ANTENNA MEASUREMENTS

Important measurements on antenna, such as, input and mutual impedance, radiation pattern, gain, phase front and polarization are considered.

1. Input and Mutual Impedances

For radio frequencies below 30 MHz, bridge measurements are commonly employed. The fundamental Wheatstone-bridge shown in Fig. 1 is quite useful for this measurement. This bridge utilizes a null method, and is useful for measurements of impedance, resistive or reactive from dc to the lower VHF band. The measurements are usually preceded by a calibration of the bridge in which the latter is balanced with the unknown impedance terminals short-circuited or open-circuited. There are many bridges, derived from Fig. 1, with many fixed known resistors, inductances and capacitances and with one or more variable calibrated elements. The generator signal source should give at least 1 mv output, and the detector should be a well-shielded receiver having at least a sensitivity of 5μv.

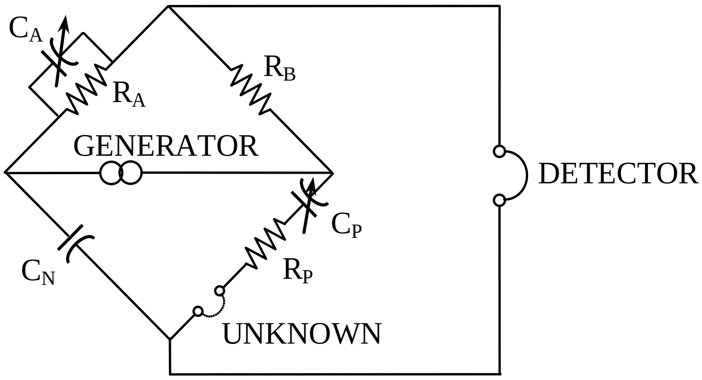

Fig. 1. Wheatstone-bridge.

At higher UHF frequencies and microwave frequencies, slotted-line measurements are more convenient. Figure 2 shows the set-up for slotted-line impedance measurement.

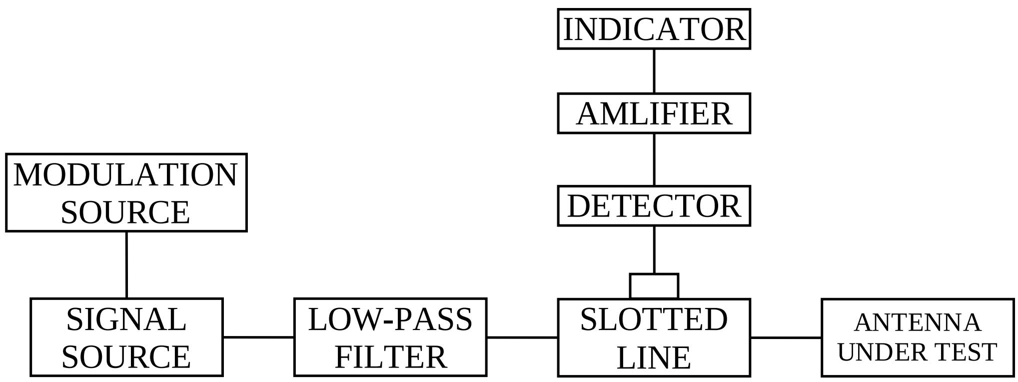

Fig. 2 Set-up for slotted-line impedance measurement.

Slotted-lines may be coaxial lines, slab lines or waveguide lines. The characteristic impedance of coaxial or slab lines is usually 50 ohms, and waveguide slotted-lines are available in different sizes corresponding to different waveguide sizes for different bands. The standing wave patterns with the slotted-line shorted, and with the antenna as load are drawn as shown in Fig. 3.

