Basic HF Antennas

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When I was first licensed in 1961 I didn't know much about antennas. I put up the longest wire that fit on my parent's lot at the lofty height of 25' and fed it with about 30' of homemade 600Ω ladder line. I made a balanced line tuner and tuned up using a Field Strength Meter. I made plenty of contacts on 80, 40 and 20M. I didn't realize it at the time, but I was fortunate to live near the crest of a west sloping hill that enhanced low angle radiation in that direction.

Fast forward to 1988 when I decided to get back on the air. The new solid state radios needed a good VSWR to operate, so I had to learn more about antennas. I received some very good advice from Bill Orr, W6SAI (SK), to put up a dipole as high as I could, and I did. The dipole has always been my main antenna since then. The following is a list of dipole variants I have used successfully:

- Single band dipole
- Multi dipole made by putting several dipoles in parallel with a common feedpoint
- Trap dipole that uses tuned circuits to get multiband operation from a single wire
- Multi-band doublet fed with ladder line

The *ARRL Antenna Book* has design data for dipoles and multi-dipoles. Don't expect to cut a wire using the formula and have it work without tuning. Other antennas, structures and trees can affect the resonant frequency. Since you may want to test the antenna outside the ham bands as part of your tuning process you should buy or borrow an antenna analyzer.

The single band dipole is the easiest to put up and tune. I always start with 5% of extra wire, so I can trim it to the frequency I want. If you put up several dipoles in close proximity you need to be careful that they do not interact. I keep records of VSWR vs. frequency for my antennas and check them for changes when I put up a new one.

Multi dipoles are a good alternative for those wanting multiple band coverage. Three or four dipoles are put in parallel and trimmed for resonance starting with the longest one. This will not work for all bands though. Since a full size 40M dipole will also tune on 15M, parallel 40 and 15M wires may not tune well. Multi dipoles are also mechanically more challenging and can get twisted in heavy winds. (Voice of experience)

Trap dipoles have been popular for many years. Three bands are about the most I would use since the trap reduces the lower frequency bandwidths considerably. The traps are also lossy; I estimate about 0.5dB for a well-made trap. There are several commercial sources for trap dipoles.

Multi-band doublets have long been a favorite of mine. Properly designed they can work efficiently on 3-4 bands over a 2:1 bandwidth. I have squeezed 3:1 bandwidth from this design once or twice. This is my experience after designing and fielding a dozen or so doublets over the past 10 years. Trying to get wider frequency coverage results in matching losses and multi-lobed azimuth patterns. They are fed with low loss ladder line so VSWR losses are minimized. 300Ω ladderline often yields the easiest to match impedances in the shack. Common mode currents on the balanced feedline can cause problems in your shack. A good balanced line tuner followed by a 1:1 line isolator is recommended.

Let me talk about verticals before I continue with horizontal wires. A vertical can be a very good antenna. I work many hams, especially on the low bands, who use them. A vertical has about 1 S-unit less peak gain than a dipole. It has a null at high radiation angles, but more gain at very low angles. This means it is good for long distance contacts, but poor for close contacts. Figure 1 shows the radiation pattern for a typical ground mounted vertical with 16 radials.

