Try the "FD Special" Antenna

Looking for an antenna that's simple, inexpensive, lightweight and easy to install? Here's one that fits the description.

By Roy W. Lewallen,* W7EL

While the Field Day "juices" were flowing last year, my Field Day partners and I decided to become more competitive without compromising our general philosophy: Use all homemade gear, pack it in to the site, and don't let operating interfere with watching the scenery. Since most of our gear already ran the accepted QRP power limit of 10-W dc input and had been designed to provide high output efficiency, the antenna seemed like the reasonable point of attack (our high quality superheterodyne receivers have not been the limiting item). The constraints dictated that an antenna be lightweight, portable and easy to put up. It should also have substantial gain.

Because of our West Coast location, the front-to-back ratio was not a concern. But having a reasonably wide lobe toward the East was. We desired a low SWR because of the relatively high loss of our RG-58/U and/or RG-174/U feed line. We were interested only in the CW portion of the band, but this antenna works well over all of the band. It seemed that 20 meters would be our main "money-maker," so we designed the antenna for that band. It can be scaled for other bands, too.

The Research

Although a number of antenna types might have done the job, I settled quickly on a horizontal, close-spaced, driven array. Experience has shown that driven arrays are generally more tolerant of imperfect construction and erection than are parasitic arrays. Experience and much measurement have convinced me that horizontal arrays outperform vertical ones in the high-frequency bands, except perhaps from an exceptional location. In addition, we didn't want the nuisance of establishing a decent ground system — which most vertical arrays require.

The theoretical gain and front-to-back ratio of 2-element arrays with 1/8-wavelength spacing between the elements are shown in Figs. 1 and 2. Note the lower curve of Fig. 1. It shows the effect of losses on the gain (losses don't affect the front-to-back ratio, and change only the scaling of the pattern). Fig. 3 shows the patterns of arrays with 135, 160 and 180-degree relative spacing. All are drawn to the same scale. The 1/8-wavelength-

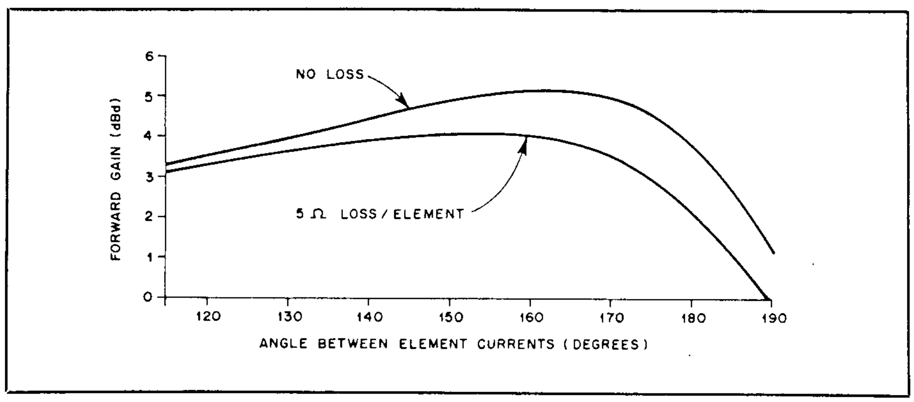

Fig. 1 — Curves that show gain versus phase angle for two-element arrays with 1/8-wavelength spacing.

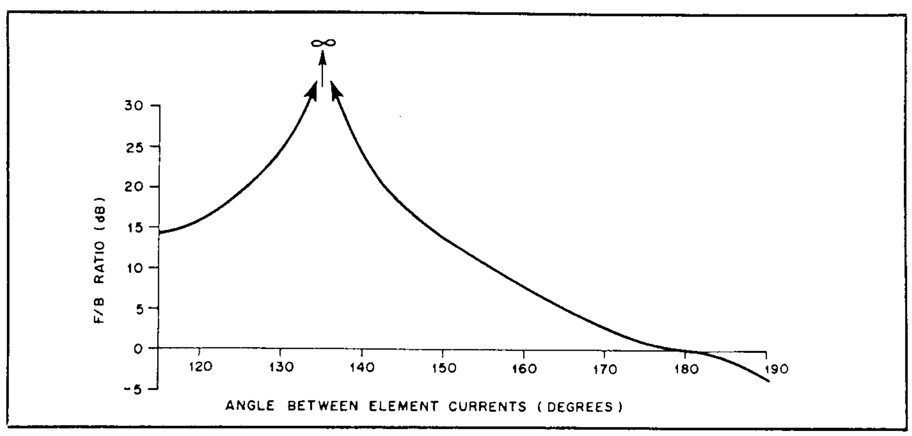

Fig. 2 — Theoretical F/B ratio for a two-element array with 1/8-wavelength spacing.

