Wire Beam Antennas and the Evolution of the "Double-D"†

Need a compact beam antenna? Try this aerial, developed by one of our neighbors across the pond. Build one for your favorite HF or VHF band.

By Peter Dodd,* G3LDO

During March 1979, I wanted a beam antenna to take further advantage of the sudden improvement in conditions on 28 MHz. It had to be lightweight because of the tall, unguyed mast in use, and a quad was not feasible because of the obstructions encountered when the mast was tilted over. This article describes the development of an antenna that met these requirements.

VHF modeling is a well established technique and is used by many designers as a method of testing HF-antenna design.[1,2] Using this method to design different types of amateur antennas seems to be beneficial and has been used extensively in this project.

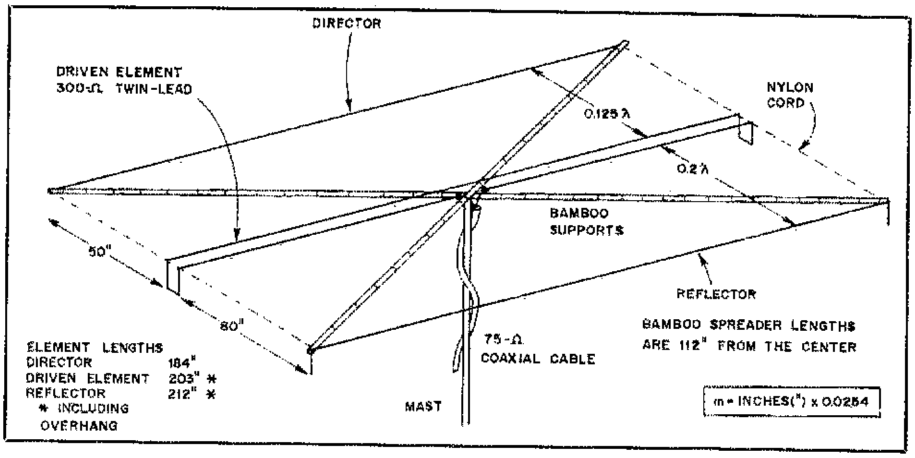

Fig. 1 — Construction details of a 28-MHz wire Yagi.

First Attempt

The first wire Yagi beam was constructed using graphs from *The ARRL Antenna Book* as a guide.[3] The wire elements were laid on a crossed bamboo support as shown in Fig. 1. The support was not quite large enough, and the driven element and the reflector were allowed to dangle over the edge of the support. The elements were pruned for a low SWR and reasonable directivity. The beam proved quite successful, giving an average improvement of two S units when compared with a dipole at the same height.

The only problems encountered were with the dangling ends of the elements, which caused fluctuation in SWR and, presumably, gain, in windy weather. Heavy rain caused an increase in SWR from 1.4:1 to 1.8:1.

Wire Yagi Experiments

To obtain some insight into the performance of the wire Yagi, a VHF model was constructed and measurements performed with test equipment used on previous tests.[4] The elements were pruned for minimum SWR and maximum forward gain, which fortunately occurred at the same element dimensions (Fig. 2). The driven element of the Yagi was not located halfway between the director and the reflector because it would be too close to the metal of the support mast.

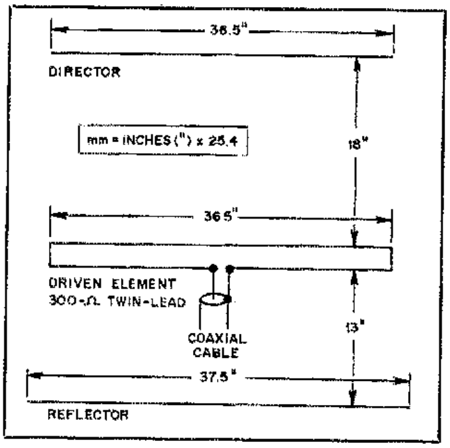

Fig. 2 — Dimensions of a 145-MHz Yagi optimized for maximum gain.

