"My Feedline Tunes My Antenna!"

Plain Talk About a Fancy Subject

BY BYRON GOODMAN, W1DX

• Over a period of time one hears some weird and wonderful discussions and explanations of what takes place in transmission lines. The cumulative effect of all this loose talk is to propagate some misconceptions. It is the purpose of this article to clear away some of the clouds that surround the subject.

You don't have to be in ham radio very long before you hear some self-styled antenna expert talking about "cutting the line to reduce the standing-wave ratio." An allied problem — and misconception — is exemplified by the card that came in the mail some time ago:

> "I carefully cut an antenna for 7 Mc. according to formula in the *Handbook* and fed it in the center with 300-ohm Twin-Lead. Using a grid-dip meter I found the frequency was 5 Mc. instead of 7 Mc. It had dips at 10 Mc., 20 Mc. and 25 Mc. Adding more 300-ohm Twin-Lead brought the frequency in to 7 Mc., but what I don't understand is why the feeders affect the flattop frequency in untuned feeders. If they are supposed to, then how can I check the flattop for its resonant frequency?"

This is a good subject. If you know the correct answers to all of the questions in the quote above, you aren't likely to have trouble understanding most of the common feedline problems. Let's see what it's all about.

Transmission Lines

Ask any amateur if he knows all about coaxial cables and he will probably say, "Sure. RG-8/U is 50-ohm line and RG-11/U is 75-ohm line. What else is there to know?" The answer to that one is "Everything."

In the first place, RG-8/U is *not* 50-ohm line It has a "characteristic impedance" of 50 ohms. This fancy language can best be illustrated by Fig. 1. Here we show a long length of RG-8/U with a 50-ohm resistor connected at one end (we'll call that end the "load" end). If we measure the impedance at the input end (by using an impedance bridge), it will measure 50 ohms. This, of course, is just what you expect, and you're probably wondering what we're driving at. Patience, please.

Now suppose we take this same piece of RG-8/U and connect a 100-ohm resistor at the load end, as shown in Fig. 2. Measuring the impedance at the input end, what should we get for an answer? 50 ohms? 100 ohms? 200 ohms?

If you came up with an answer, any answer, you had better continue reading this article, because there isn't any answer to the question in the preceding paragraph! There isn't any answer because the problem isn't definite enough to be capable of solution. In order to know what the input end of the 50-ohm line looks like when a 100-ohm resistor is connected at the load end, you must also know the *electrical length* of the line. This is another way of saying that you have to know the frequency and the physical length, from which you can compute the electrical length. (Electrical length is measured in wavelengths, so any given length of line has an electrical length that varies with the frequency. A line one wavelength long at a given frequency is two wavelengths long at twice that frequency, etc.)

Actually, with the "50-ohm" line terminated in 100 ohms, some interesting things happen along the line. Take the lines shown in Fig. 3. If the line is a quarter wavelength long, we find that the impedance bridge would measure the input impedance as 25 ohms. If the line is a half wavelength long, the bridge would come up with an answer of 100 ohms. If the line is 1/8 wavelength long, the bridge would measure the

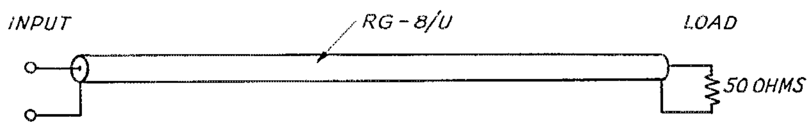

Fig. 1 — A length of RG-8/U with 50 ohms connected across one end will look like 50 ohms at the input end of the line.

