Question and Answers
by Gene Ferguson, W4FWG

ANTENNAS (OR IS IT ANTENNAE?) AND TRANSMISSION LINES

Part V

1. (Q) In Part IV, it was stated that we could expect considerably more about transmission lines in our study, other than just getting the RF signals from the antenna to the receiver, or from the transmitter to the antenna. What more could be expected of transmission lines? Can you explain all this without getting too deeply into math?

(A) The answer to this question opens a completely new world of knowledge and understanding. Moreover, I think we can explain the phenomena quite well without a deep sprinkling of advanced math. A section of a certain length of transmission line can be substituted for physical components to make a number of specific devices. These include, but are not limited to, series resonate circuits, parallel resonate circuits and insulators or isolators, delay lines, capacitors and inductors and impedance transformers. Many such devices are in everyday use and we take them for granted. We shall attempt to scratch the surface on some of these applications and show how they work.

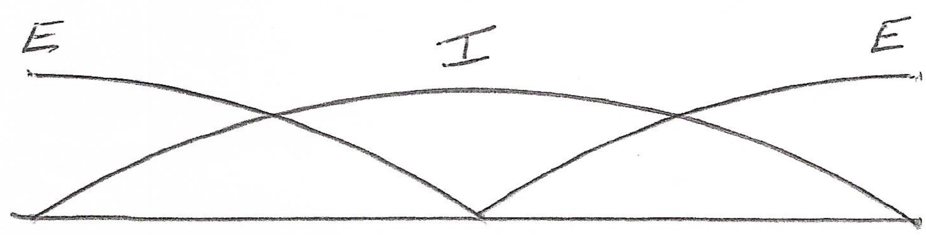

Figure 1

All study of transmissions lines used for our specific needs start with the simple dipole antenna, with or without the center insulator, which we explained in Question 6, Part I of this series. As a review without the necessity of searching for the earlier issue, please refer to Figure 1, above.

It can be seen that, at the center of a dipole, cut to length for the operating frequency, the "I" line is at a maximum value and the "E" lines are at, or near, zero. For this and further study, it is important that we fully understand this characteristic. Further, we need to recall that this is a 1/2 wavelength antenna (end to end) and that it is constructed of 2 elements, each 1/4 wavelength that are series connected. Thus, we can look at each electrical length; 1/4 wavelength and 1/2 wavelength and draw some very valid conclusions without dwelling into deep theory or math. Let us list the known quantities that can be developed just by the observation of these "E and I" nodes.

A. The center, where we have a maximum current (I) and a minimum voltage (E), represents a very low impedance point. Actually, at the true electrical center, both the voltage and impedance will be zero. Remember Ohm's Law? R = E/I. If "E" is low, the resistance (or impedance) must be low. At the electrical center, this will be very low, equal to zero.

B. The ends, where we have a very low current (I) and a high voltage (E) would be the extreme opposite of the center. At the ends, we will have a very high impedance, R = E/I where E is very high, resulting in a high R (resistance) or Z (impedance).

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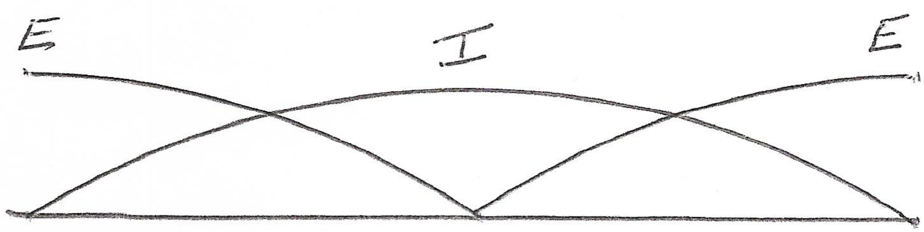

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C. In both examples, A and B above, we have shown what happens to a quarter of a wavelength of wire. We are looking from the CENTER to the END of either, the RIGHT most of the antenna element, or the LEFT most of the element. Either one constitutes a study of a 1/4 wavelength of line. Please note that what is present on one end of a ¼ wavelength is reversed on the other end. The end connected to the insulator at the feed point has a very low impedance while the end of the antenna has a very high impedance, a complete reversal of impedance.

D. We now look at a full 1/2 wavelength, which is equally important: Both ends are the same, in this case, both are shown as very high impedance. We shall make good usage of these phenomena as well. Again, please make note that the same impedance is present on one end of a 1/2 wavelength of transmission as is present on the opposite end.

Looking back at these simple statements, we can see that we have some well defined "KNOWNS" that we can ALWAYS refer back to as being absolutes.