Antenna field strength was compared with a reference dipole whose performance had been optimized. The model performed as well as an all-metal beam at the center of the band, with a comparative directivity pattern shown in Fig. 3.[5]

These models were constructed from no. 18 wire, which gave a length-to-diameter ratio in the range of 10^2:1. When the model is scaled to the HF band, the range will be in the 10^3:1 region. The appropriate factor will have to be applied if the antenna is scaled directly from the VHF model, using the graph in Fig. 4. When an attempt was made to calculate the factors for scaling up, it was obvious something was wrong: On checking the dimensions of the model it was noted that all the elements were nearly 2 inches shorter than normal 144-MHz antennas.[6] The model was rebuilt using insulators at the end of the elements, and the tuning and testing procedure was performed again. The elements finished up slightly longer, but the increase was less than ¼ inch.

When the model was rebuilt a third time, using uncovered wire for the parasitic elements, the measured length returned to "normal" proportions, and it was evident that the insulating material had a loading effect. To determine the loading effect of PVC insulation, a 15-foot length of wire was measured for resonance using a GDO. The measured frequency was 31.1 MHz. This is very close to the theoretical value given by:

$$\ell(\text{ft}) = \frac{468}{f(\text{MHz})} \qquad \text{(Eq. 1)}$$

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[1] Notes appear on page 23.

† Adapted from an article by the same title in *Radio Communication* (RSGB), June/July 1980, p. 616.

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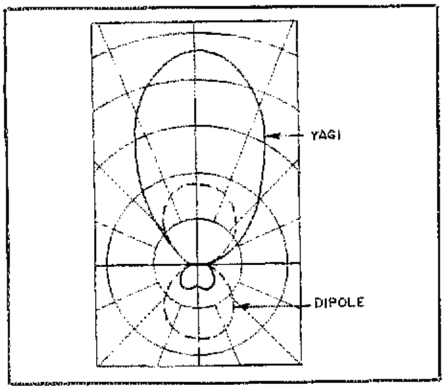

Fig. 3 — Wire Yagi and dipole directive patterns compared.

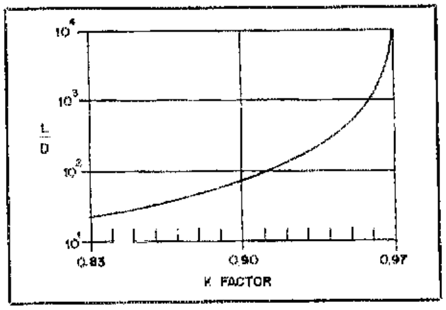

Fig. 4 — Graph of length/diameter correction factors for antenna-element lengths.

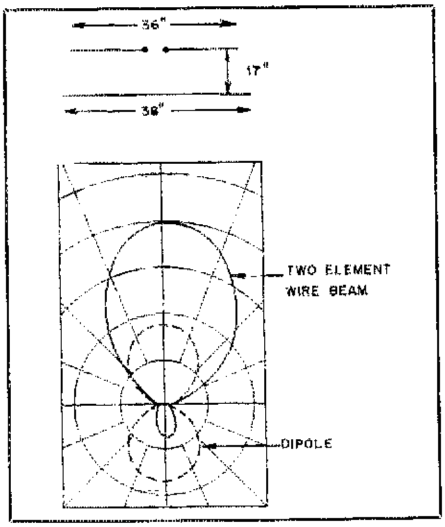

Fig. 5 — Two-element wire beam dimensions are shown at A. At B, the directive pattern is compared with that of a dipole.

Different thicknesses of a 15-ft length of PVC-covered wire were also checked, and were found to vary between 29.9 and 30 MHz. It would seem that the velocity factor of PVC-covered wire is about 0.965.

Two-Element Wire Beam

A two-element model was constructed. The dimensions and radiation pattern are illustrated in Fig. 5. A 28.6-MHz antenna was scaled from this model and fed directly with 75-Ω coaxial cable. The minimum SWR of 1.5:1 probably results from a driven element center impedance of 50 Ω, so the antenna would perform better if 50-Ω cable were used.

