A Compact and Efficient Multiband Beam Based on a Modified W8JK Array

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Introduction

About 10 years ago I was looking for a design for a beam antenna that would be simple, multiband, compact, easy to construct, reasonably efficient, and inexpensive. I'm not asking much, am I? Up to that time I had been using a single delta-loop which had a bidirectional figure 8 pattern that covered 20-10M using ladderline feed. It was basically a full-wave loop on 17M but had some gain over a .5λ dipole on all bands from 20M to 10M. I had found that a 20M full-wave loop had a very peculiar radiation pattern on 10M so it was not suitable for 20-10M operation. However, I wanted more gain. I considered a delta-loop quad but since I wanted to hang my low band dipole from the top of my tower, I needed an antenna for the high bands that was in a horizontal plane and would not interfere with another wire antenna below it.

The Antenna

One of the antenna designs I started modeling (using EZNEC) was a W8JK array using 20M .5λ dipoles. The W8JK (John Kraus - sk) 2-element array (1) is a venerable design dating back to the '30s but has appeared in every Antenna Handbook (3) since then and has even appeared in QST (2) in recent years. The classic '8JK array consists of 2 ~.5λ dipoles at the lowest operating frequency closely spaced (~.1λ) with a phasing line (often 450 ohm ladder line) connecting the feedpoints. This phasing line is twisted to impart a 180 phase shift between the elements. The antenna is fed at the midpoint of the phasing line – see figure 1. In Kraus' day these arrays were fed with open wire feeders so multiband operation was readily possible. An array designed for 40M could be used on 20M and 10M (no 12/15/17/30M available in that day). The gain was slightly higher on the higher bands due to the longer effective length. The radiation pattern was bidirectional – a narrow figure 8 and nearly 6dbi could be expected on the lowest frequency. Of course, a balanced tuner was required to match the open-wire feedline to the transmitter.

I was willing to accept the bidirectional performance if I could get reasonable gain in a compact design. The modeling showed gain of slightly under 6dbi on 20M slowly increasing to about 6.5dbi on 10M. That was a lot better than my old delta-loop. Of course I wondered if making the '8JK elements .5λ on 17M would work reasonably well from 20M through 10M – and lead to any even more compact design – as I had found with my delta-loop. I was astonished to find that the gain was even greater (>6dbi) on 20M than it had been with the 20M .5λ design and that the radiation pattern was somewhat unidirectional. With further modeling, I discovered that moving the feed point on the phasing line slightly away from the midpoint (~6" – see figure 2) improved the F/B ratio substantially. I could get essentially the same unidirectional radiation pattern (and gain) as a full sized 2-element 20M yagi! It was hard to believe that I had stumbled on to something so novel and exciting considering that the W8JK array has been around for over 70 years.

The performance of this compact array on the other bands (17-10M) was essentially like the classic '8JK array – a bidirectional figure 8 pattern. There was a slight asymmetry (F/B) on 17M of about 2 db. Well, I built the beam and installed it on my tower and it performed pretty much as the modeling indicated. There was a distinct F/B noticeable on 20M and decent gain on all bands with no discernable F/B on bands above 17M. I have used this array for nearly 10 years now. Figure 5 shows my current installation.

Several years after I first modeled, built, and installed this antenna, I bought Les Moxon's book (4) on HF Antennas. In it I found that my discovery was not original but merely a (very) little known adaptation of the '8JK array. What a disappointment! Les also explained how it worked.

The classic W8JK array is not fundamentally a resonant antenna (even thought it is composed of .5λ elements) in the sense that the reactive component of the feed point impedance goes to zero at the fundamental frequency. Indeed, for the .5λ 20M array, the feed point radiation resistance is very low (~4-5ohm) and there is a significant and sizeable reactive component. Of course in Kraus' day, everyone used the very low loss open wire feeders and matching such a feed-point impedance with a tuner was no problem. In fact, the feed point impedance of the array varies all over the map as the operating frequency goes from 20M to 10M. Modeling easily allows investigation of the feed point characteristic of this adaptation (see figure 3). The modified array is, indeed, resonant in the 20M band in the sense that the reactive component goes to zero but the radiation resistance is still very low ~5ohms. There is also another point where the reactive component goes to zero near the 12M band. In this case the radiation resistance is very high (several thousand ohms). Les explained it this way: The total effective length of the elements can be figured as the sum of the element length (~27') plus the twice the phasing line length from the element to the feedpoint. With the feed point offset 6", you find that the front element effective length is ~33 feet and the back element is ~35 feet. These are just the lengths of a 2 element yagi. Indeed the modeling shows that keeping the feedpoint at the center of the phasing line and lengthening the back element by a foot and shortening the front one by the roughly same amount produces an equivalent result to moving the feedpoint 6" away from center with equal length elements. And the performance of either configuration is indistinguishable from a standard W8JK array on the other bands. So take your pick.

