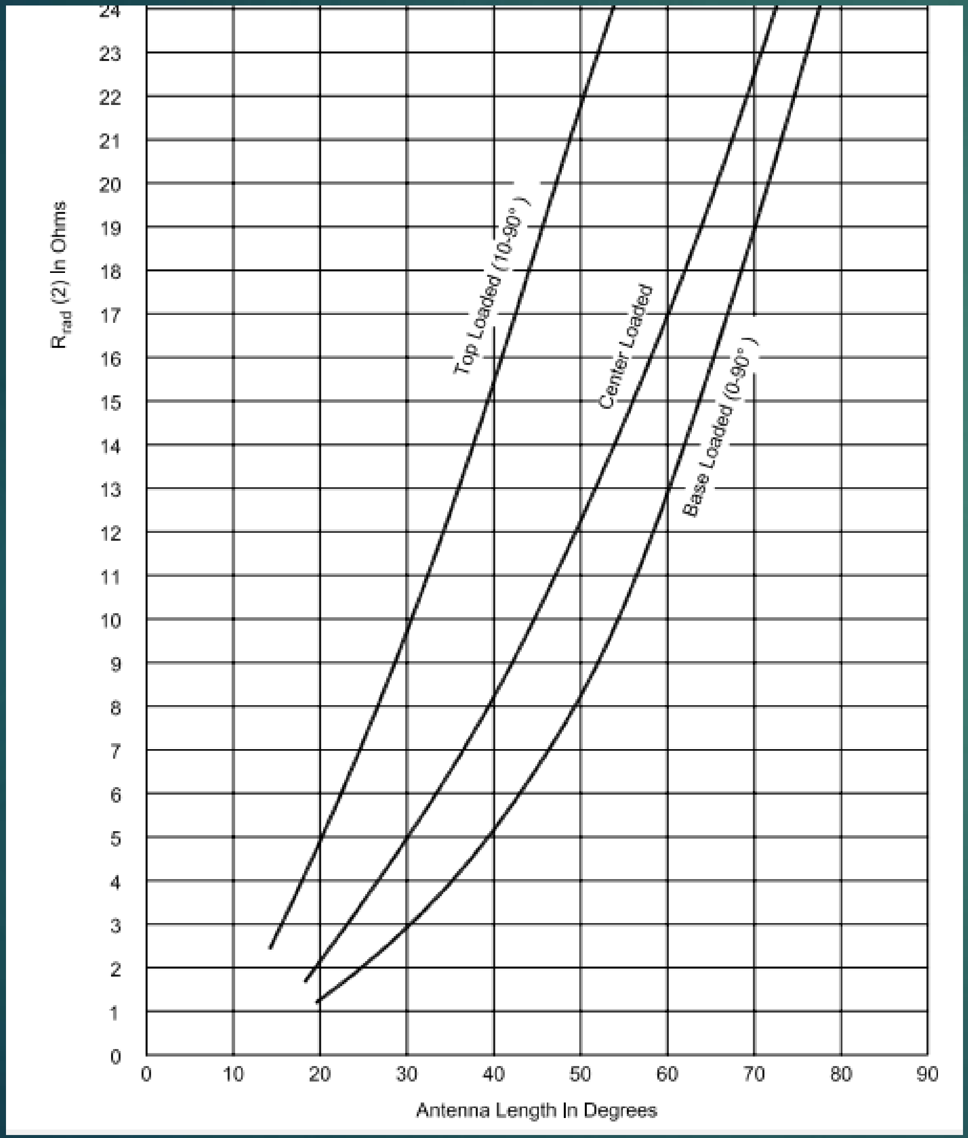
Al Christman, K3LC, used *NEC-4* to study the influence of the number of elevated radials and their height on antenna gain and antenna wave angle (Ref 7825) and came to the conclusion that if the height of the radials is at least 0.0375 λ (3 meters on 80, 6 meters on 160) there is very little gain difference between using four or up to 36 radials. He also concluded that the gain of antennas with an elevated radial system compared in gain to the same antenna with about 16 buried radials. Incidentally, the modeling also showed that for buried λ/4 radials the difference in gain between 16 radials and 120 radials is *only* about 0.74 dB (although almost 1 dB on 160 when signals are riding in, on or under the noise can be a lot). When raising the elevated radials to a height of 0.125 λ (20 meters on 160), the gain actually approached the gain of a vertical with 120 buried radials. The publication of

Antenna efficiency

How raise radiation resistance?

