Broad-Band 80-Meter Antenna

The cage is back! Almost forgotten since the 1920s, this multiwire antenna, arranged as a center-fed dipole, provides edge-to-edge band coverage without the help of a tuner. The low SWR will make you and your rig happy!

By Allen B. Harbach,* WA4DRU, VP5AH, VP1AH

I dislike antenna tuners! I suppose there is a place for them when one can put up only one piece of wire to cover all bands, but they definitely slow down the ability to QSY quickly from one end of the band to the other to catch the rare one.

When I began chasing DX in the early '70s, I rapidly became aware that something had to be done to broaden the response of my antenna system — particularly on the 80-meter band. The reason 80 meters is so tough is that it has the greatest percentage bandwidth of any of the popular amateur bands (see Table 1). Percentage bandwidth is a concept that gives a clue to the required Q of an antenna in order to have low SWR from top to bottom. It is calculated by dividing the bandwidth (in kHz) by the band-center frequency (in kHz) and multiplying by 100 to get percent. The 80-meter band is 13.3% wide

$$\left(\frac{500}{3750} \times 100\right)$$

which means that it requires an antenna Q of 7 or below to be able to cover the whole band at low SWR. To further illustrate the concept, the 15-meter band is nearly as wide as the 80-meter band, in kHz, but is much narrower in percentage bandwidth

$$\left(\frac{450}{21,225} \times 100\right)$$

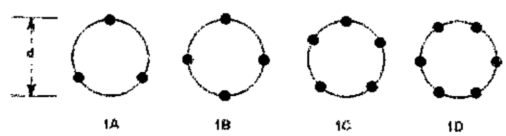
An antenna Q of 45 or less will cover the entire 15-meter band with reasonable SWR (a dipole of no. 12 wire). On 80 meters the typical dipole of no. 12 wire has a bandwidth of 75 kHz at the 1.5:1 SWR points, or in excess of 5:1 at the band edges when resonated at 3750 kHz (band center).

To get around this problem, I did some reading in the library at the local engineering college. I arrived at the well-known fact that the fatter one makes an antenna, the lower the Q; hence the greater the bandwidth. But how thick? Doing some more reading and a lot of paper scratching, I arrived at some relationships that could be solved with the average scientific calculator. Later, I programmed these into our company computer to speed calculations and print tables and graphs.

Table 1

Percentage Bandwidths for the Popular Amateur Bands

Band (meters)	*160*	*80*	*40*	*20*	*15*	*10*	*6*	*2*
Percent Bandwidth	10.5%	13.3%	4.2%	2.5%	2.1%	6.3%	7.7%	2.7%



CONFIGURATION	EQUIV. DIAMETER
1A	0.4214d
1B	0.5903d
1C	0.7563d
1D	0.9200d

Fig. 1 — Solid-tube equivalents of wire cages.

The equations and math I'll tackle later for those who are interested. For the others who want to know what to build, I'll cover that now. Calculating several antennas from the equations, I found that the antenna had to be at least 3 feet in diameter to cover the whole 80-meter band with a low SWR. Now, how to put up a 3-foot-diameter pipe 120 feet long! That's the question. So back to the books!

More reading showed that one can approximate a cylindrical conductor with parallel wires of various configurations. The equivalent diameter of a conductor, made up of parallel wires, is shown in Fig. 1.

The easiest type to construct is a four-wire cage. For my antenna, I used cross sticks of 1 × 1 material, 4 feet (1.2 m) long, which were held together at the center by a couple of brads. Holes were drilled in the ends of the sticks to take the antenna wire. Wire ties served to keep the spreaders from slipping (Fig. 2). I used a no. 16 wire for each element. This is equivalent in antenna resistance to a dipole made of no. 10 wire, and it keeps ohmic losses low.

Mechanical Considerations

Some mechanical considerations must be kept in mind. This antenna will swing in the wind. The first antenna I installed failed through fatigue both at the center and the end points. Therefore, the end sections of each half must be made of heavier material. I have used both no. 16 Copperweld and no. 12 soft-drawn copper wire for the end sections with no failures in over six years.

The ends of each half section are tapered over a distance equal to the spreader length to provide a transition between the large-diameter conductor of the antenna and the balun or coaxial connection. To keep construction simple, I did not attempt to optimize the end terminations.