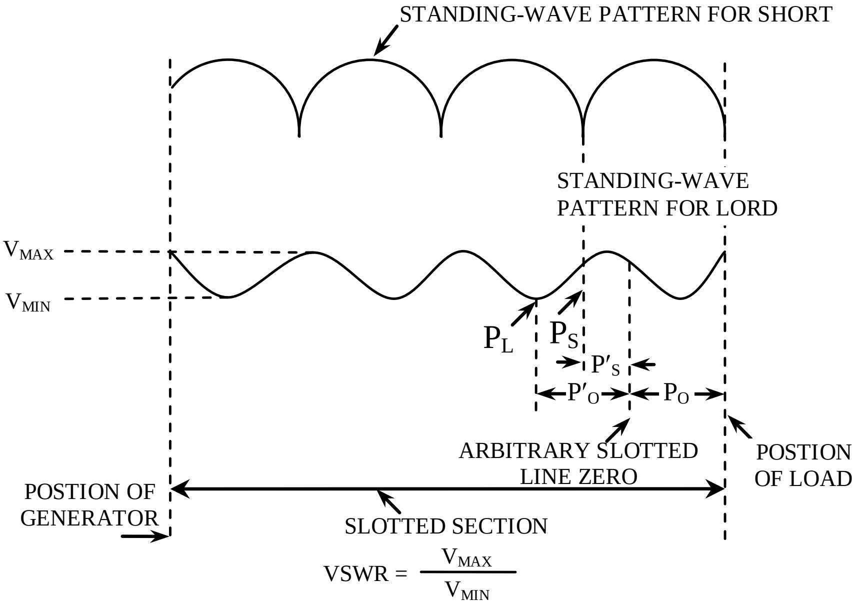

Fig. 3 Standing-wave patterns.

$$\text{SWR} = 20 \log \text{VSWR} = 20 \log \frac{V_{MAX}}{V_{MIN}} \tag{1}$$

The input impedance of the antenna is given by

$$Z_L = Z_0 \left\{ \frac{S}{\cos^2(\beta l) + S^2 \sin^2(\beta l)} + \left[\frac{(S^2 - 1)\sin(\beta l)\cos(\beta l)}{\cos^2(\beta l) + S^2 \sin^2(\beta l)} \right] \right\} \tag{2}$$

Where

S = VSWR

$\beta = 2\pi/\lambda_g$

λ_g = guide wavelength

Z_0 = characteristic impedance of line

Z_L = load or antenna impedance

And

$$\left|(P_l^{'} - P_s^{'})\right| = |\, l \,| \tag{3}$$

If P_l is closer to the generator than P_s, then l is taken as positive, and if P_s is closer to the generator than P_l, the l is taken as negative.

The Smith Chart (Fig. 4) can be easily used to determine the impedance. For Example if P_s = 25 cm = short position, P_l = 17 cm = load position, and VSWR = 4, and λ_g = 26 cm, then

$$|\, l \,| = P_l - P_s = 8$$

and

$$\frac{|\, l \,|}{\lambda_g} = \frac{8}{26} = 0.308 \ \text{wavelength.}$$

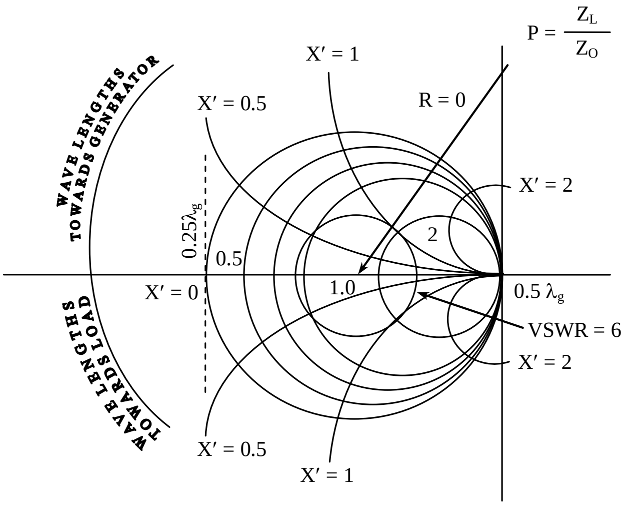

Fig. 4 Smith Chart

Assuming that P_s is closer to the load-end of the line than P_l , the value $| l |/\lambda_g$ is plotted using the position scale on the Smith Chart which reads ‘wavelengths toward load’. If P_s is closer to the generator than P_l , then $| l |/\lambda_g$ is plotted using the scale which reads ‘wavelength toward generator’. The resulting impedance (normalized value) is given by the point P at intersection at VSWR = 4 circle and the radius vector representing $l/\lambda_g = 0.308$.

