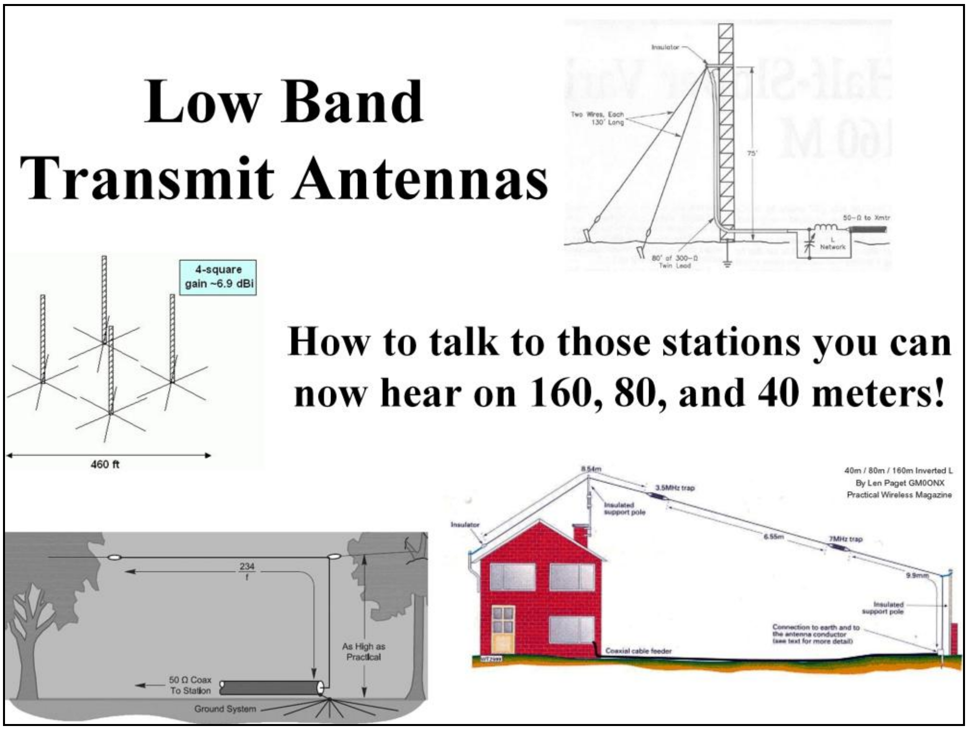
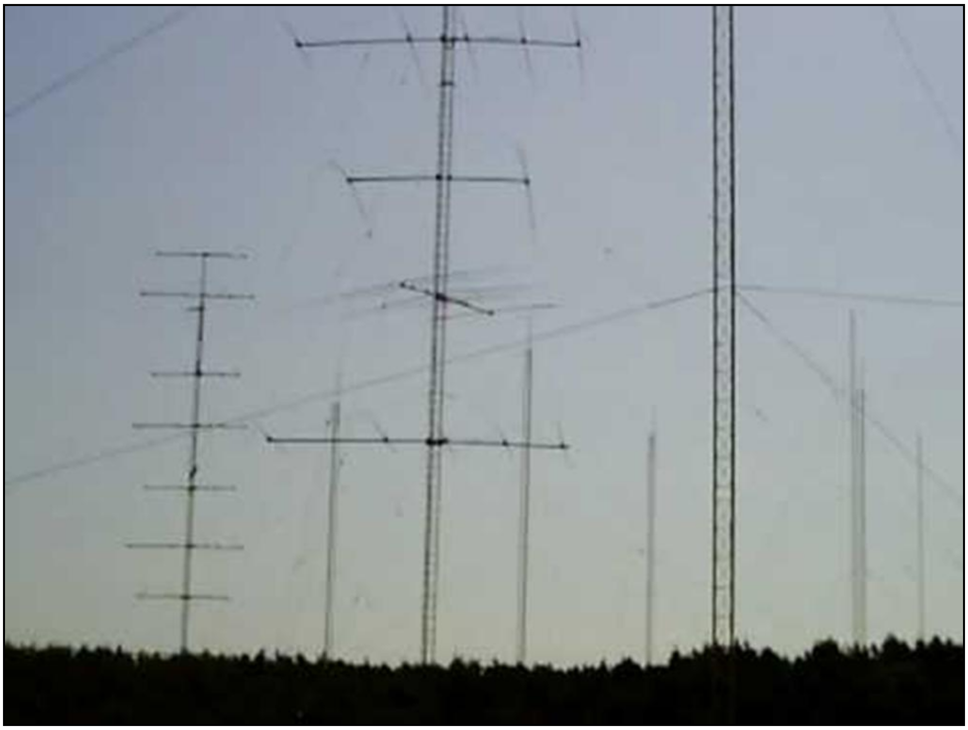


Last year I described several Low Band RX antennas that would enable you to hear DX stations on 160, 80 and 40M. This will show you how to build transmit antennas that will help you break the pileups!

Aim

- Explore Lowband transmit antenna options for the average Ham city lot.
- Won't be talking about the sort of massive arrays that Jeff VY2ZM has!
- It IS possible to put up relatively effective transmit antennas on a normal city lot however!

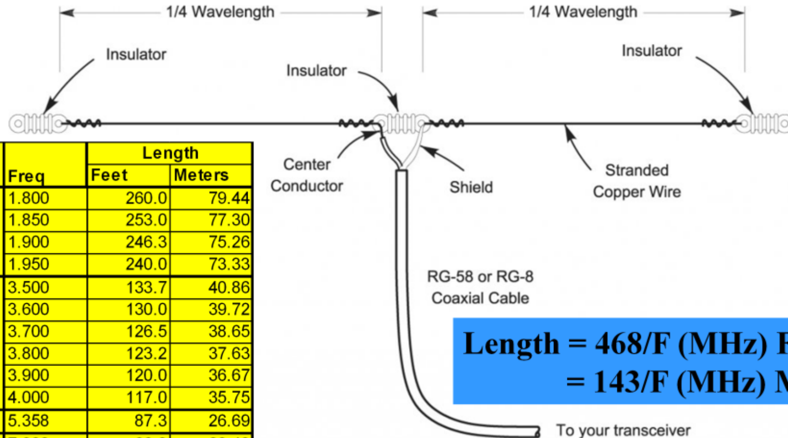


The antenna farm of Jeff Briggs, VY2ZM. We won't be discussing these types of antennas today!

Today’s Topics

- Halfwave Dipoles
- Quarter Wave Verticals
- Vertical Loop Antennas
- Phased Arrays
- Summary

Halfwave Dipole Antenna



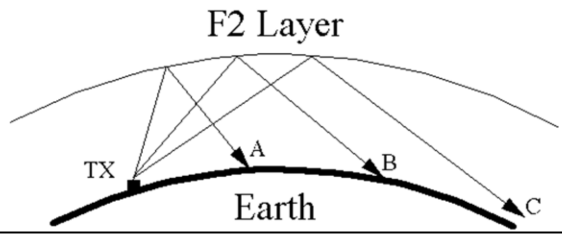
Band	Freq	Length	
		Feet	Meters
160M	1.800	260.0	79.44
	1.850	253.0	77.30
	1.900	246.3	75.26
	1.950	240.0	73.33
80M	3.500	133.7	40.86
	3.600	130.0	39.72
	3.700	126.5	38.65
	3.800	123.2	37.63
	3.900	120.0	36.67
	4.000	117.0	35.75
60M	5.358	87.3	26.69
40M	7.000	66.9	20.43
	7.100	65.9	20.14
	7.200	65.0	19.86

Length = 468/F (MHz) Feet
= 143/F (MHz) Meters

Note: Cut a little long and trim for best SWR

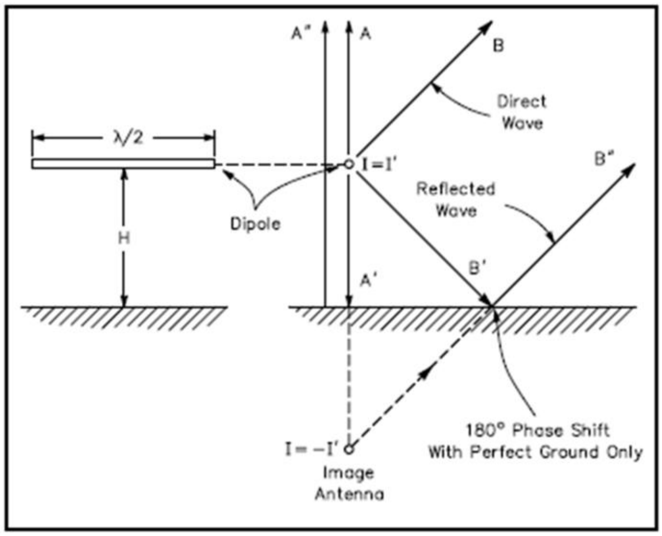
Halfwave Dipole Antenna

- Reliable, efficient and easy-to-build antenna.
- BUT, angle of radiation depends on height above ground.
- In general, to work DX we want a low angle of radiation.



In general, the lower the angle of radiation, the further a signal will reach after each trip through the ionosphere. As well, fewer reflections off the Earth will be required to reach a specified target. As each reflection attenuates the signal, the fewer reflections the stronger your signal at the DX station’s location.

Reflections off the Ground



The ground acts as a mirror for radio waves. The better the ground (I.e. the more conductive it is) the more reflective it is. The direct and reflected signals will combine, giving areas radiating outwards from the antenna where signals are in phase and so reinforce each other, and areas where the signals are out of phase and so cancel each other. The phase difference depends on the difference in path length (length is directly proportional to time as the velocity is the same), and on the amount of phase shift caused by the reflection. A perfect ground causes a 180 degree shift.

