VISUALIZING SWR

'SWR Circle' Clarifies Theories

By Morton Eisenberg, W3DYL
Defence Electronic Products Division, RCA

Most amateurs have a working knowledge of Standing Wave Ratio (SWR) and are aware that it is preferable to have minimum SWR on feeders so that power lost in the antenna feeder is kept to a minimum. However, this writer has heard numerous remarks on the air which indicate that many theories exist on the subject of how the SWR can be varied, including the erroneous idea that SWR can be varied by changing the length of the feeder.

To help clear the air of such misinformation, this article contains a graphical presentation of the relationship between the SWR on a transmission line and the length of the line. The presentation, usually referred to as the "SWR Circle", shows how the feed-point impedance can be found when the SWR and electrical length of the transmission line are known.

The SWR on the transmission line between the transmitter and the antenna coupler, "A" in Figure 1, can be varied by tuning and adjusting the coupler by inserting a device such as an impedance bridge in the "A" line. In this manner, a "flat" or nonresonant line (SWR = 1.0) can easily be realised.

The SWR circle applies to the "B"-line coupler to antenna or, if no coupler is used, transmitter to antenna. Although optimum tuning of the transmitter and coupler assures that the maximum r-f power is being transferred to the feeder terminals, it has no effect on the SWR.

In Figure 2, the SWR circle is plotted for a 52-ohm cable. Similar SWR circles can be drawn for any other cable characteristic impedance and the procedure will be described later in this article.

Referring to Figure 2, suppose an SWR of 2:1 is measured on the "B"-line because a 52-ohm coaxial feeder is terminated by a 26-ohm resistive antenna impedance. Depending on the feeder length, the feed-point impedance could be 26 ohms resistive at Point X, 104 ohms resistive at Point Y, or any one of the infinite number of complex impedances, such as Point Z. Point Z represents a feed-point impedance of 65 ohms resistive in series with a 39-ohm inductive reactance. The convenient way to write this mathematically is: $65 + J39$.

Point X is the feed-point impedance which is found when there is no feeder, or when the feeder length is equal to a half-wavelength or any multiple of a half-wavelength. Point Y is the feed-point impedance when the feeder is equal to a quarter-wavelength or odd multiples of a quarter-wavelength. The feed-point impedance at Point Z is due to the feeder length being equal to one-eight-wavelength.

It should now be clear that varying the length of the feeder cannot vary the SWR on the "B" line, nor can it vary the feeder losses per foot. When the feeder length is increased, simply "go around the SWR circle" in a clock-wise direction. Remember that one full trip around the SWR Circle is equal to a half-wavelength of feeder.

The use of different feeder lengths to obtain variation in feed-point impedance is known to hams as "pruning the feeder to get the antenna to load." "Pruning the feeder" is sometimes necessary because of the limited impedance-matching capabilities of the coupling circuits. In this manner, a feed-point impedance which will more easily match the feeder to the transmitter (or coupler) can be obtained. It is important to note that although the feeder length has been changed, the SWR remains constant. You are simply going to another point on the SWR circle.

The SWR on transmission line "B" can be adjusted for minimum only by doing one of the following: (1) changing the transmitter frequency, (2) adjusting the length of the antenna element or elements, or (3) adding or adjusting a matching device at the junction of the antenna and the feeder.

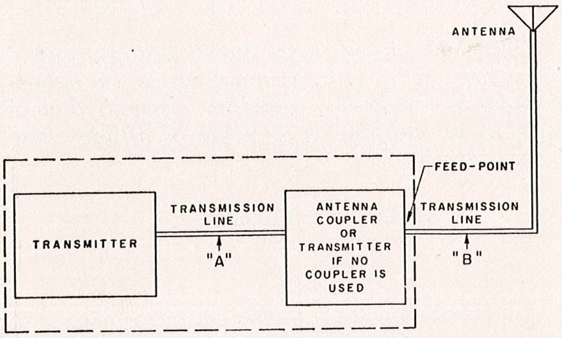

Fig. 1.