- Large contributor within our control is height of vertical element
- The taller a vertical is the higher the radiation resistance
- Taller also has the desired trait of moving the current higher and away from the ground which reduces ground losses

Antenna efficiency



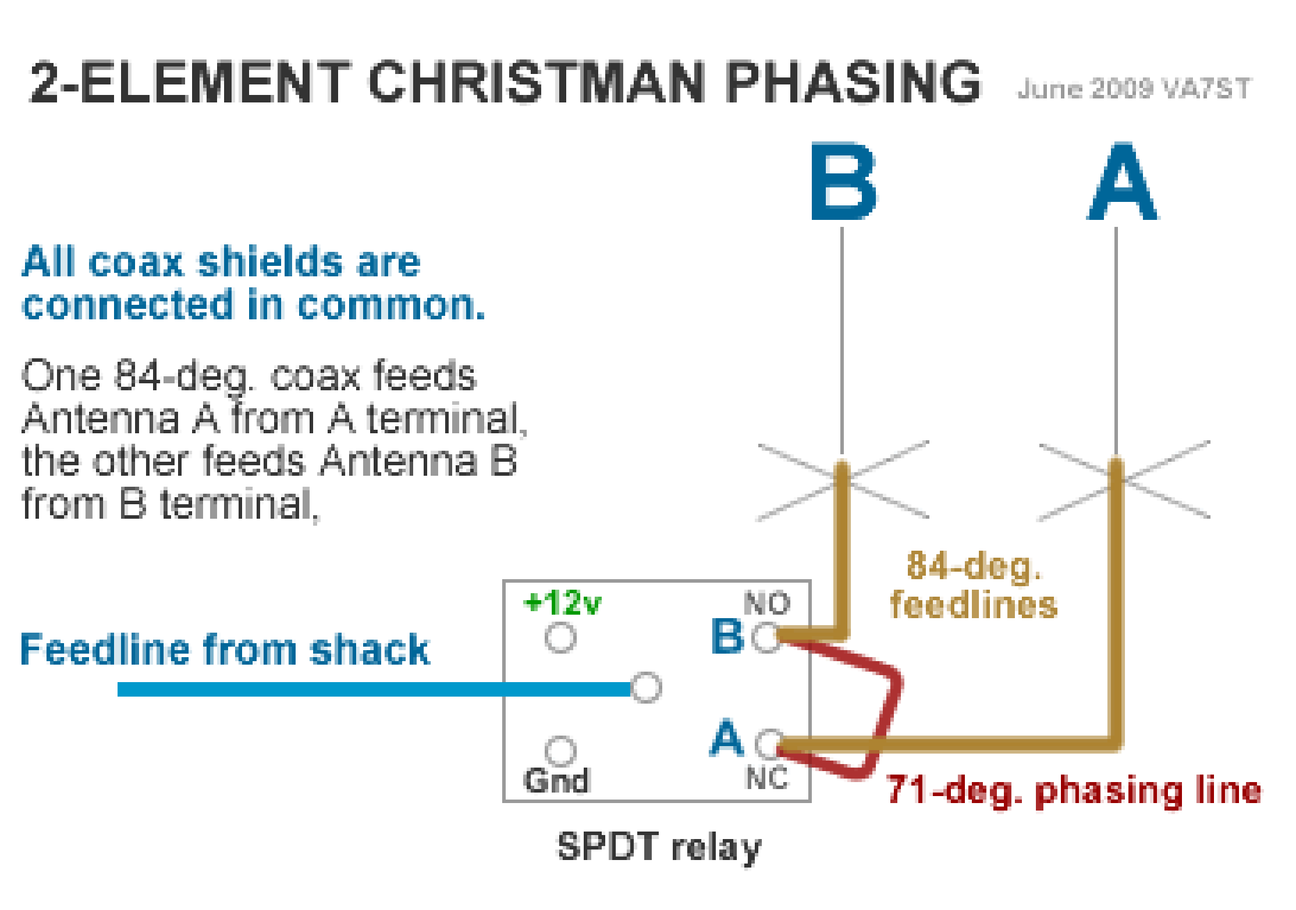
- Maximum R_{rad} is ≈ 36Ω
- Top loading has highest R_{rad}
- Difference in R_{rad} between loading types only a couple ohms as approach ¼ wavelength high