Vertical Pattern

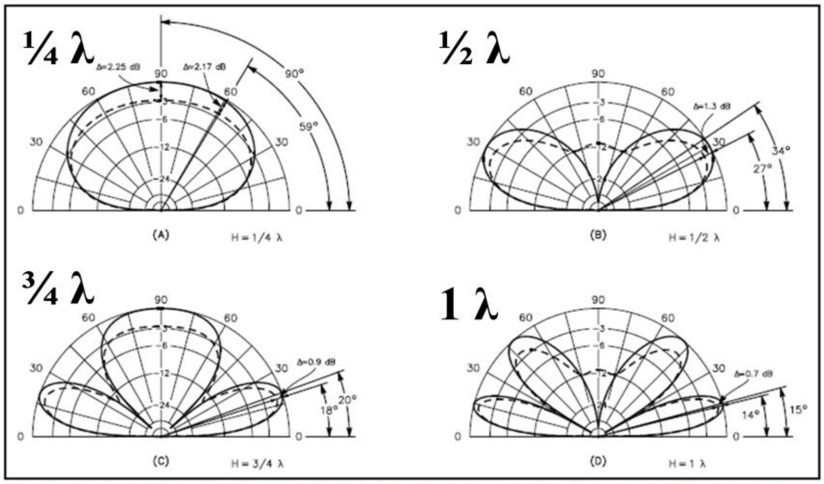
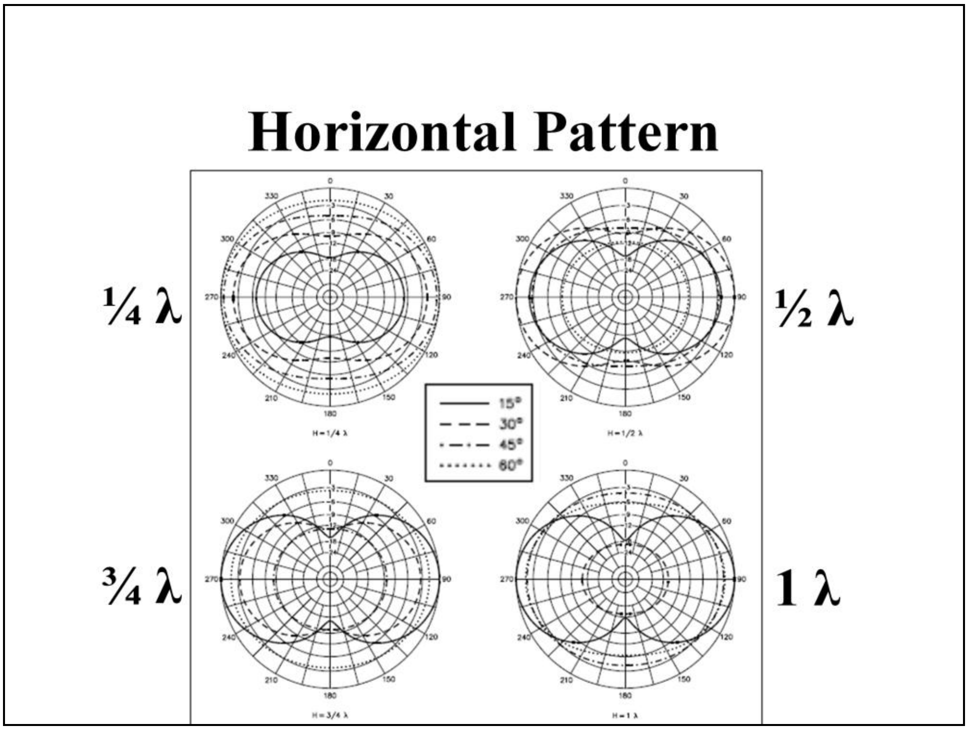


Fig 8-4 — Vertical radiation patterns over two types of earth: saltwater (solid line in each set of plots) and very poor ground (broken line in each sets of plots). The wave angles as well as the gain difference between saltwater and poor ground are given for four antenna heights.

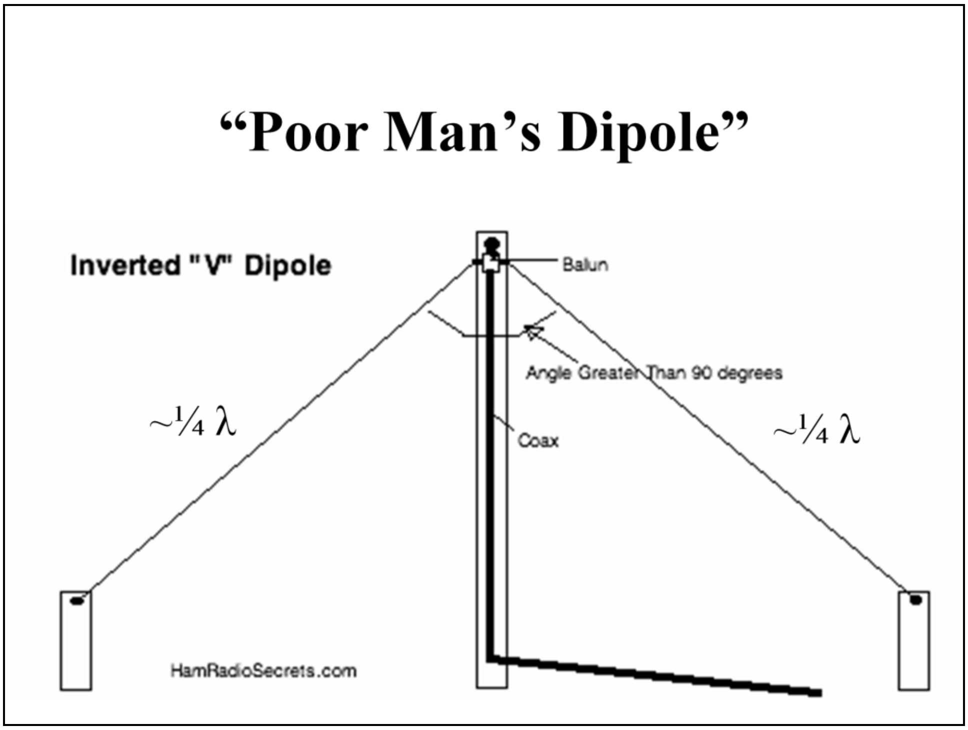
At low height, the direct and reflected waves will cancel each other at low angles, and reinforce each other at high angles. As the height starts to increase, lower angle signals start to reinforce each other, and higher angles cancel. Thus, the radiation pattern depends primarily on the height above ground, and to a lesser extent on the quality of the ground.



Still radiation off the ends of dipoles, especially those closer to the ground.

Try to orient your dipole broadside to the directions you want to work, or put up two at right angles. If the antennas are below ¼ wavelength, then it isn't worth the bother however.

To improve the efficiency of a low dipole (less than one quarter wavelength) put wires directly under the antenna running in same direction. Remember that most of the radiation will go straight up however – an NVIS antenna (Near Vertical Incidence Skywave).



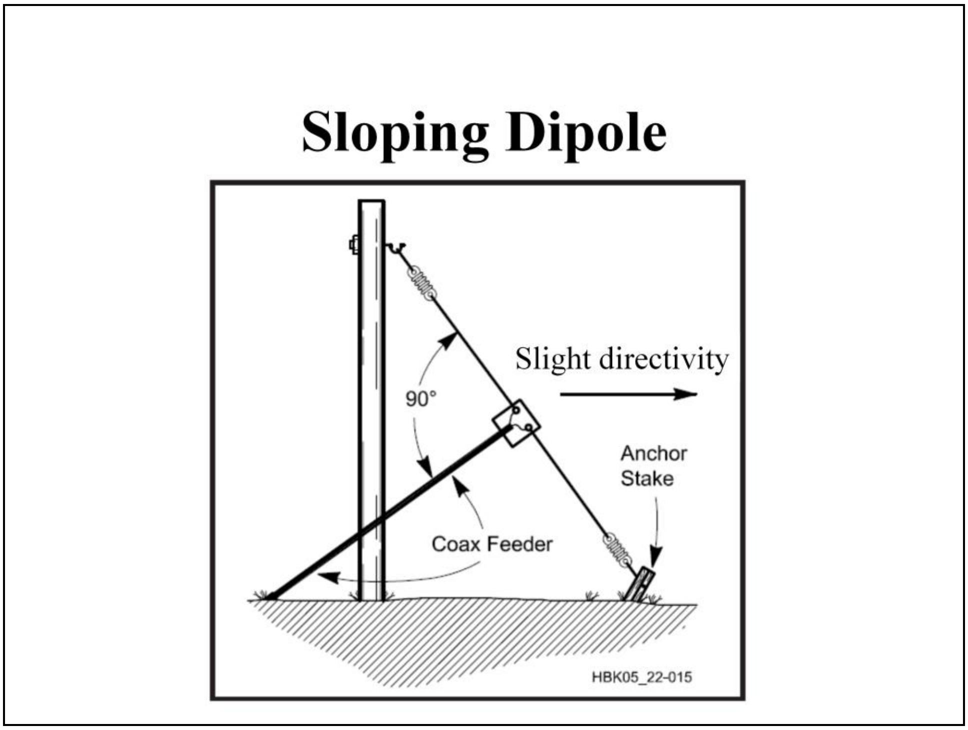
-"Poor Man's Dipole"

-May provide slightly better match to 50 Ohm coax than a dipole would.

