An Analysis of the Balun

What does a balun do for you? What happens if you don't use one? Does a balun really make a difference?

By Bruce A. Eggers,* WA9NEW

bal·un (bal'un), n. a word formed from the words "*bal*anced" and "*un*-balanced." Identifies any of a series of devices used to couple unbalanced transmission lines to balanced loads.

Okay, so that's what a balun is. But what does it do for you? You've probably heard that a balun is used to feed a balanced antenna. What is a balanced antenna? The determining factor is how the antenna is fed. Perhaps the best way to answer this question is to cite some examples. A half-wave dipole, current fed across a center insulator, is perhaps the most common example. This antenna is designed to perform best when each side is fed separate currents of equal amplitude and opposite phase.

Having established this basic idea on defining a balanced antenna, we can now look at some common variations. The folded dipole is one. The currents flowing in the various elements of a folded dipole may be of different amplitude, and you can have more than the common two radiators, but if the feed principle is the same, it's a balanced antenna. The cubical quad can be viewed as a variation of the folded dipole. From this you can see that loops, rhombics, Yagis, and a whole host of antennas, depending upon how they are fed, can all be balanced antennas. On the other hand, a vertical antenna and a ground-plane antenna are unbalanced — the current in these antennas does not flow in identical fashion away from each of the two conductors of the feed line.

In today's marketplace just about all of the transmitters use the same output circuit, the pi network. This single-ended circuit has become very popular for a variety of reasons, not the least of which is the popularity of coaxial cable. While coax isn't the answer to all of the problems with feed lines (and it certainly has high loss problems at the higher frequencies), it does have some redeeming qualities. One of the more convenient things about coax is that, when used properly, you can route it just about anywhere. No need for standoff or feedthrough insulators.

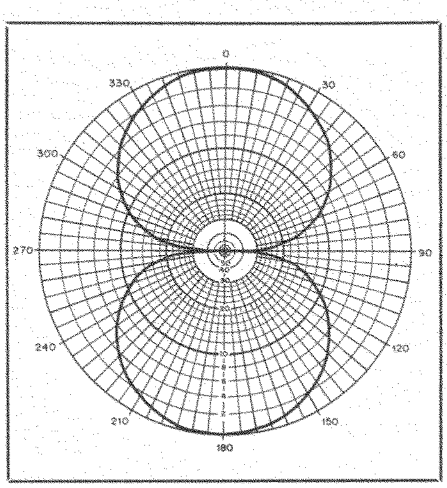

Fig. 1 — Classic response pattern of a half-wavelength dipole in free space. The concentric-circle scale is indicated in decibels down, relative to the response in a broadside direction from the axis of the dipole. The outer scale shows degrees of departure from one broadside direction. The axis of the conductor is common with the line between the 90° and 270° outer-scale markings.

But coaxial cable is an unbalanced feed line. All of the current flows *inside* the line. The inner conductor and the inside of the shield are the two conductors in this line. Therein lies the problem. Feeding a balanced antenna with unbalanced feed line may cause currents to flow on the *outside* of the shield. In fact, given a feed-line length that is significantly long at the operating frequency (e.g., greater than on the order of 0.15 wavelength), one can model the coaxial feed line connecting a single-ended or unbalanced transmitter output to a balanced antenna as a three-conductor feed line!

The "third conductor" and its associated current is the outside of the coaxial shield. The magnitude of this current is a function of the impedance to ground of this conductor. And this impedance can be controlled. If the feed-line length is greater than one quarter of a wavelength long, a "skirt" one quarter of the wavelength long can be placed around the outside of the shield and shorted to the shield one quarter of a wavelength from the load. Such a device, commonly referred to as the "bazooka," is adequately documented in all recent editions of the ARRL *Handbook* and *The ARRL Antenna Book*. It is also well described in any of several other references.[1]

If the feed line is not a quarter wavelength long, or if one wants to accomplish the same effect with lumped components, then there are a variety of other ways to accomplish the same thing. One of the more recent and original ideas presented in the literature on this subject is contained in the article by Reisert, W1JR, in the September 1978 issue of *Ham Radio*.[2] So now let's move on to the question, "What happens if you don't use a balun?"

