BUILD A HIGH-PERFORMANCE LOW-PROFILE 20-METER BEAM

This neighbor-friendly antenna performs like a big beam

With the fast declining sunspot cycle, 20 meters remains one of the best choices for amateur radio communications. However, due to current marginal conditions, once successful wire and vertical antennas have become increasingly difficult to use on this band. In addition, local QRN can make DX almost impossible to work with these antennas. I soon discovered for myself the old Ham saying, “if you can’t hear them, you can’t work them.”

For the past several years, I’ve tried some compromise antennas that promised the world but delivered little. I needed good performance in a simple, but efficient antenna that would work well under local QRN. A full-size 20-meter beam was desirable but out of the question because of limited space, and a tower height of just thirty feet. While miniature antennas were commercially available for 20 through 10 meters, I decided against them because of their many compromises.

In the end I concluded that, for my application, it would be better to design and develop
Design criteria

I started work on the project with a literature and product search which revealed that two-element short beams perform well when compared with full-size beams having the same number of elements. I then used a computer program to model the design. The reference literature stated clearly that in two-element Yagi designs, long booms are undesirable because gain falls off with boom length. This is primarily due to reduced excitation of the parasitic element as the spacing increases. Invariably, the largest gains are obtained at small spacing. The paper design showed a theoretical isotropic gain of 7.1 dBi for the two-element beam. (Note: Antenna gain is referred to as the gain over a fictional isotropic antenna which has the same radiation intensity in any direction.) According to the literature, if one wishes to obtain good gain with a fair front-to-back ratio over a bandwidth of say ±10 percent, a boom length of about 0.15 wavelength will provide an optimum isotropic gain of about 7.5 dBi. However, experience proves that the boom’s length can be reduced further. A more practical 0.1 wavelength will provide almost similar performance if care is exercised when tuning the elements (see Figure 1).

The literature search showed that efficient short beam antennas have been described by Walsh, by the ARRL’s 1970 edition of The Radio Amateur’s Handbook, and by several others. A short two-element beam known as the Trim-Tenna (TT-20) was manufactured briefly by Dentron Radio in the 70s.

With the exception of the TT-20, these older designs used capacitive hats and gamma matches to achieve efficiency. I decided to take such a design, streamline its physical characteristics, and optimize it electrically for even better performance. To achieve this goal, the new beam uses very high-Q inductors for increased gain. The enhanced performance is also due to the proper placement of these inductors and a simple method of matching the driven element to the transmission line.

The final beam uses short, electrically lengthened elements of about 16 feet for the driven element and 14 feet for the reflector. The boom 0.1 wavelength on 20 meters (7 feet). I selected this length after considering the previously stated criterion. I also felt it was the best compromise between efficiency and bandwidth on one hand, and gain versus front-to-back ratio on the other.

In the actual implementation of the beam, I
have optimized the peaks on the gain curves from Figure 1 for the 0.1-wavelength spacing. I did this by adjusting the lengths of the two elements so that their coupled mutual reactance would be optimum at resonance. Consequently, the forward gain performance of the two-element beam approached that of a theoretical three-element beam. The only difference I noticed was in the front-to-back ratio, which is better for the three-element design. I rationalized that the limited front-to-back ratio (6 dB) was a good tradeoff for the reduced size of this antenna.

The key to the beam’s success lies in the location of its coils. I minimized losses by placing the loading coils closer to the ends of the elements, where loss-resistance is at a minimum. This resulted in lower current distribution patterns that increase current flow on the elements rather than the coils, thus increasing gain. (Note: In some antennas loading coils are installed closer to the center of the elements and, therefore, can be less effective because of the higher current-distribution patterns that exist there.) I replaced the capacitance hats from the previous designs with simple aluminum tubing extensions. These were placed on the outer sides of the coils and mechanically supported with solid acrylic rods, also intended to provide DC isolation between the elements and their extensions (see Photo A).