Figure 1: Ground Mounted Vertical Antenna Radiation Pattern

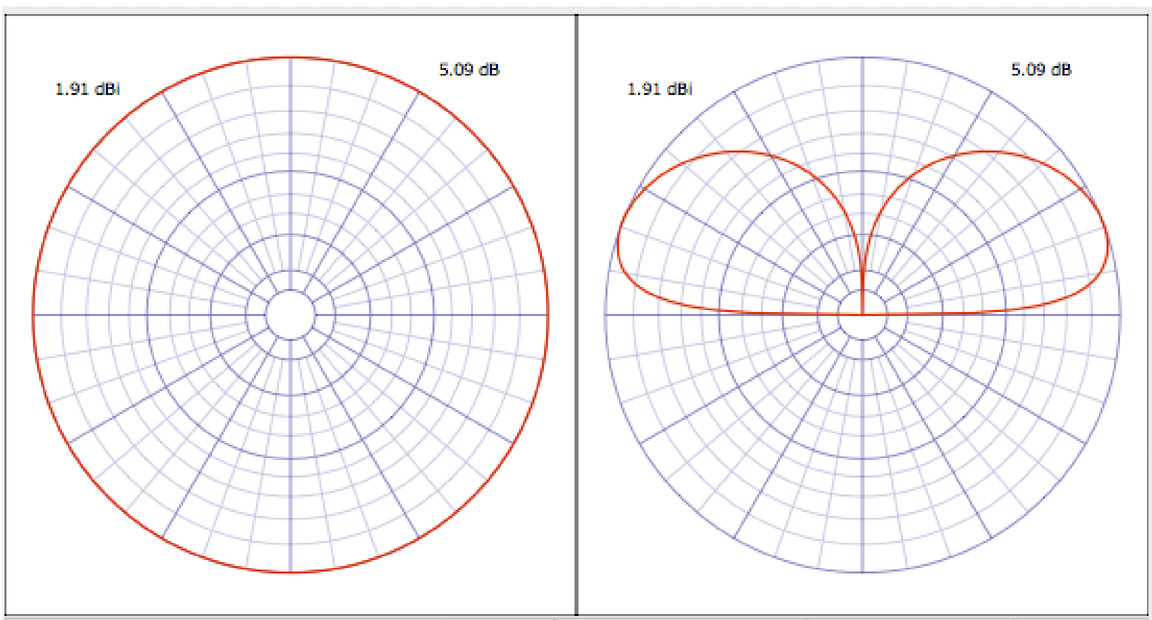


Figure 2: Dipole up 1/4λ Radiation Pattern

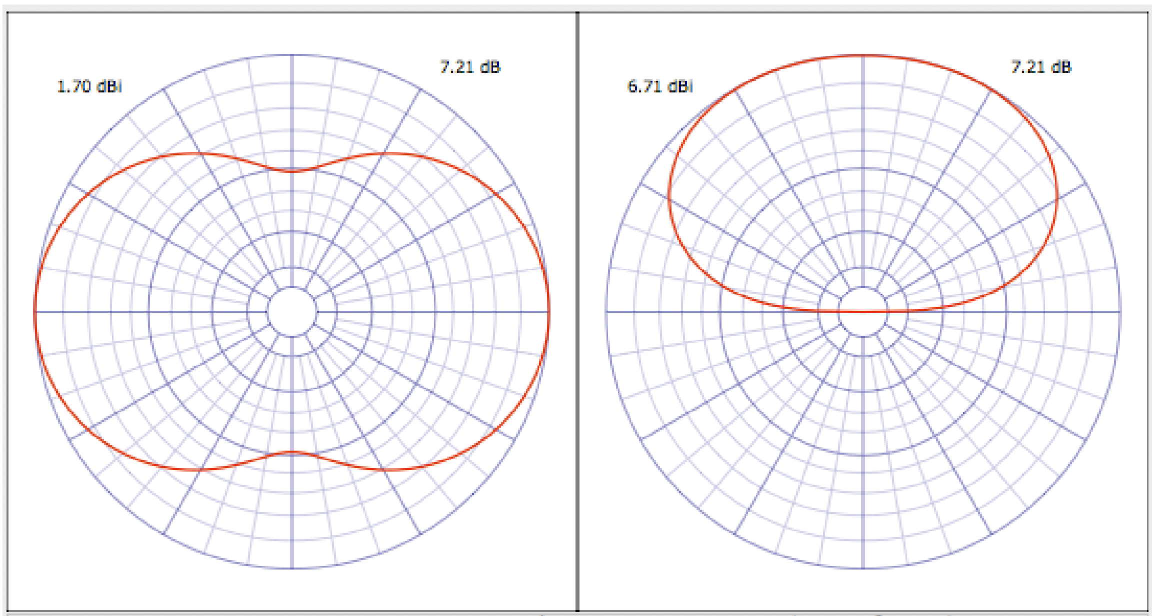


Figure 3: Dipole up 1/2λ Radiation Pattern

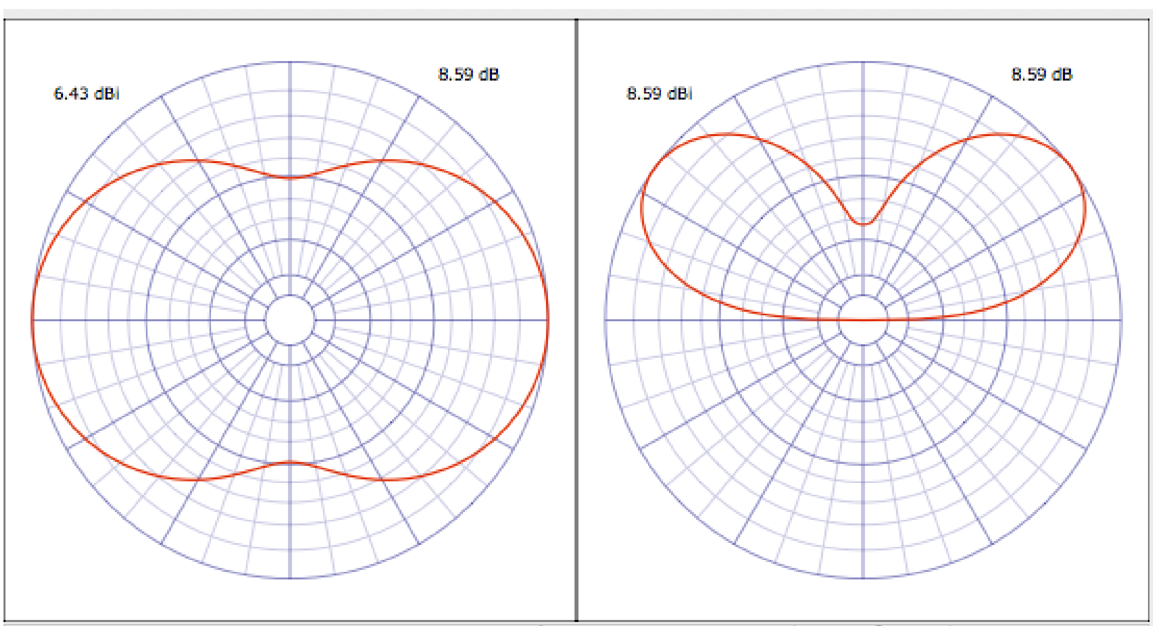


Figure 2 shows a low dipole which is best for local contacts. Figure 3 shows what happens if you raise the dipole to 1/2λ; the low angle gain improves but you get an overhead null. The *ARRL Antenna Book* has a more complete set of patterns for dipole radiation pattern vs. height.

Table 1 shows a comparison of gain for a ground mounted vertical and a low dipole:

Table 1: Dipole vs. Vertical Gain

Radiation Angle	Single Hop Distance (miles)		Antenna Gain (dBi)	
(degrees)	f1 layer	f2 layer	Vertical on Gnd.	Dipole @ λ/4
5	1200	2300	-2	-8
10	800	2000	1	-3
20	500	1200	2	2
30	300	800	2	5
40	240	650	0	6
50	200	500	-2	7
60	200	400	-4	7

The optimum radiation angles for contacts over 1000 miles are 3-17°. The vertical has a clear advantage below 10° and it's a draw at 20°.

I'll finish the vertical discussion with the so called "No Radials" design. Coils, capacitance hats and stubs are used to make a short vertical look like it is a half wave long. 25' is awfully short for a 40M half wave design, on the lower bands you are losing some power for sure. Don't even bother with the models that cover 80M, tuning is very critical and the bandwidth will be very narrow. An ARRL review of a popular model indicated they couldn't get 80M to work at all. On 20M and above they are pretty efficient. Raising them too high in the air creates a multi-lobed pattern.

I simulated a half wave vertical doublet to show what happens to the pattern as you raise it off ground.