Let us draw our first conclusion from these. Looking at case numbers 1 and 2, immediately above, we can safely make this ironclad statement. "What is present on one end of a 1/4 wavelength conductor WILL NOT be present at the other end of that conductor, in fact, it will be the exact opposite. Thus, a quarter of a wavelength of a conductor executes a reversal of that impedance which is on the opposite end.

2. (Q) Well, that is fantastic. Now what good is that to me?

(A). There are many instances where we may want a complete impedance (Z) reversal to occur, if we can think about it a moment. We should know that with a low impedance (Z) present on one end of a wire and a high Z present on the other, that at different points along that conductor, there are an infinite number of various impedance points. We can make use of the ¼ wave section to make impedance matching transformers. Then what about elevating a pair of wires above ground, say, running a parallel feed line from the transmitter to the antenna. If we take several pieces of 1/4 wavelength of good conductor material and stand on their ends, firmly grounding one end, the end that is not grounded will appear as an open (remember the 1/4 wavelength REVERSES what is on the other end). Now we have a conductor grounded on one end and it is elevated 1/4 wavelength above ground (an insulator) on the other end. If we place one conductor of our feed line on the ungrounded end of this upright conductor, it will be a good insulator for the active feed line conductor. We can duplicate that all along the line to make a serve as stand off insulators to support the one feed line conductor. We can do the same for the remaining conductor, as well. Thus, a quarter wavelength of wire becomes a good insulator.

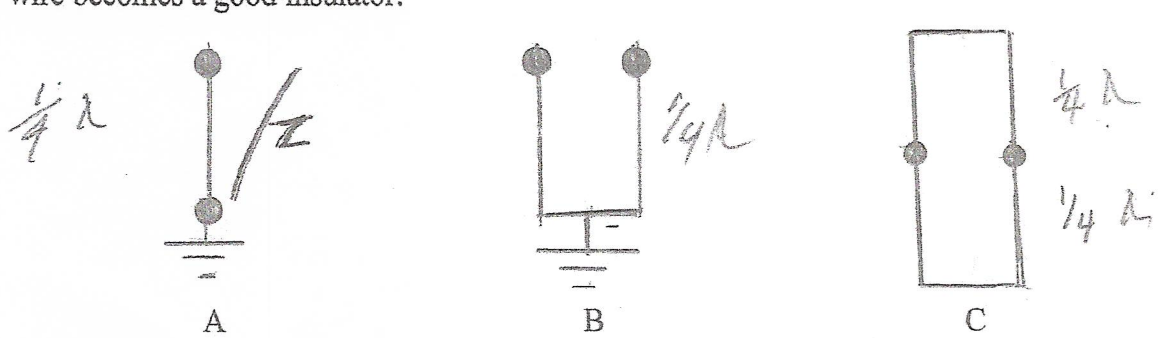


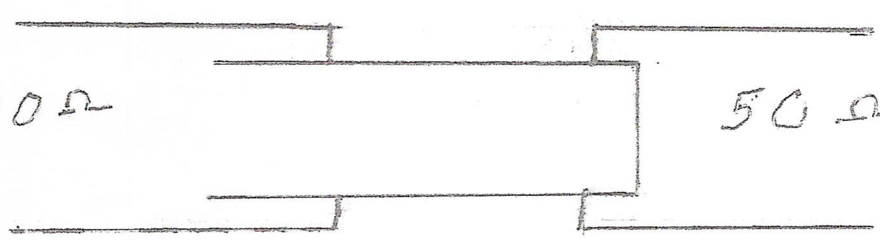
Figure 2

Figure 2 A shows us how a single wire can support a conductor and be an insulator in so doing. In Figure 2B we have tied the bottom ends of two such ¼ wavelength conductors together, formed a "U" like arrangement and used this to both, support and act as insulators for our two wire feed line. Can we get away with this? Yes, this makes an excellent insulated mount for out transmission lines. Then by making two of these, inverting one over the other, the original concept of a "Wave Guide" was constructed. Since the earliest waveguides were placed into service using this concept, a much improved method of inserting and retrieving the signal has been developed, but the basic waveguide remains two of the structures shown in Figure 2B to become Figure 2C.

Think about it. A ¼ length a conductor, shorted on one end, open on the other – low impedance on one end, high impedance on the other. Sure, it works great.

3. (Q). You mentioned that we could use a ¼ wavelength line as an impedance matching transformer. How is this possible?

(A). Let us take a look at the following sketch. Notice that one end of the shorted ¼ wavelength transmission line has an impedance near zero while the open end has a very high impedance. Somewhere along this line, there will be found points where we can find not only the values shown, but many other values of popular impedance(s).



4. (Q). It was mentioned that we could make use of the entire 1/2 wavelength phenomena as well. How?