The reflector is tuned lower in frequency (13.880 MHz) when compared with the driven element (14.200 MHz), providing improved front-to-side ratio. The element sizes were optimized through extensive experimentation. The front-to-side ratio for this beam tested at better than 18 dB. The beam has a minimum SWR of 1:1 and a maximum of 2:1 across the entire 20-meter band (see Figure 2).

Figure 2. SWR curve for the two-element short beam as installed at WB3JZO.

Actual gain measurements were made between my QTH and a friend’s house located 5 miles away. We placed the beam at the same height as a 20-meter reference dipole and took alternating measurements using an HP-8551B spectrum analyzer as a field strength meter. We consistently measured a forward gain of 8 dB, although theory shows that the gain of a small beam over a perfect dipole is only 3 to 5 dB. Tests over the long path with DL3KCT and others produced consistently superior results when compared with wire or vertical antennas.

The difference between the calculated and measured gain values can be attributed to having to make the measurements in an environment other than free space. After all, it isn’t possible to construct an absolutely perfect dipole; those exist only in theory. Ground con-

Photo B. Prototype installed on a 30-foot tower.
ductivity and proximity, the direction in which the antenna is aimed, interaction between the beam and dipole, and inability to construct a perfect dipole are all contributing factors to the difference in values.

Other design considerations

Mechanically, the beam uses seamless heavy-gauge hardened aluminum and has been tested over extended periods of time in the extreme climate of Minnesota. It has resisted winds of more than eighty miles per hour and temperatures ranging from −40 degrees Fahrenheit (also Centigrade) to +100 degrees Fahrenheit (or +38 degrees Centigrade) with no mechanical or electrical impacts. You could use softer aluminum tubing, like the kind found in hardware stores, at the cost of reduced mechanical strength (see Photo B).

I fed the system with RG-8 coaxial cable, matching it to 50 ohms through the natural capacitance of the driven elements to ground through the dielectric of the supporting fiber glass tubing. Figure 3 shows the details.

Construction

Figure 4 gives physical specifications for the beam. The construction is straightforward. I used 1/4 inch thick tempered aluminum tubing sold under the name ALCAD 6061-T6. This is the strongest aluminum alloy tubing commercially available and is especially intended for antenna work. In addition to aluminum and other elements, this alloy contains Titanium, Zinc, Chromium, Magnesium, and Copper.

I used several diameters of tubing in the beam. The boom was made of 1 1/2 inch diameter tubing. The elements were constructed of a combination of several diameters, from 1 inch through 1/2 inch, and 1/4 inch. You may choose to simplify this design at the cost of mechanical strength. For the inserts supporting and isolating the coils, I used 3/8 inch acrylic stock obtained from a local plastics house. The fiber glass insulating tube support for the driven element was 8 1/2 inches long and 1/4 inch thick. I inserted the two tubes for the driven element into the fiber glass tubing as shown in Figure 3 to form two 12-pF capacitors to ground. You can substitute a fiber glass vaulting pole from a sporting-goods store for the fiber glass.

I made the coils from B&W no. 3029-3905-1 stock. They are constructed of no. 12 silver-plated wire. The front coils have sixteen turns (11 µH), the back seventeen (12 µH). The prototype beam didn’t have coil covers. I observed
no signs of reduced performance on rainy days. In the final model, I fitted plastic covers made of PVC over the coils. Ample amounts of stainless U-bolts, saddles, and All-Stainless brand hose clamps were used throughout the design. Tubing was cut to size and slots were sawed at the ends for fitting.

Assembly and testing
For all parts and installation refer to Figure 4. The boom is assembled by installing the 5 1/4 inch mast-mounting plate in the center of the boom (3 1/4 feet away from either end). Tighten the 1 1/2 inch U-Bolts. Mount the element brackets at each end of the boom as shown in the Figure 4. Make sure you align these brackets at a 90-degree angle to the mast bracket plane and tighten using 2-inch U-bolts.

To assemble the reflector, insert the two 6" x 3/8" tubes into one of the mounting brackets until they meet at the center of the 1" aluminum tube. Tighten the clamps and U-bolts.