The Great Experiment

Everybody recognizes the classic "figure-eight" radiation pattern of a half-wave dipole in free space. Fig. 1, taken from *The ARRL Antenna Book*,[3] shows

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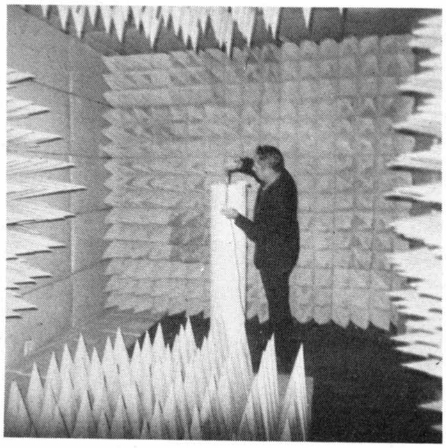
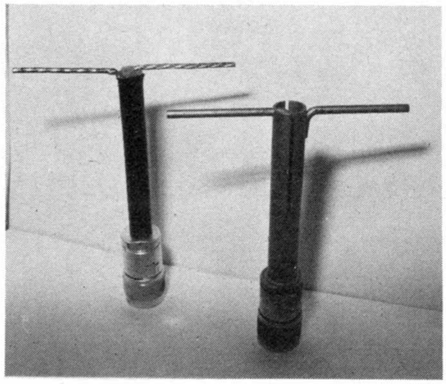
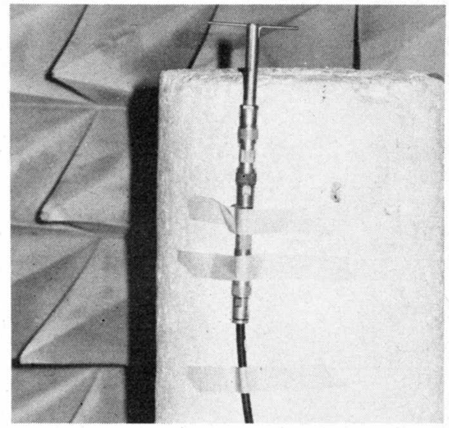
[1]References appear on page 21.



The author positioning one of the test antennas on the rotatable Styrofoam support in the rf anechoic chamber.



Close-up photograph of the two 1.6-GHz half-wave dipole antennas used in the author's tests.



The balun-fed test antenna mounted on the antenna support. (This mounting technique is not recommended for regions subjected to high winds or heavy icing.)

what this looks like. But this figure is an idealized pattern based on current flowing only in the antenna. What does this pattern look like in a real-world situation and what happens to it if we allow current flow on the outside of the feed line? Figs. 2 and 3 answer the question.

The radio-frequency anechoic chamber at North Carolina State University was available to us. An rf anechoic chamber is simply a room in which the walls, floor and ceiling are covered with a material that is designed to break up an electromagnetic wave and absorb its energy. If you put an antenna in such a chamber it can not "see," or be influenced by, any surface or objects that can reflect or reradiate electromagnetic energy. How about that! "Free space" right here on earth! But putting just one antenna in a chamber isn't going to do you any good. You still can't see or measure the radiation pattern. To take care of that problem you have to provide a source of radio-frequency energy. Then if you put an antenna in the chamber, you can observe how it performs as you change its orientation.

For these tests the source of the rf was a half-wave balun-fed dipole, similar to the one on the right in the photograph above, mounted horizontally at one end of the chamber. The balun is electrically equivalent to the quarter-wave bazooka balun discussed above and in reference 1. It was mounted at the same height as the receiving antenna and fed a few milliwatts of power at 1.6 GHz. The test antennas were then mounted, one at a time, horizontally, at the other end of the chamber, on a rotating support. The supports for both antennas were made of Styrofoam with a relative permittivity of about 1.03.[4] (No metal towers to affect this pattern!) The test antennas were then rotated a full 360 degrees. The received signal was carried to the receiver outside of the chamber on a coaxial feed line. The feed line dropped away from the antenna perpendicularly for a distance of about nine wavelengths. (How would you like to

