Question and Answers
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ANTENNAS (OR IS IT ANTENNAE?) AND TRANSMISSION LINES

Part VI-A

NOTE: FOR THIS DISCUSSION, I REQUEST THE AUTHOR OF OUR NEWSLETTER TO PRINT THE SHEET LABLED "LONG LINES AND VARIOUS TERMINATIONS" ON A SEPARATE PAGE AND ATTACH AT THE END OF THIS PART, MAKING IT POSSIBLE FOR THE READER TO DETACH THE DRAWING AND VIEW THE PAGE AS WE PROGRESS THROUGH OUR DISCUSSION.

(Q) We know that making a feed line (transmission line) longer than absolutely necessary can cause an increase in loss of our signal. Is there ever an advantage in making such a line longer than required just to reach from our radio to the antenna?

(A) Maybe. In certain applications, especially on a single band antenna, we may use the length to lower our SWR or for other reasons. This is an area that text books and other reference books never seem to publish, leaving us in the dark about such usage. Let us analyze the drawings on the attached chart. I KNOW, you've seen these before, but if you stick with me, we may cover this in a different manner AND you may soon see things in a different perspective!

In the first sketch, Figure "A" we assume a perfect, no loss transmission line. We see a line that is both fed and terminated in the line's impedance. The dark solid line above the circuit represents the"E" or voltage reflected wave, while the dashed line shows the "I" or current wave. We shall attempt to discuss the impedance of each Figure as we progress.

To have the "E" and "I" lines both parallel to each other and parallel to the line itself (actually no reflected wave), the impedance of the generator, line and termination or load, must be perfectly matched, all the same impedance. We rarely see this condition in real life.

In Figure "B" we see a more practical circuit, one with losses such as occurs on any real transmission line. Notice that the E and I lines remain parallel from end-to-end, something that can only happen when the load or termination is pure resistive. The E and I lines are not to be confused with the generators actual current, for we know that in a series resistive circuit, the current remains constant throughout the circuit while we have voltage drops all long the circuit. These lines shown represent the REFLECTED WAVES. The generator must produce a voltage greater than what would appear across the load to offset the loss along the line, however.

Figure "C" represents a long line, in excess of one wavelength *(wl)*. From the open end termination, we need to trace the solid "E" line back to the left to a point where the E line dips to a minimum. Then from that point, continue to follow the E line back to the point where it once more reaches a minimum. That point would represent a 1/2 *wl* of feed line, or 180 degrees of rotation of our generator.. Then continuing still farther to the left on the E line to the point where it once more reaches a minimum and we will have traced the E line through two excursions, or one complete cycle or one Hertz or one wavelength. At the terminal end, we can

see that the voltage is at a maximum while the current is at minimum. If we apply Ohm's law here we will find that the Impedance is very high, the generator is delivering a minimum Power.

We would be remiss if we stop here. The real point in understanding these drawings is to start at the termination end and trace back a certain wavelength or part thereof. Again, we will start at the termination end, an open, and trace back one wavelength. We should note that the "E" line is at a maximum and the "I" line is at a minimum at the termination. Trace the "I" line back to the left to its next minimum point. This would represent 1/2 wavelength (*wl*). *At this point let us stop briefly and observe what the E and I lines look like! This is our beginning to REALLY understand what this REFLECTED WAVE talk is really about!* Notice that, at this ½ wl point that the E line is at a maximum and the I line is at a minimum, exactly the same at the termination end. We know that at the open end termination when Ohm's law is applied we will see a maximum E and a minimum I resulting in exactly what we would see it we were observing the E and I across a PARALLEL RESONATE circuit. An important point to remember in this study; A ½ wl section of a transmission line may appear to have the same characteristics as a PARALLEL RESONATE CIRCUIT, both at the termination, if open, and at the generator. Looks like a Parallel Resonate circuit, acts likes a Parallel Resonate circuit, must be a parallel resonate circuit!

So, RULE ONE of this part of study is; a ½ *wl* of open transmission line can be used as a PARALLEL RESONATE CIRCUIT. Hello! This is what our ½ wavelength antenna looks like to our transmission line, a parallel resonate circuit.

But we are not through yet. We were tracing the I line from the termination end back toward the generator when we stopped at the point where the I line reached its first minimum point from the termination, or open; this being the ½ *wl* point. Let us continue the I line back to its SECOND minimum, this point being the one full wavelength point. Let us once more observe the E and I amplitudes. This looks exactly the same as at the ½ *wl* point doesn't it? So, can't we safely state that there is zero phase shift in either, a full or a ½ *wl* section of a transmission line? So, what does this tell us? RULE ONE applies here as well; meaning that each ½ wl of transmission line is simply a replication of another ½ *wl* of feed transmission line, a full wavelength simply being two ½ *wl* sections in series.

RULE ONE PREVAILS.

A further study of these E and I lines are in order. Let us start all over again. Once more, beginning at the termination end of this open terminated line, let us trace the "I" line from its" minimum point, hack to the left to its first MAXIMUM point. Stopping here for a moment, we must observe that we have progressed back from the termination end, exactly ¼ wavelength. At this ¼ *wl* point we see that we have a maximum I and a minimum E. If our generator were to be placed at this ¼ *wl* point, it would be looking into a load which has a very high current (I) and a very low voltage (E). A circuit that come to mind that exhibits this same characteristic is that of a SERIES RESONATE circuit. Now we have two KNOWNs:

RULE 1. A one-half wavelength of transmission line, terminated in an open appears as a Parallel Resonate circuit.
RULE 2. A one-quarter wavelength of transmission line, terminated an open appears as a Series Resonate circuit.