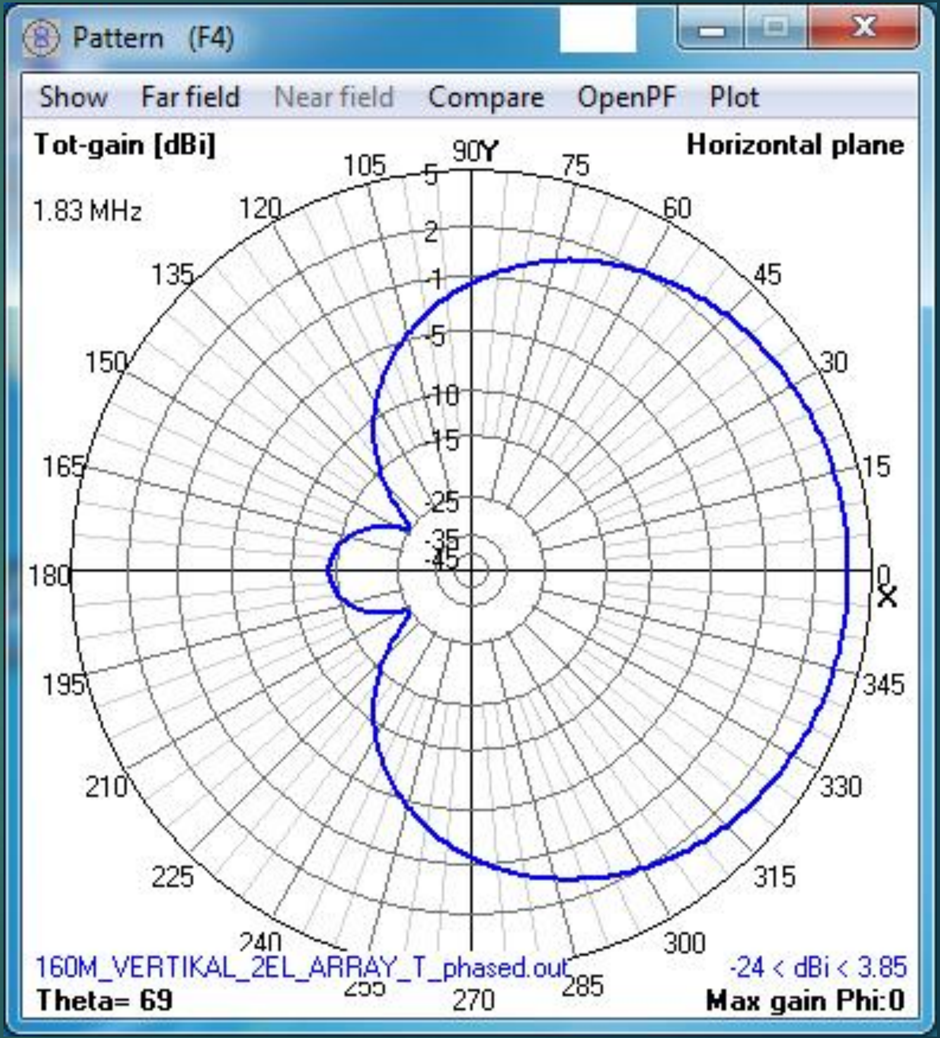
Phasing Verticals

A yagi beam antenna has a driven element and other elements that direct or reflect the signal from it to give directionality and gain.

Verticals can work the same way. Space two or more at the right distance and phase them so their signals interact and give directionality. Each needs a good ground system though.