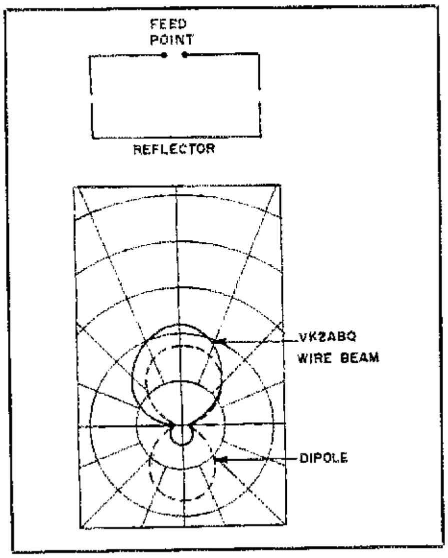

Fig. 6 — The VK2ABQ-antenna configuration is shown at A. At B, the directive pattern of this antenna is compared with that of a dipole.

The antenna's performance over a three-month period was comparable to the three-element model previously used. This could be accounted for by the difficulty of adjusting three elements for optimum performance.

Two-Element Wire Beam Derivatives

A number of experiments were performed to investigate methods of making the two-element beam more compact without compromising gain. All theoretical and previously published work on the subject was ignored, and an empirical approach was used in performing the experiments.

A further objective was simplicity. This is necessary because the more complex the array, the more interacting parameters that require adjustment. It is also more difficult to scale and build a complex array. Simplicity means ignoring traps and loading coils, which leaves element bending as the only solution to making a compact antenna. When an element is bent, the resonant frequency appears to rise. A GDO is necessary to determine the exact resonant frequency of a bent element.

What to do with the bent elements is a mechanical problem. One way out of this is to make a VK2ABQ configuration as shown in Fig. 6. This has good directivity, but poor gain compared with the two-element antenna. If the mechanical aspects are ignored and the elements are allowed to droop (like the top half of a quad), the gain returns to that of the two-element antenna (Fig. 5). As this seems to have the same gain as a quad, there appears to be little point in making a full-wavelength loop quad.

Table 1
Equations for Calculating the Dimensions of an HF-Band Double-D

Dimension	*Length (inches)*†
A and B	$\ell = \frac{3350}{f(MHz)}$
C	$\ell = \frac{2370}{f(MHz)}$
D	$\ell = \frac{700}{f(MHz)}$
E	$\ell = \frac{1336}{f(MHz)}$
Total element length	$\ell = \frac{6022}{f(MHz)}$

†m = inches × 0.0254

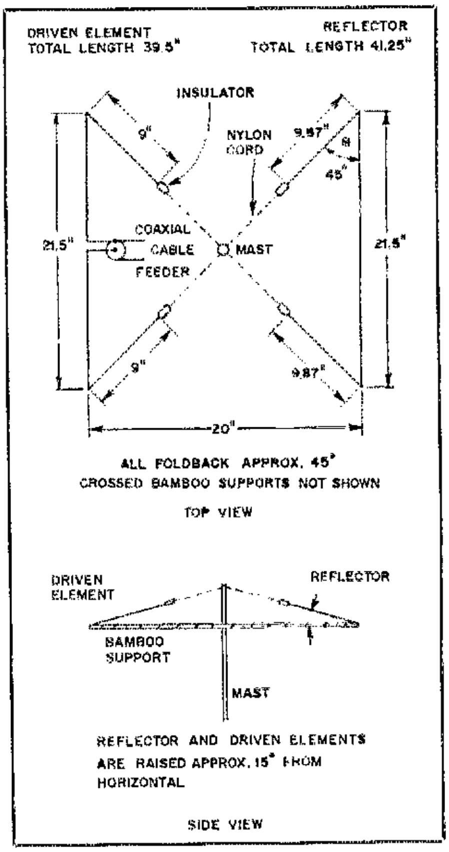

Fig. 7 — A Double-D antenna, showing construction details and dimensions for a 145-MHz model.