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spaced, 135-degree-fed array is frequently called the "ZL Special."[1] The close-spaced, 180-degree-fed array is known as an "8JK."[2] From 135 to 160 degrees, phasing was chosen because of the combination of relatively high insensitivity to loss, reasonable gain and wide forward lobes. Note that the gain stays about the same in this range, ensuring good performance if the phasing isn't exactly as predicted. Actually, it's much easier to generate and maintain precise 180-degree phasing than the angles I've chosen — particularly over a wide frequency range.

There's one major flaw (usually fatal) in a simple analysis like the one presented here: It assumes that equal-magnitude currents are flowing in the elements. This is not easy to realize, for even in arrays with elements spaced ½ wavelength or greater, mutual coupling has a profound effect on element impedances. This changes them dramatically and unequally, as a rule. This impedance change is a function of not only "mutual impedance," but also the relative magnitudes and phases of the currents flowing in the elements. In an array as closely spaced as these, coupling is so intimate that it could be argued that the term "driven array" is a misnomer. For example, the feed-point impedances of the elements in a 1/8-wavelength-spaced array, assuming equal currents can be made to flow, are

Phase Angle Between Currents (Degrees)	*Loading Element (Ohms)*	*Lagging Element (Ohms)*
135	28 − j46	28 + j46
160	13 − j22	13 + j22
180	9 + j0	9 + j0

This shows quite a change from the 74 + j0 ohms value that each element exhibits when it is not coupled to another element. The fact that the resistive parts of the two-element impedances are equal, and the reactances are equal in magnitude, is a peculiarity of the particular element spacing chosen. For other spacings they will be unequal, and the reactances can be different in magnitude, as well as in sign.

This mutual coupling isn't undesirable; in fact, it's essential for obtaining gain in the presence of rather severe pattern cancellation that is common in these closely spaced arrays. The lower impedances cause more element current to flow for a given power input, thereby increasing the fields from the elements. In these arrays, the increased field strength is sufficient to compensate for the fact that the fields from the elements don't add in phase in any direction. They partially or completely cancel instead. But, the lower feed-point impedances make them more sensitive to losses, and the low resistance with relatively high reactance makes them tricky to feed properly.

[1]Notes appear on page 24.

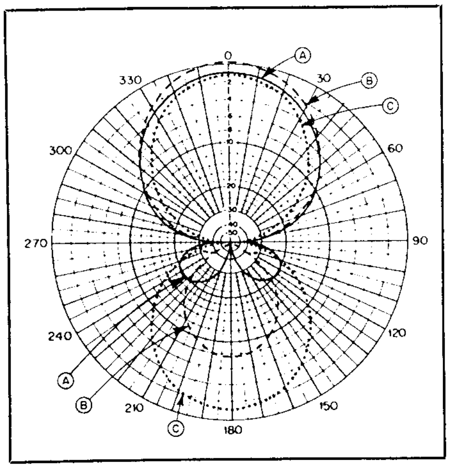

Fig. 3 — Dipole array patterns for 135, 160 and 180-degree relative phasing at λ/8 spacing. Curves A, B and C, respectively, represent these conditions. Add 5 dB for dBd. These curves are based on the array being fed with equal currents.

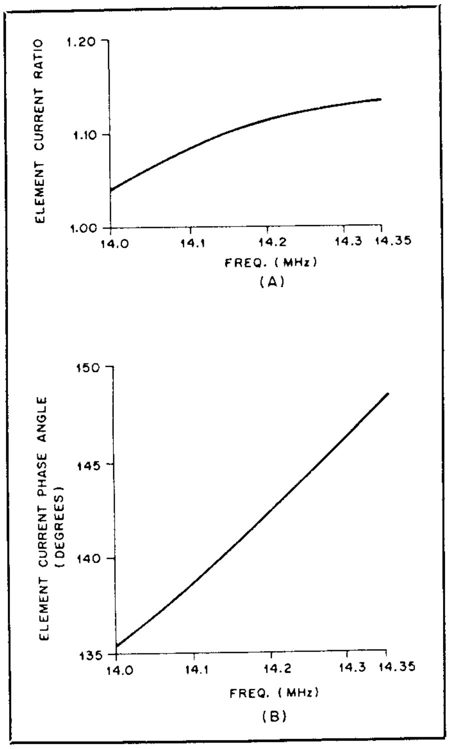

Fig. 4 — Element current ratio (A) and phase angle (B) as a function of frequency.