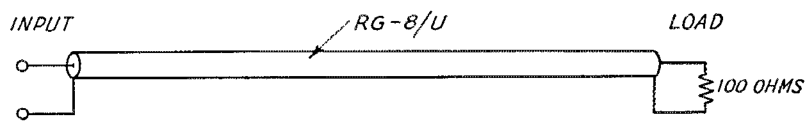

Fig. 2 — With 100 ohms connected at the load end of a length of RG-8/U, the problem is to determine what the line looks like at the input end.

input as a 40-ohm resistance in series with a capacitor, and a ⅜ wavelength line would be measured as 40 ohms resistance in series with an frequency of the antenna proper. By changing the physical length of the line our friend was able to get a length that showed "resonance"

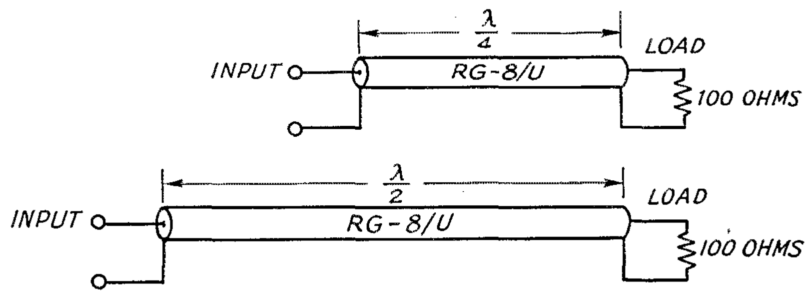

Fig. 3 — Part of the answer to the problem posed in Fig. 2. When the line is a quarter wavelength long, it looks like 25 ohms at the input end when the load is 100 ohms. When the line is a half wavelength long, the input end shows an impedance equal to that connected at the load end.

inductance! These effects repeat every half wavelength along the line, as shown in Fig. 4A.

The example we just discussed used a load for the transmission line that was higher than the characteristic impedance of the line. When the termination is lower than the characteristic impedance of the line, the impedance varies along the line in the manner shown in Fig. 4B.

Now let's get back to that "characteristic impedance" thing again. Here's what it is: *The characteristic impedance of a transmission line is the value of resistance that, when used as a termination for the line, makes the input impedance of the line independent of the electrical length of the line.*[1]

Measuring Antenna Impedance

By now you may begin to see where the card-sender of the opening paragraph went astray. He connected an antenna to a length of "300-ohm line" and expected that the line was acting as a direct connection between antenna center and the shack, adding no effects of its own. It wasn't, of course. The antenna was probably resonant at 7 Mc., and a half-wave antenna looks like 70 ohms at its center. Hence this was the same as connecting a 70-ohm resistor to the end of the 300-ohm line, for measurements made at 7 Mc. At other frequencies the antenna becomes a complex termination, involving both resistance and reactance. From the previous discussion you know that the 300-ohm line terminated in something other than 300 ohms is going to show various values of resistance and reactance at the input end, depending upon the electrical length of the line. Consequently, the resonant frequencies checked with the grid-dip meter (these would be the frequencies where pure resistance showed at the input end of the line) have no bearing whatsoever on the resonant at the frequency for which he cut the antenna, but all this means is that his electrical line length at 7 Mc. is now a multiple of a quarter wavelength, since it takes that length to show pure resistance at the input end when the load is a pure resistance (we're assuming it is).

OK, how do you measure the resonant frequency of the antenna? Well, it isn't too easy, but fortunately, it isn't too important.

(WHAT?!!! It isn't important that the antenna be resonant? What kind of sacrilege is this?)

Our friend of the postcard is using what is known as a "tuned antenna system." He is terminating a 300-ohm line with a load other than the characteristic impedance, and consequently, what the impedance looks like at the input end of the line depends upon the electrical length of the line (see Fig. 4). To put power into the antenna, the line is connected to the transmitter through a network that compensates for any reactance showing at the input end of the line, and a resistive load is presented to the transmitter. In plain language, the "network" is the output stage plate tank or, to handle a wider range of conditions, the plate tank plus an antenna coupler.

Perhaps we should mention at this point that only resistance can use up power, reactance can't. You know this from practical work; you can pass a.c. through a capacitor but the capacitor never gets hot (if it's a pure capacitor) or uses power in any other way. The same is true of a pure inductance, but they are harder to come by because the conductor of the coil has some resistance. When a coil heats up, it is the resistance of the coil that causes it, not the reactance.

