unidirectional antenna

for the

low-frequency bands

End-fire and broadside characteristics are combined in a steerable array using a simple switching circuit

Malcolm M. Bibby, GW3NJY, 2748 Juno Place, Akron, Ohio 44313

Rotary beams for 40 meters are too large for the average garden of the European amateur or for most American amateurs' backyards. Many aspiring DX operators who want to work below 7 MHz have tried some form of vertical antenna because of its low vertical radiation angle. Generally what happens is that, after the initial excitement has passed and the DX operator starts the hard work of chasing countries using an omnidirectional antenna, he starts thinking of ways to eliminate noise and interference from locals. To put it mildly, a single vertical antenna isn't too well known for this. The books don't give much help, so if the DXer wants to compete at all he must rely on basic principles and good old amateur ingenuity.

there is a way

One of the simplest forms of directional antenna systems is the spaced vertical two-element array.[1] The radiation pattern for such a system fed in phase and spaced one-half wavelength apart is shown in **fig. 1**. The beamwidth at the half-power points is 60 degrees.

If one of these elements is fed 180 degrees (one-half wavelengths) out of phase with respect to the other, a horizontal pattern appears as shown in **fig. 2**. The half-

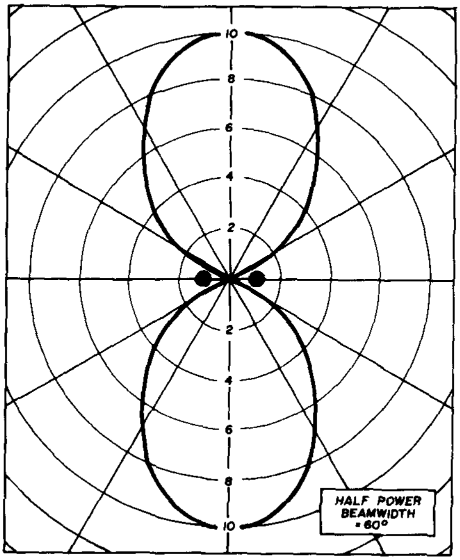
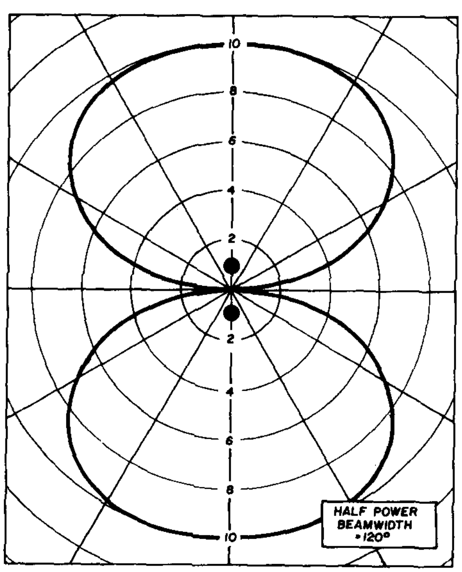


fig. 1. Horizontal pattern for two V elements spaced one half-wavelength and fed in phase.

power beamwidth is 120 degrees. Both systems are bidirectional, which is an improvement over the single vertical antenna. Such systems, or a variation of them, have been used by many amateurs.[2,3] However, the problem with either arrangement (broadside or end-fire radiation) is that they are bidirectional and have different bandwidths depending on their phase relationships. This is fine for broadcast service, for which they're primarily used, but broadcast stations don't work DX in the crowded amateur bands.

fig. 2. Horizontal pattern for two elements spaced one-half wavelength and fed 180 degrees out of phase.



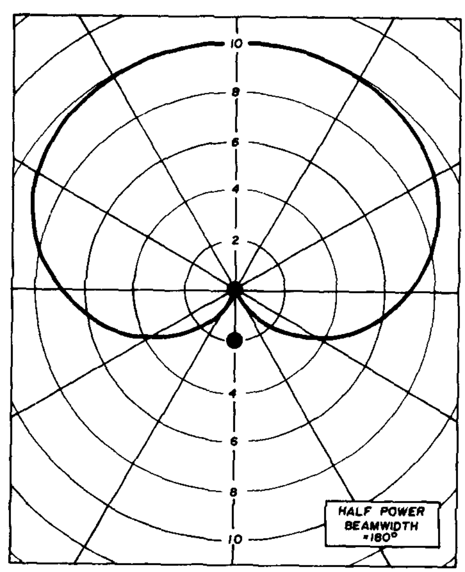
When the spacing between the two elements is reduced to one-quarter wavelength, the phase difference is reduced by 90 degrees. Then the pattern of **fig. 3** results. The beamwith is 180 degrees, but a unidirectional pattern has been obtained that can be switched to cover two directions. The beamwidth is as broad as the side of a barn, though. The question is, can anything be done to improve it using simple techniques? Yes, indeed. Read on.

a solution

By using four vertical elements and the principles of the systems whose patterns are shown in **figs. 1** through **3**, a unidirectional system can be obtained having a half-power beamwidth of 88 degrees. It can be made steerable in four directions by simple switching methods.