Figure 4: 25' Center Fed Vertical with its base 6' off ground

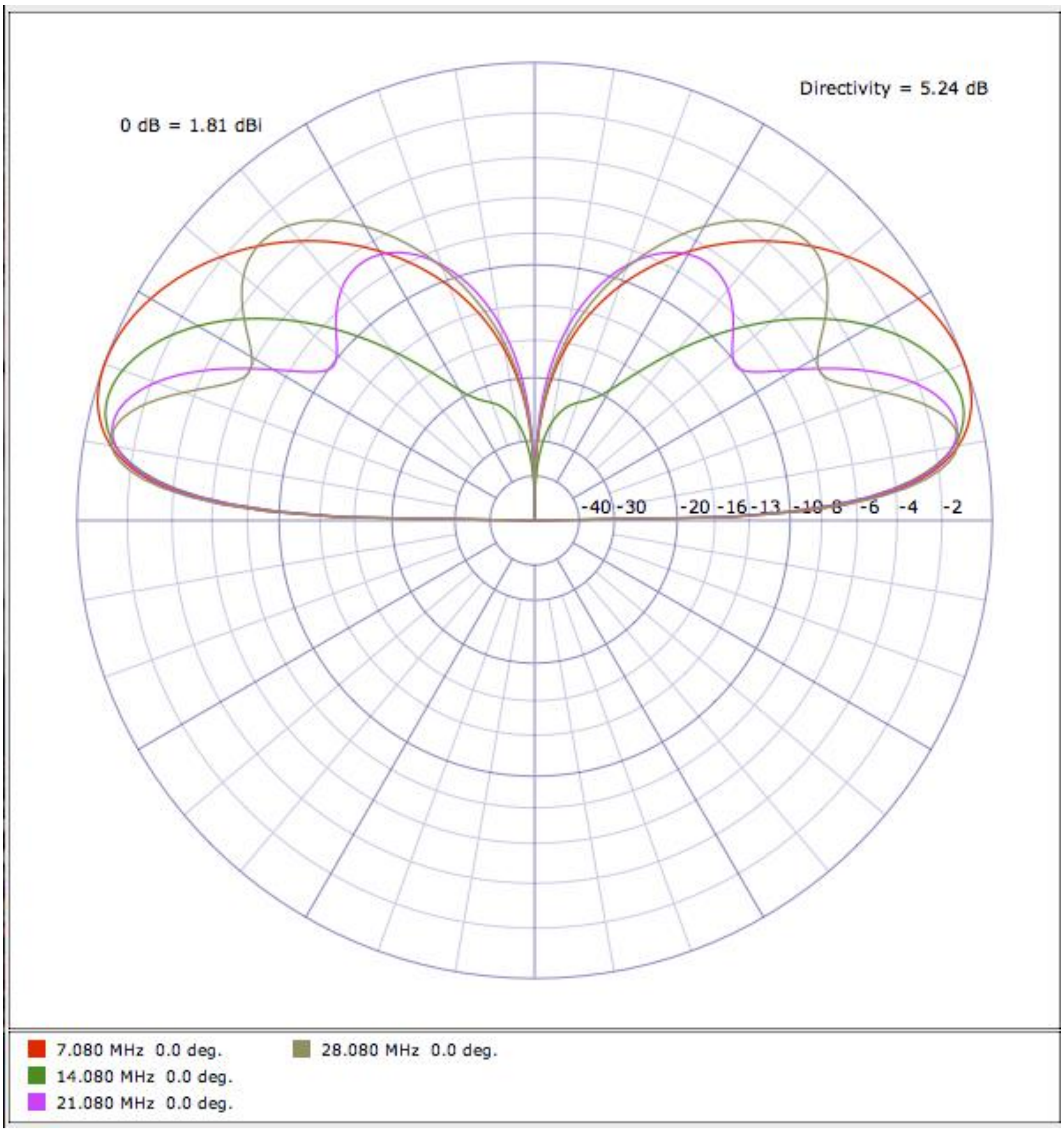
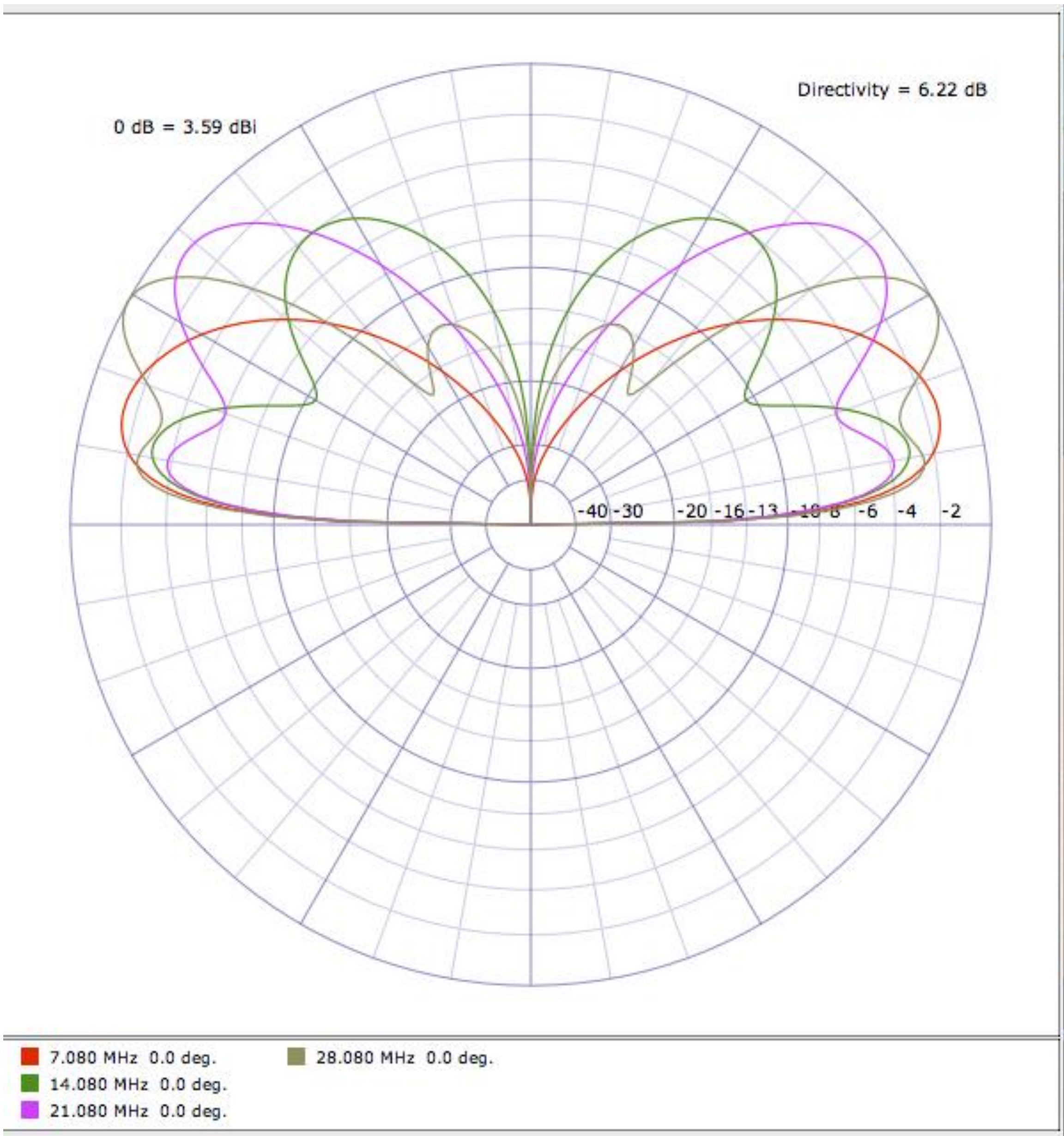