Use fairly heavy insulators at the center support, as this is a heavy antenna; wind loading is five times that of the usual

*2318 S. Country Club Rd., Melbourne, FL 32901

Table 2

Characteristics for the 80-Meter Band

Freq.	*Ohms*	*Reactance*	*SWR*
3.500	53.4	−45.0	2.18
3.520	54.2	−41.3	2.03
3.540	55.0	−37.5	1.90
3.560	55.8	−33.8	1.78
3.580	56.6	−30.1	1.67
3.600	57.4	−26.4	1.56
3.620	58.2	−22.7	1.46
3.640	59.0	−19.0	1.37
3.660	59.8	−15.4	1.29
3.680	60.6	−11.7	1.21
3.700	61.4	−8.0	1.14
3.720	62.2	−4.4	1.07
3.740	63.0	−0.7	1.02
3.760	63.8	2.9	1.06
3.780	64.7	6.6	1.12
3.800	65.5	10.2	1.18
3.820	66.3	13.9	1.25
3.840	67.1	17.5	1.33
3.860	67.9	21.1	1.40
3.880	68.7	24.8	1.48
3.900	69.5	28.4	1.56
3.920	70.3	32.0	1.64
3.940	71.1	35.7	1.73
3.960	71.9	39.3	1.82
3.980	72.7	42.9	1.91
4.000	73.5	46.5	2.01

Note: Calculations for an antenna 124 feet (37.8 m) long and 3 feet (0.9 m) in dia covering 3.5 to 4.0 MHz. Zo = 62.

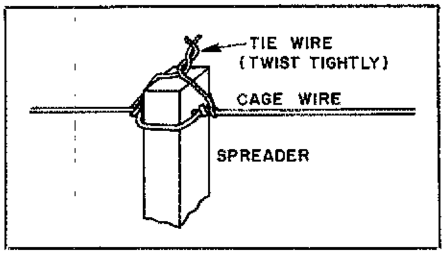


Fig. 2 — Detail of spreader ties.

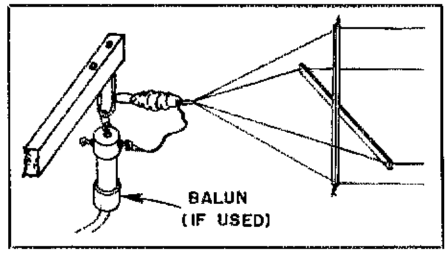


Fig. 3 — Center-support and end-taper detail of the cage.

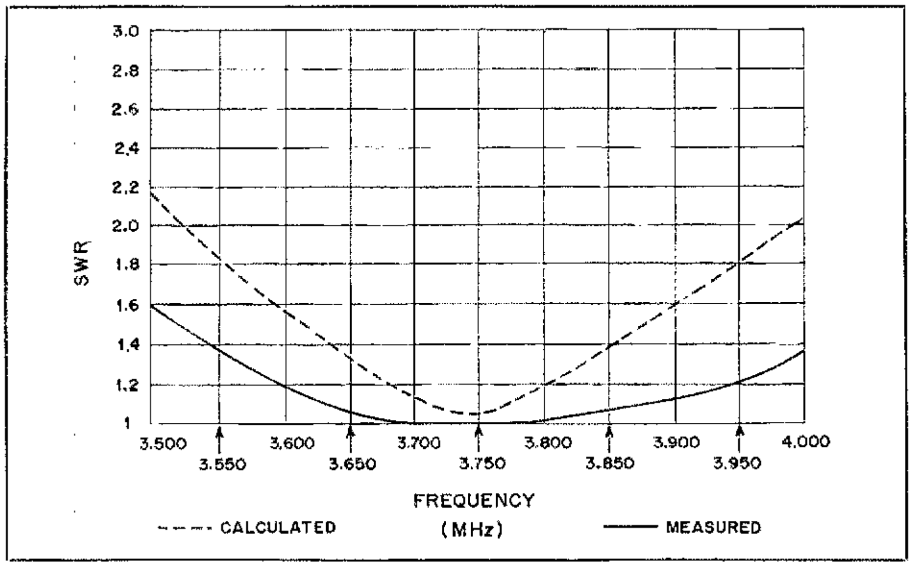


Fig. 4 — This graph shows the calculated vs. measured SWR values for the broad-band cage antenna over the entire 80-meter band. The gradual slope of the measured curve and the low SWR range indicate good bandwidth and matching.

dipole. (Do not despair! Mine has survived a twister and a hurricane!) I used a separate insulator for each half with each fastened to a U bolt in a wooden arm protruding from my tower (Fig. 3). Separate insulators at the center allow each half to be made and raised separately. A no. 12 flexible wire connects the center of each half to the balun or coaxial line.

