# Multi-band antennas

In our discussion so far, we have been concerned with single band or single element antenna types. Quite often, it is convenient and desirable to operate multiple bands with a single antenna and coax. In order to do this successfully, a number of factors are to be considered in design and construction or purchase of a multi-band antenna.

Lets take the case of the 5BTV vertical monopole antenna from Hustler®. This is a very good example of a well designed multi-band monopole vertical antenna. It is also a good illustration of how multi-band antennas in general theory are constructed, whether vertical or duplicated for horizontal orientation as a dipole. The overall length of the antenna is 25 feet. With just a little calculation, we can observe that it is a shortened vertical for the bands below 15 meters. It is a 5/8 wavelength vertical for 15 meters and above. So, how is this possible?

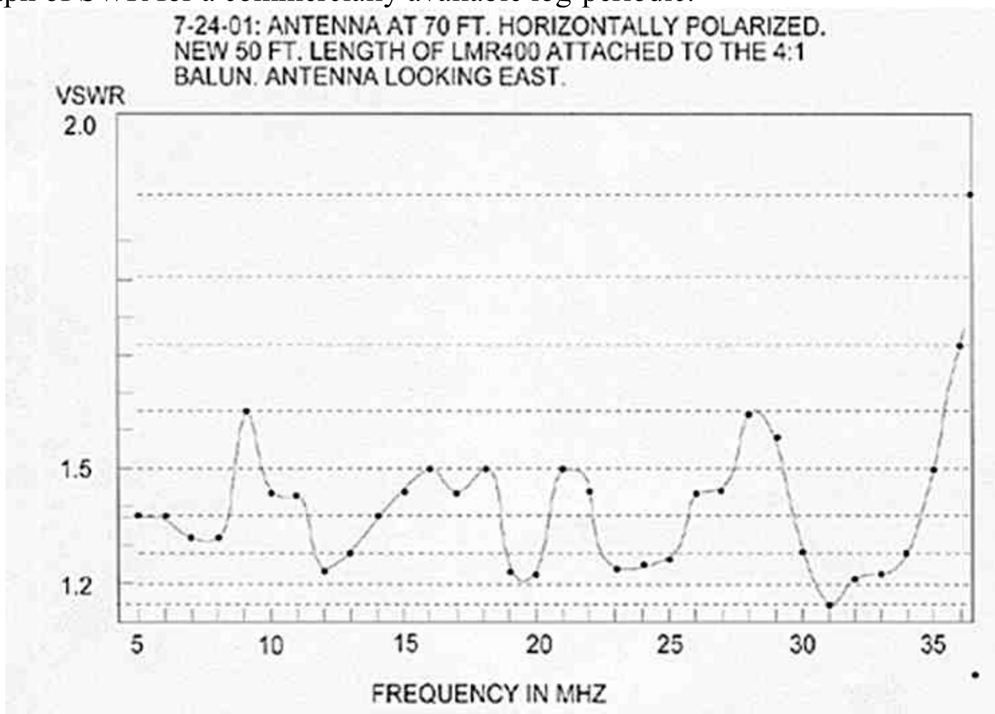
This type of antenna uses resonating elements along its length to either load a portion of the element or electrically eliminate part of the length. In the case of the lower bands (80 thru 20), the resonating components provide loading that causes the shortened vertical to appear to be electrically much longer. This technique was discussed in an earlier chapter. For the bands 15 meters and above, the resonating components act to “cut off” part of the antenna so that it becomes electrically the right length. These components are often called “traps”. This name originates from the characteristic nature of parallel resonating circuits. The flow of current in a parallel circuit is mainly within the parallel components and not in the series connection. So RF current flowing along the antenna element will become “trapped” in the parallel resonators and not allowed to flow further down the length of the element to the end. The reality is that some of the RF does flow the full length, but at a dramatically lower current. The lower frequencies are allowed to flow the full length of the element but meet considerable loading at key points in order to maximize current flow in as much of the antenna length as practicable. Since we are talking about 5 different frequency bands, this becomes a very complex “juggling act”.

Now, consider duplicating the one element and positioning it horizontally opposed to the original element. Now we have a multi-band horizontal dipole. Commercial versions of this type antenna are available from several manufacturers including MFJ, Mosley, Cushcraft, and M2.