Phasing Verticals



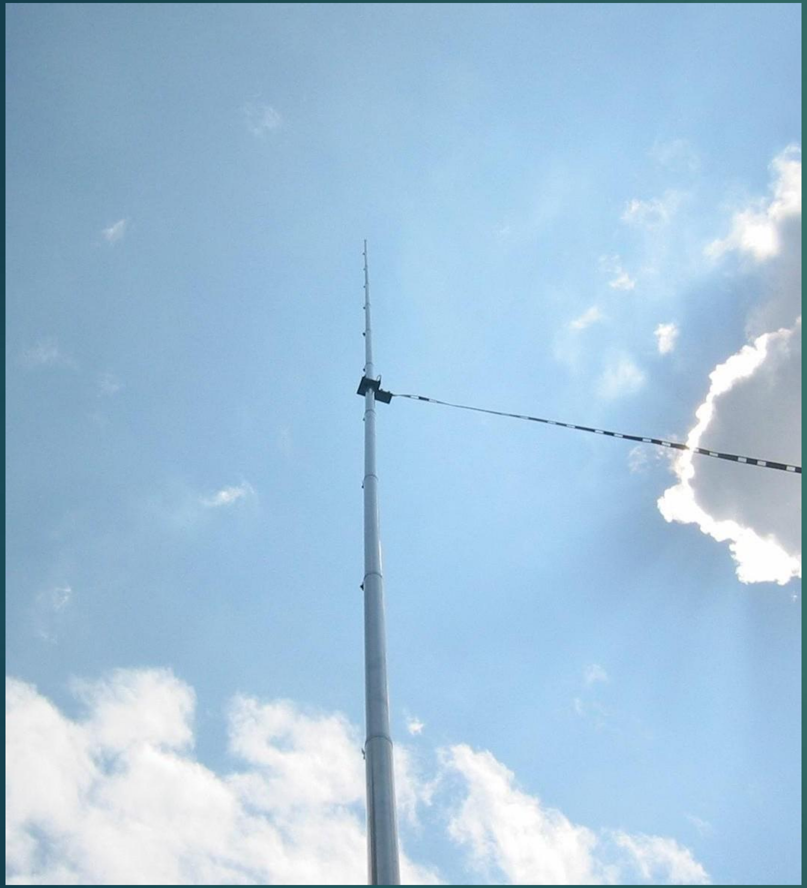


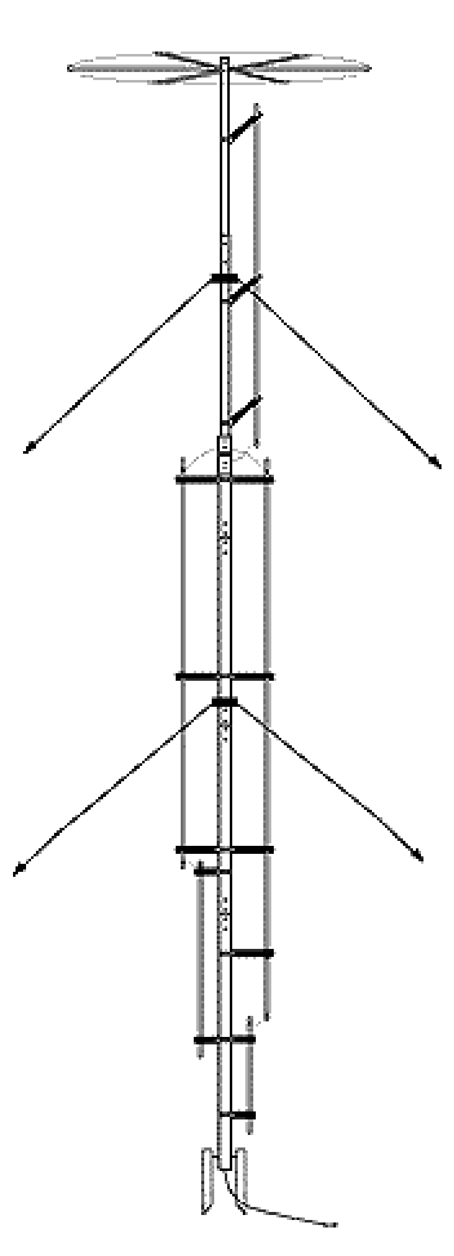
Vertical Dipoles

Up to now we have talked about a “monopole” vertical

Vertical dipoles are far more independent of ground and have stronger signal strengths