Why do these different and reactive feed impedances make feeding the arrays so difficult? The first problem is that, with few exceptions, the magnitude of current out of a line not terminated in its characteristic impedance won't be equal to the current into the line. In classic "If you can't fix it, feature it!" fashion, this impedance-transforming property is put to good use in the form of the ¼-wavelength Q section.[3] The second (and almost always overlooked) difficulty is that, again with only a few exceptions, the phase delay of current in an imperfectly terminated transmission line doesn't equal the electrical length of the line. This effect isn't minor: The phasing of a casually designed array can easily be off by tens of degrees. In one design I investigated, an 80-degree line produced 139 degrees of phase shift.

The Solution

There are a number of approaches toward correct feeding of an array. My choice was to investigate some simple feed systems to see if any would yield results that came close to the desired characteristics. I wrote a computer program that would solve, iteratively, for element-current magnitude and phase angle, plus feed-point impedances for this one type of array, given the array specifics. Several configurations looked promising, and one of the simplest proved adequate. This was an array of two folded dipoles that were self-resonant, spaced 1/8 wavelength apart and connected by a taut piece of 300-ohm TV ribbon with one half twist. The feed impedance was close to 50 ohms resistive. There was some inductive reactance that could be corrected by adding two small-value capacitors at the feed point. The element current ratio was 1.13:1, with element phasing that was 154 degrees. This was not the 124 degrees one might expect from the 56 electrical degrees of line — assuming a velocity factor of 0.8 — minus the 180 degrees caused by the half twist.

It was this array that we used for Field Day, with very good results (see section on performance). However, when the array was reconstructed at the home QTH, a dramatic rise in SWR was noticed when operating the antenna at other than the low end of the band. Computer analysis showed that, above the design frequency, the phase angle increased. This caused a substantial lowering of the element feed-point impedance, plus narrowing of the forward lobe. The analysis also showed the antenna to be well-behaved *below* the design frequency. Consequently, a similar array was designed (figuratively speaking) for 14.5 MHz. It gave good results over the 20-meter band. Element phasing varies from 135 degrees at 14.0 MHz to 148 degrees at 14.35 MHz, with current ratios from 1.04 to 1.13:1 (see Fig. 4). The gain can be calculated as fairly constant from 4.5 to 4.6 dBd across the band. Again, the array feed-point impedance can be corrected easily to provide a low SWR. The calculated patterns for the antenna at the top and bottom ends of the 20-meter band are shown in Fig. 5. These take into account the changes in element phasing, spacing, current magnitude and element self-impedance with frequency.

Construction

The antenna is made from quality

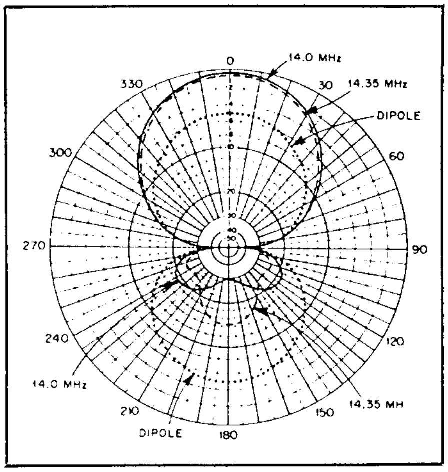

Fig. 5 — Calculated antenna patterns for the high and low ends of the 20-meter band. Add 5 dB for dBd.

300-ohm TV line to the dimensions given in Fig. 6. Sketches of the insulators are provided in Fig. 7. They are made from scrap pieces of epoxy-glass PC-board material. This results in ruggedness and minimum weight. The spreaders are readily available 10-foot lengths of "1 inch" (1-5/16 in OD)[4] schedule 40 PVC pipe. The capacitors are used only to provide a good match to 50-ohm feed line: They don't otherwise affect the performance of the array. Small 500-V mica or monolithic ceramic units may be used for power levels up to a few hundred watts, since they are at a relatively low-voltage part of the system. Open-ended stubs could probably be substituted for the capacitors, if desired. I recommend that a balun transformer be used with this antenna. Attempts to measure the impedance of one element of this array resulted in a unique experience — the first substantial evidence of the need to use a balun transformer. The antenna-bridge readings varied greatly as the measuring equipment was moved, or as I placed my hand around the feed line. This ceased when I added a balun transformer. The phenomenon is explained by Maxwell in a recent paper.[5] Nearly any style of balun transformer will prevent the unwanted flow of current on the coaxial cable outer conductor. I use a choke type of balun transformer. It consists of 10 turns of small-diameter coaxial cable wound on a ferrite toroid core. The OD is approximately 1¼ inches, and it is mounted at the feed-point insulator by means of small nylon cable ties.

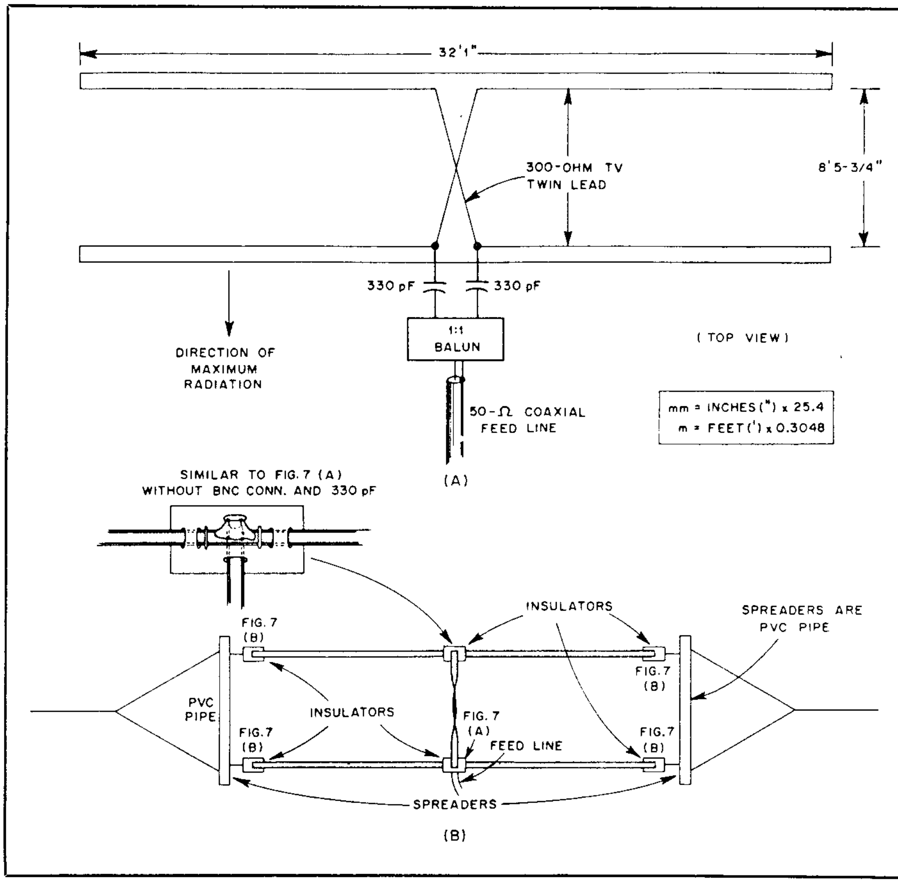

Fig. 6 — Electrical dimensions for the W7EL array (A). Illustration B shows how the antenna is assembled on spreaders of PVC pipe.

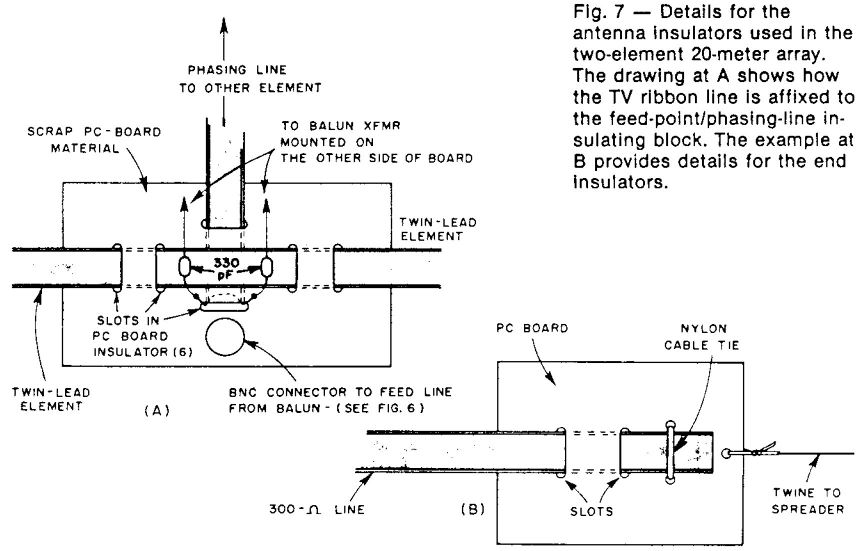

Fig. 7 — Details for the antenna insulators used in the two-element 20-meter array. The drawing at A shows how the TV ribbon line is affixed to the feed-point/phasing-line insulating block. The example at B provides details for the end insulators.

If you use the array for portable operation, as we did, the 10-foot spreaders are out of the question, at least in their original form. We cut ours in half for "packing in," then used PVC cement to glue them together at the FD site. PVC pipe couplings were used to join the sections. The glue container was enclosed in polyethylene sandwich bags, just in case a leak developed. At the end of our FD exercise, we used the saw blade of KØED's Swiss army knife to cut the PVC pipes again for easy transport. The spreaders were glued together again for use at the home station. The antenna is held horizontal easily by attaching a piece of twine to the nondirectly driven element insulator. This counteracts the weight of the feed line that is connected to the other element.

Performance

The "FD Special" has been in use at W7EL for some time. Array gain has been compared to that of an inverted V at the

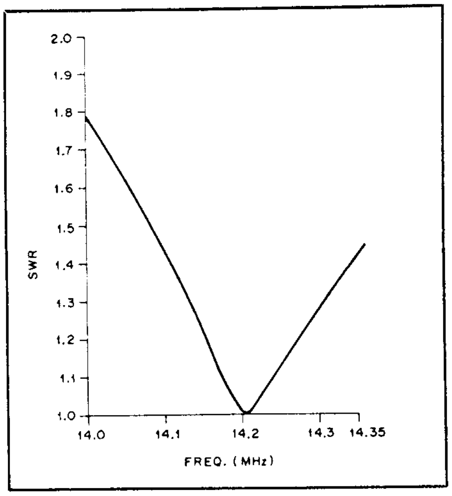

Fig. 8 — SWR curve obtained at the end of a 45-foot length of RG-58/U coaxial cable.

same height. The calculated performance values appear correct within the measurement capability. The front-to-back ratio has not been measured. The SWR at the end of 45 feet of RG-58/U feed line is shown in Fig. 8. The SWR is important only when a lossy line feeds the array, or when it is driven by an intolerant transmitter (with built-in SWR shut down), which is now the norm.

Perhaps the most revealing performance indication was provided by a person who encountered us several times on 20 meters during Field Day. He was operating for another, very competitive local club. After the exercise he remarked, "The only reason I believe you guys were running an honest 10 W is that I know Wes Hayward (W7ZOI) was there." Indeed, we used 10 W or less input while operating — and 0 W while watching the mountain scenery!

Notes

[1]My apologies to the first person who described or named this antenna. I don't know its history. (See L. A. Moxon, "Two-Element Driven Arrays," *QST*, July 1952, p. 28.)

[2]Named after W8JK, Dr. John Kraus, "Antenna Arrays with Closely Spaced Elements," *Proc. IRE*, Feb. 1940.

[3]G. Hall, ed., *The ARRL Antenna Book* Newington: ARRL, 1982).

[4]mm = in × 25.4; m = ft × 0.0348.

[5]W. Maxwell, "Some Aspects of the Balun Problem," *QST*, March 1983.

Additional information about this antenna can be found in http://eznec.com/misc/fdsp~.exe. This file is a self-extracting ZIP file, and includes a program for designing the Field Day Special as well as extensive notes. Running it will expand it into several files. The documentation file, FDSP.txt, explains how to use the program as well as containing information about how to make a switchable array and tips for choosing the feedlines.

I've used a 20 meter version of this antenna for Field Day nearly every year for the past 20. I've never found an antenna that gives such an ideal pattern for working the U.S. and southern Canada from the West Coast, combined with being rugged and lightweight. 40 and 15 meter versions have been used when Field Day equipment isn't brought in by backpack. Lightweight PVC spreaders have been packed in on a number of occasions; they're cut into two pieces, with PVC-to-threaded pipe adapter on each piece so they can be screwed together at the site. When weight is critical, I've simply used dead branches found at the Field Day site. Two shorter branches have also been used for each spreader, lashed together with twine. If the yokes are made fairly long, there's very little bending stress on the spreaders, so even fairly brittle branches can be used.