IMPEDANCE, SMITH CHARTS, SWR

BY

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This paper is a summary of information contained in the *ARRL Antenna Book*, *Understanding Your Antenna Analyzer* by ARRL, and an outstanding article in November 2006 QST by Darrin Walraven K5DVW entitled *Understanding SWR by Example*.

The purpose of my paper is to renew a very basic understanding of impedance, quickly examine Smith Charts basics, and relate feed point impedance to SWR for the purposes of stimulating understanding of the common terms and provide sources for further reading. I am not an expert and do not pretend to be an expert in this field.

In an electrical circuit impedance is a measure of the opposition to current flow in the circuit when voltage is applied. In a DC circuit impedance is resistance and from Ohm's Law E=IR the impedance (resistance) is R = $\frac{E}{I}$ ohms. In an AC or RF circuit there are factors other than resistance namely inductance and capacitance. The opposition to current flow for inductance or capacitance is called reactance and these two can be combined and is commonly denoted by X. So impedance Z has two components R and X and is frequently denoted in several ways. We could write Z = (R,X) or also Z = R + jX. Other notations are also used.

If we wish to graphically represent impedance, we cannot just put it on a number line because impedance has two components R and X. To graphically represent impedance we must show impedance as a point in a plane. One such useful plane is a Smith Chart. The equations relating transmission lines and matching circuits such as antenna loads are complicated and involve complex numbers. Smith charts were invented by Phillip H. Smith in 1939 as graphical aids to solving the complicated problems. The charts are scaled by circles which are generated by holding R constant and then X constant as shown in the first attached chart. Factors involved in the circles include the characteristic impedance Z_0 of the transmission line. Instead of having charts for each possible value of Z_0 impedance values are "normalized" by dividing the impedance by Z_0. If we are using 50 ohm transmission line, then R + jX is replaced by R/50 + jX/50. So 50 + j0 is replaced by 1 + j0. So the point (1,0) becomes important because here the SWR is 1:1. Therefore any transmission line/matching circuit system with a normalized impedance other than 1 + j0 will have an SWR higher than 1:1. The SWR will be dependent on the distance of the normalized impedance from 1 + j0. A circle of radius r is the locus of all points at a distance r from the center. Hence all points on a given circle with center (1,0) will have the same SWR. We may use the Smith chart and related table to determine SWR at any given point which is also the SWR for any other point on the circle with center (1,0) through the given point.

An antenna system using 50 ohm cable has impedance 69 + 18j at 3.45 mhz measured at the generator feed point. The normalized impedance is 1.38 + .36j . We may use the Smith chart and table to determine the SWR Is approximately 1.56 : 1 .

PROBLEM FOR THE NEXT MEETING

If an antenna system using 50 ohm cable has impedance 69 + 18j at 3.45 mhz measured at the generator feed point and the transmission cable is 75 feet, what is the impedance at the load? Hint: The SWR is the same as measured at the generator feed point so we are looking for another point on the same circle.