FRIIS TRANSMISSION EQUATION

A general radio system link is shown in Figure, where the transmit power is P_t, the transmit antenna gain is G, the receive antenna gain is G_r, and the received power (delivered to a matched load) is P_r. The transmit and receive antennas are separated by the distance R.

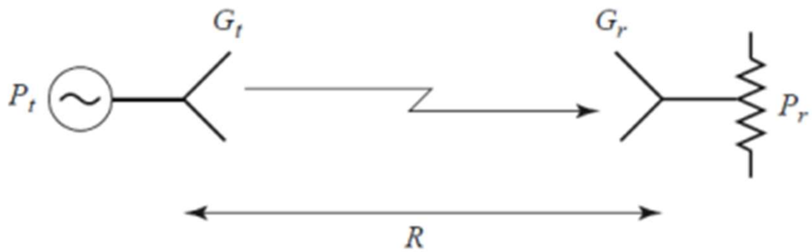

Figure 1.17 A basic radio system

The power density radiated by an isotropic antenna (D = 1 = 0 dB) at a distance R is given by

$$S_{avg} = P_t/4\pi R2 \ \ W/m^2$$

This result reflects the fact that we must be able to recover all of the radiated power by integrating over a sphere of radius R surrounding the antenna, since the power is distributed isotropically, and the area of a sphere is $4\pi R^2$. If the transmit antenna has a directivity greater than 0 dB, we can find the radiated power density by multiplying by the directivity, since directivity is defined as the ratio of the actual radiation intensity to the equivalent isotropic radiation intensity. In addition, if the transmit antenna has losses, we can include the radiation efficiency factor, which has the effect of converting directivity to gain. