

# Some Notes on FM BC Antennas

## Part 5: The Batwing Antenna and Array



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In all of the preceding episodes of this series, we have looked at conventional antennas whose elements were all in the same horizontal plane. As we move toward higher and higher gains in these antennas, the boom lengths grow ungainly and more difficult to support, especially if one is using a light mast system. In a neighborhood of non-hams, even 7' of boom extending from each side of a mast can look dangerous and threatening.

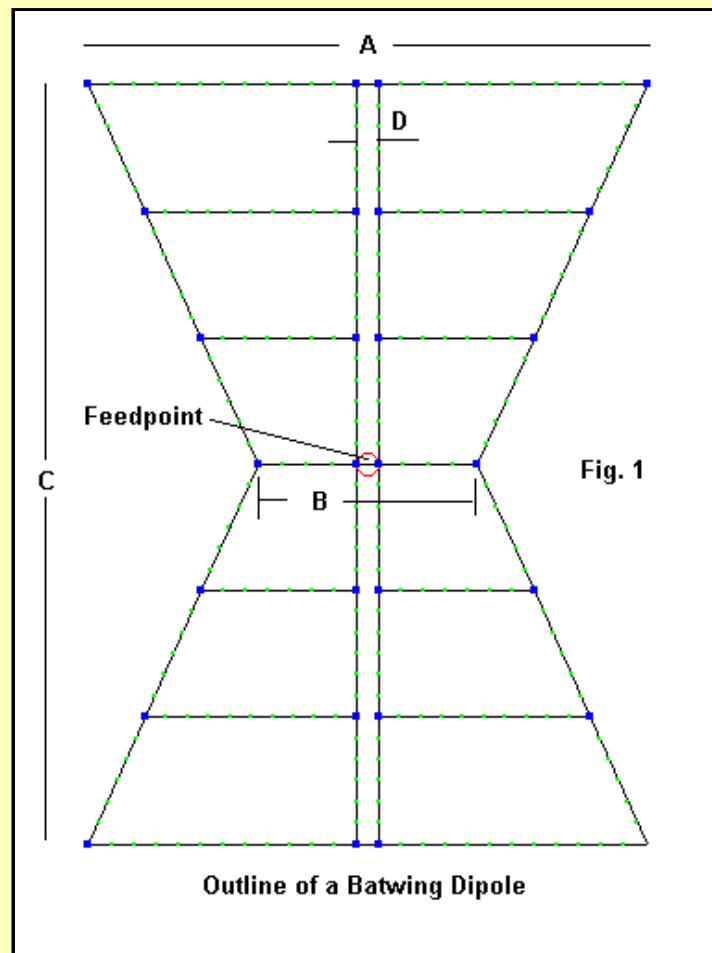
There are ways to shorten the boom. The chief means is to begin with an antenna that has width and height instead of length and width. Enter the batwing, one of the broadest band dipole-type antennas available. With suitable construction, the batwing can cover the FM band either as a dipole or as a directional beam.

As we shall see from the dimensions, it may not be easy to build a batwing. However, for some, it may offer a construction challenge and fool the neighbors into thinking that your home is a cell tower.

Let's take matters a step at a time, and begin with the simple batwing.

### The Batwing Dipole

To understand why the antenna bears the name "batwing," we only need to look at **Fig. 1**.



The outline sketch shows the general shape of the antenna. It consists of dipoles of different lengths, with all of them connected at the outer edge, left and right. Although fed at the very center, the inner vertical lines form a transmission line to distribute energy. As we change frequency, the most active elements above and below the vertical midpoint also change, with longer elements being more active at lower

frequencies. However, to some degree, every element is active on every frequency within the design range.

The sketch shows that the transmission line is shorted at its upper and lower ends. Performance is not affected by this short. However, the top and bottom shorts do make handy points for attaching the batwing dipole to a non-conductive mast.

The letter designations mark out the most important dimensions. A is the broadest width, and b the shortest at the center. C marks the total height. The two intermediate horizontal elements above and below the center element are equally spaced. Hence, one may deduce their exact lengths by taking a line between the outer end of A and B and using either 1/6 or 1/3 of C (upward or downward) as their vertical positions.

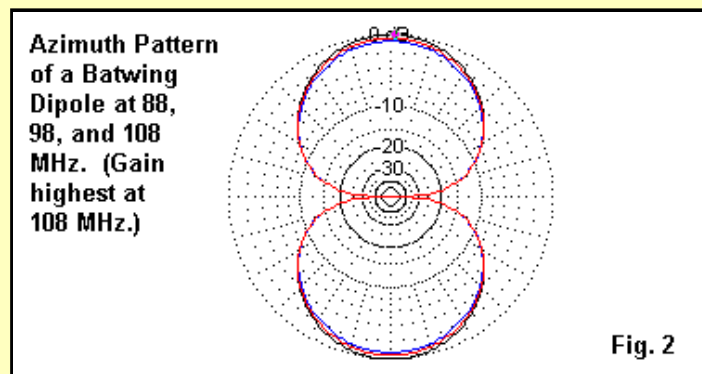
D is the center-to-center spacing between the phase lines. The distance between these lines is designed for 0.5" diameter material. The remaining structure can use materials from 0.1 to 0.5 inches in diameter. However, it is wise to make the top and bottom shorting "bars" of the larger material to form solid support points for the entire antenna. Below is a table of dimensions for a batwing dipole suitable for 88-108 MHz.

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**Batwing Dipole Dimensions**

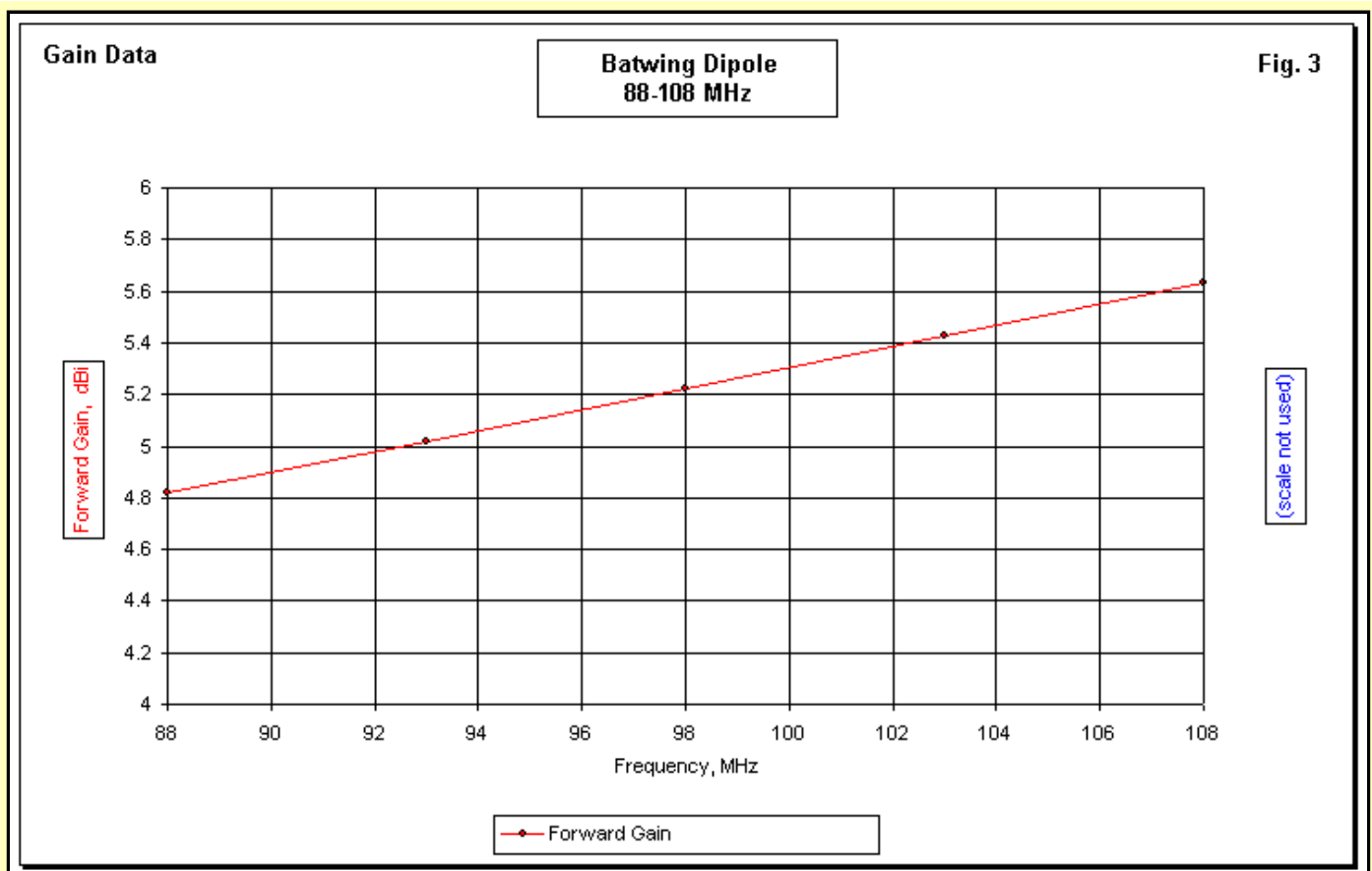
Dimension	Length in Inches
<b>A</b>	<b>57.70</b>
<b>B</b>	<b>22.73</b>
<b>C</b>	<b>78.39</b>
<b>D</b>	<b>2.22</b>

.....

