

# Lecture-6

## Antenna parameters:

### 1.4.14 Impedance Bandwidth

Impedance bandwidth is defined as

$$\text{Impedance bandwidth} = \frac{f_U - f_L}{f_c} \times 100\%$$

The symbols in the above equation are depicted in Fig. 30 below.

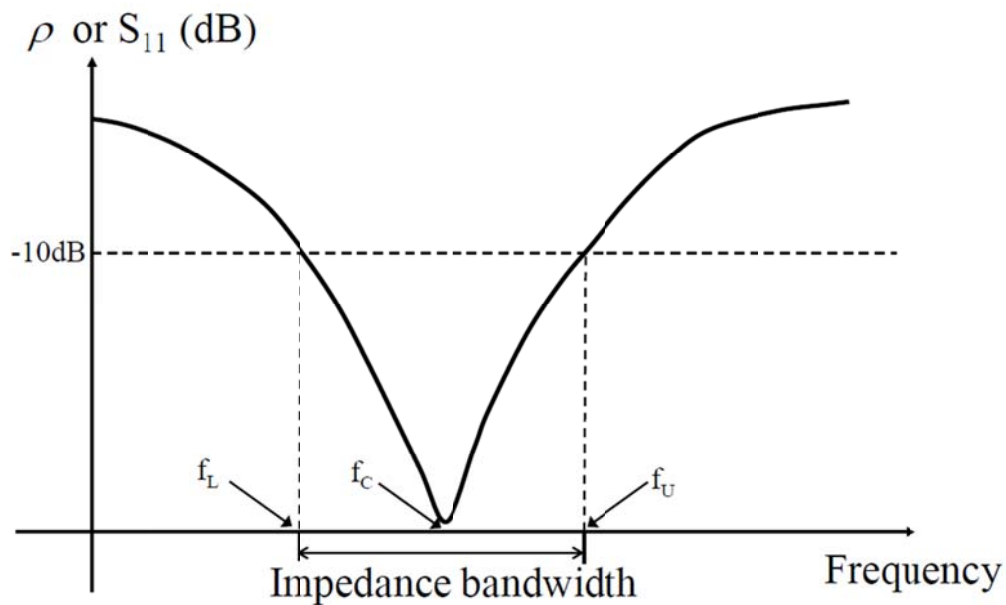


Fig. 30: Concept of impedance bandwidth

**Note:** When  $\rho = -10$  dB,

$$\begin{aligned} \text{VSWR} &= \frac{1+|\rho|}{1-|\rho|} = \frac{1+0.3162}{1-0.3162} \\ &= 1.93 \\ &\approx 2 \end{aligned}$$

Hence the impedance bandwidth can also be specified by the frequency range within which  $\text{VSWR} \leq 2$ .

### 1.4.15 Effective Aperture

It is a measure of the ability of an antenna to collect power from an incident wave and deliver it to its terminals.

The effective aperture (area) of a receiving antenna looking from a certain direction  $(\theta, \phi)$  is the ratio of the average power  $P_L$  delivered to a matched load to the magnitude of the average power density  $P_{\text{avi}}$  of the incident electromagnetic wave at the position of the antenna multiplied by the normalized power pattern  $|P_{\text{av}}(\theta, \phi)|$  of that antenna.

$$A_e(\theta, \phi) = \frac{P_L}{P_{\text{avi}} |P_{\text{av}}(\theta, \phi)|}$$

The effective aperture is related to the directivity as:

$$A_e(\theta, \phi) = \frac{\lambda^2}{4\pi} D(\theta, \phi)$$

A maximum effective area  $A_{\text{em}}$  can be defined when the antenna is receiving in its maximum-directivity direction. That is,

$$A_{\text{em}} = \frac{\lambda^2}{4\pi} D_0$$

## 1.5 Communication Link and Friis Transmission Equation

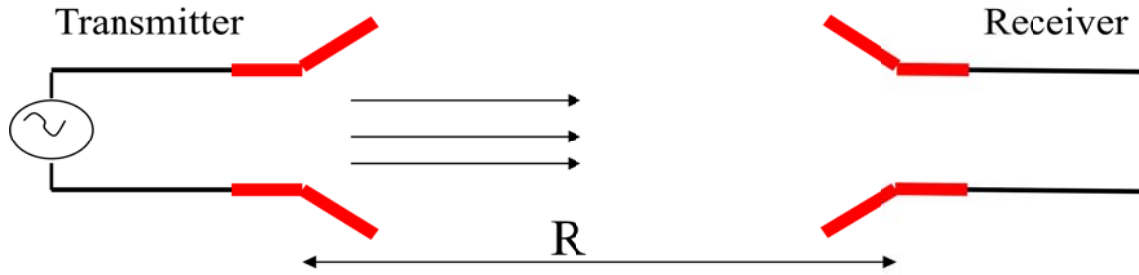


Fig. 31: Transmitting and receiving antennas for derivation of Friis transmission equation

The Friis transmission equation relates the power received to the power transmitted between two antennas placed in the far-field of each other.

If  $P_t$  is the input power to the transmitting antenna, then the isotropic power density at a distance  $R$  from the antenna can be given by:

$$W_o = e_t \frac{P_t}{4\pi R^2}$$

where  $e_t$ : efficiency of the transmitting antenna.

For a directional transmitting antenna, this value changes to

$$W_t = e_t \frac{P_t}{4\pi R^2} D_t$$

where  $D_t$ : directivity of the transmitting antenna.

Not all of the transmitted power density is received by the receiving antenna. In order to find the value of that, we need to consider the effective aperture of the antenna and the absorption losses in the atmosphere.

Thus the received power can be expressed as:

$$P_r = A_{er} W_t$$

But 
$$A_{er} = e_r D_r \left( \frac{\lambda^2}{4\pi} \right)$$

So 
$$P_r = e_r D_r \left( \frac{\lambda^2}{4\pi} \right) \bullet e_t \frac{P_t D_t}{4\pi R^2} = e_r e_t D_r D_t \left( \frac{\lambda}{4\pi R} \right)^2 P_t$$

This equation is known as the **Friis Transmission Equation** and it relates the power  $P_r$  (delivered to the receiver load) to the input power of the transmitting antenna  $P_t$ . The term  $(\lambda/4\pi R)^2$  is called the **free-space loss factor**, and it takes into account the losses due to the spherical spreading of the energy by the antenna. Friis transmission equation is the basis to find the RADAR range equation.

At this point, we are in a position to define the term **effective (or equivalent) isotropically radiated power, EIRP**, a term frequently used in communication systems. It is defined as the power gain of a transmitting antenna in a given direction multiplied by the net power accepted by the antenna from the connected transmitter. Suppose an observer is located in the direction of maximum radiation from a transmitting antenna with input power  $P_t$ , then

$$EIRP = P_t G_t .$$