

# Lecture-5

## Antenna parameters:

### 1.4.9 Axial Ratio

The polarization state of an EM wave can also be indicated by Axial Ratio (AR). It is defined as

$$AR = \frac{OA}{OB}, \quad 1 \leq AR \leq \infty, \quad \text{or} \quad 0 \text{ dB} \leq AR \leq \infty \text{ dB}$$

where OA and OB are the major and minor axes of the polarization ellipse respectively (see Fig. 25).

**Note:**

$$\begin{aligned} AR = 1, & \quad \Rightarrow \text{circular polarization} \\ 1 < AR < \infty, & \quad \Rightarrow \text{elliptical polarization} \\ AR = \infty, & \quad \Rightarrow \text{linear polarization} \end{aligned}$$

Very often, we use the **AR bandwidth** and the **AR beamwidth** to characterize the polarization of an antenna. The AR bandwidth is the frequency bandwidth in which the AR of an antenna changes less than 3-dB from its minimum value. The AR beamwidth is the angle span over which the AR of an antenna changes less than 3-dB from its minimum value.

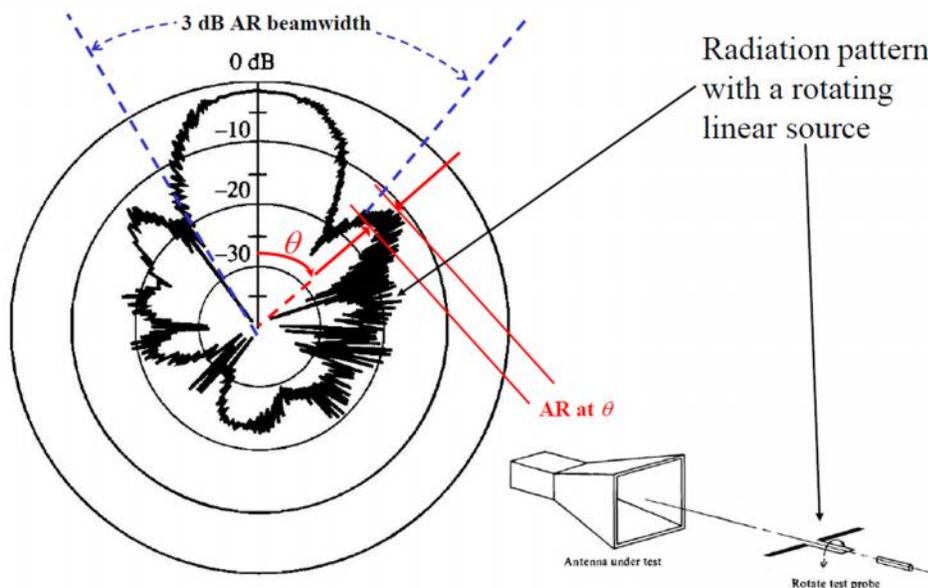


Fig. 26: AR beamwidth concept and its experimental measurement system

AR can be measured experimentally and the concept has been explained pictorially in Fig. 26 and Fig. 27.

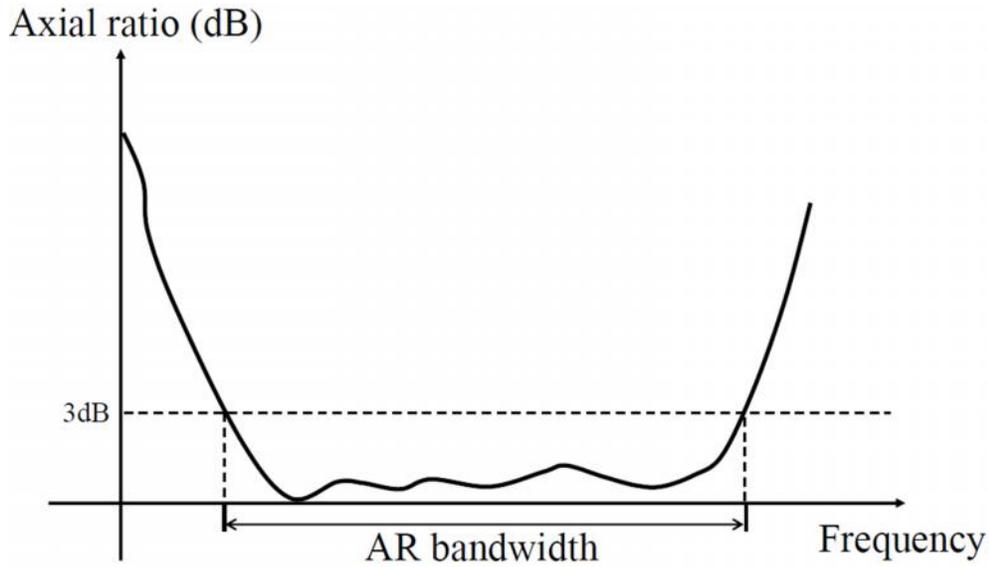


Fig.27: Concept of AR bandwidth

### 1.4.10 Input Impedance

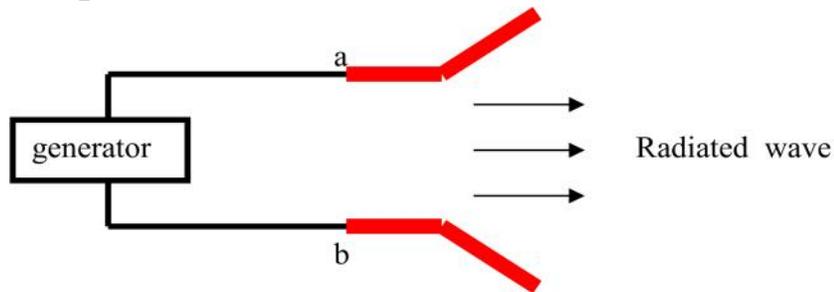


Fig. 28: A transmitting antenna system

The input impedance  $Z_A$  of a transmitting antenna is the ratio of the voltage to current at the terminals of the antenna.