Since only resistance can use up power, what difference does it make if the antenna is resonant or not? When the antenna is resonant it appears as a pure resistance (made up of the conductor resistance plus the "radiation" resistance), but when it isn't resonant it looks like a resistance and a reactance. Only the resistive part can use up power, so we don't throw anything away. We do want the antenna to be resonant and look like a

[1] This is strictly true only for a lossless line, where the input impedance will be equal to the characteristic impedance for any length of line. Lines with appreciable loss will show a gradual variation in input impedance, depending upon the length, as a result of the cumulative effects of series resistance and shunt conductance. In most amateur applications, however, this aspect of the effects of the losses can be neglected. — Ed.

resistance if we are planning to use it as a load for an "untuned" transmission line, but to do this we have to use a line with a characteristic impedance equal or close to the value of resistance the resonant antenna shows. We can't feed a 70-ohm antenna with a 300-ohm line and expect it to be anything but a "tuned antenna system," exhibiting the variations shown in Fig. 4. We can feed a 70-ohm antenna with 70-ohm line, and then no matter how long we make the line, it will always look like 70 ohms at the input end, and we won't have to use an antenna coupler if 70 ohms will load the transmitter satisfactorily. But the antenna *has* to be a 70-ohm antenna, resonant at the frequency we're interested in.

Standing-Wave Ratio

By this time it may or may not have occurred to you that all this talk about the way the input impedance varies with a mismatched line may have something to do with that old conversation piece the "standing-wave ratio." It does. Since the power at any point along the line must be constant, you can see that as the resistance and reactance vary along the line, so must the voltage and current. Take the line of Fig. 4A. Let's say we're putting 100 watts into that 100-ohm load. The current at that point is 1 ampere and the voltage is 100. ($W = I^2R = E^2 \div R$).
quarter wavelength from the load, the line looks like 25 ohms, and 100 watts at this resistance level is a current of 2 amperes and a voltage of 50. At the half-wave point from the load we're back to 1 ampere and 100 volts. Thus you can see that the current and voltage vary along the line, and of course they can be measured and that will give us something called the "standing-wave ratio." This s.w.r. is the ratio of a current maximum to a current minimum, or the ratio of the voltage maximum to the voltage minimum, and in this case it is equal to 2.0. We say, "The s.w.r. of the line is 2.0." Note that this ratio of 2.0 is also the ratio of the resistive load to the characteristic impedance of the line (100 ÷ 50 = 2). It always works out this way; the s.w.r. of the line is equal to the ratio of mismatch between load and line, for resistive loads. (When the load is smaller than the characteristic impedance, you divide by the load, because the s.w.r. is normally stated as a ratio larger than 1.0.) The solution is more complicated with some reactance in the load.

And now you can see why those "brains" who change the s.w.r. on the line by changing the line length just don't know what they're talking about. What they are doing is adjusting the length of the line so that at the input end it looks like a resistance and hence becomes a little easier to couple to. But *the s.w.r. is determined by the load*, and don't you forget it.

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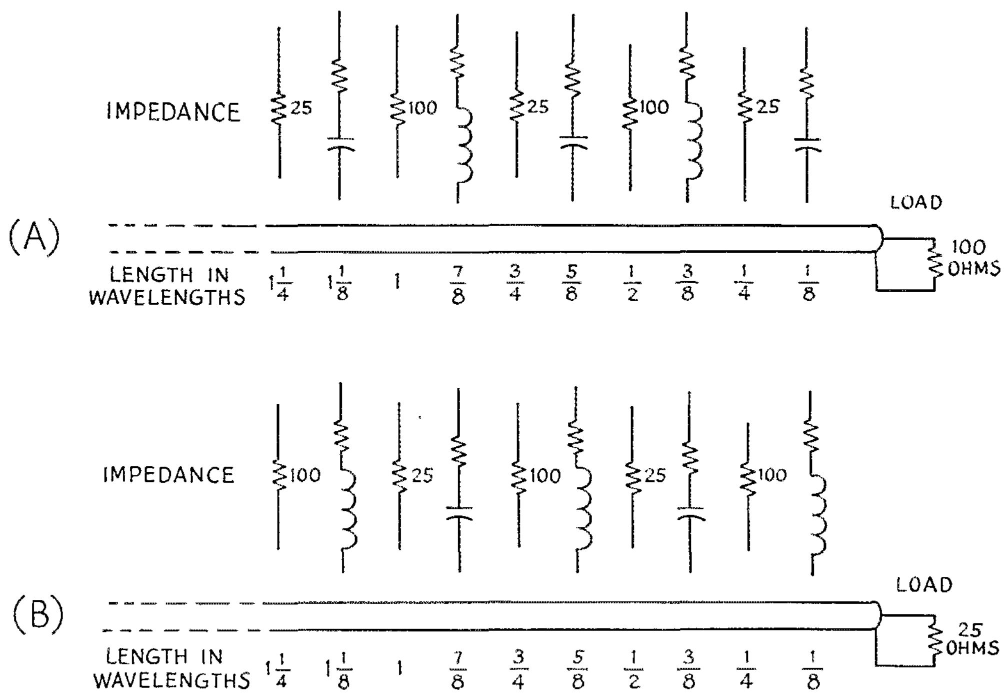