Figure 5: 25' Center Fed Vertical with its base 20' off ground



As you raise these antennas, the higher frequency bands develop high angle lobes and nulls reducing their effectiveness for DX. These verticals still have the overhead null. My advice is to mount them no higher than 10' off ground. I used a Cushcraft R4 (20-10M) for many years and it was good for long haul DX.

As you can see there is no one size fits all. Operating interests, available space, aesthetics and budget drive antenna choices. Understanding your antenna's limitations and strengths will help you get the most enjoyment from using it. Up until now I have described conventional designs. Now I will venture into some interesting alternatives.

Multi-band doublets fed with ladder line were very popular when I was first licensed. I have designed and built dozens of them at my present location. I still have one in place for 20-10M (E-W). Let me discuss some constraints:

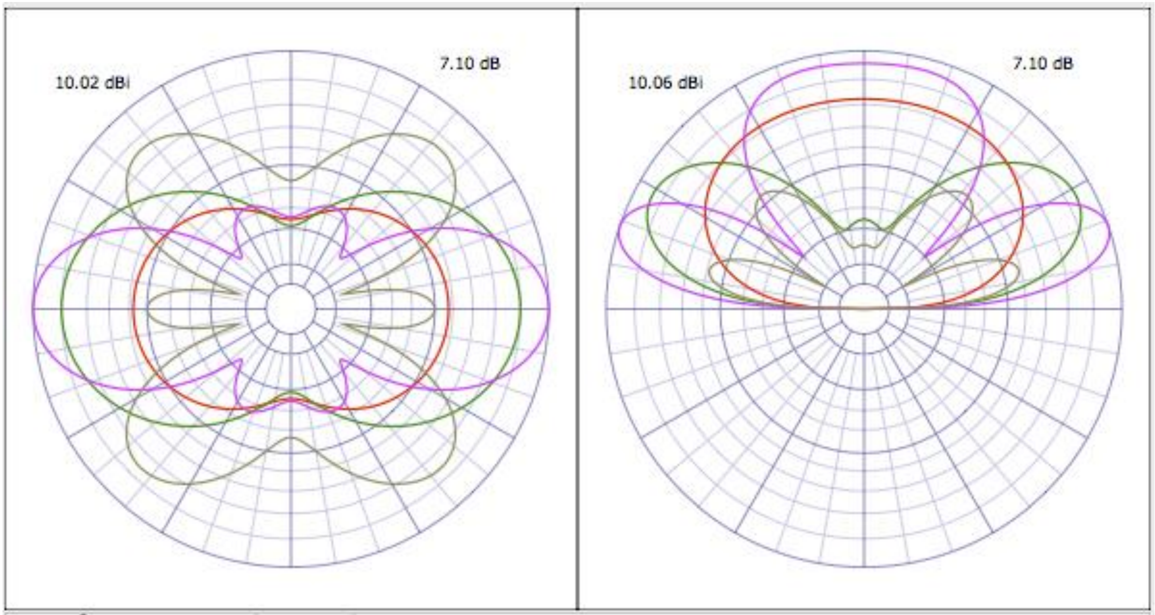
1. Short antennas have low radiation resistance which can be difficult to match with low losses
2. Antennas longer than 1.25λ exhibit multi-lobed azimuthal patterns
3. Feed line lengths are critical, odd multiples of 1/8λ at the lowest frequency provide impedances that are easier to match
4. Feed line impedance of 300Ω makes matching easier. Balanced feedlines have lower losses at high VSWRs.
5. A balanced line tuner like the Palstar BT 1500 is best, but a 1:1 line isolator and a high power L or T Network tuner will work. >5KΩ of isolation impedance is best

These constraints plus my experience limit the useful frequency range to 2:1. You can increase the frequency range, but the pattern will be lobed, not dipole like, on the higher bands.

Reference: *Baluns: Choosing The Correct Balun* by Tom, W8JI. Found on the DX Engineering Website URL:
https://static.dxengineering.com/global/images/chartsguides/c/choosing-the-correct-balun.pdf

The section on "Ladder Line or Open Wire Fed Dipoles or Doublets" presents an excellent design approach for a Multi-band Doublet. I won't repeat all his information but will show radiation patterns for several designs.