Naturally, the higher the antenna, the better it is for DX. Mine is 68 feet (20.7 m) at the center, with one end held at 55 feet (16.8 m) and the other at 40 feet (12 m) above ground.

Testing

Once in place, the antenna is ready for testing. Each installation seems to have its own peculiarities, the result of nearby objects such as trees, houses and metallic structures. These affect the resonant length of the antenna to a greater extent than they would affect a single-wire dipole because of the larger capacitance between the antenna and nearby objects. While the length was calculated to be near 124 feet (37.8 m), I had to shorten mine to 115 feet (35 m) to have it be resonant at the center of the band. I performed the shortening in the last outboard section rather than redo the end termination. That, however, was a personal choice.

All the theory in the world is useless if the thing doesn't work! I'm delighted to say, though, that the antenna does perform well. Observe, for instance, the calculated SWR plot and the measured SWR curve in Fig. 4. The return on invested time is very high. It took me only one afternoon to put the thing up. My rewards for the 80-meter portion of both 5BDXCC and 5BWAS were gained with the use of this cage dipole. The significant advantage of this antenna, however, is that you can throw away that 80-meter antenna tuner and QSY all over the band with ease without concern about the SWR!

Math 'n Stuff

The characteristic impedance of an antenna with a length-to-diameter ratio greater than 15 is given by the expression

$$Z_{in} = R(k\ell) - j[120\,(\mathrm{Ln}\; 2\ell/a - 1)\cot(k\ell) - X(k\ell)]$$

where

2ℓ = total length

a = conductor radius

$k\ell = 2\pi(\ell/\lambda)$, or the length of one half the antenna measured in radians.

Ln = natural logarithm

Since $\lambda = 984.25/f_{MHz}$, then $k\ell = 6.384 \times 10^{-3} f_{MHz}\ell$, where ℓ and λ are in feet.

$R(k\ell)$ and $X(k\ell)$ are quite complex functions, but are calculated as a table in Ref. 1. Fortunately, we are interested in antennas near 1/2 wavelength long. In this region, these functions can be approximated by the following linear equations:

$$R(k\ell) = 102\,(k\ell) - 87.86$$
$$X(k\ell) = 48.54(k\ell) - 34.86$$

Some error is introduced by this approximation, but it is less than 5%. Antenna location, height and trees will introduce larger errors than that! Now, the equation for the center impedance is simplified to the point where one can calculate values with the average scientific hand-held calculator.

For angles calculated in radians:

$$Z_{in} = (0.6512 f_{MHz}\ell - 87.86) - j[120\,(\mathrm{Ln}2\ell/a - 1)\cot(6.384 \times 10^{-3} f_{MHz}\ell) - 0.3099 f_{MHz}\ell + 34.96]$$

For angles calculated in degrees:

$$Z_{in} = (0.6512 f_{MHz}\ell - 87.86) - j[120\,(\mathrm{Ln}2\ell/a - 1)\cot(0.3658 f_{MHz}\ell - 0.3099 f_{MHz} + 34.96]$$

SWR calculated by the *Antenna Book* formula:

$$SWR = \frac{1 + k}{1 - k};\; k = \frac{(R - Z_0)^2 + X^2}{(R + Z_0)^2 + X^2}$$

where R and X are the resistive and reactive parts of the load, and Z_0 is the transmission-line impedance.

References

[1]Jasik, *Antenna Engineering Handbook*, first edition, McGraw Hill, 1961, pp. 3-2 through 3-7.
The Radio Amateur's Handbook, fifty-eighth edition, ARRL, 1981, p. 19-2.