Vertical Dipoles





Vertical Dipoles

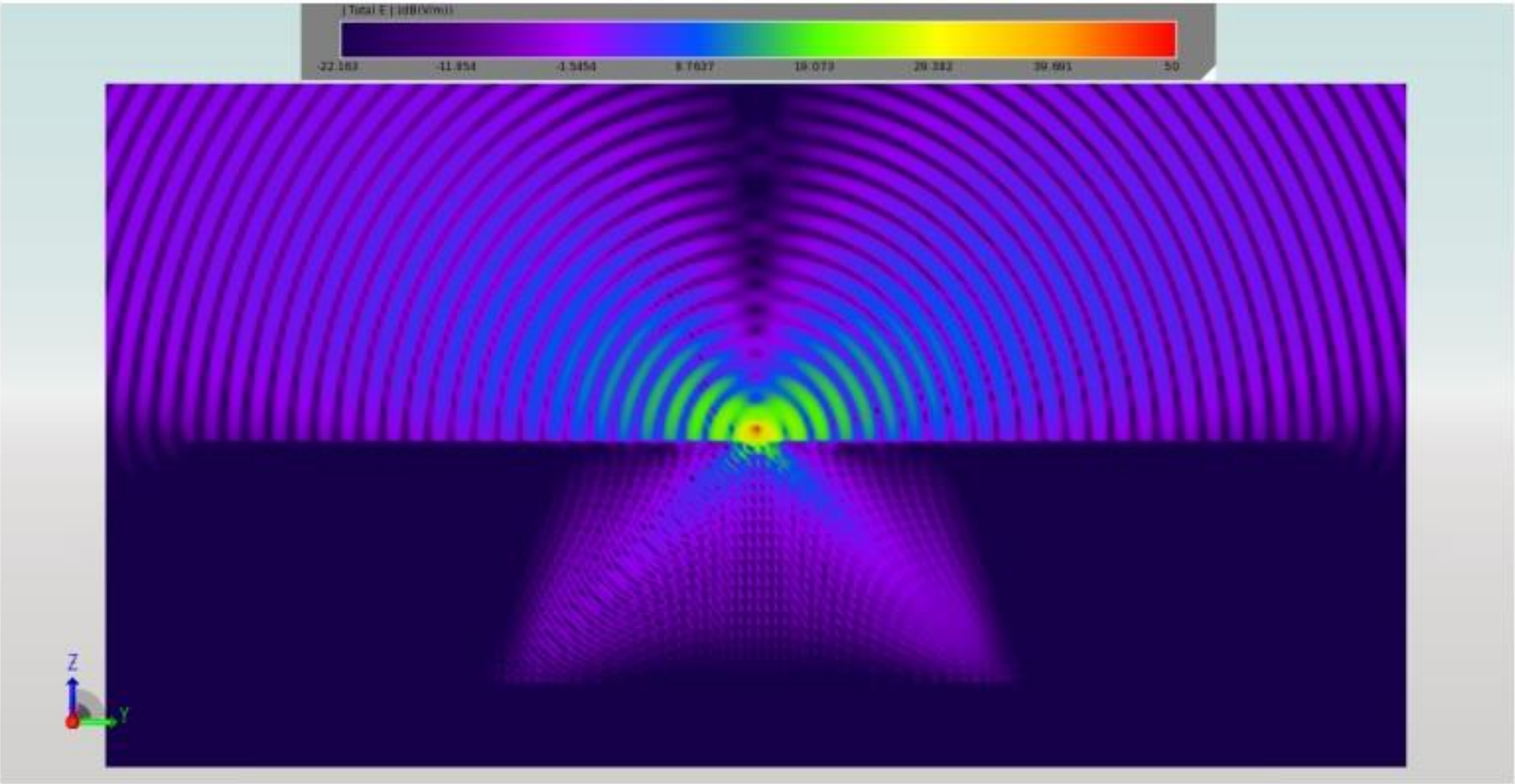


Figure 7 — Elevation plot of a base-fed ¼ λ monopole, on 24 λ diameter real ground (0.005 S/m, ε=14). Soil thickness is 5 λ. The antenna ground system is a solid ½ λ in diameter disc of a perfect conductor, to simulate a perfect antenna ground or an infinite number of ¼ λ radials.