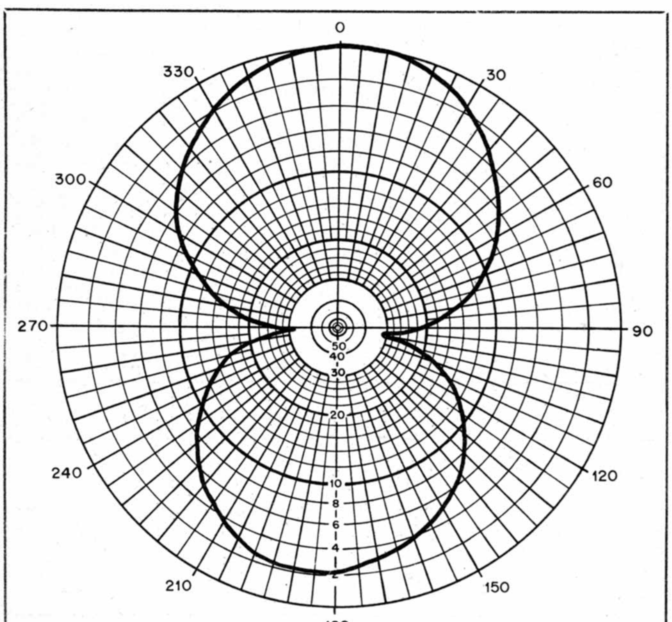


Fig. 2 — Response pattern of the balun-fed half-wavelength dipole in the rf anechoic chamber. The apparent front-to-back ratio exists because the antenna was not located at the exact center of the rotating support. This response and that of Fig. 3 are drawn to the same relative scale.

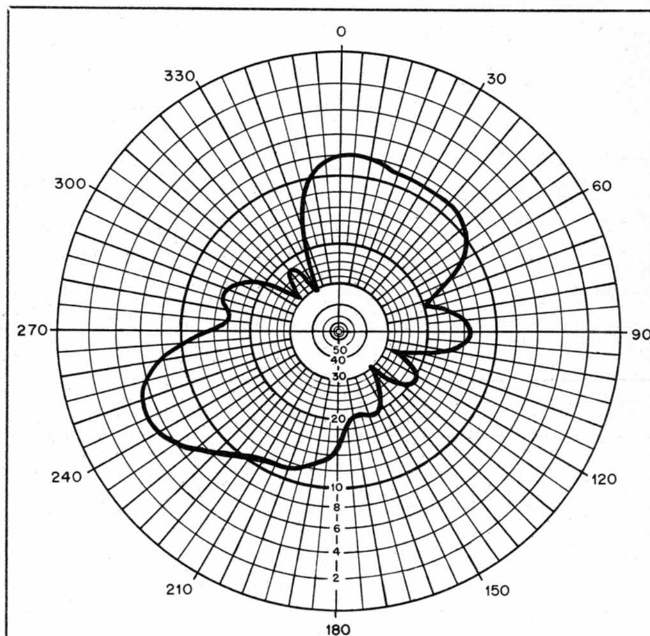
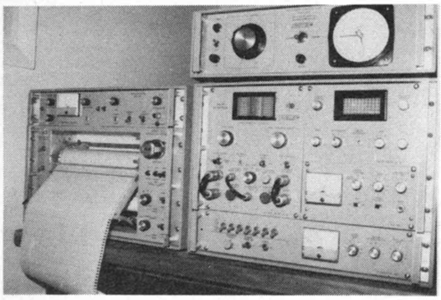


Fig. 3 — Response pattern of the half-wavelength dipole without a balun. The pattern changed significantly during tests if the coaxial feed line was relocated, no doubt caused by changes in the amplitude and phase of currents flowing on the outside of the line.



The Scientific-Atlanta, Inc. test equipment outside of the chamber. The series 1520 rectangular recorder is on the left. The series 4100 position-control unit sits atop the series 1600 receiver.

have your 80-meter dipole that high!)

The receiving, recording and antenna-positioning equipment are all from Scientific-Atlanta, Inc. The series 1600 receiver tunes from 50 MHz to 32.8 GHz in nine bands. The received signal level is fed to a series 1520 rectangular recorder,[5] where the feed rate of the chart is controlled by the series 4100 position-control unit. The recorded signal level is kept as low as possible, consistent with producing a usable output signal with the antennas in the least optimum position, to minimize the effects of any reflected energy that might be received and processed.

Fig. 2 shows the pattern of the balun-fed antenna. The signal level in the nulls off the ends of the antenna is about 32 dB below the "broadside" signal level. Noise precludes identifying nulls significantly deeper than that level in this particular setup.

Fig. 3 shows the pattern of a dipole without the benefit of the balun. The peak amplitude of the signal is about 5 dB below that of the balun-fed antenna and one of the nulls, 30 degrees from broadside, is just as deep as was the null off the end of the balun-fed antenna. There are a couple of points about this trace that need to be considered. First, the exact location of peaks and nulls is highly dependent upon the relative location of the feed line as the antenna is rotated. In repeating the experiment with a different relative position of either, the pattern changes. Fig. 3 can only be considered as representative of how a half-wave dipole performs as a receiving antenna when used without a balun and when used with a long feed line. Second, the overall drop in signal level is not necessarily representative of what you should expect from the antenna in a transmit application. Reciprocity notwithstanding, antenna currents flowing on the outside of the coax are, in general, lost to the receiver. These same currents, in the transmit mode, can radiate energy which effectively fills in the nulls noted here. The pattern of Fig. 2 is fully predictable and can be easily reproduced in a repeated experiment. That of Fig. 3 cannot.