$$Z_A = R_A + jX_A$$

$R_A$ : input resistance,  $X_A$ : input reactance

$$R_A = R_r + R_L$$

$R_r$ : radiation resistance,  $R_L$ : loss resistance

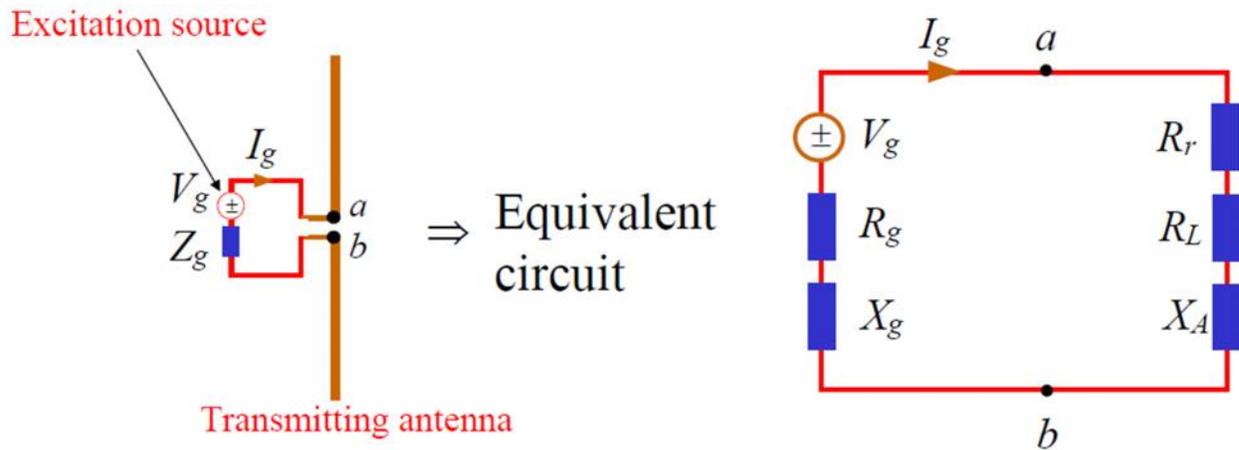


Fig. 29: Antenna input impedance concept

If we know the input impedance of a transmitting antenna, the antenna can be viewed as an equivalent circuit, as shown in Fig. 29, where

$$Z_g = R_g + jX_g$$

$Z_g$ : internal impedance of the excitation source

$R_g$ : internal impedance of the excitation source

$X_g$ : internal reactance of the excitation source

$I_g$ : antenna terminal current

The knowledge of  $Z_A$  is required when connecting an antenna to its driving circuit.

If  $Z_A = Z_g^*$ , antenna is matched.

If  $Z_A \neq Z_g^*$ , antenna is not matched and a matching circuit is required.

The radiation resistance  $R_r$  can be calculated from the power radiated  $P_{\text{rad}}$  as:

$$P_{\text{rad}} = \frac{1}{2} |I_g|^2 R_r$$

Power loss as heat in the antenna:

$$P_{\text{loss}} = \frac{1}{2} |I_g|^2 R_L$$

Power loss in the internal resistance of the excitation source:

$$P_{\text{internal}} = \frac{1}{2} |I_g|^2 R_g$$

Maximum power transfer from the excitation source to the antenna occurs if the antenna is matched. That is,

$$Z_A = Z_g^*$$

$$R_r + R_L = R_g, \quad X_A = -X_g$$

If the antenna is connected to the driving circuit via a transmission line with a characteristics impedance  $Z_0$ , then the antenna should be matched to the characteristic impedance of transmission line. That is,

$$Z_A = Z_0, \quad R_r + R_L = Z_0, \quad X_A = 0$$

The impedance looking into the terminals of a **receiving antenna** is called internal impedance  $Z_{\text{in}}$ . In general  $Z_{\text{in}} \neq Z_A$ . The internal impedance is used to model the equivalent circuit of a receiving antenna as the input impedance is used to model the equivalent circuit of a transmitting antenna.

### 1.4.11 Reflection Coefficient

The reflection coefficient of a transmitting antenna is defined by:

$$\rho = \frac{Z_A - Z_0}{Z_A + Z_0} \quad (\text{dimensionless})$$

- Reflection coefficient can be calculated or measured.
- The magnitude of reflection coefficient is from 0 to 1.
- When the transmitting antenna is not match, that is,  $Z_A \neq Z_0$ , there is a loss due to reflection (return loss) of the wave at the antenna terminals. When expressed in *dB*, ... is always a negative number
- Sometimes we use S11 to represent ...

### 1.4.12 Return Loss

The return loss of a transmitting antenna is defined as:

$$\text{return loss} = -20 \log |\rho| \quad (\text{dB})$$

- Possible values of return loss are from 0 dB to  $\infty$  dB.
- Return loss is always a positive number.

### 1.4.13 VSWR

Same as ... and the return loss, the voltage standing wave ratio (VSWR) is also a common parameter used to characterize the matching property of a transmitting antenna. The VSWR of a transmitting antenna is defined as:

$$\text{VSWR} = \frac{1 + |\rho|}{1 - |\rho|} \quad (\text{dimensionless})$$

- Possible values of VSWR are from 1 to  $\infty$ .
- $\text{VSWR} = 1 \Rightarrow$  perfectly matched,  $\text{VSWR} = \infty \Rightarrow$  completely unmatched.