Mechanical Details

I constructed the elements using nested tubing (readily available from Texas Towers, DX Engineering, etc). In a '8JK beam both elements must be electrically isolated from the boom. I accomplished this by using 1" PVC pipe roughly 2' long at the center. 1" aluminum tubing fits snuggly into the PVC. I also used a 2' long ¾" dowel inside the aluminum tubing to stiffen the center. There was a 2" gap at the center between left and right side of the aluminum tubing. This insulated arrangement was clamped to the boom using beam hardware from DX Engineering. The phasing line was attached with a brass screw threading thru the PVC into the ends of the aluminum tubing, this also served to hold the aluminum tubing in place in the PVC sleeve.

Feeding the antenna

For single band usage on 20M, the feedpoint radiation resistance of ~5 ohms can be stepped up with a 9:1 balun to ~45 ohms – a good match to 50 ohm coax. The result is a compact beam array (27' element length) with the gain and F/B characteristics of a full-sized Yagi type beam. One could even entertain the possibility of installing a parasitic director in front to further improve gain and F/B – just as parasitic elements are sometimes added to log-periodic arrays.

Multiband operation is possible with this compact 2-element array if ladder feed line is used. In order to minimize feed line radiation which would adversely affect the directionality of the array, balanced feed-line currents are absolutely essential. This can be assured by using a current balun at the tuner and spacing the feed-line well away from the metal tower. With 300ohm ladder line (see table 1), the SWR at the feed point on 20M is very high (~60) which leads to significant loss even with the best present day ladder line (~1.5 db over 50'). The open wire line of Kraus' day had much less loss. 600 ohm open wire feed line is still available and advertised in QST today if you want to try it. The modeling showed that the SWR at the feed point dropped significantly on the higher bands (see table 1). By using a 1:2 step-up transformer at the feed point, I was able to lower the 20M SWR while not significantly raising it on the other bands. With this arrangement the SWR was always less than 30:1 on the lower bands (and much less than that on the higher ones).

One of the problems encountered by anyone using ladderline to feed an antenna with the object of multiband operations is that the transformed impedance at the tuner on some bands may not be in its matching range for the length of transmission line used. I have developed a scheme for handling this problem that has been very successful – I am sure others have found the same technique but I have not seen it documented anywhere. I run the shortest length of ladderline necessary for the installation. If I am lucky, the tuner will match the line on all bands but usually I am not and there will be some band(s) where I can not get a good match. I cut three pieces of ladderline, one 1' long, one 2', and third 4' long. I can now insert an additional length of ladderline from 1' to 7' in increments 1'. I have never had a case where there was not some combination in that range that led to a satisfactory match on all bands.

Figure 5 shows how I have installed the 300 ohm ladderline on my tower. It is spaced a little over a foot away from the nearest metal leg on the tower. The Antenna handbook (3) says that spacing ladderline 5-6 times the spacing of the wires in the ladderline from a metal object should be sufficient isolation – for 300 ohm line this is ~3". Earlier, I had used standard TV ribbon feedline standoffs (obtained at Radio Shack) on the tower which provided this ~3" standoff and that had performed satisfactorily. I had spaced these every 2' up the tower. However, after many years, the small flexible plastic inserts in the standoffs dried-out, cracked, and fell out. Recently I decided to replace these with PVC standoffs seen in the figure 5 – fewer standoffs with much larger spacing. This should provide adequate standoff even in windy conditions and these should last a long time!

The modeling was done using 450 ohm ladderline for the phasing line between the elements. With the very low feed point impedance, I decided to use something of heavier wire gauge to reduce any potential losses in the phasing line. I employed ¼" aluminum rod for the phasing line with judiciously placed spacers and twisted, of course, to impart the required 180 phase shift. This is common on log-periodic arrays. This can be seen in Figure 6. The modeling shows, however, that this provides only a modest reduction (a few tenth of a db) in losses over the standard 450 ohm ladderline which were only several tenths of a db in the first place. Thus, this design feature was probably not required.

