Sometimes, without expecting it, we get more than we bargained for. If you happen to own one of the popular antenna analyzers available, WC0Y explains what else they're capable of telling.

How To Get More Information From Your Antenna Analyzer

BY WARD HALL*, WC0Y

Advances in technology have brought us new instruments to help us build homebrew antennas and understand their performance. Antenna analyzers are available that provide readouts of standing wave ratio (SWR) and impedance (Z). These instruments are simple to use, are portable, and provide great insight into how well an antenna is operating. What I have discovered is that these instruments actually provide more information than many realize! If you would like to get more performance from your SWR analyzer, read on.

The techniques discussed in this article pertain to antenna analyzers that give measurements of SWR and impedance. This includes the RF ANALYSTTM RF-1 sold by Autek Research, and SWR Analyzer™ with RF Resistance Meter™ models sold by MFJ Enterprises, Inc. I own the RF-1 and have found it extremely useful in my antenna work.

While working with it, I felt that more information must be available from it than the instructions said. A check of equations available in *The ARRL Antenna Book*, and a call to Autek Research, revealed that this is true, and that an antenna's input resistance (R) and the magnitude of its reactance (X) can be determined from measurements of SWR and impedance (Z). This is possible even at frequencies away from the antenna's resonance.

Knowing the antenna's R and X values is extremely useful in determining how to change the antenna or design a matching network to lower SWR.

An antenna's impedance is purely resistive only at its resonance frequencies. Away from resonance and without readjustment, the antenna's impedance will contain a reactive component in addition to the resistive part. This reactive component does not contribute to radiation, and in fact, it increases the antenna's SWR. The equations that relate resistance and reactance to SWR and impedance are as follows (Ref. 1):

$$\mathrm{SWR} = \frac{(A + B)}{(A - B)} \qquad \text{(Eq 1)}$$

where:

$$A = \sqrt{(R + Z_o)^2 + X^2} \qquad \text{(Eq 2)}$$

$$B = \sqrt{(R - Z_o)^2 + X^2} \qquad \text{(Eq 3)}$$

R = resistive component, ohms
X = reactive component, ohms
Z_o = characteristic impedance of the feed line (ohms)

The antenna analyzers provide measurements of SWR and Z. However, R and X are related to Z as follows:

$$Z^2 = R^2 + X^2 \qquad \text{(Eq 4)}$$

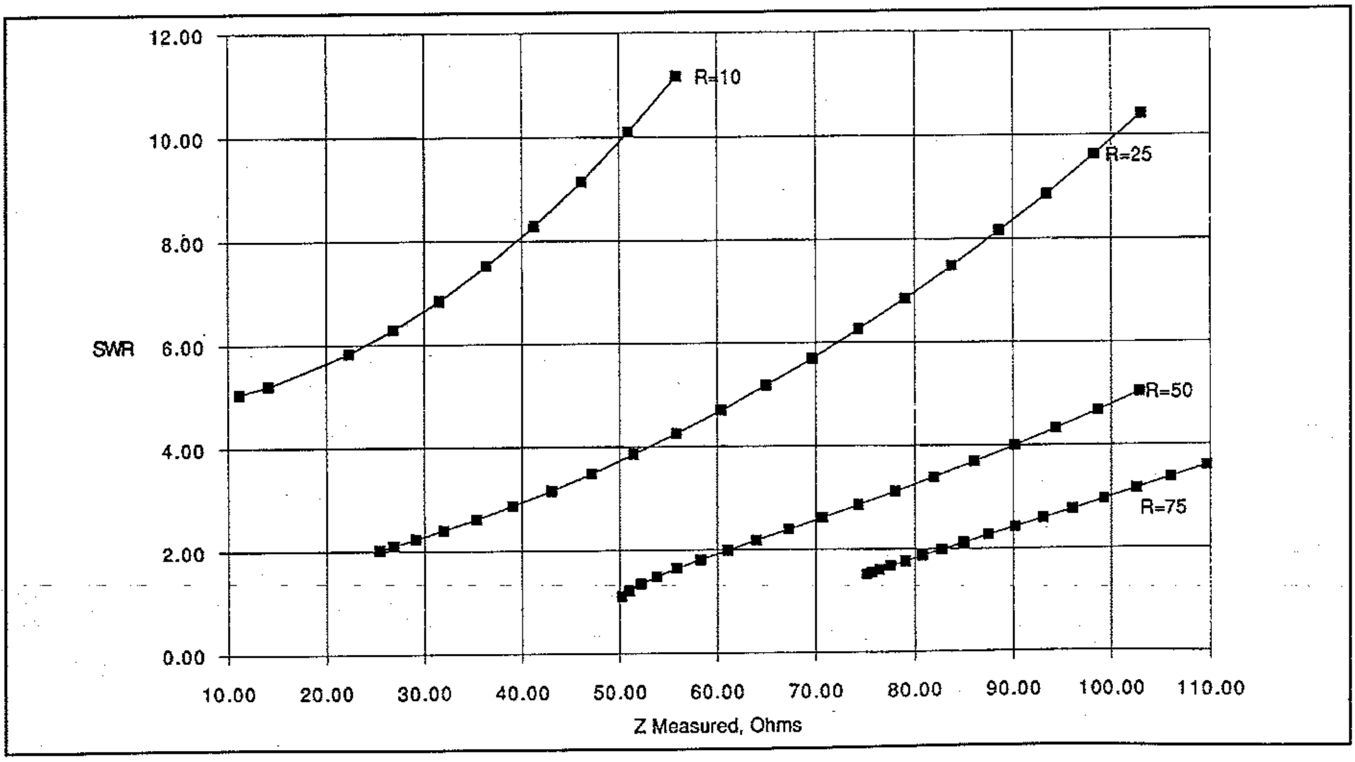

Fig. 1– The relationship among VSWR, Z, and R.

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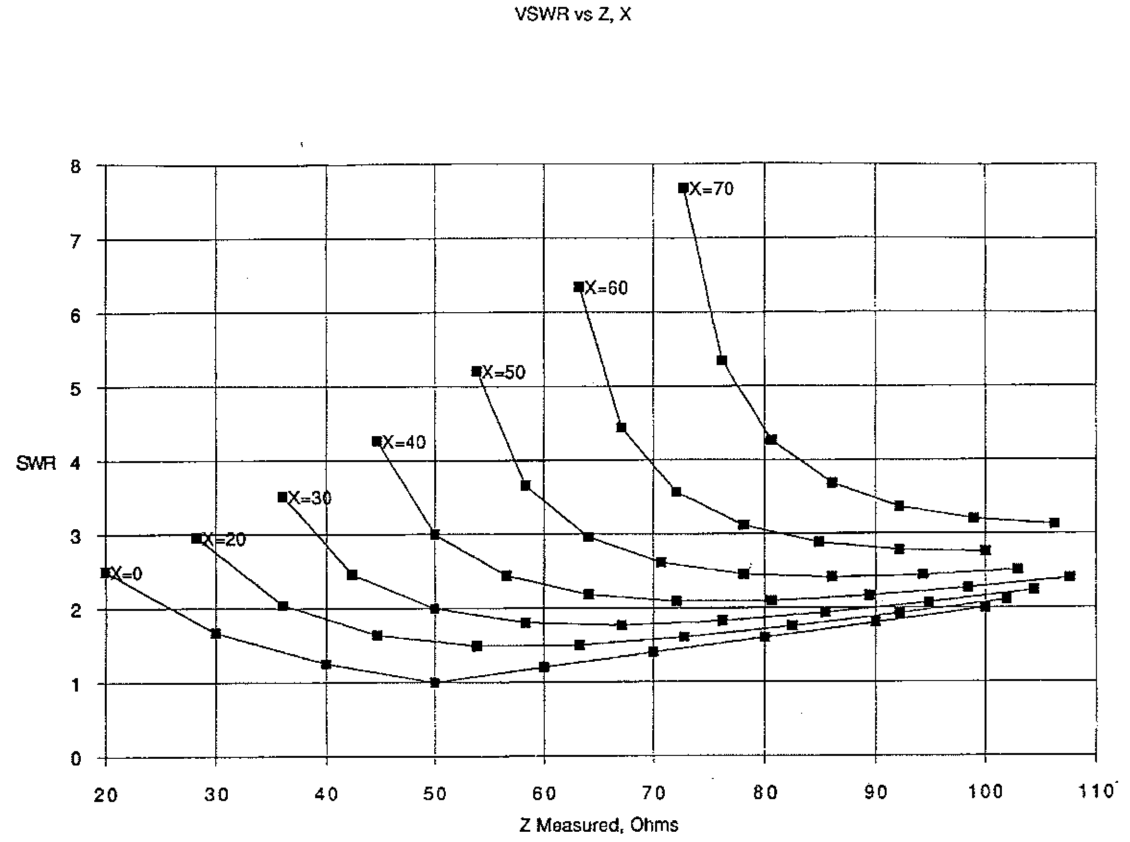

Fig. 2– The relationship among VSWR, Z, and X.