Positioning other resonate dipoles near this horizontal radiator, at specific distances, we can direct our signal and improve overall gain in comparison to the dipole alone. Voia La! We have the multi-band beam antenna.

In beam antennae, directivity and gain are the two most important factors of design. It is quite often the case that one is slightly sacrificed for the other in order to meet other design factors such as cost or size. That is why there is no less than 30 different 3 element Yagi designs available for the amateur. Each major antenna manufacturer has one or more of these designs for various frequency ranges – single band and multi-band and with differing gain and directivity characteristics.

A unique variation of the multi-band Yagi is the log periodic dipole array (or LPDA). This design attempts to provide a smooth impedance curve over a very wide frequency range. It is not unusual to see log periodic designs that span several bands. There are no “traps” or other resonating elements in this design. Instead, many self-resonate elements of varying lengths are combined. The variation in length and spacing follows a logarithmic progression (hince the name “log periodic”). In this design directivity and gain are compromised (vs. the Yagi design) to provide a very good match on a very wide frequency range. Commercial designs for marine and ham bands span frequencies from 4.5 mHz to 30 mHz with a very good SWR range over the entire bandwidth of the antenna design. The chart below is an actual graph of SWR for a commercially available log-periodic.

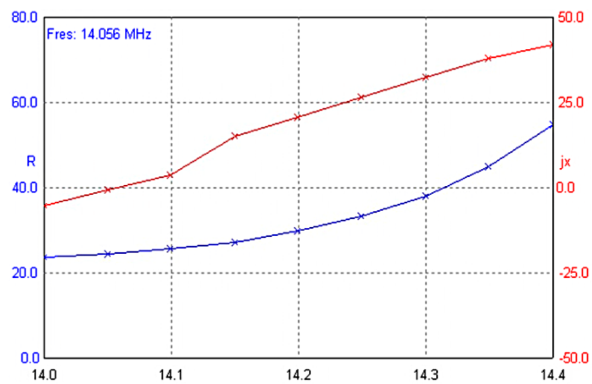


Courtesy M2 / ArraySolutions 2006

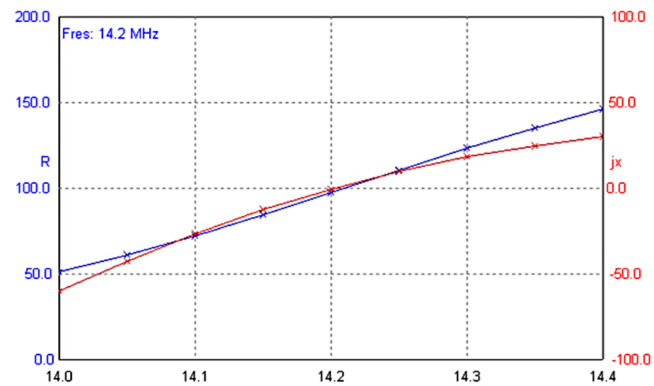
It is easy to see why this type of antenna is so appealing. The SWR curve only goes above 1.8 at the very high frequencies. An antenna of this type makes it possible to operate comfortably on all but the 80 and 160 meter frequencies. The prohibitive factors for most hams is: #1 Cost, and #2 Size. This guy is BIG! It has a turning radius of 65 feet! And you should know that it takes the budget of a small country to buy it. Homebrew construction techniques could render a similar design cost effectively if the size could be accommodated. The SWR graph is of one particular commercial antenna spans a 7:1 frequency range. Fewer elements and a less severe frequency span would make construction simpler and probably cheaper. Similar performance should be expected from any log-periodic design. Software design programs available online, are available to aid the homebrew constructor. It should be noted that fewer elements usually result in a more dramatic SWR curve over the same frequency span of the design. Adaptation to supported wires in a frame could make a log-periodic design very affordable for 40 – 10 meters with very good results given adequate real estate to put it up. The down side is it is stationary – so you would have to construct it in the direction most used or desired.

# Vertical and Horizontal Loops and Quagis

In an earlier chapter we discussed the traditional Yagi as an array of horizontal dipole radiators in close proximity. The proximity/gain/directivity displayed in the Yagi is also displayed with other antenna types, such as the vertical loop array. An array of vertical loops in an array similar to the Yagi exhibits similar characteristics where proximity effect of the elements, increase in gain, and directivity are concerned. A comparison of these characteristics will reveal some interesting features of this antenna type. Below is a side by side comparison of the reactance displayed by a 4 element Yagi and a 2 element Quad beam.

