Basics for Beginners

The Whys of Transmission Lines

Part III — Putting the Antenna and Line Together

BY GEORGE GRAMMER*, W1DF

The half-wave dipole is the basis for most amateur antenna designs. Different types of lines can be used to feed power to it. The line should just carry power to the antenna and not get into the radiating act itself. When this is so, the dipole does all the radiating, and one dipole is the same as another no matter how power may be fed to it. This obvious fact is too often overlooked. Amateurs frequently let themselves be dazzled by some trick name tacked on a dipole-plus-feeder combination, but names don't do the radiating.

The best place to feed a half-wave dipole is at the center. The dipole is a balanced antenna — that is, it is symmetrical about its center. To maintain this symmetry a balanced line — *i.e*, a parallel-conductor line — should be used. The dipole *can* be fed at one end, but this also upsets the symmetry of the system.[1]

If the impedance at the center of the antenna matches the characteristic impedance of the transmission line the two can simply be connected together and the line will operate without standing waves. One advantage of this matched operation is that the line length has very little effect on the coupling required between the line and the transmitter. Another is that the losses in the line are least, for a given length, when the line is properly matched. The line losses can either be very important or completely unimportant. They are quite important at v.h.f. even when the best possible job of matching is done. They are unimportant at the lower frequencies, even with a considerable mismatch. The only exception here is when a major error is made in selecting the proper type of line for the use to which it is to be put.

A matched antenna system is actually matched only for one frequency. At best, the system will stay matched over only a small band. As the 7-, 14-, and 21-Mc. bands are narrow, in terms of percentage, an antenna that is matched at the center of one of these bands should work over the entire band without having the s.w.r. get too large at the band edges. But you can't do quite as well with antennas of this type on 3.5 and 28 Mc. Here it is best to cut the antenna for the section of the band that interests you most.

Matched Antenna Systems

Since the dipole has a center impedance of about 70 ohms, it will match a line having a characteristic impedance of 70 ohms, or something close to it. (A small — e.g., 20 per cent or so — discrepancy doesn't cause any difficulty. When 70-ohm or 75-ohm line is mentioned it is to be understood that any impedance in that immediate vicinity is meant.) There is a polyethylene-insulated two-conductor 75-ohm line available for this purpose (Amphenol 214-023). The antenna is simply cut in the center and a connection made to each line conductor, as in Fig. 1A.

In spite of the fact that it is desirable to keep the system balanced, a good many amateurs use

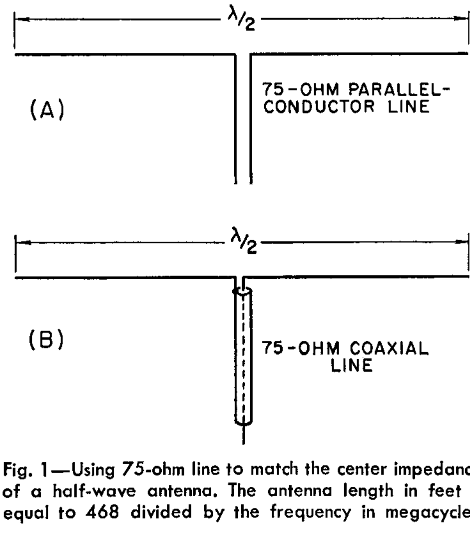

Fig. 1—Using 75-ohm line to match the center impedance of a half-wave antenna. The antenna length in feet is equal to 468 divided by the frequency in megacycles.

75-ohm coax for the same purpose, as in Fig. 1B. This is not the best practice, although it will work. One side of the dipole is unavoidably connected to the *outside* of the outer conductor as well as to its inside. This makes the outside of the coax line a part of the antenna system. Thus the outside of the line radiates — but not in any predictable way, because everything depends on where and how the line is installed and how

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[1] An exception to this is when *two* dipoles are fed from a parallel-conductor transmission line. An example is described shortly.

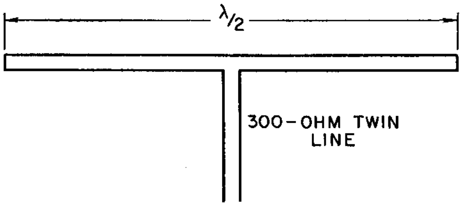

Fig. 2—The folded dipole. The antenna length is calculated in the same way as for a single-wire dipole.

long it is. The principal thing to be said for this system is that the coax line is easy to get.