So what does a balun do for you? It gives you a predictable pattern. The biggest benefit which accrues from this feature is applicable to using a balanced element in a directional array. Can you imagine using a radiator with a pattern like that of Fig. 3 in a parasitic array? But many do! In such an application, the presence of the parasitic elements in the near field no doubt tends to smooth out the irregularities of the far-field pattern. But, as the old saying goes, "You can't make a silk purse out of a sow's ear."

Conclusions

The results of this experiment should not necessarily be interpreted to mean that installing a balun on your 80-meter dipole is going to result in any detectable differences. Remember, this dipole was in "free space." Your antenna interacts with all kinds of reflecting and reradiating objects. Every piece of material in the vicinity of the antenna has an effect. And it seems reasonable to assume that the number of nulls and peaks in Fig. 3, and the depth of the nulls, is related to the length of the feed line. The pattern of your 80-meter dipole might not look as bad as Fig. 3, but you can rest assured that it probably doesn't look like Fig. 2 either. The majority of the variations between a real-world antenna pattern and an idealized pattern, at least in regard to simple antennas on the lower frequencies, will result from objects in the near field of the antenna. The additional variations introduced as a result of not using a balun in an application of a coaxial-fed balanced antenna will become most significant at higher frequencies with multielement antennas.

If one had ready access to a facility such as this anechoic chamber on a regular basis, it would be most interesting to run a series of these experiments using a variety of different antenna types. Perhaps someone could do that. I, for one, would like to see the effects of a balun on other antenna types. The author wishes to express his appreciation to Dr. J. Frank Kauffman of the Department of Electrical Engineering at North Carolina State University for his assistance in the conduct of the experiment, and to Pershing Hicks for his photography. QST

References

[1]Jordan and Balmain, *Electromagnetic Waves and Radiating Systems,* 2nd edition, Prentice-Hall, p. 407.

[2]Reisert, "Simple and Efficient Broadband Balun;" *Ham Radio*, September 1978, p. 12. Also see Nagle, "High-Performance Broadband Balun," *Ham Radio*, February, 1980.

[3]*The ARRL Antenna Book,* 13th edition (1974), Fig. 2-13, p. 37.

[4]Kraus and Carver, *Electromagnetics,* 2nd edition, McGraw-Hill, p. 58.

[5][Data provided in rectangular form by the author has been replotted in the more familiar polar form for presentation in Figs. 2 and 3. — Ed.]

Strays

NARROW BAND COMMUNICATIONS PROJECT

☐ Narrow Band Communicators (NBC) recently activated a 100-mW, 2-meter, linear translator in the hills of Oakland, California, about 800 feet above sea level. Signal reports from the San Francisco bay area are excellent. Stations in the San Joaquin-Sacramento valley and the Sierra Nevada mountains have also worked the translator. The system which is operating very well, demonstrates the efficiency of narrow-band communications. — *Vivian Franco, WB6VTG, Daly City, CA*

NORTHWEST ONTARIO SENIOR CITIZENS TUNE IN THE WORLD

☐ An Amateur Radio Station, VE3LMB, has been established in Grandview Lodge, a senior citizens home, in Thunder Bay, Ontario. Funds for the project were provided through a "New Horizons" grant from the Department of Health and Welfare. This project gives retired people the opportunity to share their interests, skills and talents in developing and carrying out projects of their own design and choosing.

Early last year 10 retired hams founded the Northwestern Ontario Senior Citizens Amateurs, and a search began for a site to set up a senior citizens station. They needed a site with adequate space, light and heat, as well as easy access for handicapped persons and flexible operating hours. Club members discovered that the Grandview Lodge had a ground floor room available. Soon thereafter work began on the radio room. The club gained a room and the lodge gained a hamshack. The club has fulfilled all three of its original objectives: (1) to establish and operate an Amateur Radio station for senior citizens, (2) to establish a service department where members can repair their own equipment, and (3) to assist senior citizens throughout Northwest Ontario in making contacts with friends and loved ones.

MORE MILES PER WATT

☐ Frank Crowe, WB6UNH, of Carpinteria, California, reports working nine states on 1 mW or less output. Frank has also worked about 35 states at 1 watt or less, and is working on DXCC with 10 watts or less output. His best miles-per-watt performance is from Carpinteria to WB9LTY in Indianapolis, Indiana, on 0.1 mW output. Worked All Continents at 10 watts was "too easy" — he's working on getting it with 250 mW.