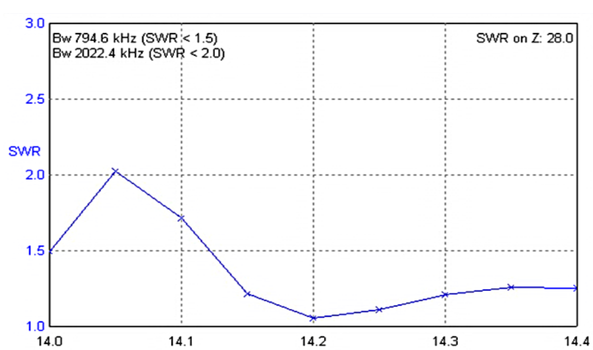



4 element Yagi

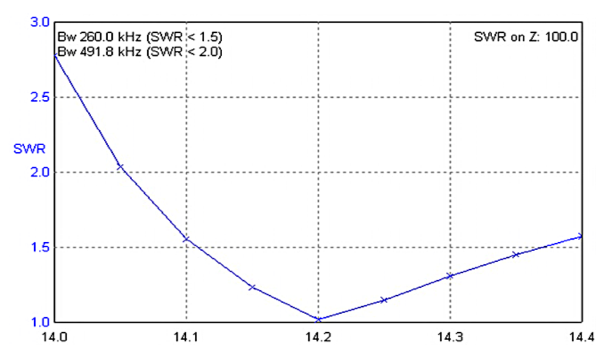



2 ekement Quad Beam

One of the first things to notice is the dramatic difference in the range of the real values between the two antenna types. The Yagi beam ranges from about 22 ohms to 56 ohms over the 20 meter band. The Quad beam on the other hand ranges from 50 ohms to 150 ohms over the same band segment. In terms of transmission line matching, the obvious conclusion to be drawn is that the Yagi can be directly connected to 50 ohm coax with some variations in SWR while the Quad beam requires an impedance transformation to 50 ohms in order to lower the overall SWR to an acceptable level. Assuming these parameters, the next illustration compares the SWR over the band segment used for these two antenna types.




4 element Yagi SWR




2 element Quad Beam

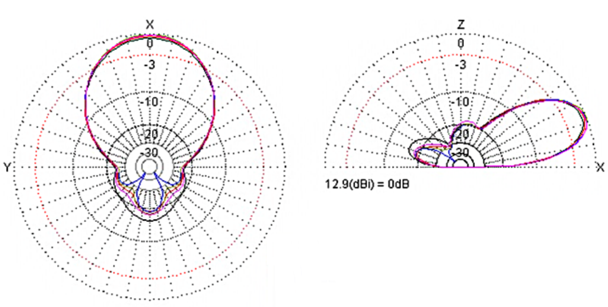
Observation of this comparison reveals one obvious feature of Yagi antennas that make them very attractive. The SWR over the entire band is 2.0 or lower even to the band edges for 28 ohms reference. This wide band performance and low impedance can be some of the compromises designed into a Yagi.

The Quad Beam on the other hand has a distinctive "notch" in the SWR curve at the resonance point with a much narrower bandwidth below the 2.0 SWR value for 100 ohms impedance. This can be a good thing where adjacent band interference is common for your location. You should also note that the ultimate SWR value at resonance is almost a perfect match (1.06:1). If your common operating frequencies are in the frequency range that yields a 1.5:1 SWR or lower, This type of antenna tuned and optimized for the center of your normal operating segment can be extremely effective.