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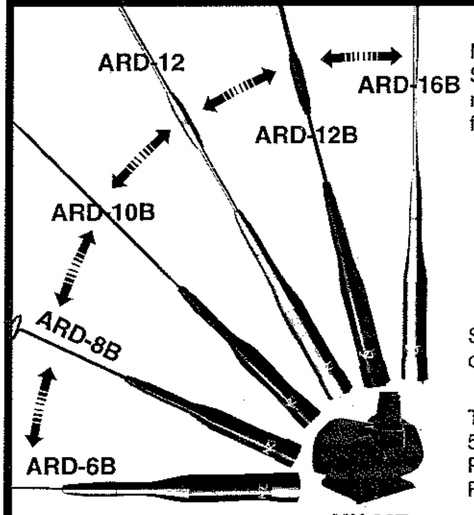

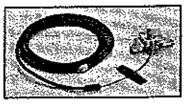

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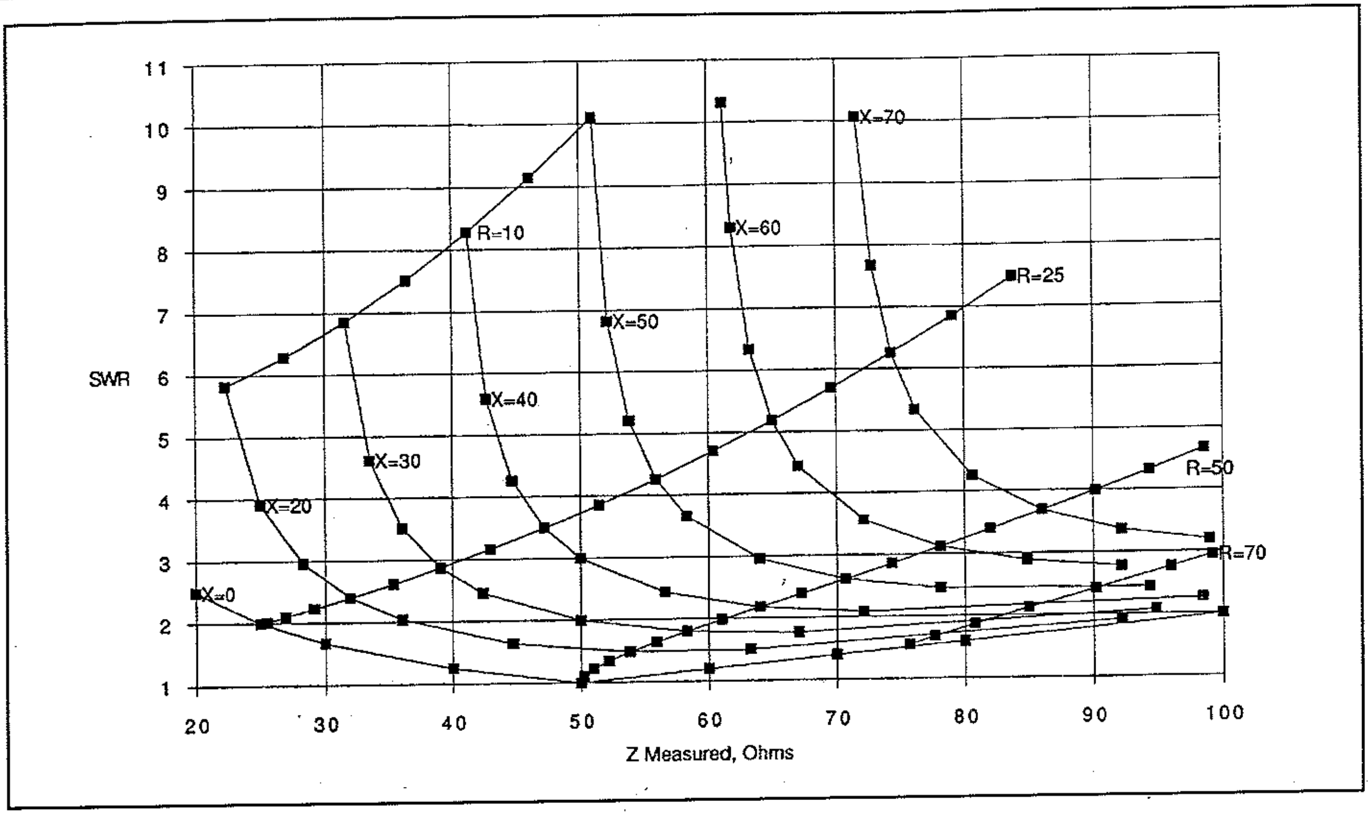

Fig. 3– Comparing the relationships of VSWR, Z, R, and X.