-In general, Inverted V has a little less gain and slightly higher angle of radiation than a dipole.

-Antenna is electrically longer as ends are closer to Earth (lower resonant frequency), but closing the legs increases resonant frequency. Cut long, adjust spacing of legs, and then adjust leg lengths if necessary.

-Ensure ends are high enough that people cannot touch them – high voltages!



Try to keep the dipole as straight as possible. Bring the feedline away at right angles to the antenna itself.

Slight directivity.

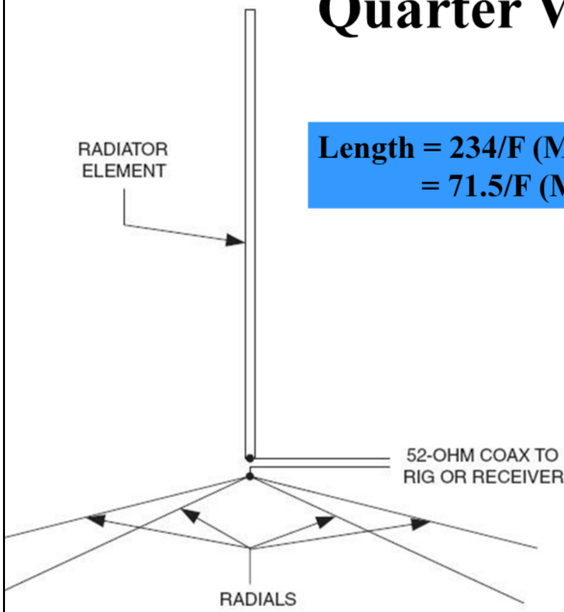
Dipoles - Summary

- Efficient and easy to build.
- On typical 50-foot tower a dipole/inverted V will work best on 40M, is satisfactory on 80M, and is a cloud warmer on 160M.
- If it is all you can put up, then get on the air and have fun – sometimes high angles work best!
- For a low angle of radiation, try a vertical!

Quarter Wave Verticals

- Can be wire, tubular, or tower.
- Some describe them as limited space antennas, BUT you must consider the radial field.
- Offers a low angle of radiation if you can't put a dipole at ½ λ (125 feet on 80M!).

Quarter Wave Verticals



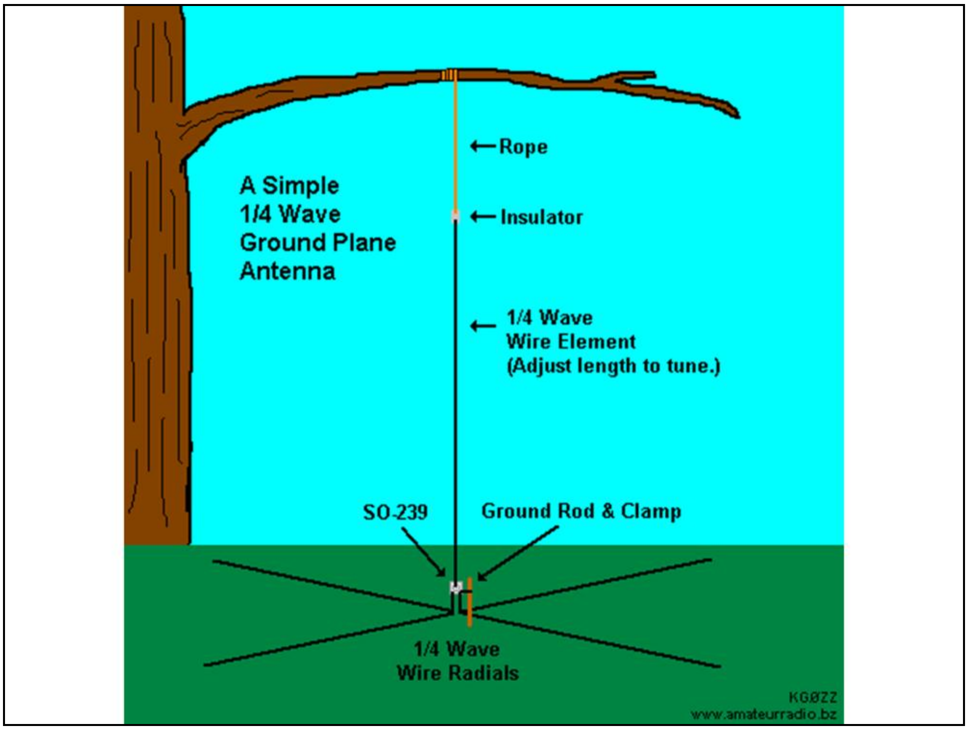
Length = 234/F (MHz) Feet
= 71.5/F (MHz) Meters

Band	Freq	Height	
		Feet	Meters
160M	1.800	130.0	39.72
	1.850	126.5	38.65
	1.900	123.2	37.60
	1.950	120.0	36.67
80M	3.500	66.9	20.43
	3.600	65.0	19.86
	3.700	63.2	19.32
	3.800	61.6	18.82
	3.900	60.0	18.33
	4.000	58.5	17.88
60M	5.358	43.7	13.34
40M	7.000	33.4	10.21
	7.100	33.0	10.07
	7.200	32.5	9.93

Heights are approximate. Actual height depends on diameter of radiator.

First is homebrew 40M vertical by Aaron VO1FOX. It consists of 8 x 4-foot long tent poles.

Second is 80M antenna of W8JI, made of Rohn 65 tower sections.



Can make a vertical from wire suspended from a tree. This is easily done for 40M, and may be possible for an 80M antenna.

40M vertical can be made from aluminum tubing, but it can be difficult to find tubing sturdy enough for an 80M vertical. Try making it with several sections of tower, with tubing on top, such as with this Hygain Hy-Tower.

Radials

- Radials collect return current and provide something for the radiator to "push" against.
- Commercial antennas use 120 x ½ λ radials.
- Fortunately, Hams can make do with fewer!
- Number, length, buried, on or above ground?
- A complicated situation with lots of misconceptions!

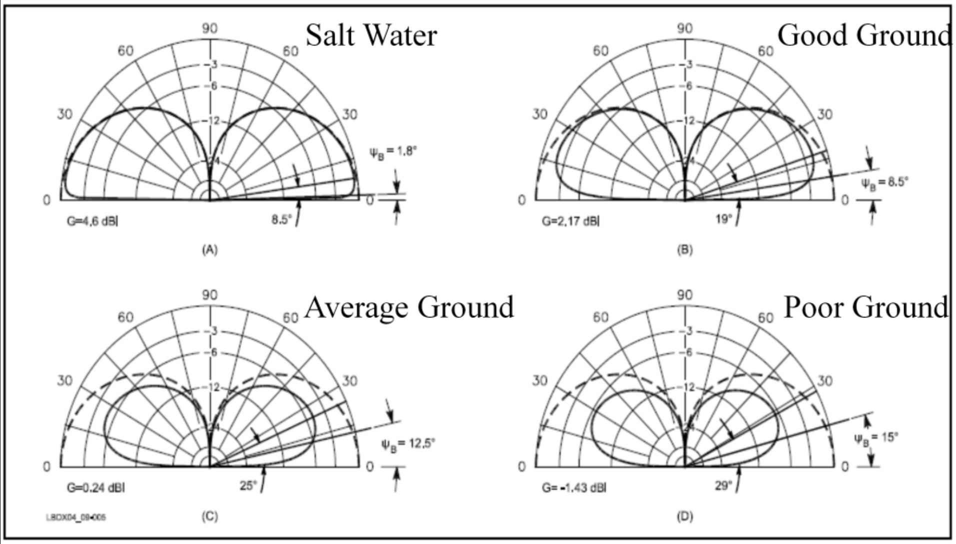
Angle of Radiation

- The angle of radiation of a vertical antenna depends primarily on the ground conditions in the far field (out to ~10 λ and further), NOT the radial field.
- The radial field determines the transmit efficiency of the antenna.
- A vertical with poor radial system over very good ground can have a low angle of radiation but a weak transmitted signal!

Over very poor ground (desert or rocky areas) it may be better to go with a horizontal dipole instead of a vertical as it may be impossible to get a strong signal at a low angle of radiation with a vertical under such conditions.

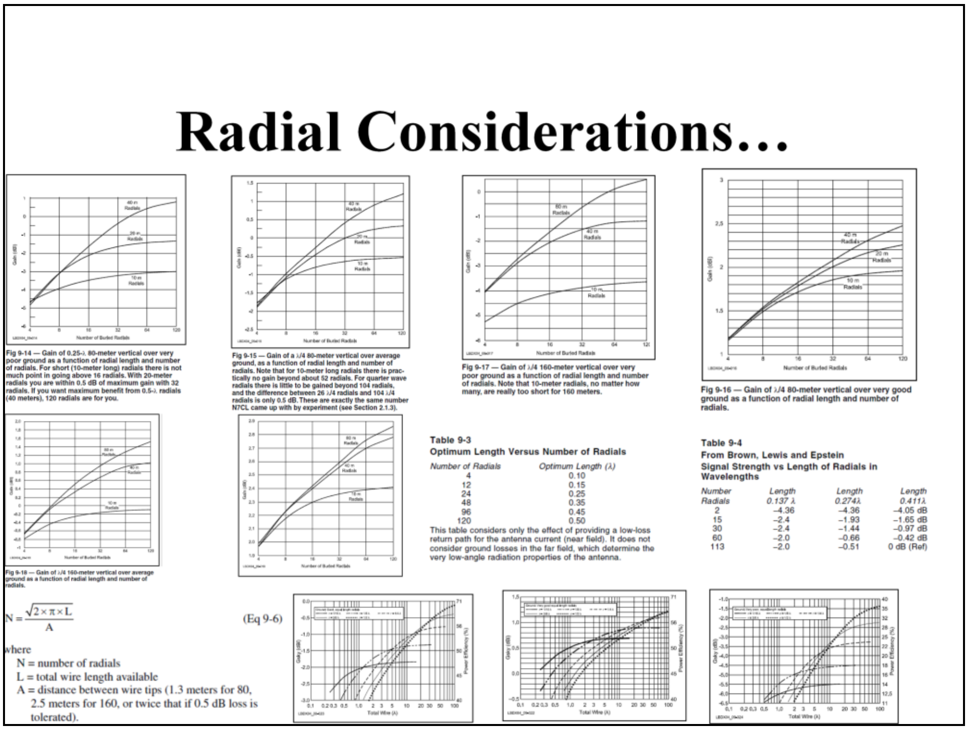
If you are close to the ocean, a vertical is the way to go!