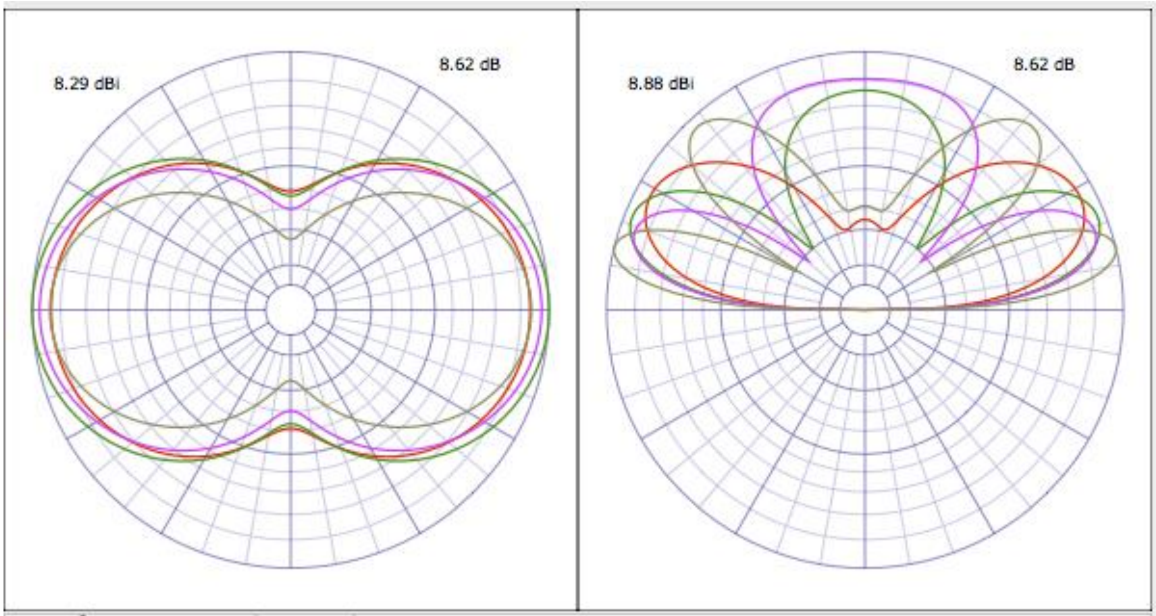
Figure 6: 55’ Doublet for 40-10M at 35’



40M –red, 20M –green, 15M –violet, 10M –gray, azimuth at 20°

Figure 6 shows a 4:1 bandwidth design; the higher band radiation patterns get narrow or multi lobed. The 10M cloverleaf pattern has a narrow elevation peak at 15 degrees. If you are a casual operator who doesn’t mind the restrictions of a multi-lobed design, you can operate over a wider frequency range with this antenna type. I prefer to have an east-west pattern and put up a second, identical antenna for north-south operation.

Figure 7: 29' Doublet for 20-10M at 35'



20M –red, 17M –green, 15M –violet, 10M –gray, azimuth at 20°

Figure 7 shows a more conservative 2:1 bandwidth approach. The patterns are all dipole like for this 2:1 bandwidth doublet that covers 5 ham bands. In general, the impedances in the shack will be easier to match. This is similar to my present antenna.

For a ham looking for the most flexibility with less wires in the air a multi-band doublet is often good choice. You do need a high isolation line isolator and wide range antenna tuner (10:1). Most radio ATUs do not have sufficient tuning range, they are limited to 3:1. A manual tuner or wide range external ATU is required. A remote isolator/tuner is also an option.

Summary:

There are no bad antenna types, the goodness usually depends on your installation constraints. This paper was written to provide you with a basic understanding of performance differences and options for simple antennas.

An internet search on almost any antenna type will provide you with more information than you ever need. If you have severe space constraints or homeowner's association restrictions there are still many ways to get on the air. Antennas can be bent without major performance changes. I have found them to be a hobby in itself since my lot is very space constrained.

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Appendix: Low band operation

Antennas for 80 and 160M are difficult to fit on a city lot with half wavelengths in the 133 and 232’ range respectively. Verticals are popular but too tall. An Inverted L is a popular alternative. The vertical section goes up as high as you can and then the top wire completes the quarter wavelength. You do need a good radial system like any vertical. I put one on my roof with elevated radials that works well on 80M but was inefficient on 160M. I enjoy 80M, 160M is all contesters and DXers these days, so I disconnected the 160M section. My 80M inverted L uses a 32’ vertical section and a 32’ top wire.

In a city environment a receiving antenna helps a lot. My Pixel Loop provides a 6dB improvement in Signal-to-Noise Ratio on 80M. It is horizontally polarized at low angles; most man-made noise is vertically polarized. I can also use it to null out strong low angle noise sources. These loops need to be mounted close to the ground or they lose their effectiveness against local noise sources.