Consider the four vertical elements of **fig. 4**. Elements 1 and 3 are spaced one-

fig. 3. Horizontal pattern for two elements spaced one-quarter wavelength and fed 90 degrees out of phase.



half wavelength. Element 3's phase leads that of element 1 by 180 degrees. Both produce the horizontal patterns of **fig. 5A**. Elements 2 and 4, also spaced one-half wavelength, have the horizontal pattern shown in **fig. 5B**. So far it seems nothing has been gained. However, when elements 2 and 4 are fed with their phases advanced by 90 degrees with respect to element 1, the two lobes in the upper part of **figs. 5A** and **5B** will add, while the two

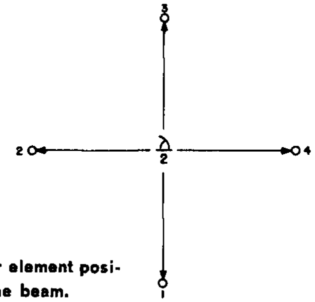


fig. 4. The four element positions used in the beam.

lower lobes will cancel. Thus the pattern of **fig. 6** is obtained.

The beamwidth at the half-power points, while not as narrow as a three-element Yagi or quad working under optimum conditions, is nevertheless a re-

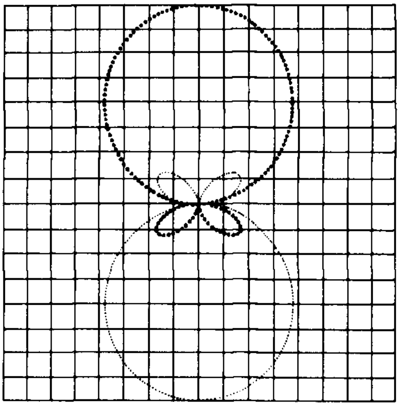


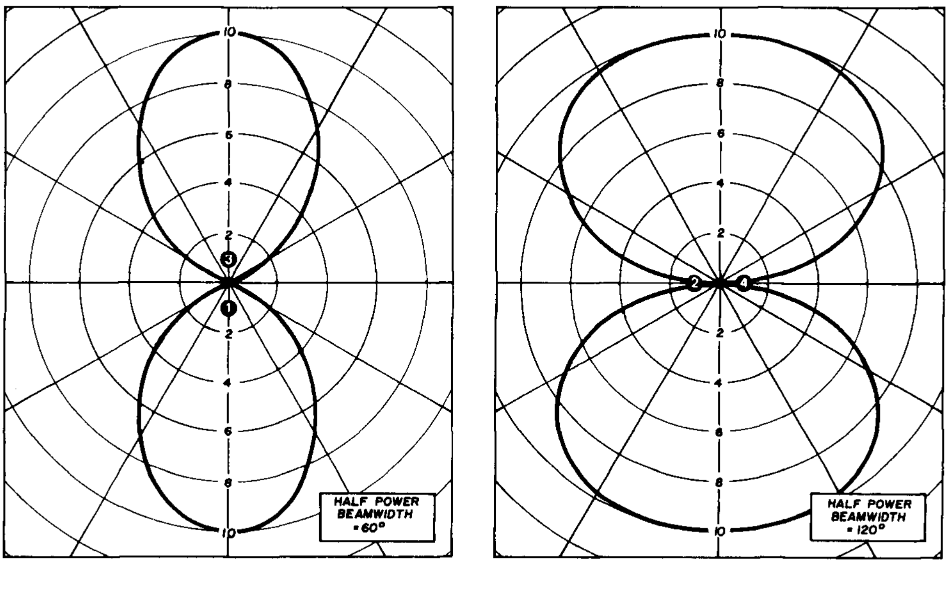
fig. 6. Computer-derived oscilloscope display of the horizontal polar patterns of the beam. The display of the less-dense dots was achieved by interchanging the feed lines to elements 1 and 3.

spectable improvement over that of a single vertical element.

practical considerations

Like many antenna systems, this one is frequency sensitive, and dimensions should be chosen for the part of the band of greatest interest. As the operating frequency moves away from the design frequency, the small side lobes will decrease but the main lobe will broaden very rapidly—for frequency deviations of four percent or more.

fig. 5. Horizontal patterns produced by elements 1 and 3 (A) and 2 and 4 (B).



A further point to remember is that in the theory used to design the beam the assumption is that each vertical element will not only have an identical horizontal radiation pattern (circular in this case) but will also have an identical radiation pattern in the vertical plane. Thus the four elements should be **identical in size** and placed over similar ground systems. For low-angle radiation the ground systems should be as extensive as possible. At the base of each element a rod should be driven into the ground at least six feet with all the radials electrically connected to the ground rod. The radials, which can be any length (the longer the better) ideally should be equally spaced about the base of the vertical with a good electrical connection to the ground rod. The elements don't have to be exactly one-quarter wavelength high, but whatever their height, they must be the same length.

impedance matching

The elements will have a reactive as well as a resistive component. If the element length is shorter than a quarter wavelength the reactance will be capacitive; if longer, inductive.