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We can combine these expressions to solve for R from measurements of SWR and Z (Ref. 2).

$$R = \frac{(2500 + Z^2) \times SWR}{50 \times (SWR^2 + 1)} \qquad \text{(Eq 5)}$$

Resistance (R) can therefore be solved for, and then the magnitude of reactance (X) can be solved for using Eq 6.

$$X = \sqrt{Z^2 - R^2} \qquad \text{(Eq 6)}$$

Figs. 1 and 2 were generated using these equations. Fig. 1 is a reference chart to look up resistance values (R) for measured values of SWR and impedance (Z). Fig. 2 provides the magnitude of reactance (X), also for measured values of SWR and impedance (Z).

For example, suppose you used an antenna analyzer to check the performance of a dipole antenna and measured an SWR of 4:1 and impedance value (Z) of 90 ohms. In fig. 1 lines drawn from 4.00 on the SWR (vertical) axis and 90.00 on the Z (lower) axis intersect on the curve labeled R = 50 ohms. That might sound like a nice match to a 50 ohm coaxial line, but remember that the SWR was measured as 4:1. Next check fig. 2 for the reactive value (X). Lines drawn from 4.00 on the SWR (vertical) axis and 90.00 on the Z (lower) axis intersect outside the X = 70 ohm curve at about 75 ohms, the cause of the high SWR. A matching circuit that cancels the 75 ohm reactive component would create a good match condition to a 50 ohm coaxial transmission line.

Now for the cautions and disclaimers for using these look-up charts. As mentioned, this method only gives you the magnitude of the reactance, not whether it is positive (inductive) or negative (capacitive) reactance. There are methods of determining this by experiment that will be discussed later. Also, caution must be used for certain combinations of SWR and Z, because measurement inaccuracies may lead to inaccurate values of R and X.

The effects of instrument errors can be seen in fig. 2. The lines of constant reactance become close together for values of Z greater than 70 ohms and SWRs around 2:1 and less. For instance, an SWR measurement error of ±0.1 for a SWR of 2:1, and Z = 90 ohms can result in a reactance error of up to 20 ohms. Likewise, errors in measurement of Z will compound the problem. The good news is that verticals, dipoles, Yagis, etc., typically have resistive and reactive components in the region where the results are not sensitive to measurement errors. As a rule of thumb, you should be cautious of results when they are derived from measurements of large Z at low SWR.

Fig. 3 is provided as a single look-up chart that contains curves for R and X. It covers an SWR and Z range that includes most antennas.

Whether the derived reactance is capacitive or inductive is not directly available through this method, but usually can easily be determined through knowledge of antenna behavior or with a little experimentation. We know that reactance is zero at an antenna's resonance, where an SWR minimum occurs. We also know that as frequency is varied from resonance, these antennas typically will have a capacitive (negative) reactance below resonance, and an inductive (positive) reactance above resonance. By experiment, a small-value capacitor will decrease an inductive reactance and a small-value inductor will decrease a capacitive reactance. Care must be taken not to swamp the reactance you are trying to determine with the reactance of the added component. The following equations will assist you in determining the correct value to use:

$$C = \frac{1}{6.28 \times f \times |X_C|}$$

$$L = 6.28 \times f \times |X_L|$$

where:
C = capacitor value
L = inductor value
f = frequency of measurement
$|X_C|$ = magnitude of capacitive reactance from the look-up charts
$|X_L|$ = magnitude of inductive reactance from the look-up charts

Since you will not know ahead of time whether it is an inductive or capacitive reactance, try one or the other and see if it increases or decreases the measured reactance.

Conclusion

Antenna analyzers are popular test instruments that can provide much useful information for improving antenna performance. With a little effort, these devices can provide information similar to an impedance bridge instrument at a fraction of the cost.

References

1. *The ARRL Antenna Book*, 16th ed., p. 24-9.
2. Instructions, RF AnalystTM Model RF-1, Autek Research, April 1994, and private communications. ■