Vertical Pattern



A good ground makes a big difference in the angle of radiation and strength of the signal radiated from a vertical antenna.

Radial Considerations…



Just some of the graphs, equations and charts dealing with radials in ON4UN’s Low Band Dxing book.

Okay, Let's Simplify…

Table 9-3
Optimum Length Versus Number of Radials

Number of Radials	*Optimum Length (λ)*
4	0.10
12	0.15
24	0.25
48	0.35
96	0.45
120	0.50

This table considers only the effect of providing a low-loss return path for the antenna current (near field). It does not consider ground losses in the far field, which determine the very low-angle radiation properties of the antenna.

Number of Radials…

- 30 x ¼ λ ground or buried radials should be plenty.
- 60 x ¼ λ ground or buried radials = point of diminishing return.
- Use at least 8 elevated ¼ λ radials – more is better.
- Given practical considerations, I recommend ground or buried radials instead of elevated.

16 radials would give acceptable results, but 30 would be better.

Elevated radials can be tricky. While 2 elevated radials can work, it is difficult to obtain equal currents, reducing their effectiveness. People who have studied the issue recommend at least 8 elevated radials to ensure that current imbalances are not a problem. Given the practical difficulties in trying to keep them in the air without strangling someone, I recommend surface or lightly buried radials instead.

No Room for 160M Vertical?

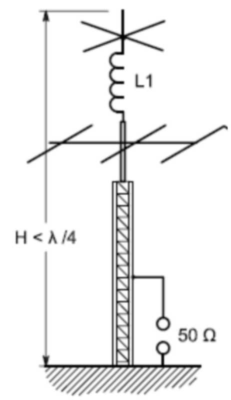
- Typical 60’ tower with tribander and 40/80M dipoles in back yard.

No Room for 160M Vertical?

- Typical 60' tower with tribander and 40/80M dipoles in back yard.
- No room for a separate vertical.

No Room for 160M Vertical?

- Typical 60’ tower with tribander and 40/80M dipoles in back yard.
- No room for a separate vertical.
- Consider Shunt-Feeding your tower!

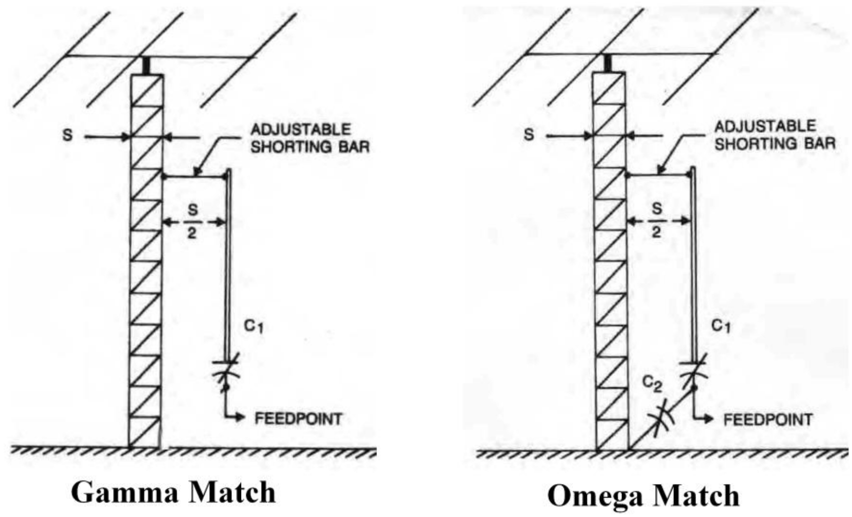


Shunt Fed Tower

- Use Gamma or Omega matching system.
- Tower is less than ¼ λ
- Yagi acts to electrically "lengthen" tower.
- Tower is grounded.
- As with any ¼ λ vertical, radials are a MUST!

Yagi adds capacitive loading to the tower, making it electrically longer. Note that yagis with elements insulated from the boom have much less effect.

Shunt Fed Tower



A Gamma match will generally work for towers 60 to 180 degrees long, given proper spacing and length of the matching section. If a match cannot be obtained with a Gamma match, then try an Omega match.

Determine Electrical Length

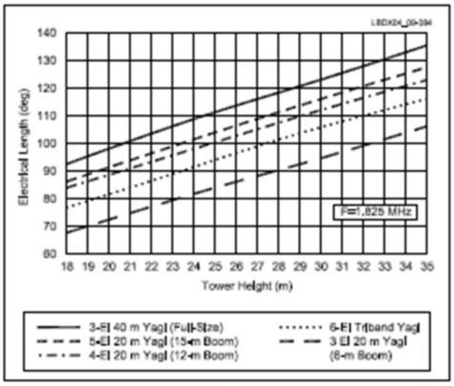
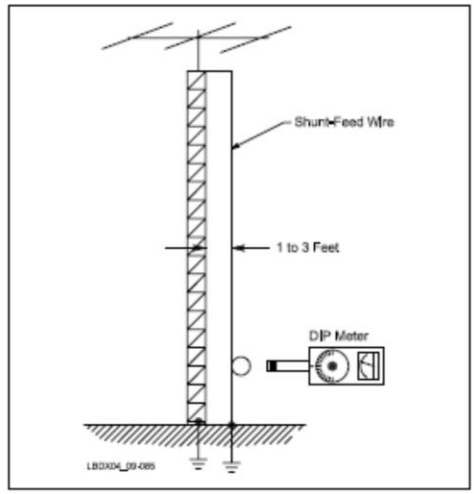
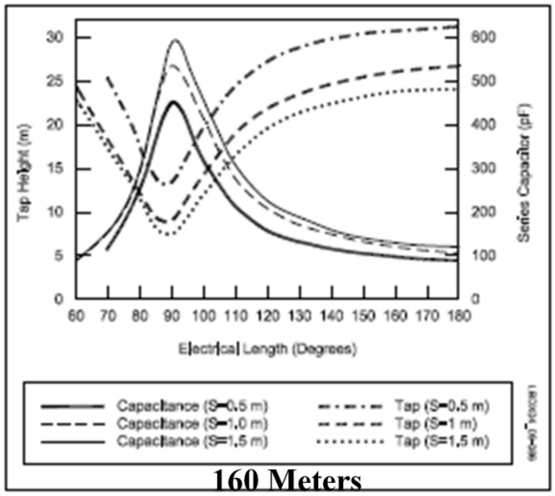


Fig 9-81 — Electrical length of a tower loaded with a Yagi antenna. The chart is valid for 160 meters (1.825 MHz) and a tower with an equivalent diameter of 30 cm. For a larger tower diameter, the electrical length will be shorter (4° to 7° for a tower measuring 60 cm in diameter).



Two ways to determine the electrical length of a tower – calculate it, or measure it with a grid dip meter.

Tap Height / Capacitances – ON4UN



Suggested tap heights and capacitor values for a 160M shunt fed tower for various spacings, as given in ON4UN’s Low Band Dxing book. Electrical antenna height is given in degrees.

Tap Height / Capacitances – W6SAI

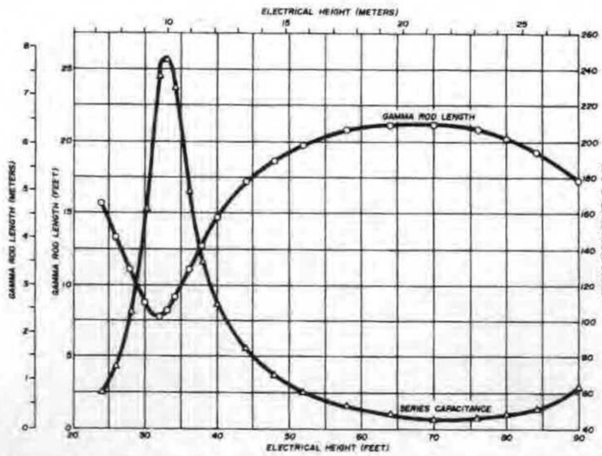
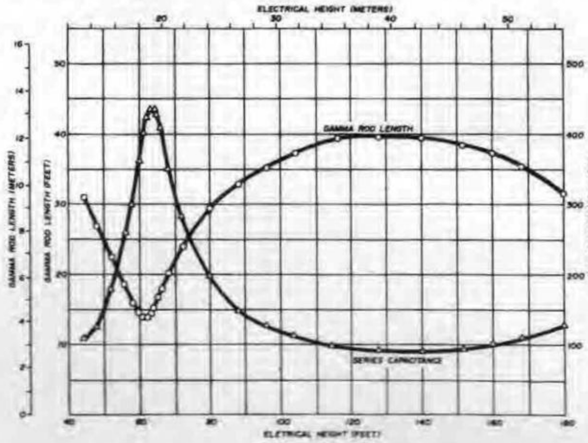


Fig. 12 40-meter vertical. Gamma rod length and series capacitance vs. electrical height of tower. Parallel capacitance required to match coax line is approximately 325 pF.