The batwing dipole is nearly 5' wide and over 6.5' high. However, if you have a non-conductive mast section, you may mount the antenna directly to it without disturbing the performance. Hence, the mass of the antenna is well centered directly down the mast. Whether the connected elements hold up in the weather will depend upon the quality of construction.



**Fig. 2** overlays the azimuth patterns of the batwing at 88, 98, and 108 MHz. Although the 3 patterns are within about 0.8 dB of each other, the 108-MHz pattern is the strongest. In fact, **Fig. 3** provides the free-space gain curve for the batwing within the FM band.

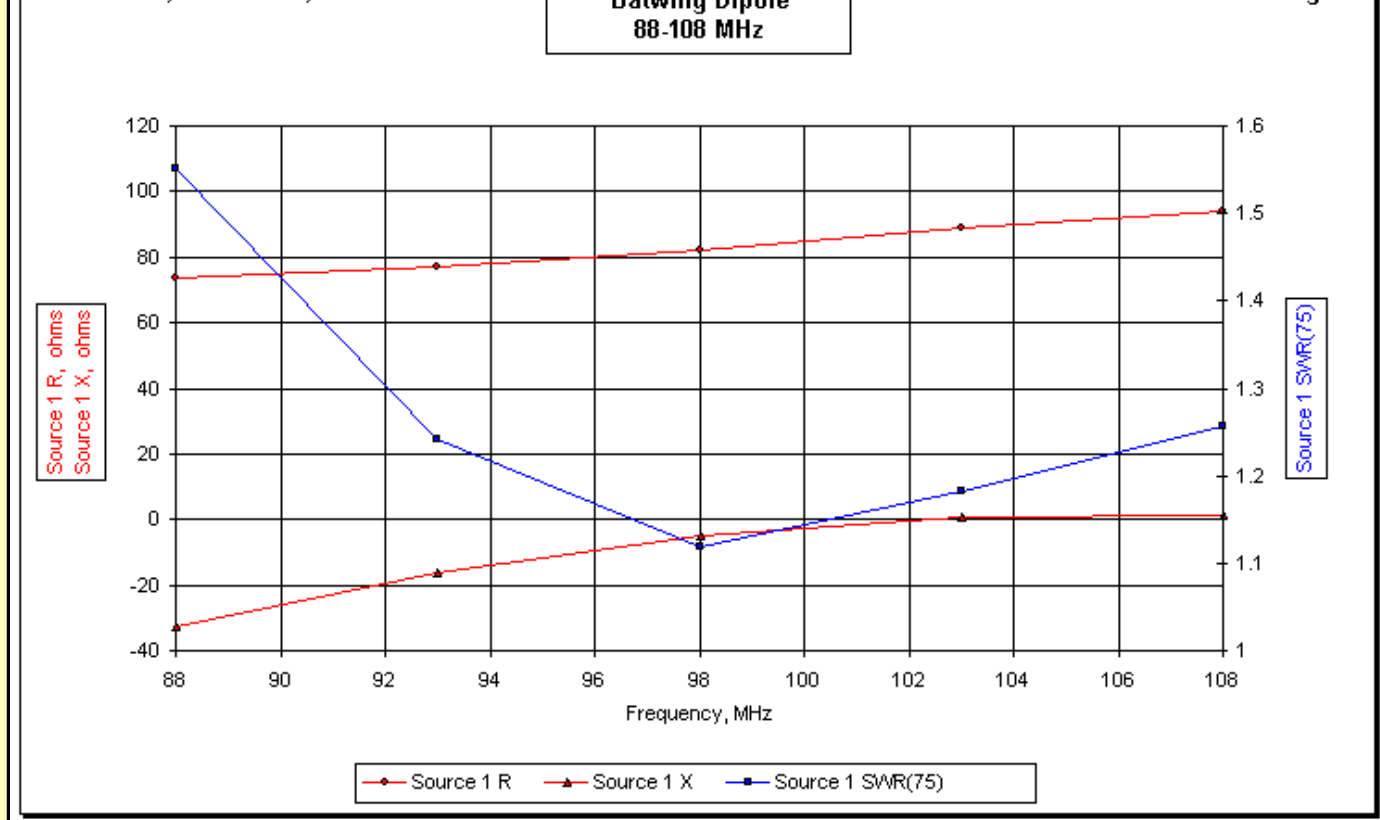


Now let's solve a bit of an initial mystery. The patterns in **Fig. 3** are virtually identical in shape to those of a simple dipole. In effect, the batwing has about the same beamwidth as a dipole, as indicated by the figure-8 pattern. However, a dipole in free space, when made from real materials, has a gain of about 2.1 dBi. The graph in **Fig. 3** shows a mean gain of about 5.2 dBi, about 3 dB higher. Whence cometh the gain?

Had we shown a free-space H-plane of elevation pattern for a dipole, it would be perfectly circular. In contrast, the H-plane patterns for the batwing resembles a peanut, with depressed gain at high angles above and below the antenna. The energy is not lost, but simply redirected broadside to the batwing plane.

As a consequence, the batwing antenna, besides being inherently broad-banded, has quite significant gain over a simple dipole. In some applications where rotation is not required and where there is no appreciable interference from the rear, relative to the direction of the desired station or stations, a batwing dipole may be quite sufficient as a receiving antenna. One may also rotate the mast, if the mast is sturdy. Rotation of 180 degrees is enough to cover the entire horizon. As noted earlier, however, we require a non-conductive mast in the region of the antenna itself. Alternatively, we may mount the antenna to a conductive mast by using non-conductive stand-off insulated braces connected to the top and bottom phase line shorting bars of the phase line portion of the antenna. We need to place the antenna a few inches away from the conductive mast so that it will not disrupt the characteristic impedance of the phase line.