Vertical Dipoles

QEX Mar/Apr 2016

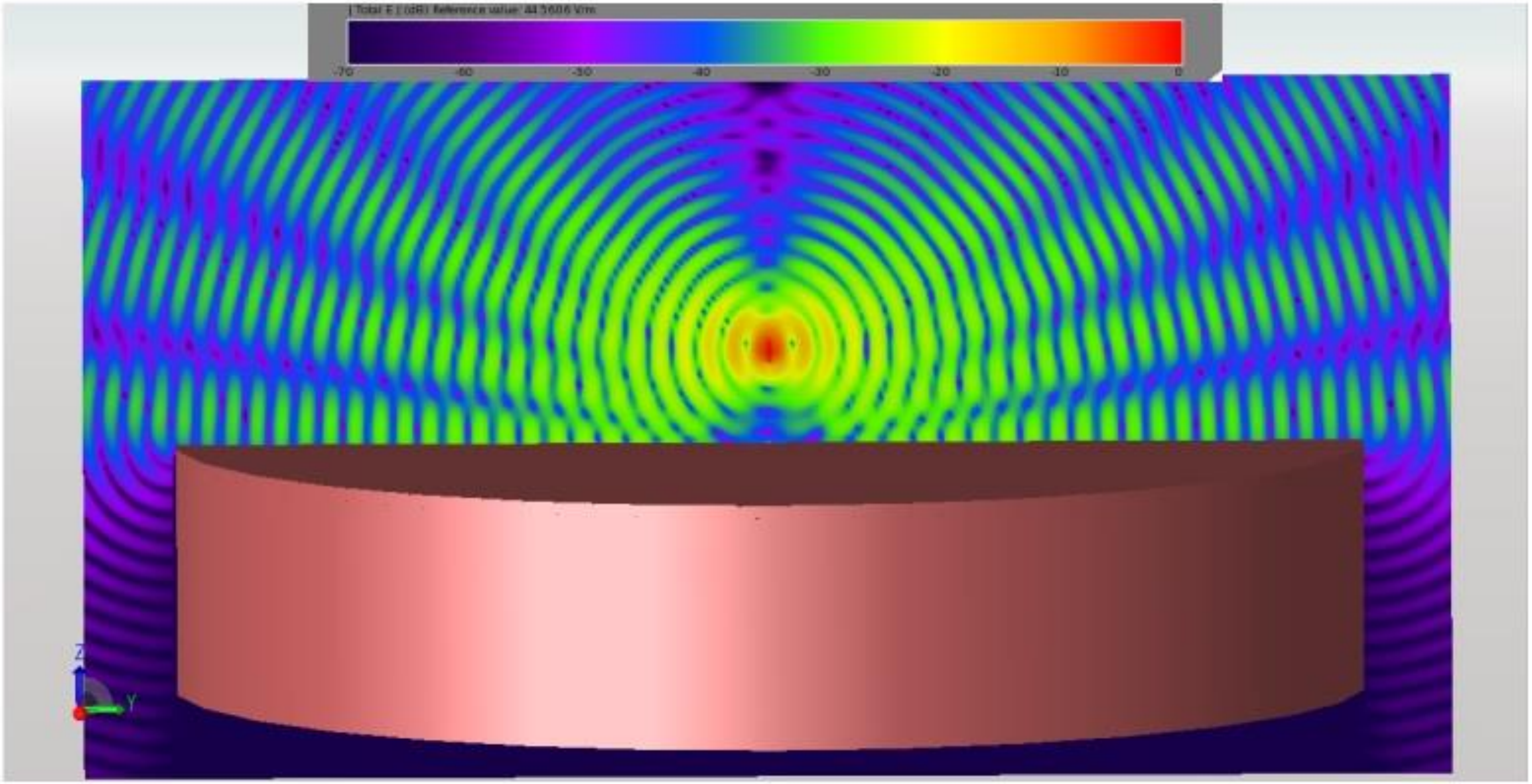


Figure 8 — The electric fields of an elevated half-wave vertical dipole, with feed point 2 wavelengths above a large slab of average ground.

Pseudo-Brewster Angle

Type of ground determines the lowest angle you can get regardless of how tall it is or how many radials it has due to Near/Far field effects

