six-element collinear antenna for 20 meters

A fixed-azimuth wire array for point-to-point communications

A couple of years ago I had a requirement for a fixed-azimuth array for reception and transmission on 20 meters between Boulder, Colorado, and Europe. A narrow beam was required for receiving European stations at azimuths of 15 to 55 degrees because of strong U.S. East-Coast interference at azimuths near 80 degrees. I was impressed with the narrow-beam characteristics of the collinear array, sometimes called the Franklin antenna.[1-5] The simple collinear, as originally conceived and still described in all the amateur handbooks, is a horizontal wire array. The collinear was later adapted to vhf omnidirectional broadcasting by positioning it vertically and using cylindrical conductors.

antenna description

The array described here consists of two or more horizontal doublets in series. The currents are in phase in each doublet. Ordinarily if half wavelengths of wire are connected directly, the current shifts phase 180 degrees from one wire to the next, so a phase-reversing circuit is used between each doublet. The circuit traditionally used is a quarter-wave open-wire line. Alternatively, a high-Q resonant L-C trap could be used and would have the advantages of small size and light weight. However, it would require high-voltage capacitors and weather protection and might not be as stable in adjustment as an open-wire line.

beamwidth and feed impedance

Reference 6 gives the horizontal beamwidths of collinear arrays. A two-element array has a beamwidth at the half-power points of about 48 degrees; a three-element array has a beamwidth of about 36 degrees. An average three-element Yagi has a horizontal beamwidth on the order of 60 degrees at its optimum vertical angle of radiation. The collinear array is bidirectional. The three-element collinear array has the advantage of symmetrical center feed at a current maximum, so this was my first serious starting point after some poor luck with a two-element array. To feed two elements or any even number of elements symmetrically, one must enter at a high-impedance point. Unbalanced coupling and losses may occur if a metal mast is used to support the feed point.

By **Dick Silberstein, WØYBF**, 3915 Pleasant Ridge Road, Boulder, Colorado 80301

A three-element 20-meter collinear array was constructed with no. 10 AWG (2.6mm) copperweld wire, and the elements were cut to the usual 95 per cent of a half wavelength in free space. The phasing lines were a full quarter wavelength long but were adjustable from a maximum of about 18 feet (5.5m). The impedance of such antennas, two to six elements in length, is said to be about 100 ohms times the number of elements.[7] I decided to match the antenna to 50 ohms by using a quarter-wave matching section according to the well-known relationship

$$Z_o = \sqrt{Z_a Z_b} \qquad (1)$$

where Z_o is the characteristic impedance of the matching section, Z_a is the input impedance, and Z_b is the output impedance.

I found experimentally that with an output impedance of 50 ohms, the characteristic impedance of the matching section had to be 140 ohms to match the input impedance. From **eq. 1**, the antenna resonant impedance was about 392 ohms. By the rule given in reference 7 stated above, I'd expected something nearer 300 ohms.

The matching section was made from two quarter-wave sections of old Belden no. 8275 twinlead connected in parallel, but almost any good 300-ohm twinlead would have been satisfactory. The actual impedance of this particular transmission line was 280 ohms. Two sections in parallel obviously gave 140 ohms. The velocity factor came out by test to be 86 per cent instead of the usual 82 per cent, making the correct length 15 feet (4.6m). The antenna swr was near unity between 13900 to 14350 kHz.