Summary

This modified '8JK array fulfills all of my objectives set out in the introduction with the addition of providing unidirectional performance on the lowest band (which was unexpected). No it is not the ultimate beam but it performs very satisfactorily for something so simple, easy to construct, and inexpensive.

References

(1) Antennas for all Applications, 3rd Edition, McGraw-Hill, J D Kraus, R J Marhefka, and A S Khan, (p 183ff, out of print, but used copies available from Abebooks)
(2) QST, Sept.2005, "Building the W8JK Beam", Dave Suggs , p31ff
(3) Antenna Handbook, 21st Edition, ARRL, (p8-51ff for W8JK, p24-27 regarding spacing standards for ladderline)
(4) HF Antennas for All Locations, 2nd Edition, RSGB (available from ARRL), L. Moxon, (p91, fig 5.19)

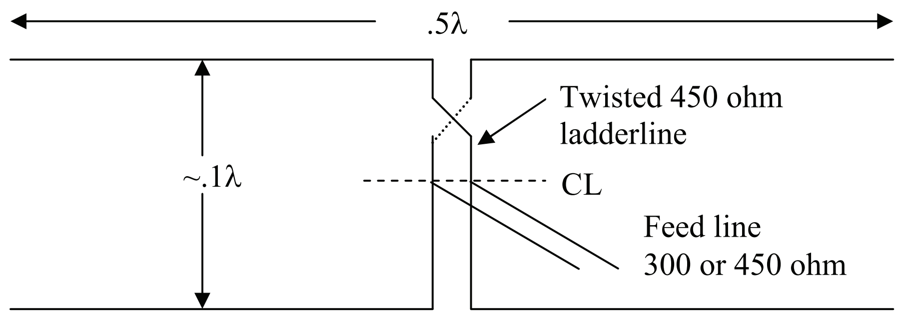

Figure 1. Classic W8JK array with .5λ elements

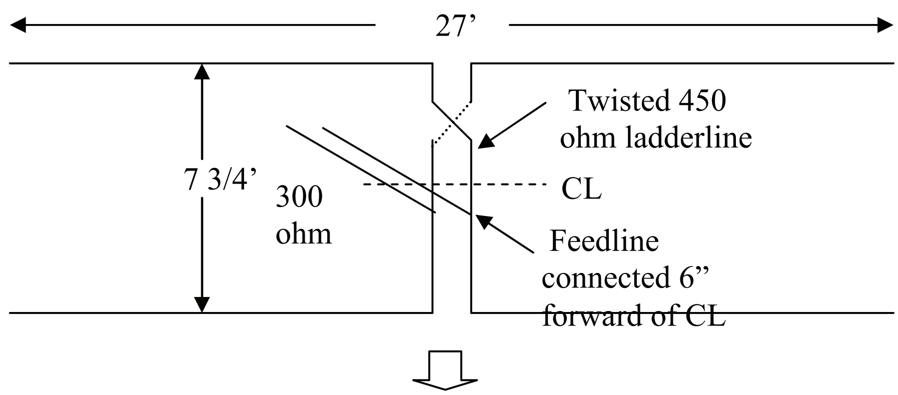

Figure 2. 20M modified W8JK array

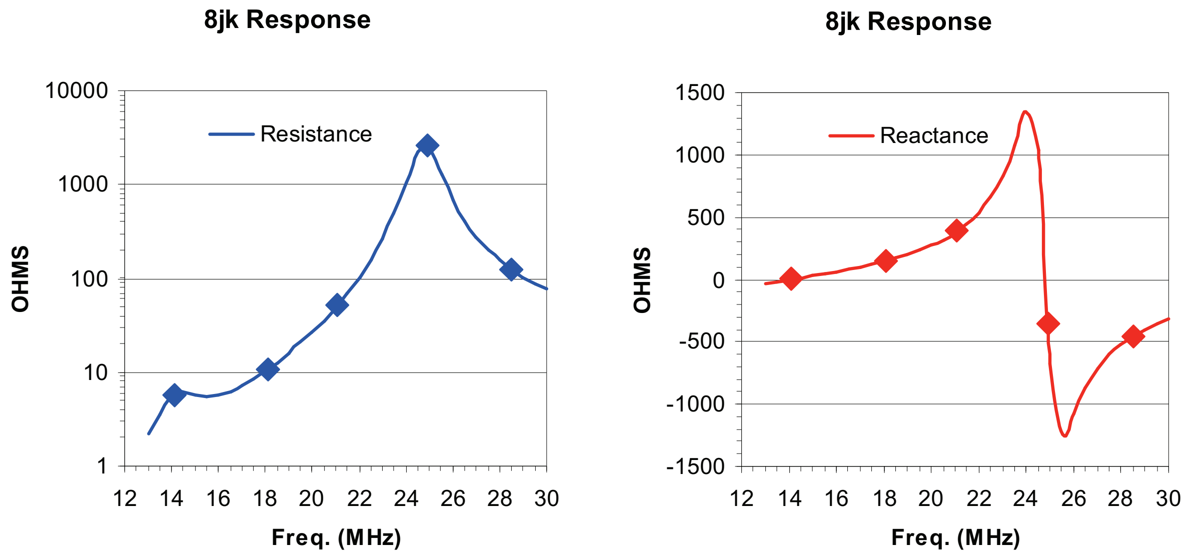

Figure 3. Real and reactive components of the modified 8JK array as a function of frequency. The diamonds show the location of the amateur bands of interest.

Table 1 Antenna characteristics (from EZNEC+)

7.9ft boom	27ft elements		6" feed offset			
Free space model			Ro=	300		
Freq.(MHz)	**R**	**X**	**Z**	**RHO**	**SWR**	**FG**
14.1	5.7	0.61	5.73	0.9627	52.6	6.5
18.1	10.8	151	151.39	0.9442	34.8	6.2
21.1	52	390	393.45	0.8797	15.6	6.3
24.9	2558	-359	2583.07	0.7937	8.7	6.4
28.5	125	-453	469.93	0.7818	8.2	6.5

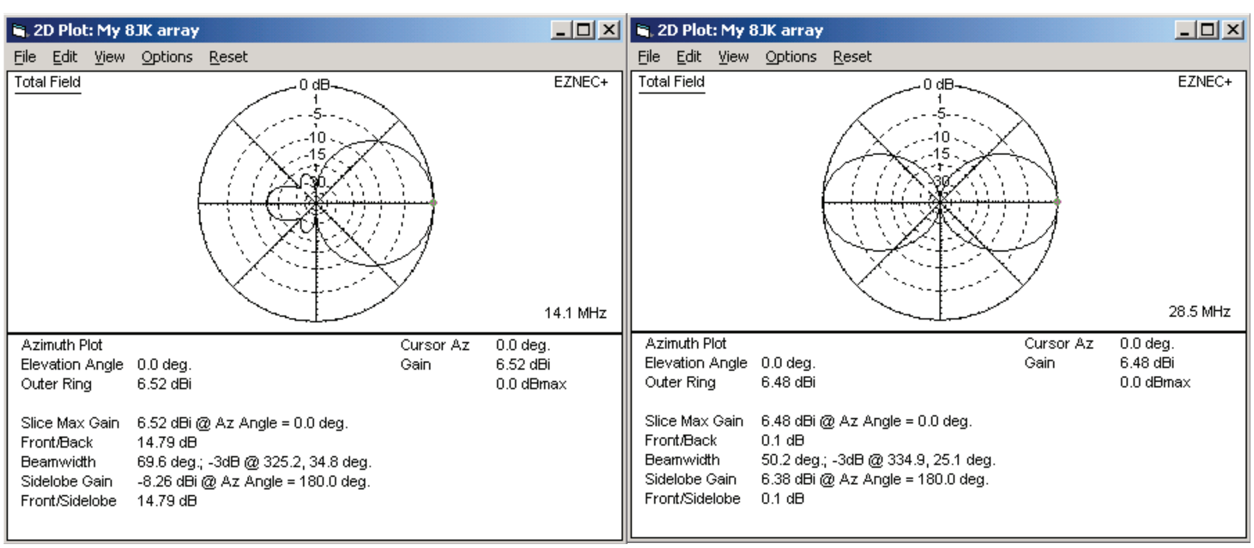

Figure 4. EZNEC+ free-space azimuthal radiation patterns for the modified 8JK array on 20M and 10M

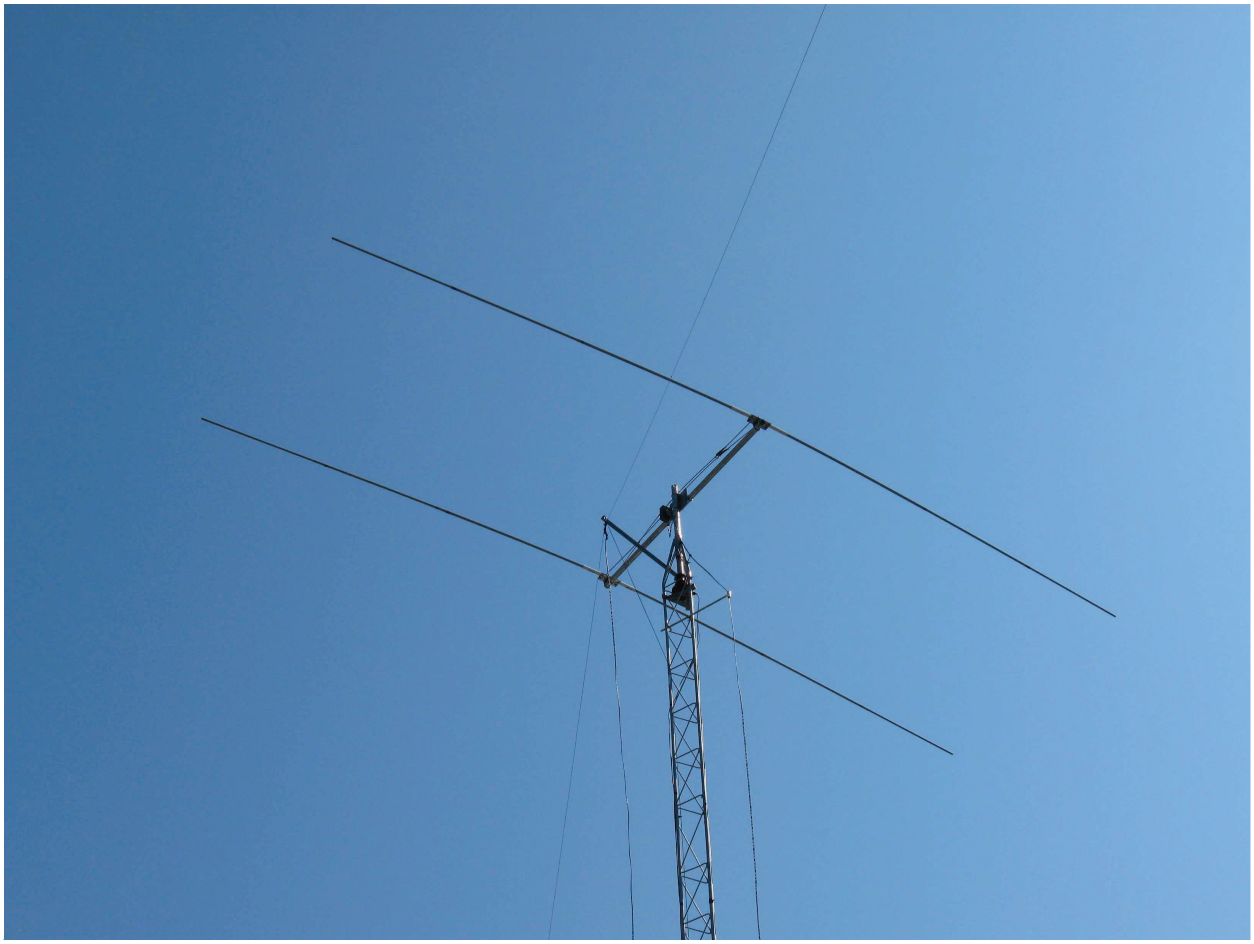

Figure 5. The modified ‘8JK array on my tower. The lanyard immediately below the beam holds the center of my 80M inverted vee. Just to the right of the tower is the 300 ohm feed line for the beam which is spaced away from the tower by PVC pipe with a tee on the end through which the feedline is threaded. There are 4 PVC standoffs about 12’ apart on the tower.

Figure 6. A closer view of the middle of the array. The black object just to the left of the mast-boom junction is the box containing the 1:2 balanced transformer. This view also shows more clearly the twisted phasing line made from ¼” aluminum rod. The Plexiglas spacer at the top of the mast holds the center of the phasing line about 8” above the boom.