# Compact Multiband Antenna Without Traps

Looking for an inexpensive, easy-to-build, portable antenna to use with your tube-type transmitter? This first cousin of the G5RV may be the aerial of your dreams.

By Taft Nicholson,* W5ANB/AAR6AG

Do you need an antenna for portable operation? I do! My preference is for making things as simple as possible. I don't like traps and matching units. The antenna shown in Fig. 1 has no traps, needs no matching unit for the 10-, 20- and 40-meter bands (when used with vacuum-tube PAs), is lightweight and installs easily. What more could you ask for?

## Construction

Construction is simple. Cut two lengths of stranded copper wire (such as Radio Shack 278-1292) to 44 feet, 2 inches each (m = ft × 0.3048). Attach 36 feet, 8 inches of 300-ohm twin lead as shown in Fig. 1. Coaxial cable attaches to the other end of the twin lead at the points marked A and B in the diagram. I wound 7 feet, 2 inches of RG-58/U coaxial cable into an rf choke to minimize problems with rf flowing on the outside of the coaxial cable. This length of cable in the choke evolved from an attempt to match the antenna to the transmitter for operation on 15 meters.

Alternatively, you could use open-wire feeders in place of the twin lead. If you choose that method, you will need to make the section 42 feet, 6 inches long. Or you could attach the twin lead or open-wire conductors to a matching unit. When using a matching unit, there is no particular merit in the lengths given in the diagram.

## SWR

The SWR of the antenna is less than 3:1 on 10, 20 and 40 meters. I have no difficulty loading transmitters with tube-type PAs (e.g., Galaxy V, Swan 350 or Drake T4X). This antenna will work with some transmitters on 15 meters, but tuning is quite critical.

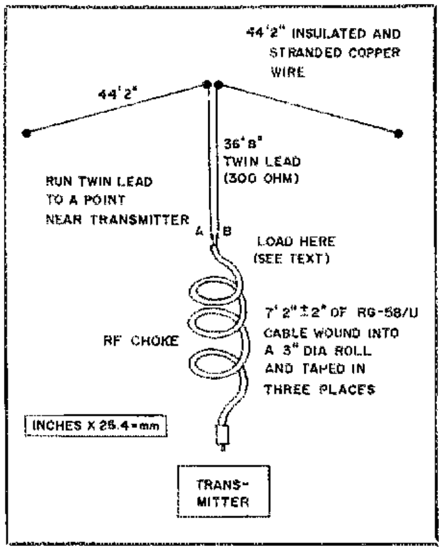

Fig. 1 — Diagram of the compact multiband antenna. For 80-meter operation the loading coil is inserted at points A and B. Banana plugs and jacks may be added here to facilitate insertion and removal of the loading coil.

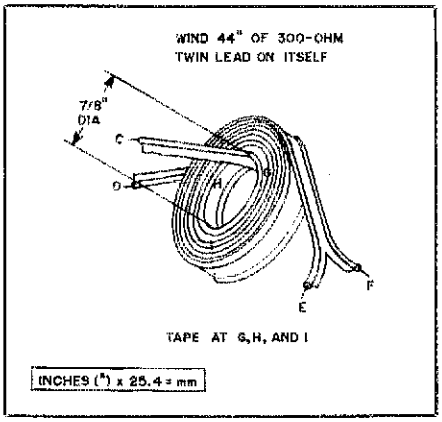

Fig. 2 — Loading coil for 3500-3750 kHz operation. Points E and F on the coil are connected to the coaxial cable. Points C and D are connected to the twin lead.

However, 80-meter operation is a problem. I have not been able to obtain full output power with these transmitters on frequencies below 3.750 MHz. The SWR measures between 5:1 and 8:1 for the lower part of the band. I constructed a loading coil to go between the choke and the twin lead (Fig. 2). The coil consists of 44 inches of twin lead wound on a 7/8-inch diameter form (my left thumb). Once the coil was wound, I removed it from my thumb and used electrical tape to secure it. For 80-meter operation, attach ends C and D to the choke and ends E and F to the twin lead. Remove the coil for operation on the other bands. Banana plugs and sockets can be used to facilitate the insertion and removal of the coil.