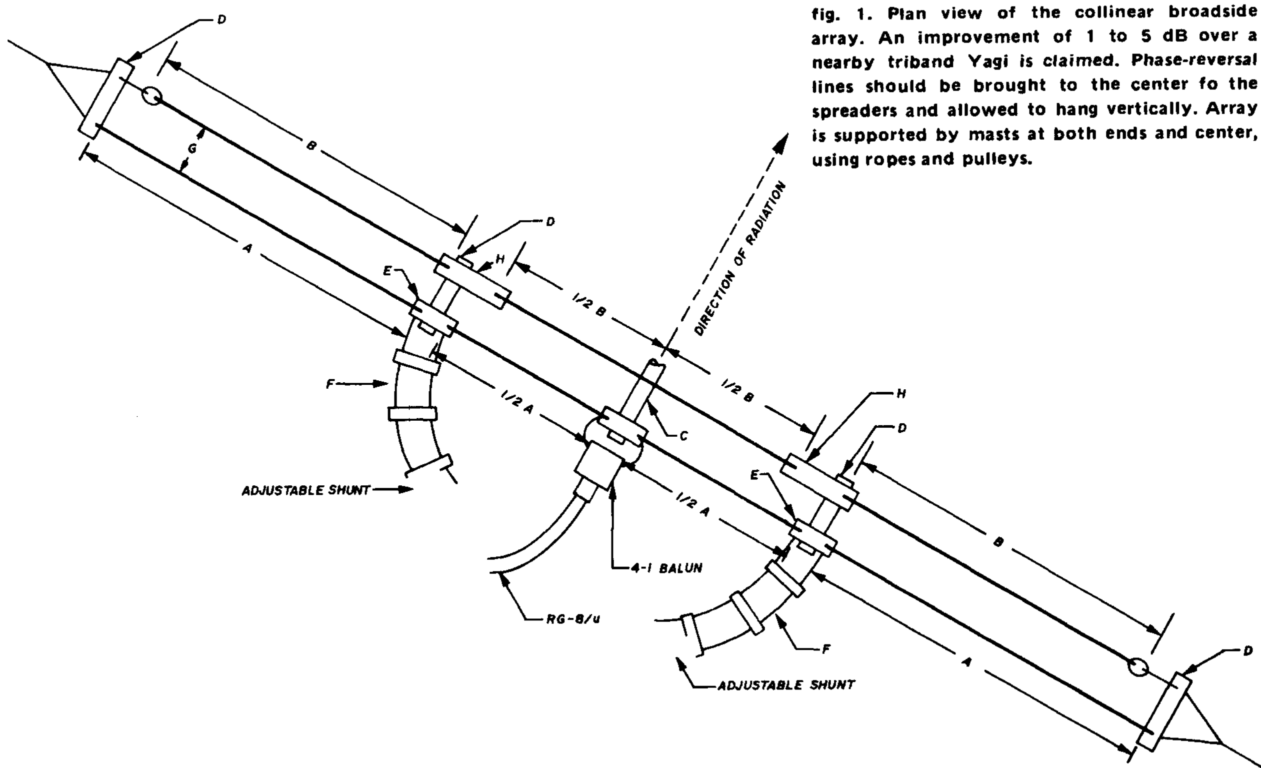

fig. 1. Plan view of the collinear broadside array. An improvement of 1 to 5 dB over a nearby triband Yagi is claimed. Phase-reversal lines should be brought to the center fo the spreaders and allowed to hang vertically. Array is supported by masts at both ends and center, using ropes and pulleys.

A. Driven elements	no. 10 AWG (2.6mm) copperweld wire
B. Directors	no. 10 AWG (2.6mm) copperweld wire
C. Center spreader	1-1/8 inch (29mm) diameter oak pole (8 feet or 2.4m long in 20-meter array)
D. Spreaders (4 required)	1 inch (25mm) PVC tubing (8 feet or 2.4m long in 20-meter array)
E. Insulators	½ inch (12.5mm) nylon or 1 inch (25mm) diameter PVC tubing 6 inch (15.2cm) long
F. Phase-reversal lines	see text
G. Separation distance	0.1 wavelength
H. Insulators	1 inch (25mm) diameter PVC tubing (2 feet or 61 cm long in 20-meter array)

During test, this antenna produced slightly stronger signals from Europe than my three-element tribander. However, to eliminate bidirectionality, increase gain, and narrow the beam a little bit more I decided to proceed further.

The most obvious approach was to make the collinear a driven element of a two-element parasitic array. The only place I've seen anything like this is in reference 6, where mention is made of a reflector with a collinear array. However, from a mechanical standpoint, a row of three parasitic reflectors would be difficult to construct since it would have to be longer than the driven array, requiring short stubs to make it fit parallel to the driven array. I chose instead a row of three directors, which would be shorter than the driven-array assembly. Each director was separated from its neighbor by a section of plastic tubing.