With the suggested phase line, the antenna shows an inherent feedpoint impedance of about 75 Ohms. Hence, we may use standard cable industry coaxial cable as a feedline across the phase line position marked by the B dimension in Fig. 1. **Fig. 4** shows the benign 75-Ohm SWR curve for the basic batwing dipole.



The curve is based on the use of 0.5" diameter material throughout the batwing structure. Such a structure would likely be too weighty for practical use, especially if soldered together with copper. Going to 0.1" diameter material for all but the phase line portions of the dipole array does not hamper the gain; nor does it do more than slightly lower the frequency of the lowest SWR for the antenna.

The phase line has a particular characteristic impedance using materials of the specified diameter and spacing. If we change the diameter of the phase line material, we would need to redesign the dimension for the entire array, especially the spacing between the wires. With round wires, about the lowest characteristic impedance that we can obtain is about 80 Ohms. A closer spacing would lower the impedance, but unfortunately let the two phase line wires inter-penetrate each other. The surfaces of the listed phase line wires are about 1.72" apart (2.22" center-to-center), for a characteristic impedance of about 260 Ohms. The feedpoint impedance for this antenna is nominally about 1/4 the characteristic impedance of the phase line.

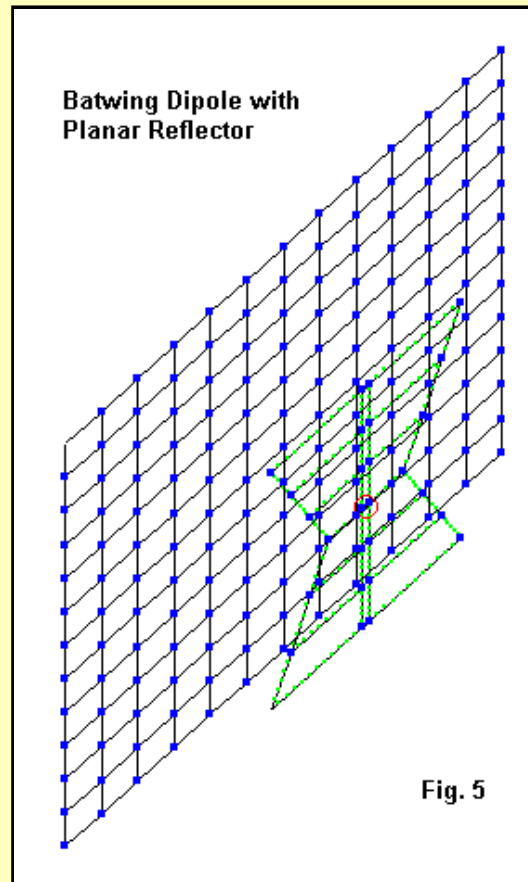
If you construct the phase line from copper tubing, be sure that the outside diameter is 0.5", not the inside diameter. L-couplings allow soldering a complete and quite strong center for the array. If you use 0.1" diameter (about AWG #10) copper wire for the remainder of the structure, then the construction of junctions becomes the main issue. Wire bends upward or downward for soldering to the phase line tubes on the portions away from the parts facing each other will have virtually no effect on the phase line impedance. In fact, the soldered portions might easily be strengthened with fasteners to the phase line tubes.