The Double-D Configuration

The Double-D was the final result of a number of experiments to overcome the problem of what to do with the folded parts of the elements. A VHF model is shown in Fig. 7, and the HF version in Fig. 8. Dimensions for the HF version can be calculated from the equations given in Table 1. The early HF models were derived by scaling the VHF-model dimensions with the correction factors from the graph in Fig. 4. Results of this approach were disap-

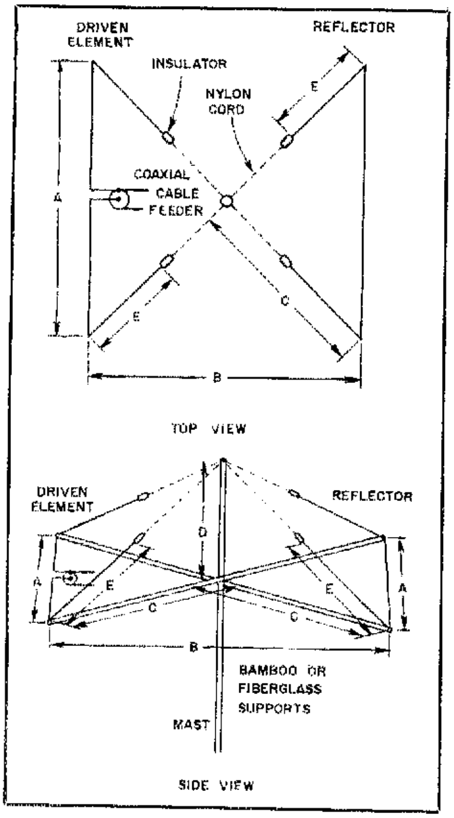

Fig. 8 — General construction details of an HF version of the Double-D. The letters refer to equations given in Table 1 for each section.

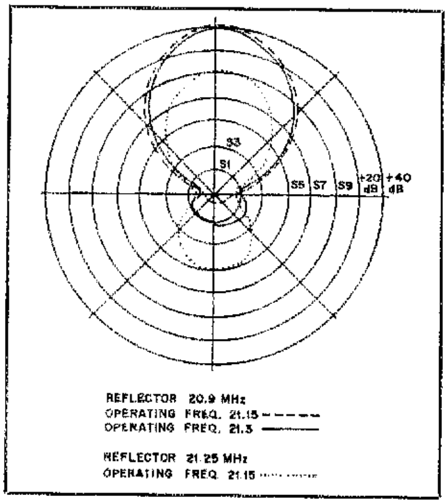

Fig. 9 — Directive-pattern variations, with changes in reflector length and operating frequency for a 21-MHz Double-D.

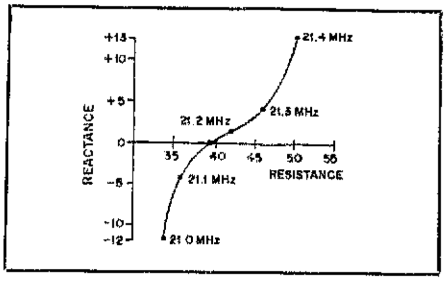

Fig. 10 — Variations in feed-point impedance with frequency changes for a 21-MHz version of the Double-D.

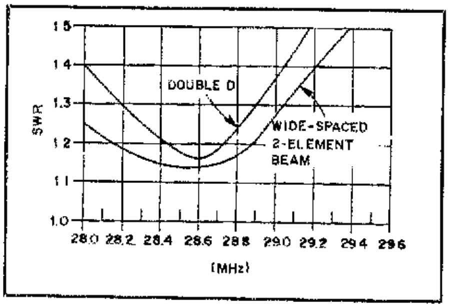

Fig. 11 — Graph comparing the SWR of a Double-D and a wide-spaced, two-element beam antenna.

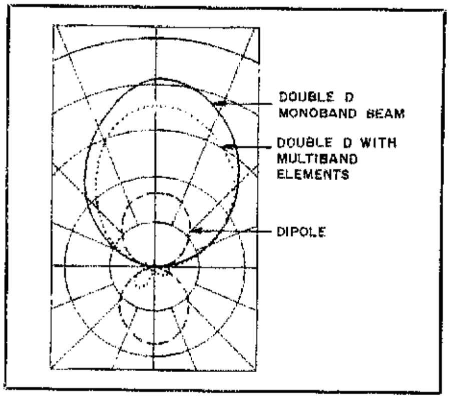

Fig. 12 — Comparative antenna directive patterns for monoband and multiband Double-D beams, along with a dipole for reference.