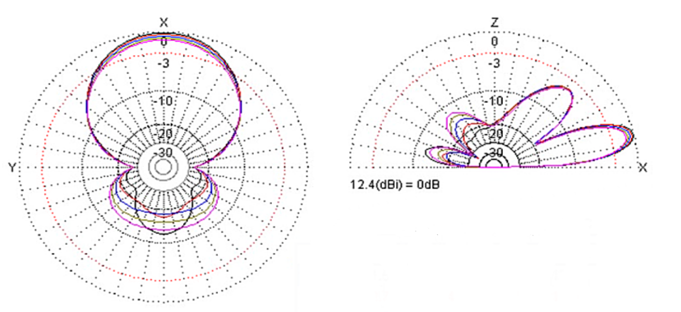
There are some myths associated with the Quad beam that we must discuss. One such myth is that the Yagi will outperform the Quad beam in all applications. One only has to look at the origins of the Quad antenna to completely break this myth wide open. The quad was invented because a Yagi used at high attitudes generates a considerable amount of corona discharge due to high voltage being present at the high impedance points along the antenna. The inventor Clarence Moore (W9LZX) correctly reasoned that a loop antenna would not develop nearly as much high voltage and consequently less corona than the dipole based Yagi (*see the ARRL Antenna Book pp 12-1 20th edition*). In the thin air of the Andes mountains his new antenna indeed did significantly lower the corona discharge while transmitting.

To understand this reasoning one must recall the current distribution of a dipole antenna. Current is very high at the feed point and low at the end points. Applying Ohm's law we can conclude that the real part of reactance is low at the feed point and high at the end. Ohm's law would also prove that the voltage present at the feed point would be much lower than at the end point. If we apply power as a variable, Ohm's law for power circuits again proves that it is possible to generate very high voltages at the end of a dipole while only modest increases in power at the feed point. The Quad loop antenna has no such endpoint. The dipole is effectively folded over upon itself with the ends connected together. However, the Quad loop is usually one wavelength long rather than the traditional quarter wave or half wave of the dipole.

Since its development and popularity, the controversy has raged as to which is the better performer – Quad or Yagi. The only objective way to evaluate this myth is to compare calculated and measured performance using modern methodology. Computer modeling reveals that performance related values are of negligible difference where gain and front to back ratios are concerned where bandwidth and boom length are roughly the same. The Quad has a slight (1 db) gain advantage while the Yagi always wins the bandwidth battle where both are optimized and tuned for the same band segment. The obvious differences become apparent when viewing the characteristic radiation patterns of these two antenna types. The next illustration compares the calculated radiation patterns of each over normal surroundings and no obstructions.




4 element Yagi




2 element Quad Beam

The obvious difference between the two are the apparent wide main lobe of the quad and the relative narrow main lobe of the Yagi. Another apparent difference is the broad rear lobes of the quad and the much smaller and narrower rear lobes of the Yagi. This difference will become less apparent when the same number of elements and boom length are maintained for each antenna type. A less obvious feature would be the elevation of the main lobes of the two antennas. The Yagi has only one main lobe at approximately 22 degrees elevation. The quad on the other hand has two main lobes – one at 14 degrees and another at about 45 degrees. If we apply a small amount of knowledge of propagation for DX to these radiation patterns, we would conclude that the Yagi is a great performer where a signal arrives at a low angle. But when high angle signals are prevalent, the quad would out perform the Yagi. This broad DX performance characteristic is what makes the Quad Beam so popular, notwithstanding the significantly lower cost of construction. The Quad Beam has suffered some durability weakness in the past. New construction materials and techniques have made modern commercially available, and home built Quad beams quite durable in warmer climates. They are, however, still very vulnerable to heavy ice and snow damage.

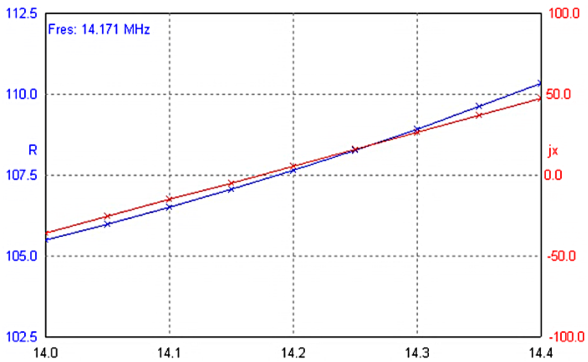
The next myth to dispel is that the Quad beam performs better than a Yagi at low heights. A comparison of the two antenna types with the same number of elements and similar boom lengths would reveal that each would have roughly equal performance at the same heights. Antennas of all types suffer the effects of ground proximity.

One note is worthy of comment at this point. The Quad beam radiating element can be electrically polarized vertically or horizontally without changing the position of the array. This accomplished by feeding an adjacent side or corner of the radiator. Quad Beam arrays are constructed for one polarization or the other and rarely accomplish both with equal performance. Depending on the band, matching techniques are very similar. The feed point impedances are very similar and a balun is used to convert the nominal 100 ohms to 400 ohms or 50 ohms for the feedline if coax is used. Quad beams using "ladderline" and no balun are very common although slightly more difficult to construct.

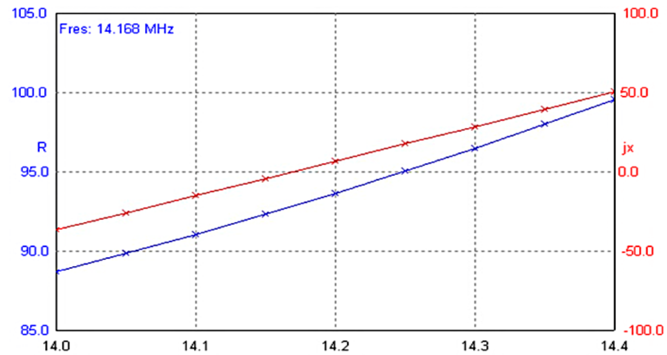
The Quad Beam does enjoy one advantage over the Yagi. That is that the quad element configuration provides some noise immunity from terrestrial and man-made noise sources. The key word here is SOME. The horizontal orientation of the conventional Yagi antenna lends itself to receiving noise from horizontally polarized sources like electrical power distribution lines. This type of noise is marginally lower with a quad loop element antenna.

The horizontal loop is well known to be a very quiet antenna where terrestrial and man-made noise sources are concerned. This type of antenna is of simple construction but requires considerable real estate where the lower bands are desired. It may be fed from the center of any side or from a corner, depending on the impedance desired and the radiation pattern selected. It can be of long wire or current loop design (both feedline connections to the antenna).

For instance a horizontal loop antenna for the 80 meter band would be 259.2 feet long, or a square of approximately 62.5 feet to a side. The horizontal loop is very sensitive to ground proximity so it must be located at a height that produces the desired radiation pattern and feedpoint impedance. The illustration below is for a horizontal loop optimized for 20 meters at the optimal height and 2 meters higher.

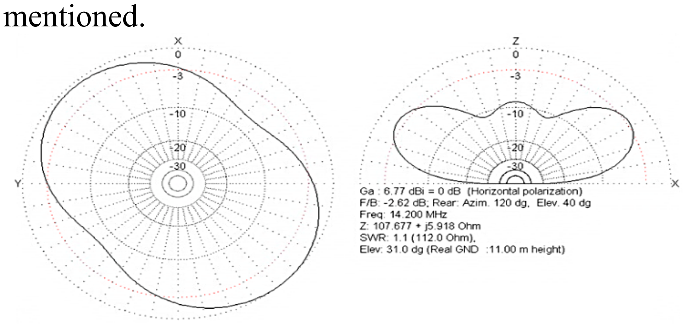



Horizontal Loop at 11 meters up

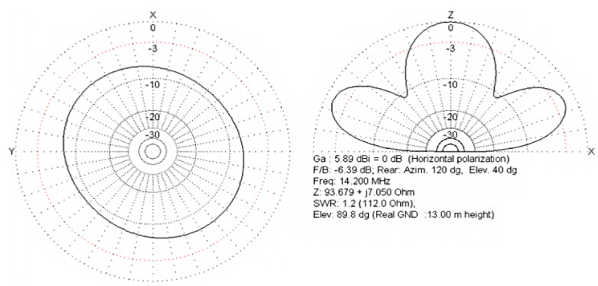



Horizontal Loop at 13 meters up

Either case presents a manageable impedance to the feedline using a 2:1 balun for 50 ohm coax. Other heights may be chosen for other feed line impedance match situations. However, impedance matching is only one compromise we must make for this type of antenna. The next illustration shows the difference between the radiation pattern of the same antenna at the two meter difference in height mentioned.




Horizontal Loop 11 meters up




Horizontal Loop 13 meters up

The radiation pattern varies significantly as does the feed point impedances. *Note: the oblique angle of the radiation pattern is due to the position of the feed point – a corner.* You must make your height selection and feed point selection based on your operational practice. Obviously, an antenna designed for use in DX contesting will be of a different height than one for general communication. The point to remember from this section is that no matter what configuration the antenna may take, the ground exhibits a significant influence on the characteristics of the antenna impedances and radiation pattern.