The goal is a strong final structure able to withstand the effects of weather. I have not tested the effects of adding a thin (for example, sprayed on) protective coating. However, bare copper will degrade under the influence of the chemical soup of the modern atmosphere, despite the pleasing green patina that might give the antenna an antique appearance.

Commercial manufacture of a batwing can use modern welding techniques to produce a very strong assembly with materials more impervious to atmospheric variables. However, the home craftsman is more limited in the available materials and techniques for assembly. Hence, the batwing dipole array is a distinct challenge.

### Adding a Reflector

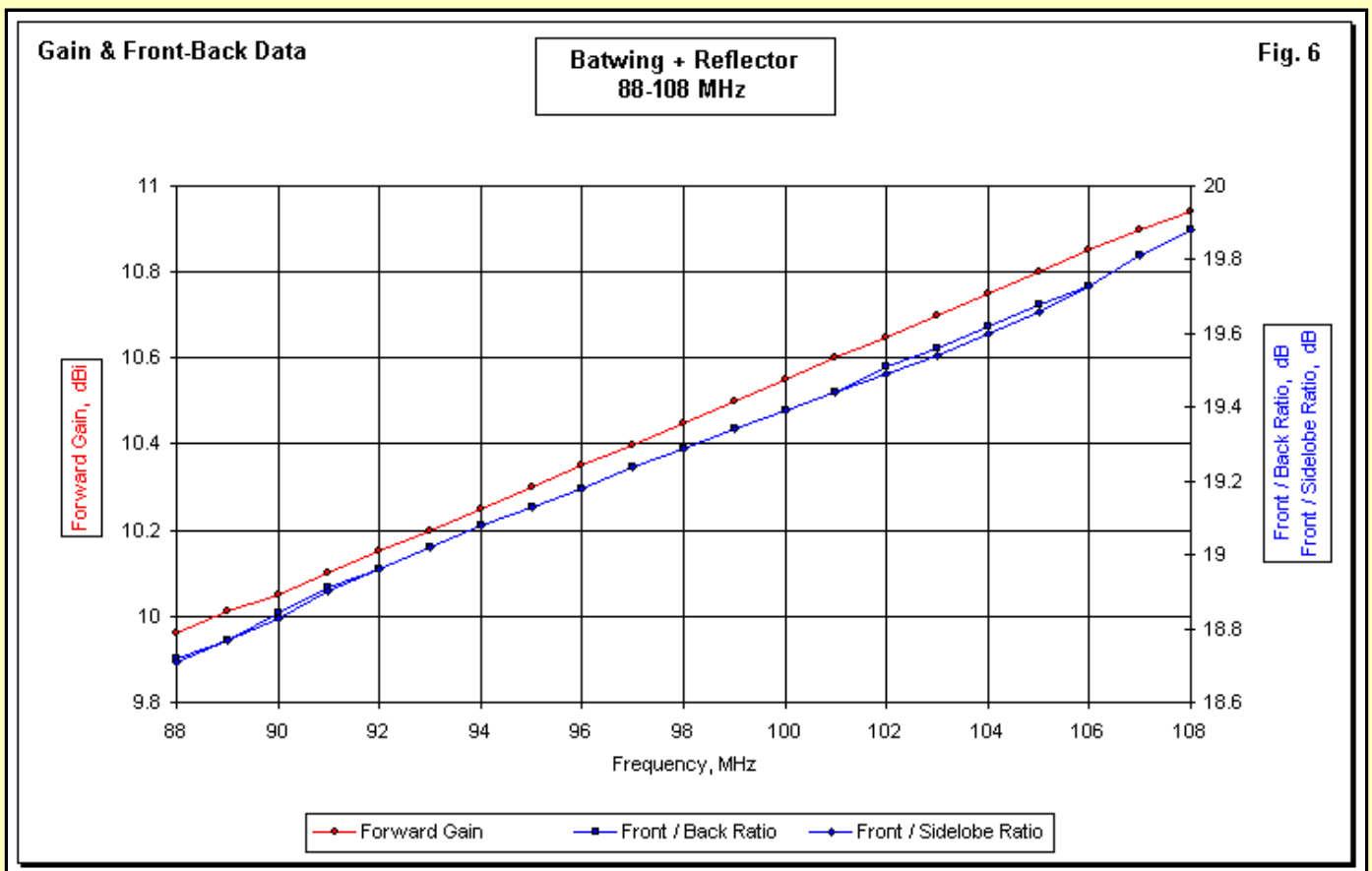
We may increase the forward gain of almost any single dipole or planar array of dipoles by the simple expedient of adding a sheet reflector behind the active antenna. The batwing is no exception. Adding a planar reflector at a given distance will convert the bi-directional batwing into a directional beam of considerable performance. **Fig. 5** shows the outlines of such a system.