Very often, 52-ohm (a nominal value) line is used instead of 75-ohm. It is not matched as well by the antenna, but the mismatch is not serious. It has the same disadvantages as 75-ohm coax.

The Folded Dipole

The advantages of matched operation also are realized with the *folded dipole*, shown in Fig. 2. The folded dipole has two half-wave conductors side by side. One is continuous, but the other is cut at the center for making connection to 300-ohm twin line. The two conductors are joined at their ends.

The wires radiate in parallel. In this respect, the pair is equivalent to a single half-wave dipole. But splitting the conductor into two parts has the effect of making the antenna impedance, as seen by the line, four times the impedance of a single-wire dipole. Thus at the point where the transmission line is connected the antenna impedance is approximately 300 ohms — just right for matching 300-ohm line.

Twin line can be used for the folded dipole itself, but ordinary TV line won't stand the mechanical stresses too well if the antenna is long. There is a special heavy-duty line available (Amphenol 214-022) which is better. TV ladder line also can be used for the dipole. The spacing between the dipole wires can be anything up to a few inches, so practically any construction that will keep the wires parallel can be used.

"Open-Wire" Feeders

Fig. 3 shows a half-wave dipole fed at the center through *open-wire* parallel-conductor line. This is line having mostly air insulation, such as the TV ladder line mentioned earlier. Here there is no attempt at matching the antenna to the line. Consequently there are fairly pronounced standing waves on the line. However, the high s.w.r. doesn't cause an undue power loss in open-wire line. The principal penalty is that more attention has to be paid to the coupling between the line and transmitter. The advantage is that the antenna can be made to take power at practically *any* frequency.

A transmission line operating with a high standing-wave ratio is often called a *tuned line* or *tuned feeder*. Actually, the only tuning necessary is that required for coupling the transmitter to the line. The line can be any length. However, it does help simplify the transmitter coupling a bit if a resonant length is used. Such a length, as you have seen, will be some multiple of one-quarter wavelength.[2] The line will "look like" a resistance at its input end in such a case, provided the antenna itself is resonant.

On the other hand, in this open-wire system the dipole doesn't have to be exactly resonant. Since there is no attempt at matching the characteristic impedance of the transmission line, the antenna doesn't *have* to look like a pure resistance, of just the right value, to the line. The over-all length of wire in the system, including both the dipole and the transmission line, is of more interest. It is this over-all length that determines whether or not the system as a whole is resonant. One line wire plus one side of the dipole (the length L in Fig. 3) should be a whole-number multiple of a quarter wavelength if you want the system to be resonant. The formula

$$\textit{Length in feet} = \frac{234}{\textit{Freq. in Mc.}}$$

will give the length of a quarter wave as accurately as is necessary.

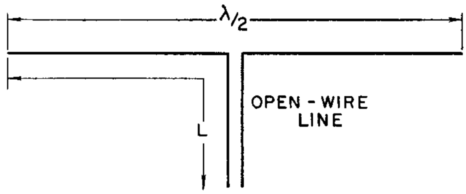

Fig. 3—Half-wave dipole fed with open-wire line.

Multiband Operation

The simplest multiband antenna, and the most versatile, is the one shown in Fig. 4, using open-wire feeder. Since the amateur bands are harmonically related in frequency, we can take advantage of the fact that wires have harmonically-related resonances. The fundamental frequency of a center-fed wire is the one for which its length is a half wavelength. At twice the frequency each *side* of the antenna is a half wavelength long, so at this frequency the transmission line is feeding a pair of half-wave dipoles end-to-end. The current distribution is shown in Fig. 4, which also shows the other resonances up to the fourth multiple.

You should note a few especially interesting things in these drawings. In the second-harmonic case the polarity of the current is the same in both sides of the antenna. There is no reversal such as there is in a continuous wire of the same over-all length. This difference comes about because we have, in effect, two half-wave antennas driven in push-pull, rather than a single antenna a full wavelength long.

There is a somewhat similar situation at the

[2] "The Whys of Transmission Lines," Part I, January, 1965, *QST*.