Suggested gamma rod lengths and capacitances for 40M shunt fed tower as given in W6SAI's Vertical Antennas book. Spacing is one half tower diameter. Height is electrical length in meters.

Tap Height / Capacitances – W6SAI

Fig 13 80-meter vertical. Gamma rod length and series capacitor vs. electrical height of tower. Parallel capacitance required to match coax line is approximately 650 pF.



Suggested gamma rod lengths and capacitances for 80M shunt fed tower as given in W6SAI's Vertical Antennas book. Spacing is one half tower diameter. Height is electrical length in meters.

Tap Height / Capacitances – W6SAI

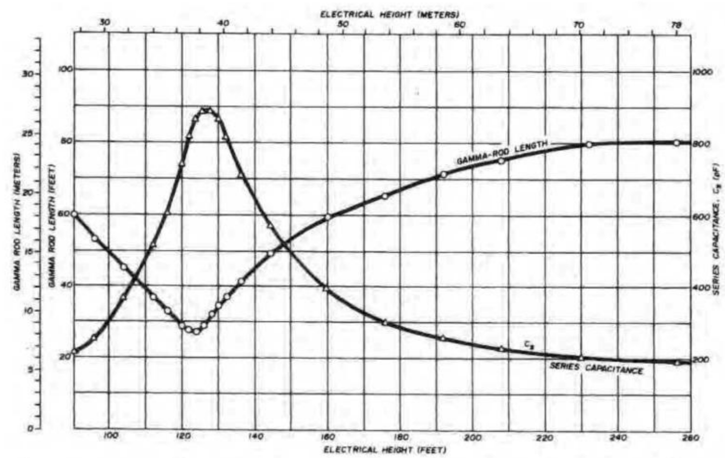


Fig. 14 160-meter vertical. Gamma rod length and series capacitor vs electrical height of tower. Parallel capacitance required to match coax line is approximately 1300 pF.

Suggested gamma rod lengths and capacitances for 160M shunt fed tower as given in W6SAI's Vertical Antennas book. Spacing is one half tower diameter. Height is electrical length in meters.

Matching Notes 1

- Tower does not need to be resonant to radiate.
- Ensure tower joints are conductive.
- Route coax and control lines inside tower, ground top and bottom if possible.
- Use heavy wire for drop wires.
- Use multiple drop wires to increase bandwidth.
- Use insulated arms to support drop wires.

A tower near resonance already will have a broader SWR bandwidth and lower voltages across the capacitors, but it is not necessary. Virtually any vertical can be loaded up.

Matching Notes 2

- Break up guy wires with egg insulators.
- For stacked Yagis, only bottom one matters.
- Use wire attached to top for extra top-loading.
- If Gamma Match won't work, use Omega.
- Can have high voltages across capacitors.
- Can use two sets of drop wires – 2 bands.
- Ferrite baluns on Yagis can be damaged!!

The wider the spacing, the shorter the gamma match, and the larger the series capacitor needs to be.

The ferrite baluns on yagis atop the tower can easily overheat when the tower is shunt fed, even at power levels below what the balun should be able to handle. Once this happens, the ferrite's characteristics are permanently changed, and it will no longer work properly. Ask me how I know!! I now use RF chokes made from coax on a section of sewer pipe for my HF yagis!

Omega Match

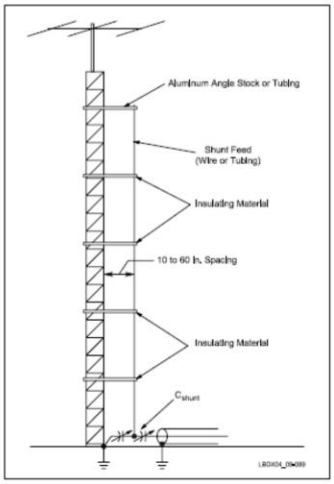


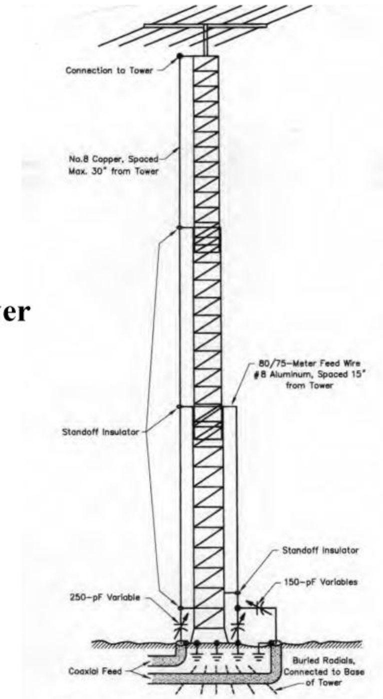
Fig 9-86 — The omega-matching system (a gamma match with an additional shunt capacitor) adds a great deal of flexibility to the shunt-fed-tower arrangement. To maintain maximum bandwidth make the gamma wire as long as possible. If the antenna is electrically longer than 120°, a variable series capacitor will make it possible to obtain a very low SWR over a wide bandwidth.

- High voltages on capacitors – use “cheese cutters”.

Use good quality capacitors, and ensure they are protected from the weather in a suitable metal enclosure.

Lots more detail on how to design and tune the Gamma and Omega matches in ON4UN’s Low Band DXing book and other references.

W5RTQ's Tower



Shunt Fed tower at W5RTQ. Tower is 70 feet high, with a TH-6 on top. Gamma match for 160M is attached to top of tower (68 feet), while Omega match for 80M is attached at 28 feet. Omega match is used on 80M to achieve greater bandwidth. It is switched in to allow operation on a different part of the band. Some people use motor-driven capacitors to cover all of the band.

Electrically, the tower is the equivalent of 125 feet. Tuning procedure is described in the ARRL Antenna Book.

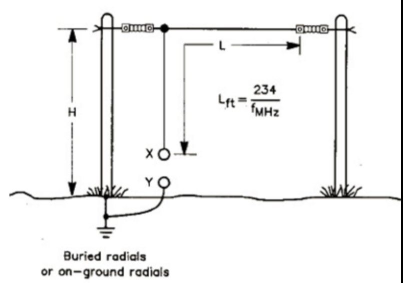
AA4LR's shunt fed antenna. Notice the metal box for the capacitors, and the use of two drop wires to increase operating bandwidth.

The 40-foot high tower I shunt fed on St. Paul Island in 1999. There are 2 sets of drop wires – for 160M and 80M.

Base of the tower on St. Paul Island. Note Rubbermaid container for the capacitors, and the Kapton radial wires.

Inverted L Antenna

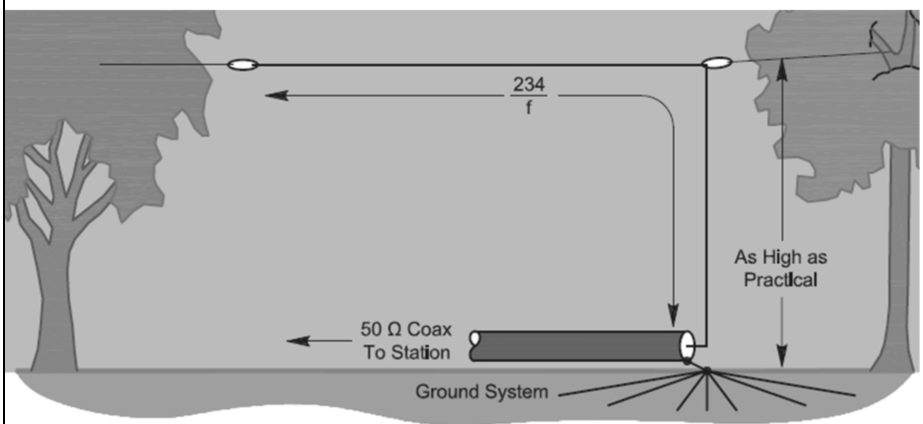
- Partly vertical, partly horizontal.
- Radiation is vector sum of two polarities.
- Both low and high angle radiation.
- Overall length is ¼ λ.
- Requires a radial system.



High angle radiation comes from the horizontal part of the antenna. Most current flow in in the lower, vertical, section of the antenna however, so most radiation will be low angle provided the ground is good (ground – not radial system).

Like any quarter wave vertical, the Inverted L requires a radial system.

Inverted L Antenna



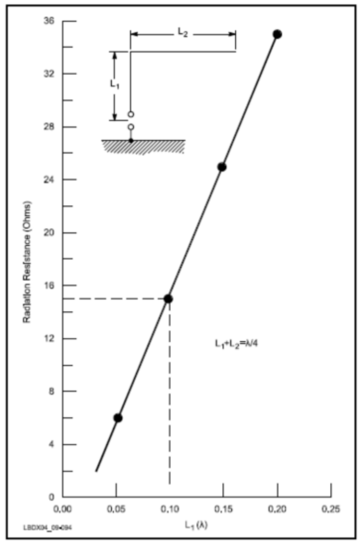
The inverted-L is a popular antenna, especially on 160 meters. These antennas are not truly verticals, as part of the antenna is horizontal and thus radiates a horizontally polarized

component. We often form the wrong mental picture of what actually happens because most antenna modeling programs only express the field in two distinct polarizations. We wrongly

picture two distinct fields. The actual field is the vector sum of the two fields, and is a single polarization wave with a tilt and a distinct total null at 90-degrees from the peak response.