Can't we now come up with a new TRUE STATEMENT? A section of a 1/4 *wl* of cable exhibits the opposite of that which is exhibited on a ½ *wl* of cable. This is true of a section terminated in an OPEN. Could it also be true of a section terminated in a short? Let us look deeper.

Figure "D" shows a long line terminated in a short. Initial observation shows that the E and I lines at the termination is just the reverse of those in Figure "C" that we just discussed. Therefore, we should expect just the opposite conditions to exist. Let us prove or disprove this. Since we did a rather deep study on Figure "C," we don't need to repeat each step here, just taking what we already know and applying it to this Figure "D". Tracing the E wave back from the shorted termination where it is at a minimum, back to its first minimum, or ½ wl point, looking at the the Wave amplitudes at this point, we see a maximum in the current (I) and a minimum voltage (E). If the generator was placed here, it would be looking into a very low impedance. It would be seeing a load that looked like a SERIES RESONATE circuit.

We have our Rule 3 now. A ½ wl line terminated in a short will exhibit the characteristics of a SERIES RESONSATE circuit.

Let us compare Rule 3 with Rule 1. They are opposites, just as we would expect.

We will now examine the ¼ *wl* section of a transmission line terminated in a short. On Figure "D," tracing the "E" line to the left from its termination point where it is at a minimum, we go back to where the E line reaches its first maximum. This is the ¼ *wl* point. Here, with a max E and minimum I, Ohm's law would tell us that the generator, if placed here, would see a very high impedance, one that would share the same characteristics as a PARALLEL RESONATE circuit. Please note that this is a complete reversal from what we saw in a ¼ wl line terminated in an open as in Rule 2.

We now have a set of rules we can state as KNOWN FACTS, to stay with us forever!

RULE 1. A one-half wavelength of transmission line, terminated in an open, appears as a Parallel Resonate circuit.

RULE 2. A one-quarter wavelength of transmission line, terminated an open, appears as a Series Resonate circuit.

RULE 3. A one-half wavelength of transmission line, terminated in a short, appears as a Series Resonate Circuit, just the opposite of Rule 1, but like Rule 2.

RULE 4. A one-quarter wavelength of transmission line, terminated in a short, appears as a Parallel Resonate circuit, just the opposite of Rule 3, but like Rule 1.

This is really nothing new – just a good review. Hopefully, the rest of this Part will cause us to see a NEED or USE of all this stuff!

We must continue to remember that these drawings are of a very long line, in excess of one wavelength.

Figure "E" represents a long line terminated in a resistive load that is greater than the characteristic impedance of the transmission line and the generator. It should be noted here that the E and I line are much lower in amplitude than when our line is terminated in either an

open or a short. Would this not stand to reason, since we are more closely approaching an impedance more closely equal to the impedance of the line itself; a load that is between the perfect match and the greatest mismatch possible? This lowered amplitude equates to a lowered SWR. The phasing shows that this line sees an inductive load along with the resistor. ***An antenna that is longer than a fraction of a wavelength will appear inductive and will require a capacitor to tune it out.***

Figure "F" shows the same long line terminated in a resistive load which is less than the impedance of the line. The same lowered level reflected lines are present, although of reversed polarity shown in Figure E. This phasing would indicate that the line sees an inductive load along with the resistor.
An antenna that is shorter than calculated by formula will appear capacitive and will require an inductor to cause it to be resonate.

Figure "G" shows what our reflected lines would look like if we terminate the transmission line with a capacitor whose Capacitive Reactance is less than the impedance of the transmission line, something that would be a natural occurrence in an antenna that is too short. Please note that the E and I lines are LESS than 90 degrees, indicating a capacitor less than the feed line impedance.

Note too, that the amplitude of the E and I lines in these two examples are rather high as compared with those with a resistive load. ***Our SWR has increased due to the reactive components.***

Figure "H" shows the same long line terminated in an Inductor. Of course, our E and I lines are reversed. Comparing these E and I lines with those in Figure "D" shows a similarity, only with a phase shift. This stands to reason, as we know that through and across an inductor, we have a 90 degree phase shift with the voltage leading the current.

SUMMARY AND CONCLUSION: Take another look at either Figure "C" or "D". It should be obvious that, starting at the termination end, tracing the E and I lines back toward the generator, there are points along the first ½ wavelength where the lines show a capacitive (Current leads the voltage by 90 degrees) or an inductive shift (Voltage leads the current by 90 degrees) point. From this, we should begin to see that we MAY use a section of transmission line as a capacitor or as an inductor. Varying the length by inches at a time, we can make a small (or large) capacitor or inductor. We need further explanation how this may be achieved, but we can state now; it may be possible to tune out the inductive component of an single band antenna by inducing a corresponding amount of capacity or induction at the termination end of our transmission line by adjusting the length of our transmission line, thereby canceling that unwanted component of the antenna.

We will discuss transmission lines of various lengths in this Part's companion Q & A, Part VI-B to follow soon. Due to the length of discussion on this subject, we split the Part VI into two parts. During the next companion part, we will show an example of a practical application of shorted sections of transmission line in the construction of a real, honest working antenna that will work great on both 2 meters and 440, one we can actually build and KNOW that it will work great; as good as having separate dipoles!!

ATTACHMENT – PART VI-A

LONG LINES AND VARIOUS TERMINATIONS