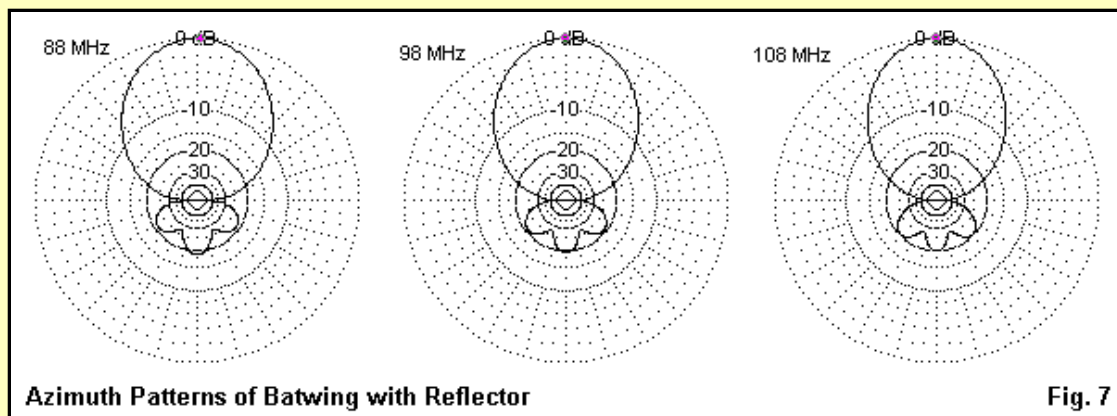
The sketch is tilted to make as clear as possible the different parts of the array, namely the batwing dipole and the reflector. The batwing portion has exactly the same dimensions as the independent dipole array that we have been exploring. Immediately apparent in the figure is the fact that the reflector outside dimensions are considerably greater than the 57" by 78" outline of the dipole array itself.

In fact, the gain of the system is dependent to a large degree on the size of the reflector behind it. Our test case uses a reflector that is about 133" on a side--or about 11', that is, about 5.5' each side of the mast. For improved performance over the figures that we shall encounter with this model, extending the reflector screen horizontally will do more good than extending it vertically.

However, with the planar reflector shown, the batwing beam provides very good performance. **Fig. 6** shows the anticipated gain and front-to-back data with the dipole array about 22.2" in front of the reflector.