Most inverted-Ls are of the λ/4 (total electrical length) variety, although this does not necessarily need to be the case.

Radiation Resistance



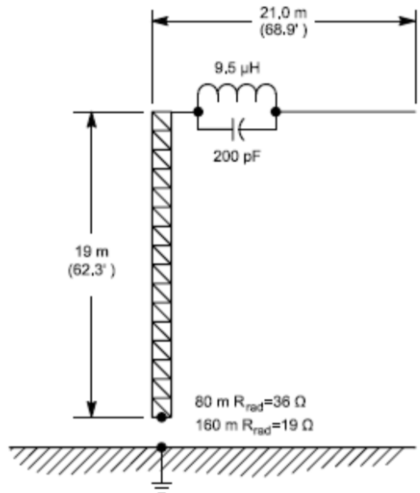
Radiation resistance of an inverted-L antenna as a function of the lengths of the horizontal wire versus the vertical conductor size. Matching system may be necessary if vertical section is short.

Ground loss will increase impedance at the feedpoint (I.e.: bring it closer to 50 ohms). This is why SWR increases when you improve the radial system.

Some people make the horizontal loading wire longer than necessary to obtain resonance with the idea of raising Rrad and making a direct feed to a 50-Ω feed line possible. In this case

you will have to make the loading wire so long that the majority of the radiation will be horizontally polarized and the radiation angle will be straight up — in other words a very poor DX antenna.

80/160M Inverted L



To cover both 80 and 160 meters, a trap can be installed at the top of the tower as shown at B. With the trap installed, the horizontal loading wire is shorter, because the trap shows a positive reactance (loading effect) on 160 meters.

Is that a cannon ball??

Remember to properly waterproof your coax connectors!

Inverted L Notes

- Can be supported by a metal tower, as long as tower not resonant on band in question.
- The higher the vertical section the better.
- Good radial system is a MUST!
- Keep horizontal section level or sloping up. Radiation resistance decreases if down.

The vertical portion of an inverted-L can be put up alongside a tower supporting HF antennas. In such a setup one must take care that the tower plus HF antenna does not resonate near the

design frequency of the inverted-L. Grid dip your supporting tower using the method shown in Fig 9-82. If it dips anywhere near the operating frequency, maybe you should shunt feed the

tower instead of using it as a support for an inverted-L.

Verticals - Summary

- Several options – mast, tower, wire.
- Can give low angle radiation if ground good.
- Good radial system is critical, but not much need to go beyond 30 ¼ λ radials.
- Elevated radials generally not worth hassle.
- Inverted L a good option for 160M.

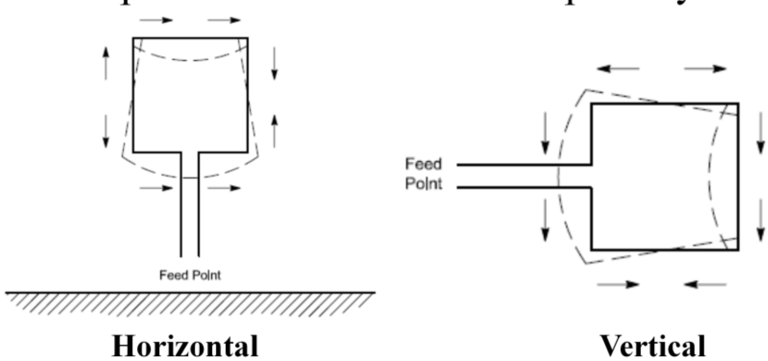
Remember – if you have very poor ground in your QTH (desert), then it may be better to use horizontal dipoles up as high as possible.

Vertical Loop Antennas

- Circumference is 1 λ.
- Plane of loop is perpendicular to ground.
- Requires 1 or 2 supports.
- Max gain comes from largest enclosed area (circular), but square and delta shapes work.
- Can gives better low angle radiation than dipole at same height IF ground is good.

Polarization vs Feed Location

- Polarization can be horizontal or vertical.
- Feed point location determines polarity.



When fed from bottom center, vertical currents cancel each other, and horizontal currents reinforce each other, giving horizontal polarized signals.

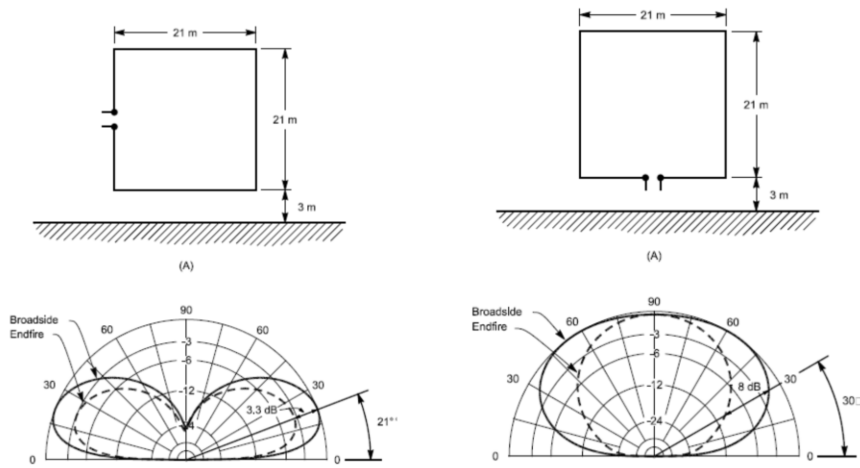
When fed from center side, the horizontal currents cancel, and vertical currents reinforce each other, giving vertical polarization.

Large horizontal loops produce horizontally polarized signals, whose takeoff angle depends primarily on the height above ground.

Loop Polarity

- Angle of radiation of vertically polarized loop determined by quality of ground in far field.
- Angle of radiation of horizontally polarized loop determined by height above ground.
- In general, horizontal good for local communications, while vertical is better for DX!

Radiation Patterns

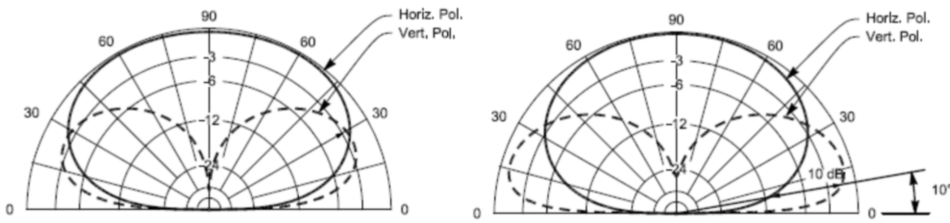


Over Good Ground

80M loop, with the bottom just 3 M above a good ground. This is a typical situation for many Hams.

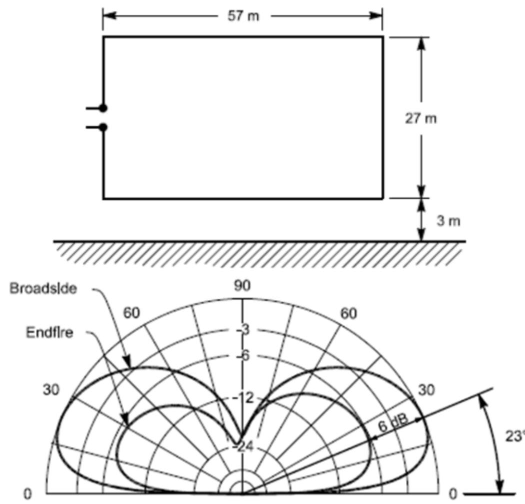
No Free Lunch!

- Over poor ground, vertically polarized loops do not provide a better low angle signal than horizontally polarized.