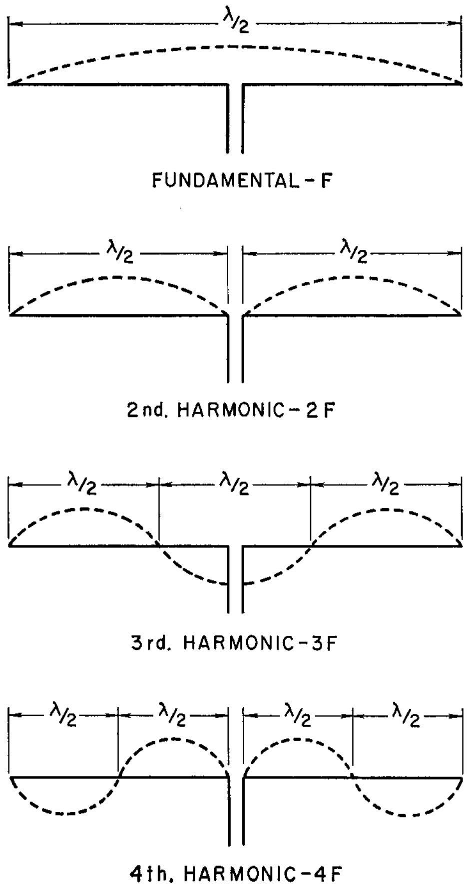

Fig. 4—Harmonic operation of a center-fed antenna. If the antenna is a half wavelength long at 7 Mc., for example, it will also be resonant in the 14-, 21- and 28-Mc. bands.

fourth harmonic. Here, too, the currents in the half-wave sections connected to the line have the same polarity. However, when we go out along either wire we find that the normal reversal occurs in the next half-wave section.

This type of current distribution occurs at all *even* multiples of the fundamental frequency. Note also that at the second harmonic the current is minimum where the feeder is connected. Although the voltage distribution isn't shown, the voltage is highest at these same points, just as in the cases discussed earlier. This means that the impedance is high at the connection point. If the antenna is resonant, it is a resistance rather than an impedance, and is of the order of several thousands of ohms. This same condition exists at all even multiples of the fundamental frequency.

Odd Harmonics

Now look at the drawing for the third harmonic. Here we have the normal current distribution for a wire three half-waves long. The antenna current has its largest value right where the transmission line is connected. The voltage must be lowest at this point, so the impedance (or resonant resistance) of the antenna is low — more like the impedance at the fundamental.

Thus for all *odd* multiples of the fundamental, the current distribution is the same as in a simple continuous wire of the same over-all length, and the impedance at the feed point is low. The impedance goes up a little with each odd harmonic — to a little over 100 ohms at the third harmonic and to about 120 ohms at the fifth harmonic.

Because these figures do not differ too greatly from 70 ohms, it is possible to operate an antenna on its *odd* harmonics when it has been matched on its fundamental. The match is not as good as at the fundamental, but it is not so poor as to result in excessive line loss. Such operation does not really qualify the antenna for multiband work, because only a few bands — not a consecutive series — can be covered.

If the antenna is fed with 50- or 75-ohm line you should not try to operate it at *even* harmonics of the frequency for which it is matched. The line losses would be excessive because of the high s.w.r.

Transmitter-to-Line Coupling

Nowadays nearly all transmitter final tank circuits are designed for coupling into resistive loads of 50 to 75 ohms. A properly-matched coaxial line will "look like" such a resistance, and when a matched coax line is used there is no difficulty in making the final amplifier load up to the rated input. But if the load isn't properly matched, or some other type of line is used, you may have problems. The loading and tuning adjustments offered by the transmitter usually will give you some leeway — even if the matching at the antenna isn't perfect you may still be able to get the power input you want. Again, you may not.

You can get around troubles of this sort by using a special coupling circuit — a *transmatch* — between the output of the transmitter and the input end of the line. As we saw earlier, the input impedance of the line is not the same as the line's characteristic impedance unless the line is perfectly matched by the antenna.[3] If the s.w.r. is greater than 1 to 1 the input impedance may differ widely from Z_0. If the line is connected directly to the transmitter, the latter may see a load that it can't handle. The transmatch takes the line input impedance and transforms it to what the transmitter wants.

It also does two other things. Practically all transmitter output circuits are single-ended — one side is grounded to the chassis, which is the right way to do it for coax line. What to do when a balanced line is used, as in Figs. 1A, 2 and 3? The transmatch easily handles this one; it provides the means for going from a balanced line to coax. In addition, it adds selectivity between the transmitter and the line — selectivity that often is badly needed. It is an

[3] "The Whys of Transmission Lines," Part II, February, 1965, *QST*.