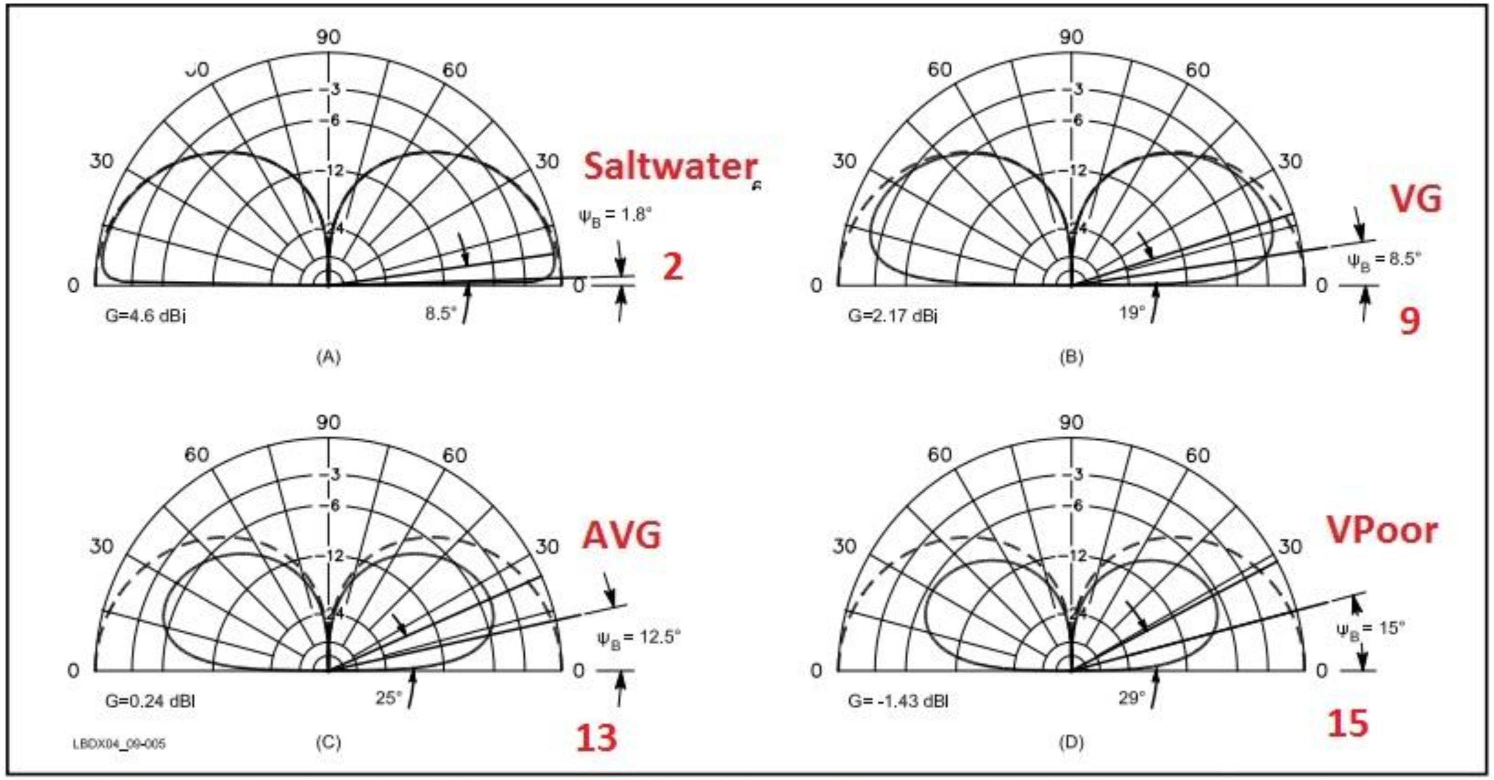


Fig 9-5 — Vertical-plane radiation patterns of 80-meter λ/4 verticals over four standard types of ground. At A, over saltwater. At B, over very good ground. At C, over average ground. At D, over very poor ground. In each case using 64 radials, each 20 meters long. The perfect ground pattern is shown in each pattern as a reference (broken line, with a gain of 5.0 dBi). This reference pattern also allows us to calculate the pseudo-Brewster angle. Modeling was

Radialess Verticals

- Think of these as asymmetrical vertical dipoles
- They have lower efficiency then ground mounted verticals
- Have to be elevated to minimize ground losses