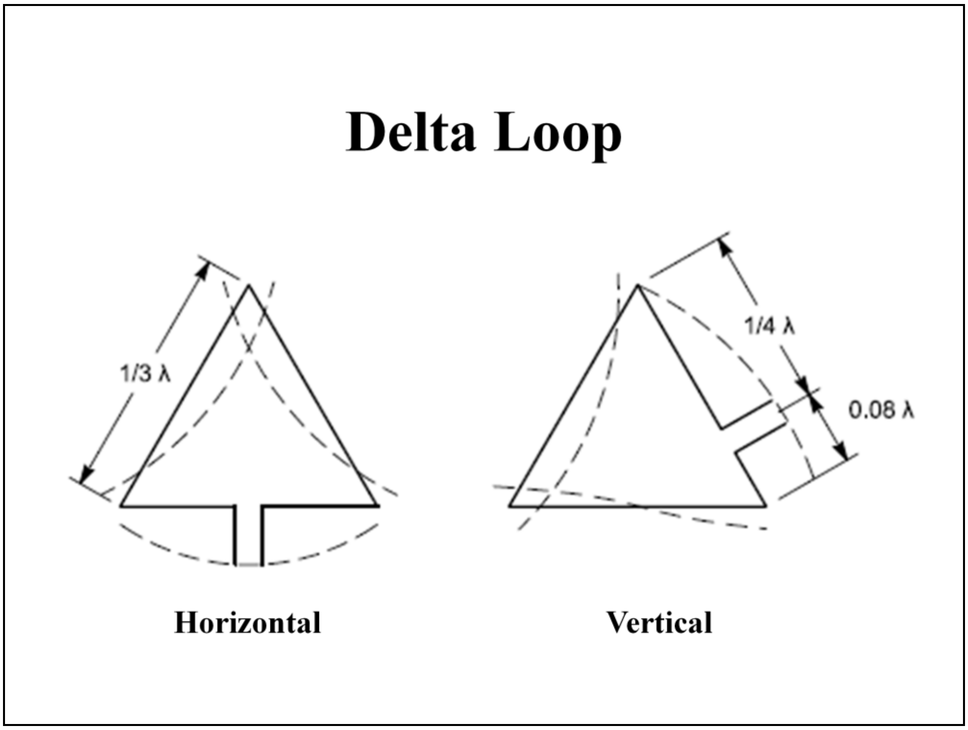


Poor Ground **Good ground**

Rectangular Loop

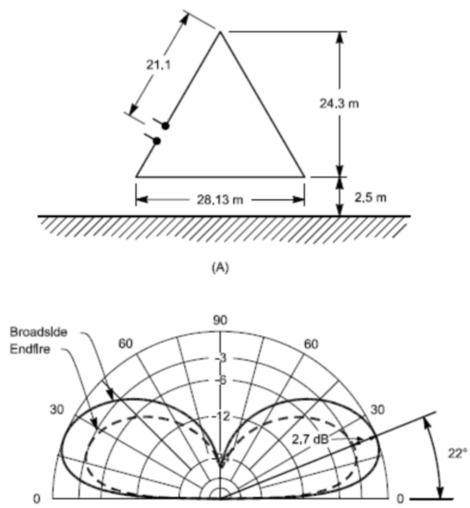


The shape of the loop can be modified to suit local conditions. This example is for 160M, but can be scaled down for 80 and 40M.



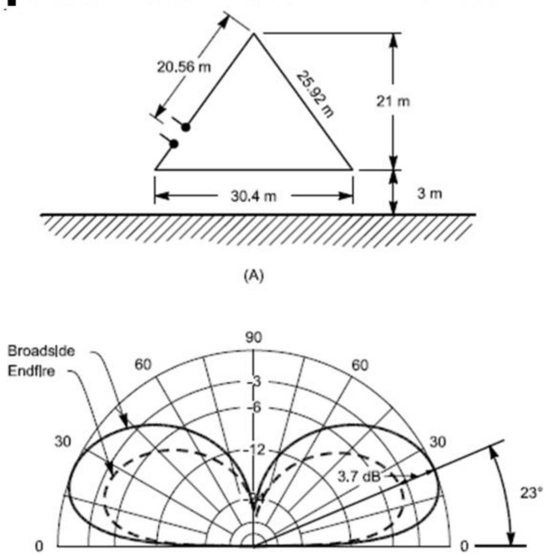
For an equilateral triangle Delta loop, you will get vertical polarization by feeding the antenna one quarter wavelength from the top.

80M Delta Loop



Good ground, 3.8 MHz

"Squashed" 80M Delta Loop

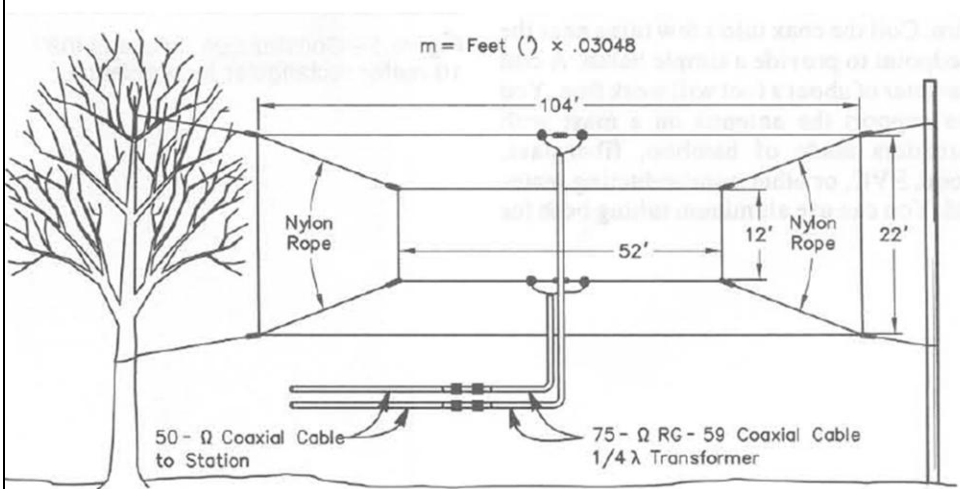


Good ground, 3.8 MHz.

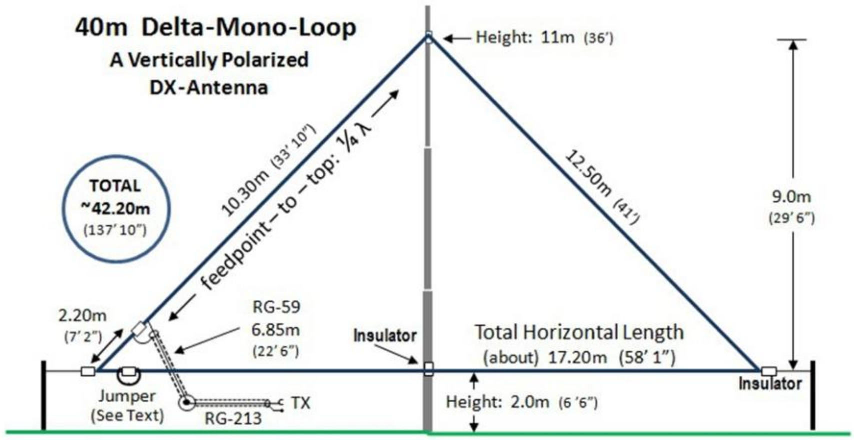
Feeding a Loop

- Impedance in free space is 120 Ohms.
- BUT – actual impedance depends on ground quality, shape of the loop etc.
- Delta loops vary between 50 and 100 Ohms.
- 75 Ohm quarter wave matching transformer can be used.
- Can feed with 450 Ohm balanced line with a transmatch.

Model your design, measure the actual impedance, or use a design that has already been tested.



40M and 80M Nested Loops



http://www.dj0ip.de/my-favorite-antennas/my-favorite-40m/

- **This antenna is a full wavelength single-delta-loop, with the point of the triangle at the top of the single support pole, and fed <u>near</u> one of the corners - One Quarter Wavelength down the diagonal leg. Feeding and matching is simple; it's fed with a quarter-wavelength of RG-11 or RG-59 (75 Ohm) coax, and then any length of 50 Ohm coax. No balun is necessary, though an RF-choke is advantageous. The easiest solution here is to slip ferrite beads of high permeability over the coax and secure with heat-shrink tubing.Advantages over a full size quarterwave vertical with a good radial network:2-dimensional (will fit in a long, narrow space) - radials should normally be in all directions.**
- **About 1 to 2 dB gain**, **Possibly Quieter on receive**
- **More broadbanded resonance than a dipole or vertical**
- Yet like a Vertical, p**retty much Omni-Directional (due to its low height)**
- **Advantages over a horizontal dipole (at 11m height):Lower angle of radiation**, S**tronger signal for DX contacts (usually +2 S-Units)**
- **Not as good as a low dipole for local (NVIS) QSOs (this is an understatement)**
- **The pole should be about 12m high (minimum 11m). (39'4"to36'). Higher is better, but then you will have to re-adjust the total length for resonance.• The feedpoint is located in either diagonal side near one corner of the antenna, enabling vertical polarization. This makes the antenna an excellent DX**

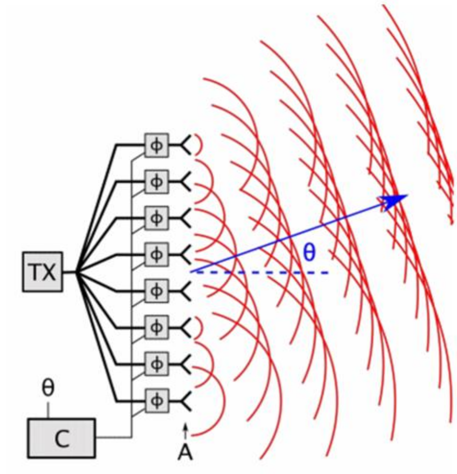
Vertical Loop Summary

- Can give good low angle performance IF the ground is good.
- Does not require a radial system.
- Simple to build, can use trees for support.
- Exact shape not critical – Delta works well.

Phased Arrays

- Yes, you CAN have a phased array in most back yards – well, at least on 40M!
- Phasing accomplished using coax delay line.
- Possible to have two endfire directions and a bidirectional broadside direction.
- Everything already covered about radials and ground quality still applies.

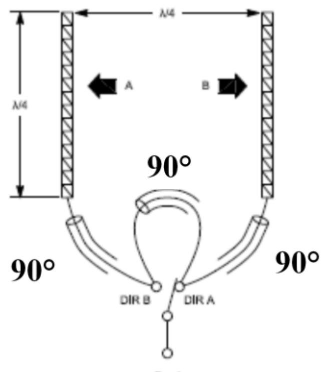
How does a Phased Array Work?



Animation showing how a phased array works. It consists of an array of antenna elements *(A)* powered by a transmitter *(TX)*. The feed current for each antenna passes through a phase shifter *(φ)* controlled by a computer *(C)*. The moving red lines show the wavefronts of the radio waves emitted by each element. The individual wavefronts are spherical, but they combine (superpose) in front of the antenna to create a plane wave, a beam of radio waves travelling in a specific direction. The phase shifters delay the radio waves progressively going up the line so each antenna emits its wavefront later than the one below it. This causes the resulting plane wave to be directed at an angle θ to the antenna's axis. By changing the phase shifts the computer can instantly change the angle θ of the beam. Most phased arrays have two-dimensional arrays of antennas instead of the linear array shown here, and the beam can be steered in two dimensions. The velocity of the radio waves is shown slowed down enormously.

