VSWR
Voltage Standing Wave Ratio

From time to time we are reminded that terms we take for granted could stand some clarification. One such term is VSWR, short for Voltage Standing Wave Ratio.

In a coaxial transmission line power propagates from the source to the load, and if the load and the line are a perfect match all the power is absorbed by the load. Such ideal conditions rarely exist and some of the forward wave is reflected back to the source (E_s, I_s) from one or more planes. The vectorial addition and subtraction of voltages of the waves travelling in both directions result in a stationary pattern along the transmission line which is called the Voltage Standing Wave (Fig. 1).

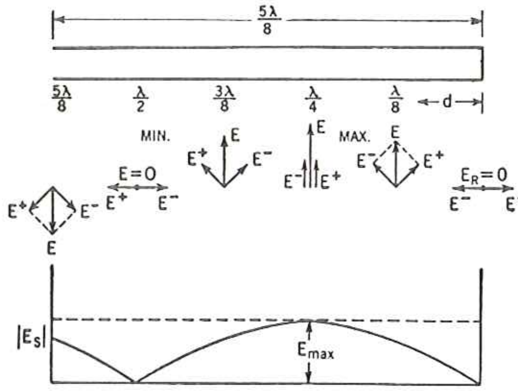

Fig. 1

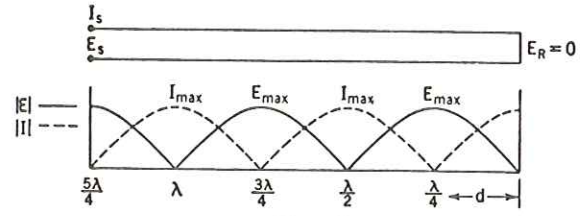

Fig. 2

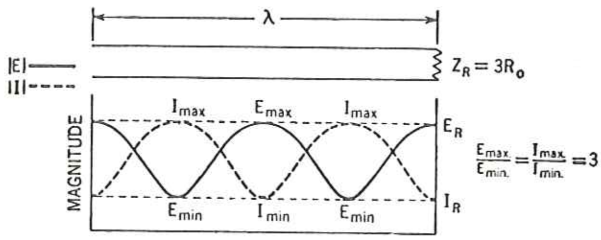

Fig. 3

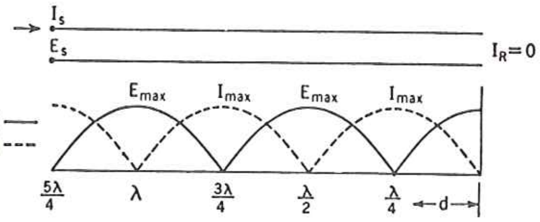

Fig. 4

E_R, I_R ... Receiving end Voltage and Current

Z_R ...... Load Impedance

R_o ...... Line Impedance (e.g. 50 ohms)

If the line is slotted, a simple probe, crystal rectifier and meter moved along the slot indicates the voltages at each point. It is this simplicity of instrumentation and the wealth of information that a plot of the pattern yields that have made standing voltage waves such an important parameter in coaxial radio frequency transmission. (The current pattern is identical, though shifted 90°, but current measurement is more complicated.)

When the load matches a line, such as a perfect 50 ohm termination at the end of a 50 ohm slotted lossless line, the voltage probe indicates the same value at all points between the source and the load. The extremes of mismatch, on the other hand, are a shorted or an open line, where all of the energy is reflected back. Since the shorted end acts like a mirror to voltage, the forward and reflected wave voltages cancel (Fig. 2). One-quarter wavelength back, the voltages of the two travelling waves are equal and in phase, resulting in twice the value of each. The ratio of the maximum standing wave voltage divided by the minimum is called the Voltage Standing Wave Ratio. A similar condition exists in an open line. The voltages add at the open end and cancel one-quarter wave back (Fig. 4). Fig. 3 illustrates line conditions with a 150 ohm load terminating a 50 ohm line.

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1.00 is Best

VSWR values range from 1.00 for a perfect match, where the voltages along the line are all equal, to infinity for an open or shorted termination. In some countries the ratio is sometimes expressed as the minimum voltage divided by the maximum and ranges from 1.00 to zero.

Since energy reflected from the business end of a transmission line serves no useful purpose, a great deal of RF measurement effort is concerned with displaying minimum reflected power, i.e. near-unity VSWR. The slotted line is still the most accurate instrument, yielding both VSWR and phase angle information. A variation of the slotted line designed for field use is a rigid cable drilled at frequent intervals for insertion of a voltage probe.

