**Question and Answers**
by Gene Ferguson, W4FWG

ANTENNAS (OR IS IT ANTENNAE?) AND TRANSMISSION LINES

Part IV

1. (Q) Part III of this discussion stated that the Characteristic Impedance of a wire pair, whether open, parallel or coaxial, depended upon the Capacities Reactance, Inductive Reactance and the Resistance of the conductors. What is the formula?

   (A) The inclusion of the Resistance portion in that section was purely for thought provoking. While it can be argued that the resistance does come into play for the Characteristic Impedance of transmission lines, the normally accepted formula for calculating characteristic impedance assumes conductor(s) with no resistance loss. For two parallel conductors, the formula is: $Z = 276 \log_{10} (2D/d)$, where Z = characteristic impedance, D = distance between the two conductors, measured from center to center of the conductors and d = diameter of one wire.

   For coaxial cables, the formula is: $Z = 138 \log_{10} (D/d)$ where Z = characteristic impedance, D = **the inside** diameter of the outer conductor and d = the diameter of the inside conductor.

   Let us take an example of each, a parallel line and a coaxial line. First, the parallel line.
   Problem 1: For a two-wire line constructed of number 12 wire (.08 inches in diameter) separated by a distance of 6 inches, what is the characteristic impedance?

   $Z = 276 \log_{10} (2D/d) = 276 \log_{10} ((2 \times 6)/.08)) = 276 \log_{10} 150 = 276 \times 2.1761$ which is approximately equal to 600 ohms characteristic impedance.

   Problem 2: For an inter conductor of 1/4 diameter and outer conductor is a piece of copper pipe with an inside diameter of .875 inches, what is the characteristic impedance?

   $Z = 138 \log_{10} (D/d) = 138 \log_{10} (.875/0.25) = 138 \log_{10} 3.5 = 138 \times 0.5428 = 75$ ohms.

   The value of DC resistance of transmission lines is given as the sum of the DC resistance of both conductors on a parallel line and the inter and outer conductors on a coaxial type transmission line.

2. (Q) The answer above and other articles mention the inside of the outer conductor, but never mentions the outside of the outer conductor. Doesn't it count?

   (A) No, not if the line is properly terminated. If properly matched at the source and the load, there will be NO, or ZERO RF traveling on the outside of the shield of a coaxial line. This brings us back to a fundamental rule. "The maximum power transfer of energy occurs when and only when the load resistance or impedance equals the source resistance or impedance." This is an inescapable fact. If, on the other hand, the load is not properly matched, a reflected wave of such phase relationship will be produced that it may attempt to ride back the outside of the outer conductor. This unwanted signal will need to be suppressed and means are available to us to reduce or eliminate such unwanted signals.

3. (Q) Why does the outgoing signal not travel on the outside as well as the inside of the conductor. It would seem that the signal would take the path of the least resistance and travel on both, the inside and outside of the outer conductor.

(A) A reasonable parallel can be drawn between the outgoing signal on a coaxial line and that of a pair of magnets. If the magnets are positioned in such a manner that the opposing poles ( N & S) are near each other, a strong attraction will exist. Opposites poles attract, like poles repeal. On the center conductor we can say that the momentary or instantaneous voltage is of one polarity, while on the outer conductor, the opposite phase or voltage is present. The two opposing voltages attract each other, resulting on a strong pull, one to the other, keeping the RF energy present on the outer conductor riding only on the inside of that conductor. I should add, this is true on parallel lines as well. More energy will travel on the inside half of a conductor on a two-wire transmission line than on the outside half of the conductor. Too, more energy rides along the outside of the conductor than down the area nearer the center. Little to none travels the center portion of a wire carrying RF energy. That is why we see so many conductors made of tubing or pipes..

4. (Q) Then the outside of the outer conductor does not offer any help to us in the transmission or reception of an RF signal?

(A) But, it does! This outer shield tends to shield the inter conductor from unwanted signals from foreign sources when in the receive mode and may prevent some unwanted radiation outward when transmitting, if our load is improper. The outer conductor is nearly always grounded to our equipment and thus, any stray signals will be grounded. It helps greatly in that regard.

5. (Q) The length of a transmission line was not mentioned in the formula(s) above. Does the length matter when computing the characteristic impedance?

(A) Not for the characteristic impedance. That is why the resistance is given in the charts and tables, along with the characteristic impedance and a number of other data. As the length of the line increases, either parallel or coax, the total attenuation will increase, due to the increased $X_L$ (Inductive Reactance), $X_C$ (Capacitive Reactance) and R (Resistance) of the line. Further, any and all mismatches will add to the losses or attenuation factor. Resistance is an important factor.

6. (Q) Why does some antenna systems seem to work better with parallel wire, while others seem to require coaxial?

(A) Mostly, it depends upon the frequencies involved, the type of antenna and builder's choice. Some antenna(s) require a higher impedance feed line or transmission line than would be practical with a coaxial constructed type - say a 12 inch outer conductor going up to a 50 foot high antenna. Another reason is that generally, an open line (parallel wires) will offer a greater band spread for a given antenna, when used with a tuner or coupler, than a coaxial line to the same antenna. This is not an absolute, but generally, it does offer wider frequency coverage. A second reason is that it will accept a little more mis-match than will the coax, which bring us back to the preceding rationale. On the other hand, when we operate in the VHF and higher bands, open wire usually proves to be a disadvantage.

7. (Q) Is this all there is to transmission lines, just to feed a signal between the antenna an transmitter or receiver. I see many textbooks with a huge chapter or more, even complete books, on transmission lines.

(A) No, the simple feed line is but one use of transmission lines. Without the theory of transmission lines and the modification of them, we would have no radar, color TV and many more benefits that we can enjoy today. The repeater duplexers that we are working with today are derived from Transmission Line theory, as are many aids available to the amateur world. We will dwell considerably deeper into transmission line theory as time and space allows and will cover the theory behind the duplexer, wave guides and other devices. It is an interesting field.

8. (Q) Earlier, mention was made that a piece of twin lead could be used as a small capacitor. Is there a formula that will provide this information?

(A) Yes, there are formulas that will tell us the expected capacitance and inductance of a section of parallel transmission line. These formulas do require the use of the log table or other means of determining the log of numbers.

For the capacitance in *pica farads* per foot of a two-wire parallel line, the formula is: $C = 3.68/ \log_{10} (2D/d)$. To determine the inductance in *microhenries* per foot of two-wire parallel lines, use this formula: $L = 0.281 \log_{10} (2D/d)$. Should one need the same info on coax lines, the published tables or charts for manufactured cables should show these data.

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We plan to continue our effort to review the many aspects of using transmission lines in our hobby in future Parts.

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Should you have any specific questions, or wish to cover any particular area, please advise.