To measure the mutual impedance between two antennas 1 and 2, antenna 2 is short-circuited and the terminal impedance Z_1 of antenna1 is measured. Then,

$$Z_1 = Z_{\text{self}} + \frac{I_2}{I_1} Z_{\text{mutual}} \tag{4}$$

$$0 = Z_{\text{self}} + \frac{I_1}{I_2} Z_{\text{mutual}} \tag{5}$$

So that

$$(Z_{\text{mutual}})^2 = Z_{\text{self}}\,(Z_{\text{self}} - Z_1) \tag{6}$$

Where Z_{self} is the self impedance of antenna1 (or) antenna2, if the antennas are identical.

2. Radiation Pattern

Figure 5 shows a set-up for the measurement of the radiation pattern of an antenna, which consists of a transmitting source, an antenna under

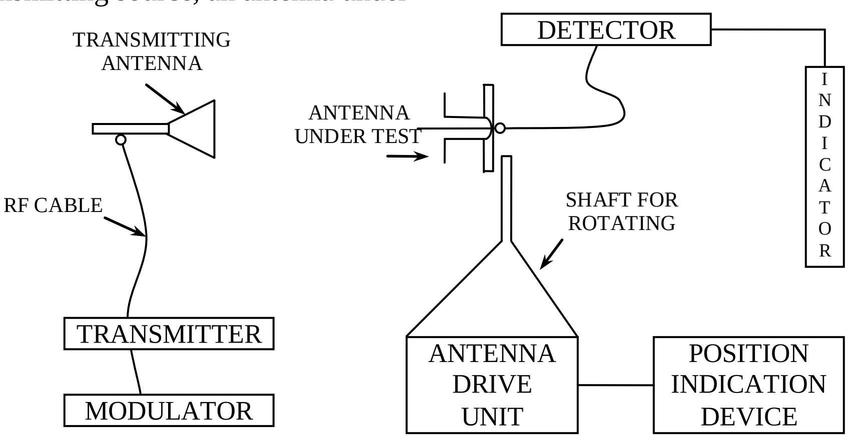

Fig. 5 Set-up for measuring radiation pattern.

test, a mount for rotating the antenna under test, and a detector for indicating the relative magnitude of the received field. The equipment may be either fully automatic or manual. The following precautions should be taken care of to be sure that the radiation patterns are correct:

(i) To obtain the accurate far-field, or Fraunhofer, radiation patterns, it is necessary that the distance R between the transmitting antenna and the antenna under test be sufficiently large so that

$$R \geq 2d^2/\lambda \tag{7}$$

Where d is the maximum dimension of the aperture of the antenna and λ is the operating wavelength. Reducing *R* tends to give broader radiation patterns and higher minor lobes and shadower nulls.

(ii) A uniform illumination of the antenna under test should be ensured. Ground reflections and reflections from buildings, trees etc. should be avoided.

(iii) Antenna measurements can be done in a properly designed anechoic chamber to avoid reflections and to simulate free-space conditions.

(iv) An automatic range equipment avoids manual errors.

(v) The transmitting antenna should have as uniform a wave-front as possible to minimize to phase error of the antenna under test. Should have as high a gain as possible, and should have very insignificant minor lobes (at least 20 dB less than the major lobe). Horns, parabolic dishes and arrays of dipoles or horns are usually used.

3. Gain

The gain and directivity of the antenna are defined as

$$\mathbf{G} = \text{Gain} = \frac{\text{maximum radiation intensity (test antenna)}}{\text{maximum radiation intensity (reference antenna)}} \tag{8}$$

and

$$\mathbf{D} = \text{Directivity} = \frac{\text{Maximum radiation intensity}}{\text{Average radiation intensity}} \tag{9}$$

Assuming that the test antenna and the reference antenna both have the same input power, the values of the radiation intensity are generally obtained by a measurement of the field intensity of the power density. In deriving the expression for directivity, the values of radiation intensity are usually obtained only in a relative manner from the radiation patterns.