Fig. 4 — These two examples show how the input impedance of a line varies with the length of the line when the line is terminated in something other than the characteristic impedance of the line. It should be realized that the impedance is continually changing along the line, repeating every half wavelength. The impedance is purely resistive only at the quarter-wave (and multiples) point, and it becomes reactive either side of this point, reaching a maximum reactive condition at the odd multiples of ⅛ wavelength.

When the load includes reactance as well as resistance, the impedance along the line varies in the same manner as shown here, but the purely resistive points do not occur at multiples of ¼ wavelength from the load.

Feedline

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That's about it. If you've learned that the s.w.r. is determined by the load and not by the line length, and if you've learned that the antenna resonant frequency isn't important when you're using a tuned line, you've come a long way. Of course, the latter doesn't mean you can use a very short (less than 1/8 wavelength) antenna and get out just as well as with a full-sized one. In this latter case the ohmic resistance of the antenna and loading devices may be greater than the radiation resistance of the antenna, and most of your power goes into heating the loading devices and the feedline.

Other Considerations

To keep this discussion simple, we have of necessity left out a number of points that often must be considered. For example, a piece of open-wire transmission line and a piece of Twin-Lead (or coaxial line) of the same physical length do not have the same electrical length. The reason for this is that the radio waves travel slower through the solid dielectric of the Twin-Lead than they do through the air dielectric of the open line, so a wavelength in air (for a given frequency) is longer than a wavelength in solid dielectric. The "velocity of propagation" in air is considered to be 1.0, and the "V.P." in a solid dielectric will be something less, depending upon the material. V.P. values for various lines are given in any good antenna book, and they must be considered when you compute the electrical length of a line.

Another aspect that was not considered was the loss in a transmission line. If the line itself had *no* loss, then the s.w.r. *would* make no difference where losses are concerned. However, any practical line does have some loss, and this loss increases with the s.w.r. and the inherent loss of the line. This is a consideration in any antenna system requiring a long run of line, and is the reason that one shoots for a low s.w.r. with coax or Twin-Lead but doesn't worry too much about it (from a loss standpoint) with open-wire line, where the inherent loss is much lower than in solid-dielectric line.

World Above 50 Mc.

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OES Notes

W1HDQ, Canton, Conn. — Ionospheric scatter tests on 50 Mc. have been heard by W4s IKK, Rome, Ga., LNG, Atlanta, OLO, Bristol, Tenn., RFR, Nashville, and HHK, Collierville. Distances are 850 miles to Rome and Atlanta, 625 to Bristol, 850 to Nashville, and 1040 to Collierville. Reception at the nearer points is mainly bursts, but these are of much longer duration and occur more frequently than in 144-Mc. tests over similar paths. At Nashville and Collierville there is enough residual signal to indicate that only slightly more antenna gain is needed to make c.w. communication quite a satisfactory matter. The bursts heard at all points reporting have been of sufficient duration and intelligibility to permit two-way work, if carefully-timed repeating transmissions are used. Tests interrupted by antenna work at W1HDQ, but hope to resume before

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