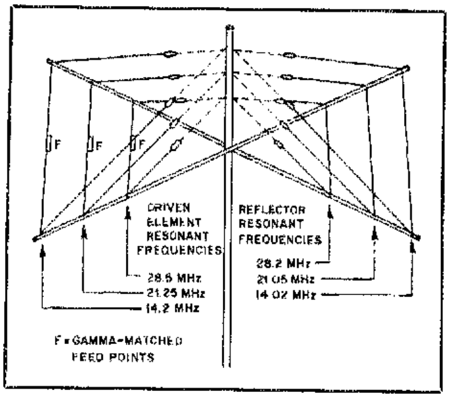

Fig. 13 — Diagram showing a suggested layout for a multiband version of the Double-D.

pointing. The equations given in Table 1 are derived from careful measurements made on a 21-MHz-band model. The most surprising result was that optimum performance occurred when the reflector was approximately the same length as the driven element.

Effects of different reflector lengths relative to the operating frequency are shown in Fig. 9. These diagrams were obtained by placing a modulated signal generator in the apex of the house roof approximately two wavelengths from the antenna. Readings were obtained from the transceiver S meter while rotating the antenna, and can only be regarded as comparative.

The radiation-resistance readings of Fig. 10 were obtained via a 3/2-λ section of 75-ohm coaxial cable, using the method described by Doyle Strandlund.[7] Separate noise-bridge measurements and an SWR of 1.5:1 confirm a feed impedance of 35 to 50 ohms. The feed impedance of a driven element without a reflector is about 50 ohms. A previously constructed 28-MHz version had a feed impedance of 50 to 60 ohms, and the VHF model matched very well into 75-ohm coaxial cable. A comparison of SWR for the Double-D and a wide-spaced, two-element beam is shown in Fig. 11.

Experiments with the VHF model showed that it was not detuned by the presence of other-band elements, although the feed impedance and radiation pattern were disturbed (Fig. 12). This seems to suggest that a multiband version is feasible. A possible configuration is shown in Fig. 13.

Construction Details

The spreaders were made by clamping bamboo canes to angle aluminum.[8] Insulators are made from any thin insulating material (such as Plexiglas®). This construction overcomes the problem of not knowing how much wire to allow for attachment to the insulator. Nylon cord rather than wire should be used between the insulator and mast, if detuning effects are to be avoided. The elements are attached to the spreaders with PVC insulating tape.

HF-Band Performance

In practice, the performance of the Double-D antenna on 28 MHz appears to be as good as was predicted by the VHF model. The front-to-back ratio, according to local reports, is about four or five S units. When the antenna was used with a QRP 3-W homemade SSB transceiver, QSOs with all continents were made in less than a week of normal operating. Versions of this antenna for 14 and 21 MHz have been tried, and they perform well. An antenna system comprising these two antennas has been mounted on a single support and fed directly with one coaxial feed line. The directional properties of each antenna are unimpaired, but the SWR on the 14-MHz antenna is nearly 2:1.

Notes

[1] P. G. Dodd, "Assessment of HF Aerials Using VHF Aerials" *Radio Communication*, Dec. 1972, p. 809.

[2] M. F. Radford, "Aerial Gain and How It is Measured," *Wireless World*, Oct. 1966.

[3] *The ARRL Antenna Book*, 14th ed. (Newington, CT: American Radio Relay League, 1982), p. 9-5.

[4] See note 1.

[5] The antenna-directivity patterns shown in this article are for comparative purposes only. No scales are shown in the graphs because they do not represent exact measurements.

[6] mm = inches × 25.4; m = feet × 0.3048.

[7] D. Strandlund, W8CGD, "Amateur Measurement of R + jX," *QST*, June 1965, p. 24.

[8] See note 3, p. 9-8.