The gain G of an antenna is always less than its directivity *D*, and

$$G = \alpha D \tag{10}$$

Where α can be called the effectiveness ratio and $0 \leq \alpha \leq 1$. Also,

$$G = \gamma_0 \, G_0 \tag{11}$$

Where G_0 is the gain of the test antenna over the arbitrary reference antenna, and γ_0 is the gain of the reference antenna over an isotropic antenna. For lossless antennas, $1 \le \gamma_0$.

Figure 6 shows a set-up for measuring the gain of an antenna by a comparison method. The distance R between the test antenna and the transmitting antenna should be $\geq d^2/\lambda$, and reflections from nearby objects should be minimized.

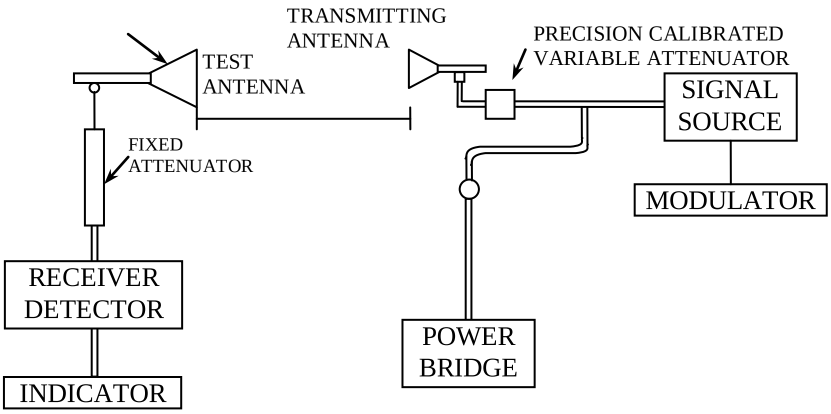

Fig. 6 Set-up for gain measurement by comparison method

A standard antenna is connected to the receiver and is pointed in the direction of maximum intensity. The input to the transmitting antenna is set to a convenient level, and the reading on the receiver is noted. Let W_1 be the attenuator-dial setting and P_1 the power-bridge reading. The standard antenna is now replaced by the test antenna and W_2 and P_2 be the attenuator dial-setting and power-bridge reading. Then the power gain G is given by

$$G = \frac{W_2 P_1}{W_1 P_2} \tag{12}$$

If $P_d = 10 \log \frac{P_1}{P_2}$, then the

$$\text{Decibel gain} = W_2 - W_1 + P_d \tag{13}$$

DRAWBACKS IN MEASUREMENTS OF ANTENNA PARAMETERS

1. It is sometimes difficult to provide far-field distance or $r > 2D^2/\lambda$, where D being aperture size and λ being wavelength for far-field pattern measurements.
2. Ground reflections are present while noting the measurements.
3. It is difficult to bring large antennas to the measuring site.
4. Measurements are time consuming.
5. It is difficult to accommodate large antennas in shielded chambers.
6. Open site measurements are not accurate.
7. Measuring equipment is expensive.

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METHODS TO OVERCOME DRAWBACKS IN MEASUREMENTS

1. Determination of far-field patterns from near-field measurements.
2. Making scale model measurements.
3. Using automated measuring equipment.
4. Using computerised techniques.

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POINTS TO REMEMBER

1. The far-field distance between the transmitting and receiving antennas should be $r > 2D^2/\lambda$.
2. GTD represents geometrical theory of diffraction.
3. The antenna measurements are mainly classified as indoor and outdoor ranges.
4. Anechoic chambers and GTEM cell are popular for measurements.
5. Wheatstone bridge is used to measure antenna impedance upto 30 MHz.
6. The slotted lines are used to measure antenna parameters like VSWR, impedance and reflection coefficient.
7. Antenna gain measurements are made by comparison methods.
8. Antenna polarisation can be easily obtained by received power measurement.

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