## Installation

The antenna should be as high as practical. I've had satisfactory results with the center of the antenna only 25 feet above ground, with the ends tied to fences or other convenient supports. Telescoping TV mast sections make a good support if nothing else is available. The legs of the antenna serve as two of the guy wires. One or two additional guy supports should be added (nonconducting material such as nylon rope is best).

This compact multiband antenna works satisfactorily on all bands from 20 through 80, and 10, meters. It has no traps and requires no matching unit when used with tube-type equipment. I have used it for portable operation in and out of the country. It is easy to pack, carry and erect. Perhaps you might want to try one. I think you'll like it! A brief discussion of the theory of operation follows in the appendix.

[Editor's Note: A description of the G5RV appears in the RSGB *Radio Communications Handbook*. Gray described it in the June 1977 issue of *Ham Radio Horizons*. A similar design was depicted in the Collins Radio manuals of the 1930s.]

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*2304 Willow Dr., Alamogordo, NM 88310.

## Appendix

This multiband antenna evolves from two connected transmission lines with critical length and ratios of surge impedances. The system is self resonant at a fundamental frequency and at most of the even harmonics and several of the odd harmonics. The first five are 2nd, 4th, 5th, 7th and 8th.

Consider the transmission lines in Fig. 3.

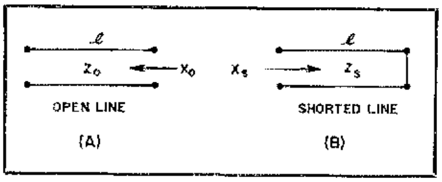

Fig. 3 — Two identical lengths of transmission line. Looking into the lines, the opposite ends are open and shorted at A and B, respectively.

The two lines are of equal length, "ℓ" and different surge impedances, $Z_o$ and $Z_s$.

Looking into the lines:

$$X_o = \frac{Z_o}{\tan(2\pi\ell/\lambda)} \text{ and } X_s = Z_s \tan(2\pi\ell/\lambda)$$

where

$\lambda$ = wavelength

$X_o$ = reactance looking into open line

$X_s$ = reactance looking into shorted line

From the theory of resonant circuits, we know if we connect the lines the system will be resonant at all frequencies where $\bar{X}_o = \bar{X}_s$, provided the two reactances are of equal value and opposite signs. The open and shorted line provide this condition except at some harmonics.

Joining the lines as depicted in Fig. 4 we find that

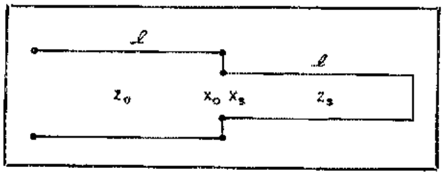

Fig. 4 — The two transmission lines from Fig. 3 are joined to form one line.

$$\frac{Z_o}{\tan(2\pi\ell/\lambda)} = Z_s \tan(2\pi\ell/\lambda)$$

$$\frac{Z_o}{Z_s} = \tan^2(2\pi\ell/\lambda) = \tan^2(360°\ell/\lambda)$$

If the angle $2\pi\ell/\lambda$ is made 60°, then the amplitude of the tangent at 120° or second harmonic will be the same. This will be true for 240° (4th harmonic) and 300° (5th harmonic). Similarly, these harmonic responses will continue at discrete angles above 360°, e.g., 7th, 8th, 10th, 11th, 13th, 14th and so on. The signs of the tangents wash out when squared.

The angle $2\pi\ell/\lambda$ becomes 60° by making $\ell = \lambda/6$ (1/6 of a wavelength) at the fundamental frequency.

$$\frac{Z_o}{Z_s} = \tan^2(360° \times 1/6)$$

$$= \tan^2 60° = (1.73)^2 = 3$$

Therefore $Z_o = 3Z_s$. This equation makes practical the multiband antenna because $Z_o$ can represent the antenna proper and $Z_s$ can represent the resonant feeder.