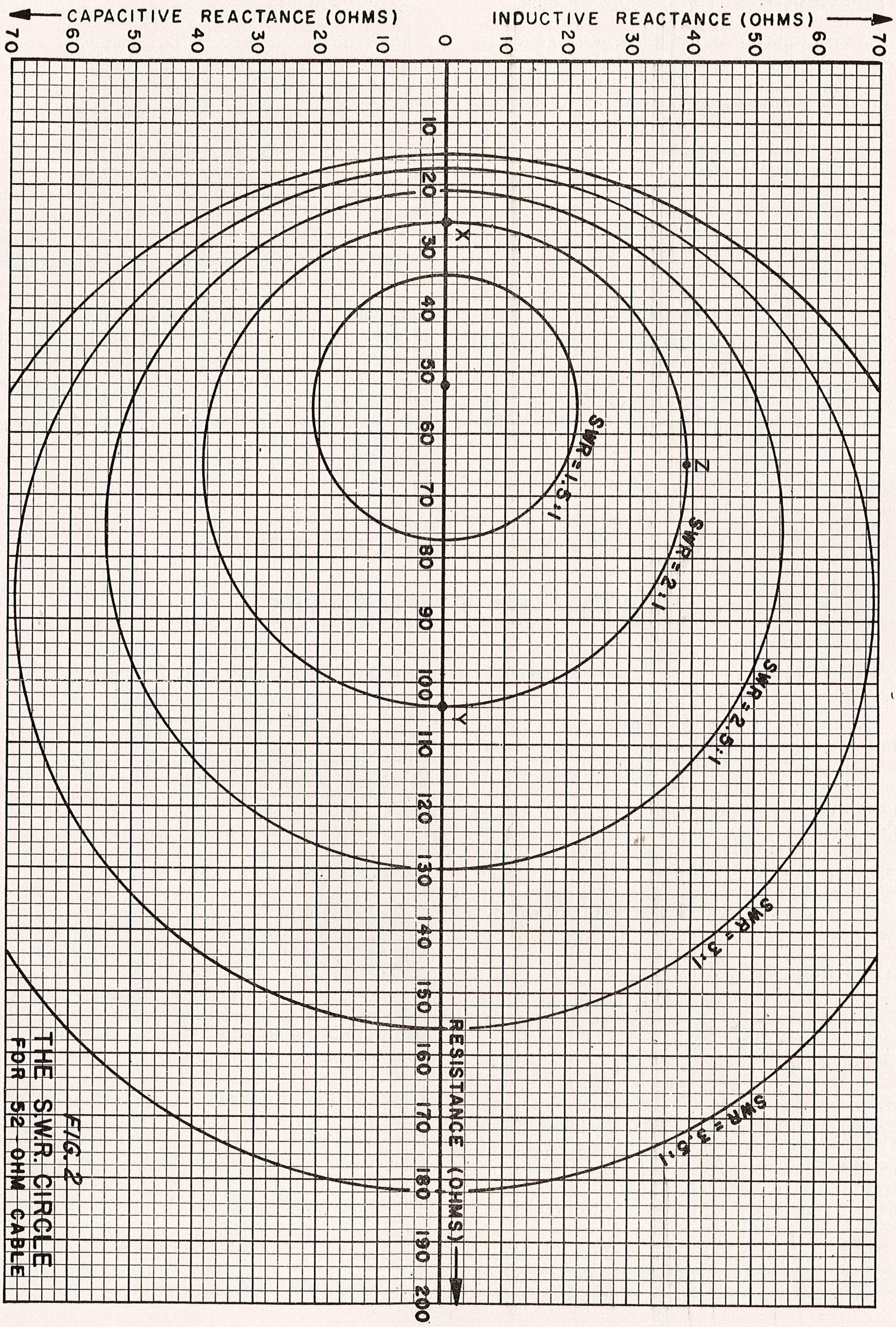

FIG. 2
THE S.W.R. CIRCLE
FOR 52 OHM CABLE

ADJUSTING SWR FOR RECEIVER FEEDERS

The SWR situation on the receiver feeder is slightly different from the problems arising in transmitter feeders. In this case, the SWR is a result of a mismatch of the input impedance of the receiver and the characteristic impedance of the feeder.

Consequently, the SWR can be adjusted to 1.0 by the use of a coupler at the input terminals of the receiver. This coupler is only necessary, of course, if the input impedance of the receiver is not equal to the characteristic impedance of the feeder.

OTHER SWR CIRCLES

For various cable characteristic impedances, SWR circles can be drawn by the procedure in the following example:

To draw a circle where the SWR = 3:1, with a 300-ohm line, the circle would cut the 100-ohm point ($\frac{300}{3} = 100$) and the 900-ohm point (300 x 3 = 900) on the horizontal axis. The centre to be used for the compasses would be $\frac{900 + 100}{2} = 500$. Setting the compasses to a distance equivalent to $\frac{900 - 100}{2} = 400$ units, with 500 as the centre, will complete the job.

The SWR circle is an extremely simple method of visualising the effect of an antenna-to-line mismatch on the feed-point impedance. It is also an easy, more understandable way of showing that varying the feeder length is a futile way to minimise losses. The SWR (or the loss) remains unchanged. To accomplish a change in SWR (or to eliminate a line loss) for any specific frequency would require a climb up to your "sky-piece."

NEW RCA RELEASES

RADIOTRON 6814

The Radiotron 6814 is a subminiature medium — mu triode with a pure tungsten low-wattage heater requiring less than 1W of heating power. This valve has a number of applications in compact electronic computers and other "on-off" equipment, and is particularly suited for use in pulse amplifier, inverter and cathode follower circuits of high-speed digital-type electronic computers. The 6814 is suitable for use in mobile and airborne equipment, and may be operated at full ratings at altitudes up to 80,000ft. without pressurisation.

RADIOTRON 7027

The Radiotron 7027 has been specially developed to meet the demands of critical AF amplifier designs, and features exceptionally high plate dissipation, high power sensitivity and high efficiency. The 7027 is a high-perveance beam power valve especially designed for use in push-pull amplifier stages of high fidelity equipment. Two 7027's in class AB1 with 450V plate voltage can handle up to 50W of AF power with only 1.5% distortion.

RADIOTRON 7200

The Radiotron 7200 is a 9-stage multiplier phototube intended primarily for the detection and measurement of ultraviolet radiation, but is also useful in applications involving low-level light sources. The envelope has a fused-silica section which transmits radiant energy in the ultraviolet region down to and below 2000 angstroms, at which figure the spectral sensitivity is nearly 80% of maximum. The spectral response of the 7200 covers the range of approximately 1800 to 6000 angstroms.

RADIOTRON 2CY5 AND 6CY5

These types are sharp cut off tetrodes designed for use as RF amplifiers in VHF TV tuners. They feature high transconductance (8000 micromhos) to provide high stage gain with corresponding reduction in equivalent noise resistance. A high ratio of plate to screen currents of 7:1 provides good signal/noise ratio. The two valves are identical except for heater voltage and current.

DEFLECTION SYSTEMS & COMPONENTS

A complete line of deflection systems and components has just been released by RCA, including ruggedised units for military applications. Included are components for use with image orthicons 5820, 6474, 6974 and 7037, one-inch vidicons 6198, 6198A, 6326, 6326A, TV monitor tube 17BP4A, TV projection tube 5AZP4, and flying spot scanner tubes 5ZP16 and 5WP11.