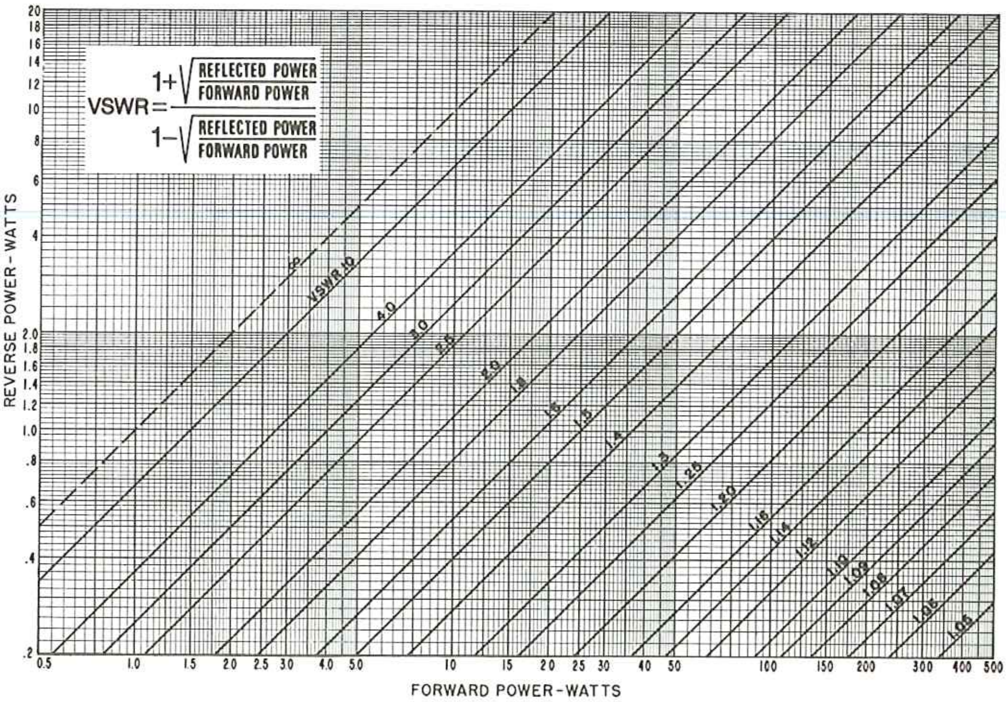
While low voltage ratios as measured by such instruments are indicative of low reflected power, actual power levels must be calculated from maximum and minimum voltage readings and the impedance of the line. It is clearly more practical and more closely related to the desired end result to measure the energy in each of the two travelling waves. The Bird THRULINE® series of Wattmeters indicate forward power with their element pointing towards the load and reflected power when the element is turned 180°. Without further calculations, the forward reading discloses whether the RF source is operating and at what level, the reflecting reading tells whether the bulk of the transmitted energy is usefully employed or wastefully returned to the source. A simple algebraic subtraction (P_{fwd}-$P_{refl.}$) yields the net power delivered to the load. Improvements in *antenna* matching are directly and immediately displayed on the meter as lower $P_{refl.}$, when P_{fwd} stays relatively constant. Furthermore, optimum adjustment of the *RF source* is as conveniently apparent from a maximum P_{fwd} reading. In other words, a THRULINE Wattmeter furnishes all the information indicating the best operating conditions without the use of so much as a slide rule.

If actual VSWR data are still required, a quick glance at a nomograph such as Fig. 5 (supplied with each instrument) yields the value from the intersection of forward and reflected power.

We are often asked to recommend the best location along a line for the insertion of a THRULINE. Since a THRULINE indicates the energy of a wave travelling in either of the two directions, and since such energy is the same anywhere along the line (neglecting small attenuation), the instrument can be inserted near the transmitter, near the antenna or at any convenient place between.

Under conditions of mismatch, high standing waves can easily damage a transmission line or the output stage of a transmitter. A short circuit, for instance, is an example where damage is easy to visualize, but less dramatic disturbances such as water seeping into a line, which can rob you of useful power, should be detected and eliminated quickly. We have a series of panel mounted instruments on which both the forward and the reflected power are simultaneously indicated by two meters. Since disturbances cause excessive reflected power, a sensing device in that branch of a THRULINE can be set to "watch" over the safe operation of a transmitter and can be incorporated in the circuit to automatically shut down transmission and to sound an alarm. We call these alarm panels the Wattcher®.

POWER VALUES vs. VSWR



FOR HIGHER POWER VALUES MULTIPLY BOTH SCALES BY THE SAME DECIMAL FIGURE