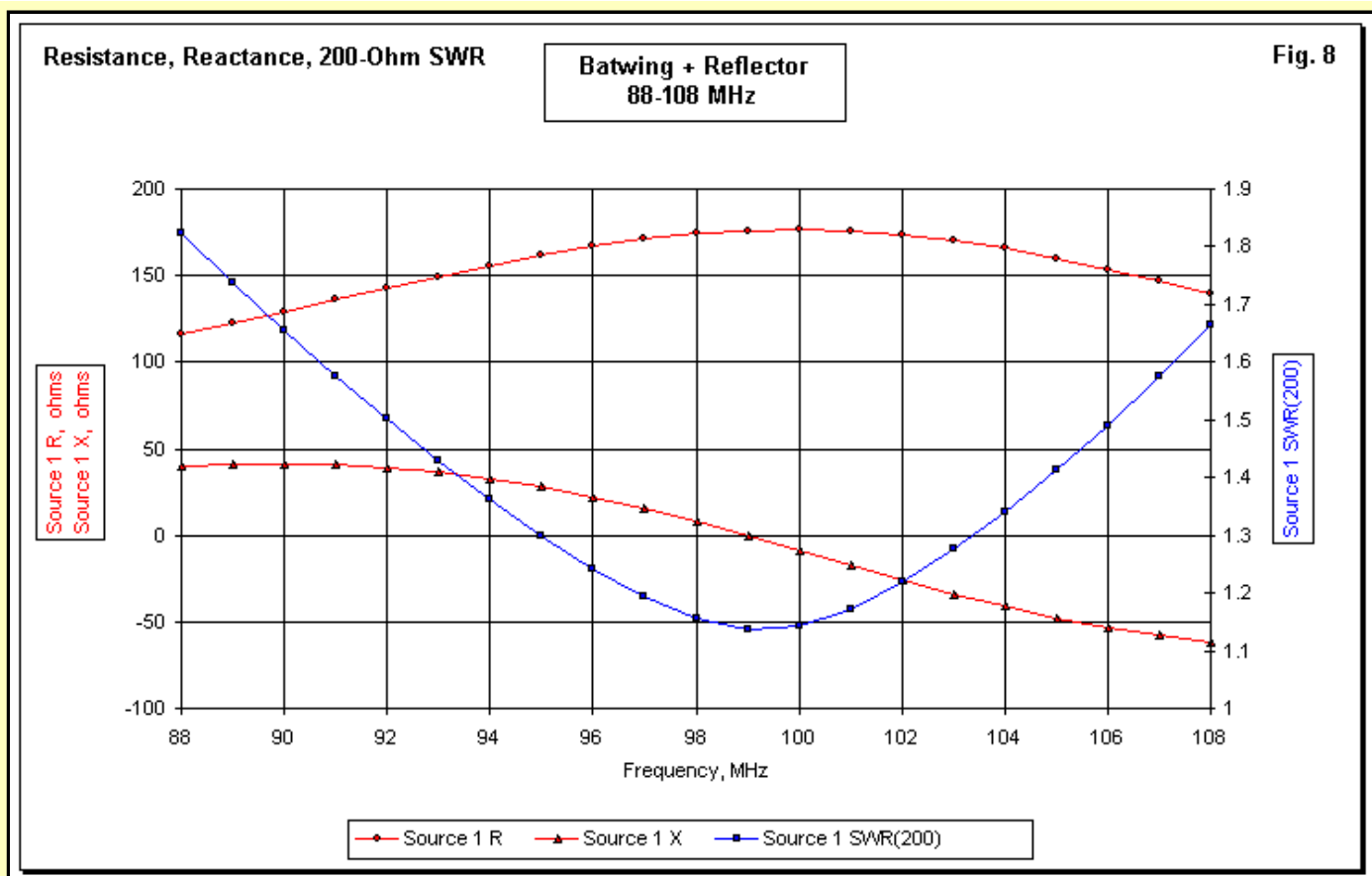


Except for a few frequencies at which there is a very slight difference between the 180-degree and worst-case front-to-back ratios, the two curves are one. The front-to-back curve parallels the gain curve, as the array copies the basic batwing characteristic of showing increasing gain with frequency. In fact, the gain increases by about 0.9 dB across the FM broadcast band, ranging from 10.0 dBi at 88 MHz to 10.9 dBi at 108 MHz. Over the same range, the front-to-back ratio increases from 19 to 20 dB. These changes are not likely to be detectable in terms of reception of distant FM stations.



In **Fig. 7**, we find a very desirable trait in antennas. Over the operating range of the array, the shape of the azimuth pattern, both fore and aft of the array, does not change at all. The forward lobe is a single oval that has a somewhat narrower beamwidth than an LPDA of comparable gain. The rear triple lobes are of modest strength. (Indeed, for comparative purposes, we might note that the narrower beamwidth of the batwing beam might be useful if interfering stations are forward but off to the side of the desired station. In contrast, the very high front-to-back ratio of the LPDA would be more desirable if interfering signals are to the rear of the array.)

The limiting factor for the batwing beam is the match to a common feedline value. The mid-band resistive component of the feedpoint impedance is about 170 Ohms. A 4:1 transformer would lower this value to about 42 Ohms, a reasonable match for 50-Ohm coaxial cable. However, the resistance value tends to decrease both above and below the design frequency, and there is also some reactance. The result is a 200-Ohm SWR curve that is quite steep (where the 200-Ohm reference value is a stand-in for the 50-Ohm reference after we add the 4:1 transformer).