$Z_o$ for the antenna may be computed from formulas in radio engineering handbooks or text books. For a piece of wire above the earth and parallel to it as shown in Fig. 5C

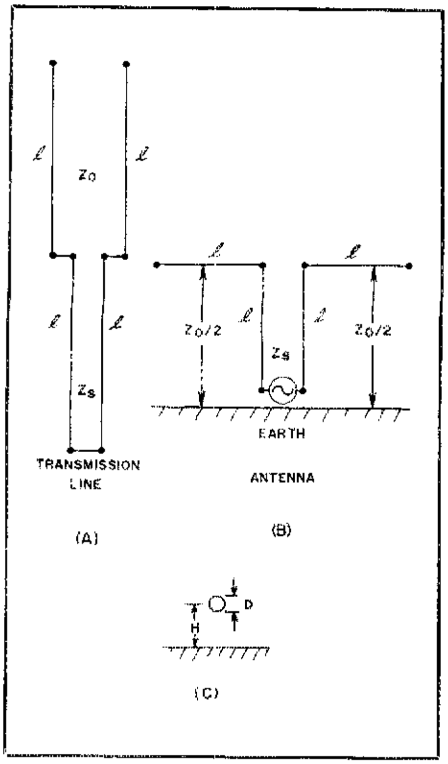

Fig. 5 — At A and B, the open portion of the transmission line evolves into the flat-top portion of the antenna. At C, diagram illustrating the formula for calculating $Z_o$ for the antenna.

$$\frac{Z_o}{2} = 138 \log \frac{4h}{d}$$

For no. 12 wire, d = 0.08081 in.

Let h = 20 feet or 240 in.

$$\frac{Z_o}{2} = 138 \times \log\left(\frac{960}{0.08081}\right)$$

138 log (11879) = 562 ohms

If the wire size had been no. 18,

$$\frac{Z_o}{2} = 605 \text{ ohms}$$

If we use no. 12 wire, then we would have 562 ohms on one side and + 562 ohms on the other side.

$$Z_o = \frac{Z}{2} + \frac{Z}{2} = 1124 \text{ ohms}$$

From the formula $\frac{Z_o}{Z_s} = 3$

$$Z_s = \frac{Z_o}{3} = \frac{1124}{3} = 374.6 \text{ ohms}$$

This value is not critical. One can use 300-ohm twin lead or 400-ohm open line with good results. The harmonics will be displaced somewhat, but with variable tuning of the transmitter the system can be brought on frequency.

The above indicates that $Z_o/2$ varies with antenna height, wire size and configuration. The function is logarithmic and a lot can be done to the antenna before $Z_o$ changes very much. The inverted V works well; just use the $Z_o/2$ formula for a horizontal wire and let h be the average height of the inverted V. A formula for surge impedance can be worked out for most any configuration, including a vertical. If the reader is interested in feeding a vertical antenna, he is referred to LaPort,[1] which has the fundamental information for finding surge impedance or characteristic impedance of antennas.

The system could be used for a single-ended antenna fed with a balanced transmission line with a balun at each end. Another possibility for a vertical is the use of a two-wire, grounded, open transmission line, as discussed in LaPort's book. The ground system would be critical.

When experimenting with these multiband lines, it is convenient to have some "stock" numbers to apply to the lines (see Fig. 6). One-sixth of a wavelength is one-third of a half wavelength. A convenient length for a half wave on 80 meters is 135 feet. One-third of that is 45 feet or $\lambda/6$ for 80 meters. One-sixth of a wavelength on 40 meters is 22-1/2 feet. When you are designing an antenna, these lengths need to be multiplied by the propagation constant of the line. After construction and testing, the dimensions can be pruned for end effect, etc.

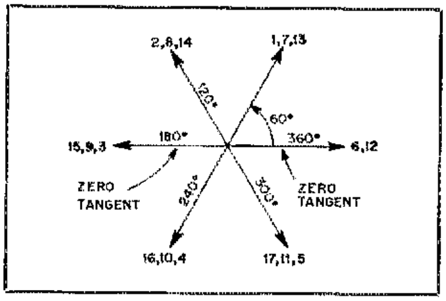

Fig. 6 — Angular position chart useful for determining "stock numbers" to apply to the chart.

When operated as a transmision line, the system as described may have application in end-feeding half-wave antennas, especially two half waves in phase. The system transforms a high impedance to a low impedance as a quarter-wave line will; however, it will do this at several even harmonics, in contrast to the quarter-wave line that is only responsive to odd quarter wavelengths.

The author wishes to thank Walt Maxwell, W2DU, for his detailed analysis of the theory section of this article. Further information about this antenna is available from the author. Please enclose a self-addressed, stamped envelope with your request.

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**Notes**

[1] E. LaPort, *Radio Antenna Engineering (New York:* McGraw-Hill Book Co., 1952).

[2] See note 1.