The theoretical lengths for a two-element parasitic antenna were used for each driven element and its correspond-in director, according to reference 6 for two-element arrays and reference 8 for the driven element and director of a three-element array:

$$\textit{Driven element (ft)} \equiv \frac{475}{f}$$

$$\textit{Driven element (m)} = \frac{144.8}{f} \qquad (2)$$

$$\textit{Director (ft)} \approx \frac{455}{f}$$

$$\textit{Driven element (m)} = \frac{138.7}{f} \qquad (3)$$

where f = frequency (MHz)

Construction details are shown in **fig. 1**. Note the generous use of rigid PVC water pipe, which provides good mechanical strength and rf insulation in a lightweight material yet doesn't warp enough to affect spacing appreciably. The antenna was built for 20 meters. Nominal values of length for 14.2 MHz are

driven elements 33 ft, 5 in (10.2m)
directors 32 ft (9.8m)
separation 7 ft (2.1m)
phase-reversal stubs 17 ft 4 in. (5.3m)

The phase-reversal stubs were actually 18 feet (5.5m) long with adjustable shunts. These shunts are needed for correcting minor errors in element lengths, compensating for height differences in different installations, and making final swr adjustments.

The antenna is driven through a 4:1 balun at the end of an RG-8/U feedline for the following reasons: The resonant impedance of a simple three-element collinear measured experimentally in the same location was almost 400 ohms. From experiments with parasitic antennas I reasoned that good gain was possible with element adjustments, which would reduce the normal resonant impedance of an antenna having no parasitic elements by a factor of about one-third. This means that the 400-ohm impedance of three collinear elements alone would be reduced to about 133 ohms with directors under certain adjustment conditions. A 4:1 balun would make the input impedance about 33 ohms, for an swr of approximately 1.5.

swr measurements

Swr was adjusted for a minimum at the desired operating frequency by moving the shunts on the phase-reversal stubs. The swr varied between 1.5 and 2.0 over most of the 20-meter band. Improved results might have been obtained with a gamma match, but I didn't use one because the match might not have held over a wide enough frequency range. Certainly it isn't good to push stub lengths too far beyond their theoretical values in optimizing swr alone. This is especially true in view of information in reference 8, which shows only 14 ohms impedance for a two-element parasitic array at 0.1 wavelength spacing, adjusted for optimum gain. The free-space impedance of the driven element alone would be 72 ohms (at resonance), giving an impedance reduction of about 5:1 due to the presence of the parasitic element, rather than the 3:1 ratio assumed above. So it would be a worthwhile experiment to start with theoretical values of element and stub length, adjust swr on a gamma match, and make corrections of driven-element length by moving the shorting stubs.

The antenna as built had some characteristics of an inverted vee. The antenna center was suspended 25 feet (7.6m) above ground, but the ends were only about 10 feet (3m) above ground on one side and 15 feet (4.6m) on the other. Proximity to ground increases losses but doesn't affect horizontal beamwidth.

results

Performance tests over about 18 months showed that the six-element array in reception gave S-meter readings on most European signals 1 to 5 dB stronger than those received on an adjacent triband Yagi. Interference from East-Coast U.S. stations was about 8 dB below that noted on the tribander, yielding even greater net signal-to-interference ratios; the advantage frequently was two S-units or more.

final remarks

The main disadvantage of this antenna is the same as any other antenna system using resonant phasing stubs or feedlines: the antenna impedance changes greatly under icing conditions. However, here in Colorado, such conditions exist only for a few hours each winter. The six-element broadside wire array should provide excellent narrow-beam, fixed-azimuth reception and transmission even at low heights. The 20-meter version is fairly long, yet it should fit into a half acre ($2024m^2$) of land. It is an easy-to-erect, high-performance antenna for those wishing point-to-point communication with a distant station.

references

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