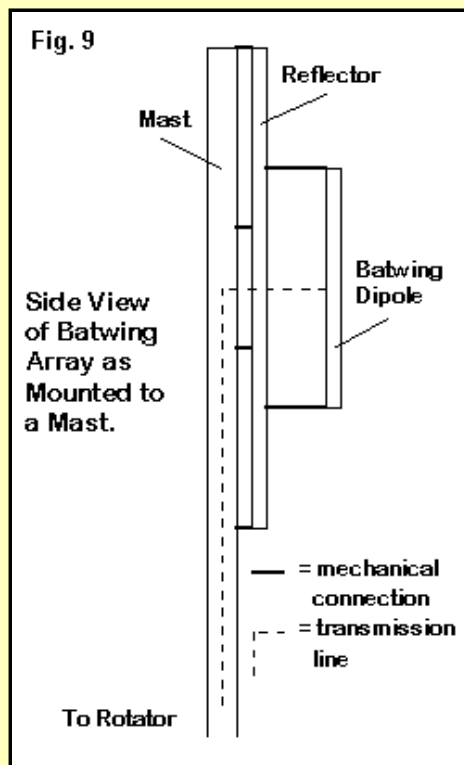


As shown in **Fig. 8**, the SWR never reaches a 1.9:1 value, although it rises higher than the values we might associate with a large LPDA. Nevertheless, the indications are that the batwing array would serve very well as a receiving antenna for the entire FM broadcast band.

The fact that we are accustomed to antennas that extend mostly in the horizontal plane may give the batwing directional beam an imposing, if not daunting, appearance from the perspective of the home builder. We can alleviate some of the dread in a couple of ways.

First, the reflector need not be a solid surface. In fact, a solid surface would not only be too heavy for most home installations, but as well give enough wind resistance to destroy the array in one or two major storms. Fairly wide aluminum mesh, commonly called chicken wire, should be sufficient to form a fully reflective surface. As long as the openings in a mesh are less than about 0.1 wavelength across any dimension, the screen will likely serve as an electrical solid. 12" openings represent to upper limits, although something of the order of 1-3 inches is more desirable from a structural standpoint. As well, the wire need not be very thick, just thick enough so that it does not deform readily within the frame. The object is to slip as much of the wind as possible while maintaining electrical and structural integrity.

Essentially, construction of the reflector will consist of an aluminum frame within which we attach the screen wire. The design of the frame will vary with the screening selected or available. A central vertical rib of some sort is necessary for two reasons. We may attached the rib directly to the mast, since the reflector can be at ground potential. As well, from this central rib, we need to provide supports for the batwing dipole portion of the beam.



**Fig. 9** shows in barest outline form the critical support points for the array. Although the sketch shows the reflector separated from the mast in order to designate connection points, the reflector may attach directly to the mast. The more critical connections are the required non-conductive supports that attach to the top and bottom of the batwing dipole and hold it 22.2" ahead of the reflector. If we run the transmission line through a non-conductive tube at the center, we acquire a third mechanical support.

## Conclusion

We have not come near to covering all of the antenna designs that we may apply to the FM broadcast band to improve reception sensitivity. Our goal has been to move toward a better understanding of the problems involved.

First, there is the question of what sort of reception improvement we need. A simple improvement in general sensitivity allows us to place a basic simple antenna in the attic or on the roof. However, if we need to separate stations at a considerable distance from potentially interfering local stations, we may need a directional beam placed as high as we can effectively support and maintain, with the additional potential need to rotate the antenna.

In the arena of directional beams, we need to decide what frequency coverage we must have and how best to obtain it. Standard Yagi designs--narrow-band in FM terms but relative broadband in Yagi design terms--will let us select the level of gain and the portion of the FM band we need.

For full band coverage, we turn to more complex antenna designs. We can choose a Yagi if we are willing to have a considerable gain change across the band, accompanied by only moderate front-to-back performance and rather fat elements. If we wish to achieve maximum front-to-back performance to reject stations to the rear, then a long LPDA may be in order, although its construction is more complex than building a Yagi. If we prefer to have the gain with a level of front-to-back performance between the Yagi and the LPDA, but without the long boom needed for either one, we may opt to try a batwing directional beam.

For full band coverage, moderate gain, very good front-to-back performance, good matching, and only reasonable levels of complexity in construction, the 8 element 88" long LPDA may prove to be the best all-round antenna. However, be aware that FM DXing can become addictive. Once we can comfortably listen to all of the first order targets we had in mind before we built the antenna, we shall then discover other stations at a greater distance that we cannot quite bring to full quieting. The discussion that follows is never of the order of whether or not to bother with those stations. Instead, we present ourselves with the following alternatives: to construction a taller and more complex support system to extend the current antenna's horizon or to build a larger antenna with high gain. Eventually, the addicted FM DXer does both.

As well, there are other antenna designs to explore, each with its own potential and with its own challenges. FM DXing takes on a life of its own. These notes are only a start in that direction.



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