(A). Yes, many applications are possible. We can think of a ½ wavelength line as being two ¼ wavelength in series. Just the opposite happens on the ½ length as compared to the ¼ section. A ½ wavelength line terminated in an open will appear as being a very high impedance at the terminated end. (Sounds reasonable, doesn't it – open = High Impedance). It may also appear as a Parallel Resonate circuit or as a capacitor, all high Z devices. The same transmission line terminated in a short can be a Series Resonate Circuit, a short, or an inductor. These have their uses. Further, there are many instances where one needs to isolate a point for study, say tuning a mobile antenna, or isolate a point AND add resistance in its path. A 1/2 wavelength of cable will do that. In the case of installing an HF antenna on a vehicle, a Noise Bridge is frequently used to determine the proper value of a shunt to add at the base of the short antenna, be it an inductor or capacitor. This in addition to the regular loading coil. A Noise Bridge will provide this info. To keep the human influence (close proximity to the antenna) from giving a false reading, a 1/2 wavelength of coax is run from the antenna to the Noise Bridge. The operator and the Noise Bridge are somewhat removed from the immediate vicinity of the antenna. Any shortened antenna using an inductor to increase its effective wavelength and radiation resistance is highly sensitive to anything in close proximity as it causes a drastic shift in the resonate frequency of the tuned antenna. By adding this 1/2 wavelength of transmission line at the base of the antenna, we move the operator and equipment a far distance from the antenna, while still effectively maintaining the equipment connection right at the base of the antenna. There are many such needs for this application. We used this same procedure to tune our duplexers for the Club repeater after all else had failed; 1/2 wavelength of coax from the transmitter to the "Can" and another 1/2 wavelength of coax from the "Can" to the Termination Load and metering circuitry. This does several things for us, like adding attenuation, providing isolation, maintaining a more constant load for the transmitter during the process of tuning the cans, etc.

5. (Q). This looks good, but what about other uses?

(A). There are so many uses for these 1/4 and 1/2 wavelength devices that it would be impossible to cover them all. Many uses have yet been thought out. We shall attempt to make mention of a few and explain how they work, both herein and in further discussions. Think of this for a moment. If we have an unwanted signal on our TV, what would be a easy way to rid ourselves of such a signal?? Simple. Cut a length of twin lead to the 1/4 wavelength of the interfering frequency and put it across our TV feed line. BINGO, the interfering signal is gone.

6. (Q) Why?

(A) Let's think about a series resonate circuit. If we put a series resonate circuit, tuned to the disturbing signal frequency, across the two wires of the TV feed line, the series resonate circuit will cause a heavy current to flow (short circuit) between these two wires, but only at the frequency to which it is tuned. In this example it would be the interfering signal frequency.

But what have we really done? We have placed a circuit across our TV feed lines which shows a high impedance for all frequencies <u>except</u> for the disturbing frequency. The disturbing frequency is effectively short circuited by the conduction of the series resonate circuit tuned to that precise frequency, thus we remove the interfering signal. If we look at part "B" of Figure 2, we can see that a stub, cut to 1/4 wavelength and shorted at one end will appear to be "open" at the other end. Let us modify this for our current application. We take a section of 1/4 wavelength line and cut it so that it is open on BOTH ends. We know that on a 1/4 wavelength conductor, what is present on one end will be reversed on the other end. Now, the fact that the stub is cut to the disturbing signal's frequency makes it resonate at that frequency ONLY, we can place this open ended stub across the TV feed line and the disturbing signal will disappear. (Open on one end, shorted on the other - at the frequency for which it is cut, only) If we make the stub of the same material as the feed line, we will have no impedance matching problems. Noise problem solved.

Important notes on 1/4 wavelength stubs.

A. If we short one end, the stub will look as though it were a **parallel resonate circuit, a very high impedance, or open circuit at the design frequency only**, on the end opposite the shorted end. This is why it works as an insulator.

B. If we cut a stub 1/4 wavelength and leave both ends open, it will appear as **series resonate circuit, a very low impedance or shorted circuit at the design frequency only.**

The question may arise as to why we didn't just make a series resonate circuit using discreet components, without doing this transmission line stub thing. The answer to this would be another plus for the transmission line application. The discreet component resonate circuit has a rather low "Q" factor due to the resistance of the wire used to make up the inductor, inductance in the leads of the capacitor and stray capacitance). The transmission line exhibits a really high "Q," meaning that it is able provide a very narrow bandwidth as compared to the built-up circuit. To make the "trap" from discreet components would result in a large, bulky arrangement, the short section of lead-in is just the opposite. This makes the transmission line more desirable, as it will only filter out the unwanted interfering signal, not some of the desired signals as well.

(Continued in future issues)