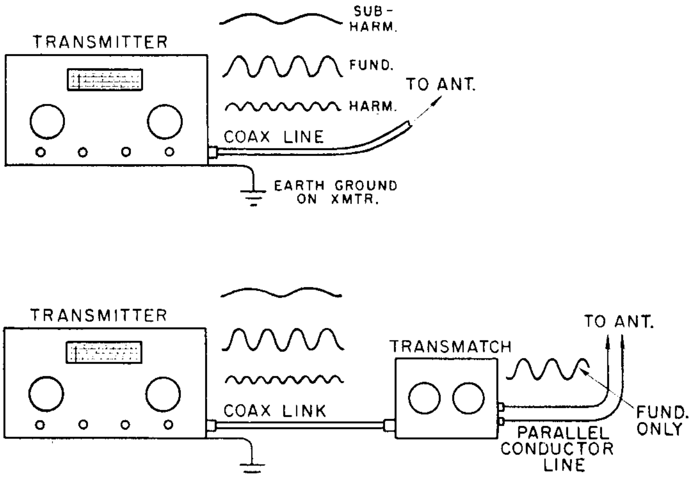

Fig. 5—The transmatch provides means for matching your transmitter's output impedance requirements, for going from a balanced transmission line to coax, and for filtering out frequencies that shouldn't be allowed to reach the antenna.

unfortunate fact that most transmitters "put out" not only the frequency you want, but also harmonics of that frequency — and, in some cases, lower frequencies too, when lower frequencies are present in the stages leading up to the final amplifier. The transmatch is a circuit that, among other things, is tuned to your desired output frequency, and so helps in keeping the unwanted frequencies from reaching the antenna.

Using the Transmatch

Fig. 5 shows how it is connected, and Fig. 6 is a typical circuit. It isn't the only circuit that can be used, but is probably as versatile as any. The circuit formed by L_1 and C_1 is tuned to your operating frequency. If the line is the parallel-conductor (balanced) type the wires are tapped on L_1 at equal numbers of turns from the center. The loading is adjusted by changing the positions of these taps. L_2 couples the power to L_1, and C_2 gives you a means for tuning this link circuit. A coax line goes from here to your transmitter's output terminal. Between these two adjustments you can transform a wide range of line input impedances into 50 or 70 ohms (whichever is the Z_0 of the coax line from the transmatch to the transmitter).

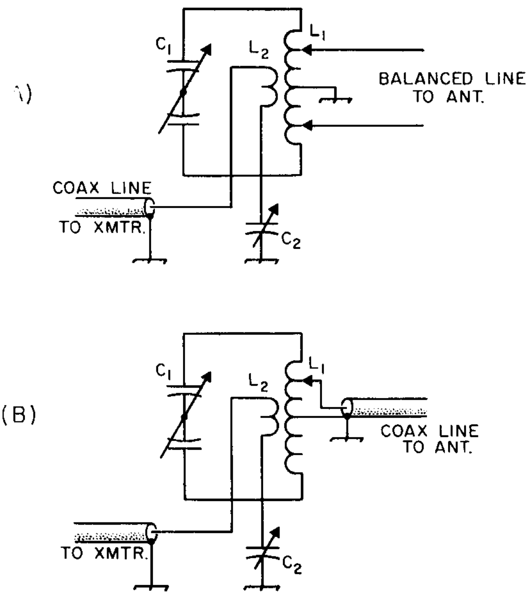

Fig. 6—A representative transmatch circuit.

The method used for coupling to a coax line feeding the antenna is shown at B. It is very similar, the only difference being that the outer conductor of the line is connected to the center of the coil and only one tap is used. The coax link circuit to the transmitter remains the same. So does the method of adjustment.

The benefits of the transmatch circuit do have their price — you have to fix things so L_1C_1 can be tuned to each band you want to use. This usually means that L_1 is a plug-in coil. L_2 is generally made part of the same coil assembly, since it is advantageous to change it, too, for various bands. The same capacitors can be used for all bands, though, over at least the 3.5–30 Mc. range.

The adjustment of a transmatch is easy if you have a bridge such as the Monimatch. Such a bridge is inexpensive and is an almost indispensable station accessory. However, you can arrive at a reasonably satisfactory adjustment simply by varying the tap positions, along with the settings of the two capacitors, while performing the normal tuning and loading operations on your transmitter. After a little cut-and-try you'll find the transmatch settings that let you load up the final amplifier to the input you want. QST