To assemble the radiator, insert the other two 6" x 3/8" elements into the fiber glass insulator as shown. Make sure that only 6 inches of each elements' end is inserted into the assembly. Make sure the measurement for each side of the element is exactly 6 feet from the side of the boom to the tip of the pipe. Tighten all hardware except the feed point wire clamps, which will be tightened later. With an ohmmeter, check that the two pipes of the radiator aren't DC shorted together or to the boom.

Insert the radiator and reflector loading coils into the elements as shown using the acrylic plastic inserts and the 2" x 3/8" extenders and clamps. Make sure that the smaller coils (16 T) are installed on the radiator and the larger (17 T) on the reflector. Tighten all clamps. This completes the general assembly.

Final tweaking
With the dimensions indicated, the resonant frequency of the beam should be around 14.150
MHz. However, the actual resonant frequency of the antenna may vary from one location to another because of height and local environmental conditions.

Tune the beam at least 10 feet above ground and preferably at the operational height. If you make your final adjustments close to the ground, you'll find the resonant points will change when the beam is erected at its final height. You can use a grid-dip meter loosely coupled to one of the coils to verify resonance. A VSWR meter will also work well at the transceiver point. You can optimize the antenna for any portion of the 20-meter band. To increase the frequency of the beam, remove half a turn from the radiator element coils to gain about 150 kHz. With variations in the electrical ground, I advise you to use a tuner at the transceiver point to allow for any impedance changes. The tuner will also help to operate the beam as a dipole on the higher bands.

Performance

The antenna operates well without a balun. You could use a 1:1 balun at the feed point; this will improve the radiated pattern somewhat. However, use only heavy-duty, toroid-type baluns for good reliability. Avoid ferrite bifilar type baluns. Similarly, you could use 300-ohm balanced transmission line to feed this antenna, if you also use a tuner equipped with a balun.

This beam exhibits a good SWR ratio on 20 meters. However, if it isn't erected over a fixed groundplane, the variable water content in the soil can change the antenna's resonant frequen-

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### Table 1. Beam Specifications.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (MHz) (SWR 1.0)</td>
<td>14</td>
</tr>
<tr>
<td>Other frequencies (MHz) with tuner</td>
<td>J8, 21, 24, 28</td>
</tr>
<tr>
<td>Number of elements</td>
<td>2</td>
</tr>
<tr>
<td>Theoretical isotropic gain (dB)</td>
<td>7.1</td>
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<tr>
<td>Measured front-to-side ratio (dB)</td>
<td>21</td>
</tr>
<tr>
<td>Measured front-to-back ratio (dB)</td>
<td>26</td>
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<tr>
<td>Maximum continuous (or PEP) power (watts)</td>
<td>1500</td>
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<tr>
<td>Beam length (wavelength)</td>
<td>0.1</td>
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<tr>
<td>(feet)</td>
<td>7</td>
</tr>
<tr>
<td>Radiating element length (feet)</td>
<td>16</td>
</tr>
<tr>
<td>Director element length (Feet and Inches)</td>
<td>13.6</td>
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<tr>
<td>Turning radius (feet)</td>
<td>21</td>
</tr>
<tr>
<td>Calculated wind load (FT)</td>
<td>2.9</td>
</tr>
<tr>
<td>(Note: Wind load is specified for materials and construction recommended in this article.)</td>
<td></td>
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<tr>
<td>Weight (lbs)</td>
<td>15</td>
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</tbody>
</table>

* Using HP 8551B spectrum analyzer located 5 miles from source.
** Using FT-ONE TRX S-meter.

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**Conclusion**

This beam has provided consistently good performance on 20 meters when compared with my dipoles, inverted Vees, long wires, and verticals. The array does a better job, not only from a signal report point of view, but also by greatly attenuating the signals off the sides due to its outstanding front-to-side ratio of more than 18 dB. From an aesthetic point of view, the antenna keeps a very low profile. Although beauty is in the eyes of the beholder, this antenna has attracted positive remarks from neighbors and visitors alike.

**REFERENCES**