Two Element Vertical Array

- One quarter λ vertical elements spaced ¼ λ.
- Phasing achieved using a ¼ λ coax cable delay line.

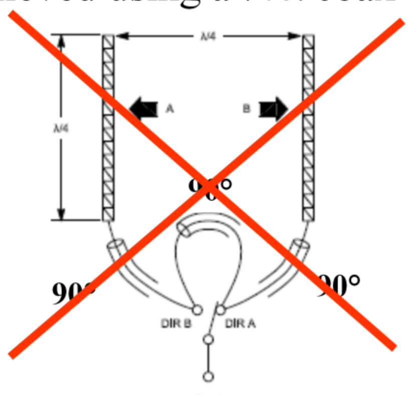


Directivity is in the direction of the antenna with the lagging current – the one with the delay line.

90 degree phasing delay – should work perfectly right?

Two Element Vertical Array

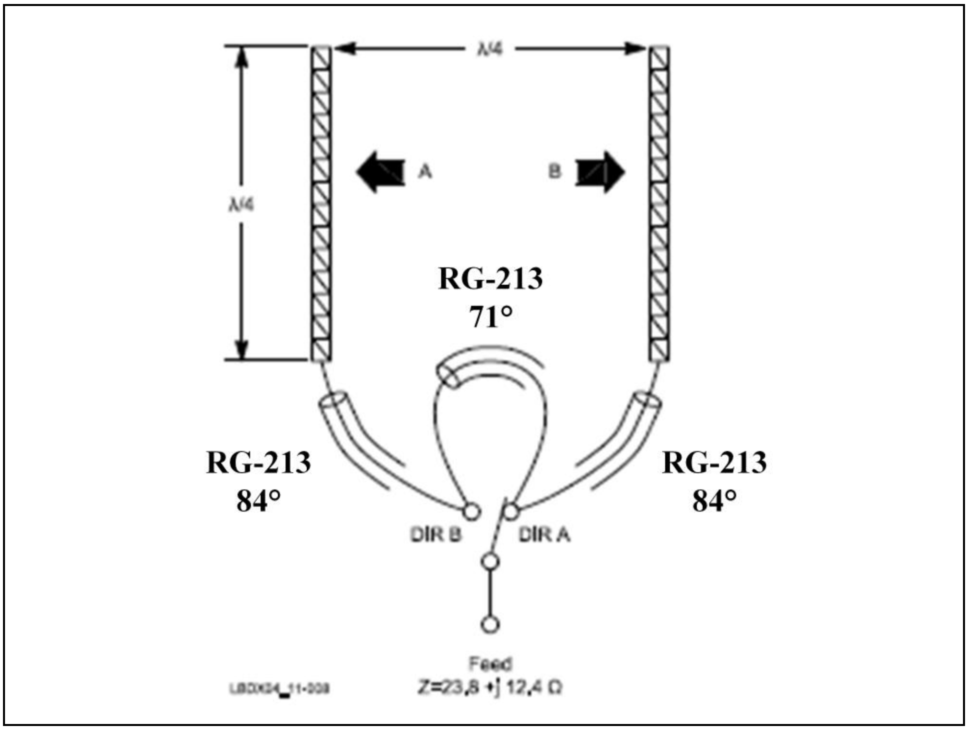
- One quarter λ vertical elements spaced ¼ λ.
- Phasing achieved using a ¼ λ coax cable delay line.



Afraid not!

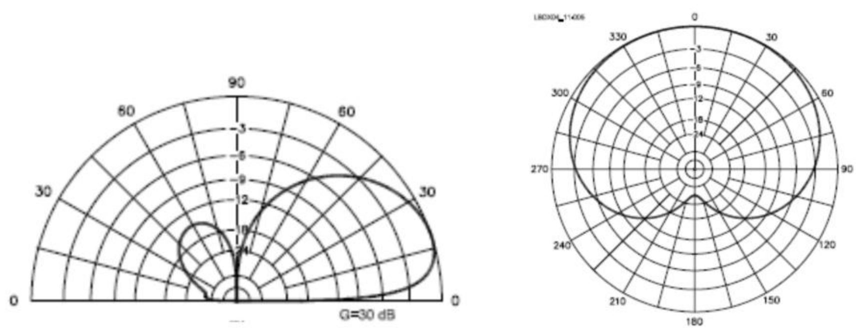
Not that easy!

- Drive impedances of antennas different from feedline impedance, causing SWR.
- Impedance, voltage and current different throughout feedlines.
- Phase shifts therefore not proportional to feedline length.
- Must therefore adjust the feedline lengths.



Fortunately, the experts have calculated optimum feedline lengths that will give the correct phasing, and give a reasonable match for the radio. Note that you may still need to use the radio's internal antenna tuner to get the radio to see a 1:1 match (50 ohm resistive load).

Radiation Pattern

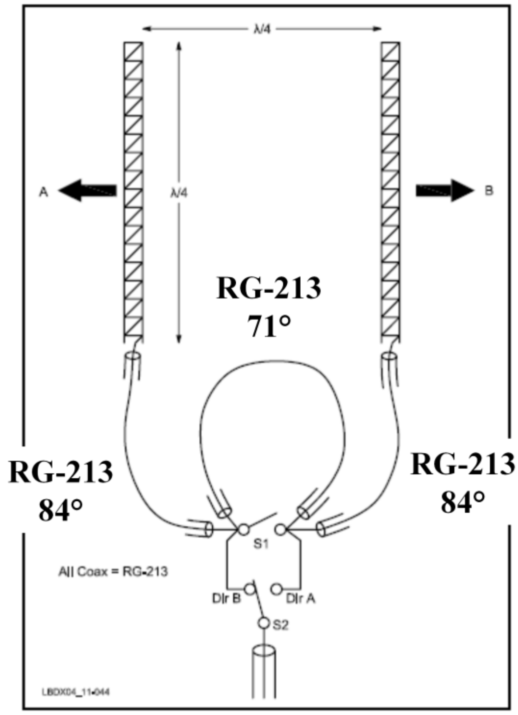


-Very good ground

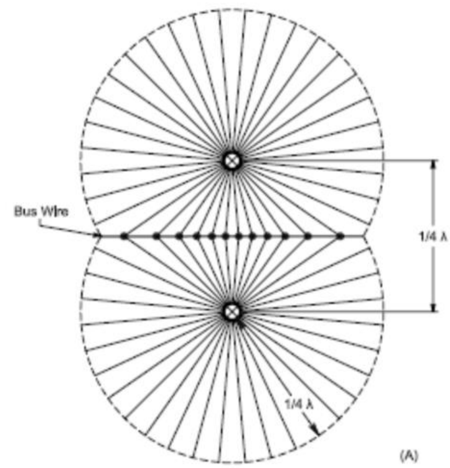
-3 dB gain over a single vertical

Broadside Pattern

- Closing S1 shorts the delay line.
- This feeds both verticals in phase, giving bidirectional broadside pattern.



Radial Arrangement



Measuring the Feed Lines

- Published Velocity Factor of coax cables may vary from batch to batch.
- Use high quality line from same spool.
- Cutting 84° and 71° lines can be tricky!
- Consult textbooks for proper techniques to determine correct lengths.
- Note that this phasing system will not give a 50 ohm resistive load – need radio's antenna tuner for final match.

To cut the coax cable to the correct lengths for the 84 and 71 degree lengths you determine at what frequencies those lengths would be 90 degrees long. You then use those frequencies and an antenna analyzer to precisely trim the coax to the right length. ON4UN's Low Band DXing and other references describe the process.

Two Element Array Summary

- Offer reasonable gain and front/back ratio.
- Phasing arrangement relatively easy to build.
- Antennas can be wires suspended from trees.
- Consider aluminum tubing from Princess Auto!
- Two element arrays work – personal experience!

It is relatively easy to build vertical antennas for 40M using tubing from Princess Auto and scrounged from other sources, or from wire suspended from trees or a support rope. Two element arrays certainly work – they have been very effective on the IOTA DX'peditions that I participate in from Bon Portage Island.

Summary 1

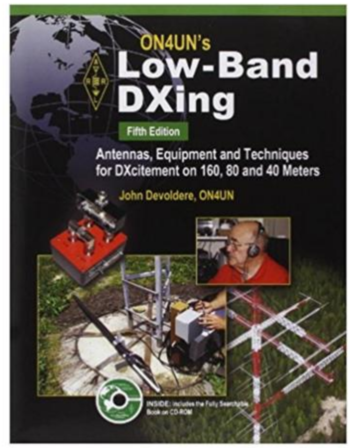
- Low angle radiation requires height for horizontally polarized antennas, or good ground out to the far field for vertically polarized antennas.
- Quarter wave verticals usually good options for 40 and 80m, and Inverted L for 160M.
- Vertical loops also easy to build, and don't require a radial system. (Delta only needs 1 support!)

Summary 2

- All these antennas have reduced-space versions that may fit your situation.
- Two element phased arrays are not beyond consideration, and work very well.
- Other antennas are possible – consult the references.
- If nothing else is possible, you can't go wrong with a dipole as high up as you can get it!

Primary References

- ON4UN's Low Band Dxing
  - Now in 5th edition!
  - The Bible!
- ARRL Antenna Book
- Vertical Antennas
  - W6SAI and W2LX



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Annapolis Valley Amateur Radio Club

http://avarc.ca/

We’re on Facebook as well!

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