A simple network for matching low-impedance transmission lines to a wide range of impedance is the L network. The two basic circuits are shown in **fig. 7.** Both use one capacitor and one inductor of nearly equal reactance. The equations are for matching resistive loads only but provide a starting point for matching R ± jX loads:

$$X_1 = \pm \sqrt{Z_0(R - Z_0)}$$

$$X_2 = \pm R \sqrt{\frac{Z_0}{R - Z_0}}$$

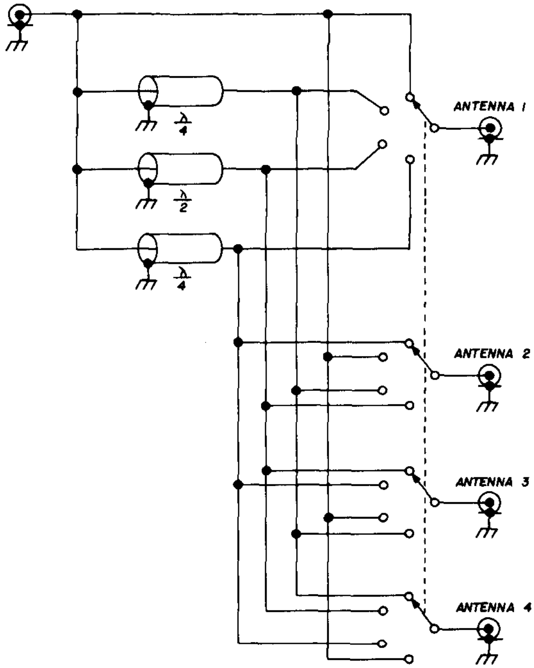
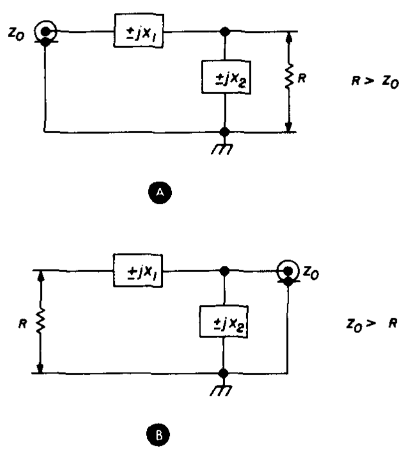


fig. 8. The wiring diagram for the phasing switch.

fig. 7. The L networks, which can be used for matching the coaxial cable to each element.



Either X_1 or X_2 can be the inductive reactance, so a maximum of four variations is possible. By connecting a reflected-power indicator in the coax line to each element, each circuit variation can be tried until no reflected power is indicated. The antenna impedance will then be matched, and a weatherproof container can be constructed and placed at the base of each element to house the matching networks.

The impedance match of each element should be checked, because there will be some element interaction. When each element is matched to a coaxial cable all elements should be connected through

equal lengths of cable (the specific length is immaterial) to a control box placed at the center of the system. This box should contain a rugged 4-pole, 4-position switch; preferably remotely controlled. The switch wiring diagram is shown in **fig. 8**.

After passing through the switch and the phasing cables (working backwards from the antenna), the four lines are joined in parallel. This has the effect of presenting an impedance of 12.5 ohms (for 50-ohm cable) to be fed from the single line from the transmitter. An impedance-matching transformer is needed at this point, and the L-network could be used again; however a better system is shown in **fig. 9.** This is equivalent to two pi-networks back-to-back. It can be installed in the control box and adjusted for a flat line to the transmitter.

Since devising this scheme I've moved from England to Ohio, and at present I have no means for testing the idea. But the principles are sound and the method should provide an incentive for those who

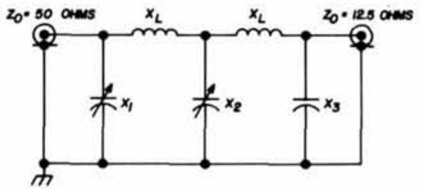


fig. 9. The 50/125-ohm impedance matching transformer. Typical values would be X1 = 20 ohms, X2 = 65 ohms, X3 = 10 ohms; inductive reactance is 2 times X2 or 130 ohms. Either X1 or X3 can be fixed.

like to work DX but don't have space or funds to put up a low-frequency rotary beam. The current sunspot maximum has passed, and DX activity will decline on the higher frequencies. I believe this antenna will give you a good chance to compete in the next DX contest.

references

1. W. D. Stead, VE3DZL, "Twins on Twenty," *QST*, May, 1961, p. 24.
2. I. A. Turner, W9LI, "A Compact Beam for 40 and 20 Meters," *QST*, January, 1954, p. 17.
3. A. D. Mayo, W5DF, "7-Mc Beam for the Small Yard," *QST*, September, 1952, p. 25.

ham radio