Radialess Verticals

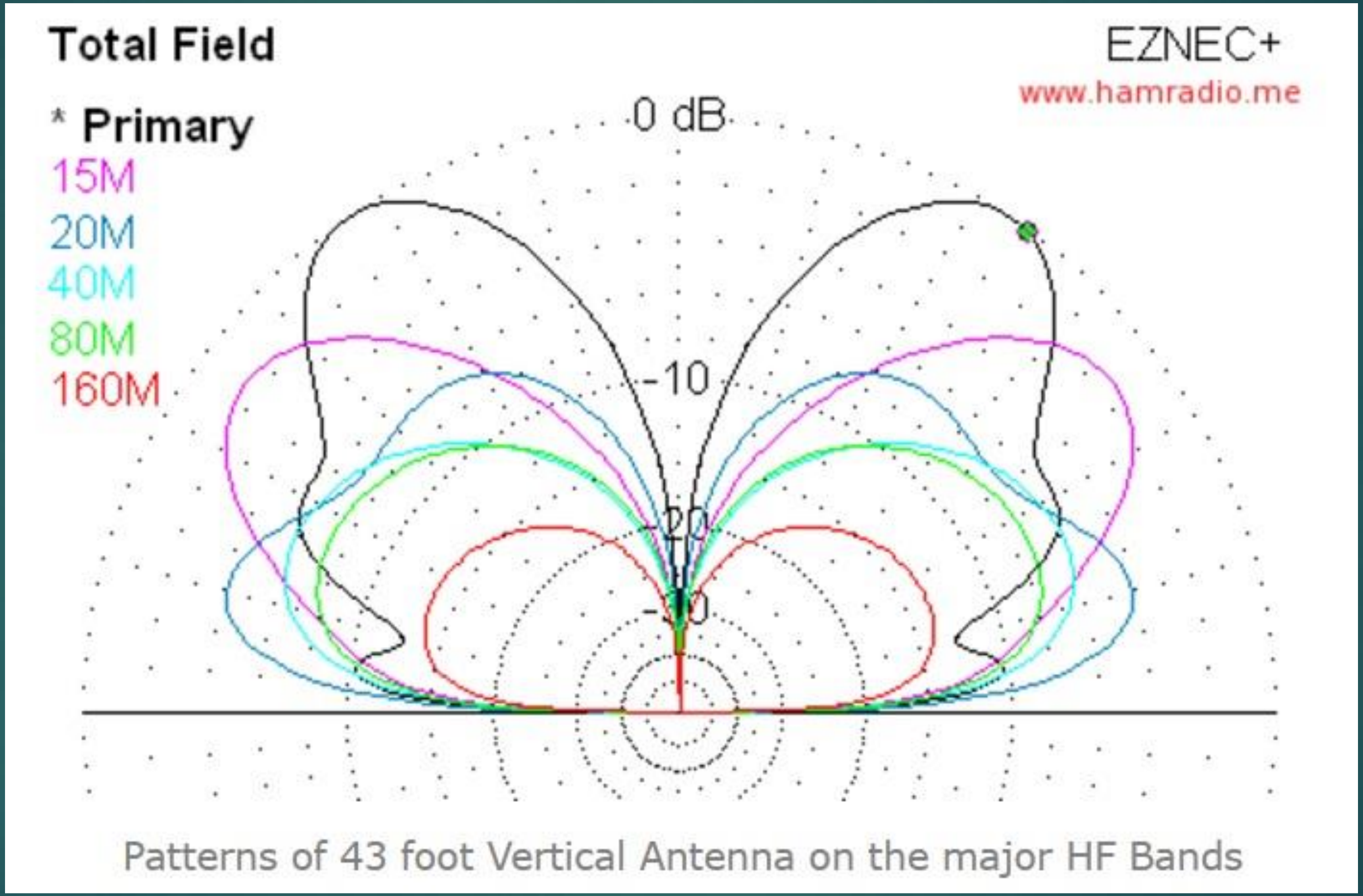
Matching Network

- Make antenna less efficient
- Can’t handle much power with 100% duty cycle loads (like FM or RTTY/Digital modes)

The 43ft Vertical

- Latest “flavor of the year” – but it is still a vertical antenna and what we just talked about applies
- Earliest versions used voltage baluns instead of current or ununs. The antenna “looked” great to operator, but that significantly reduced radiated signal strength
- Needs a matching network or tuner at base
- Actually not very good low band or low angle performance compared to a single band monopole or vertical dipole

The 43ft Vertical



http://www.hamradio.me/antennas/answer-to-everything-43-feet-antenna.html

The 43ft Vertical

Quote by KE2IV

QST is filled with ads from various manufacturers and suppliers offering "all-band" 43-foot verticals. Legitimately, all these ads make it clear that this (and any vertical) will require a good ground plane system of radials for effectiveness.

But why 43-feet? What is the "formula" to explain why this length will effectively radiate on "all bands" (i.e. 160m - 10m) with a decent ground plane system?KE2IV

Reply from W8JI (excerpt)

There is no reason, George. Somehow that number just popped up out of the blue, and then everyone started copying it.

The initial 43 foot vertical had a balun that, through an error in design, drove the coax shield with RF. This error, in some cases, made the SWR very low from 160-10 meters. Hence the "160-10" meter stuff started.

After an eHam thread, the company initially marketing the 43 foot vertical revised the voltage balun to an un-un, and then the SWR was not so good at all but the signal was better

http://www.arrl.org/forum/topics/view/235

Key Concepts

- Verticals do help with DX on the low bands
- For our ground conditions in South Carolina a dipole usually works better
- At least 30 quarter wave radials if on ground
- Elevated radials work very well
- Taller vertical length is better
- Vertical dipoles good – but not practical for low bands

In passing

Don't angle your VHF/UHF antennas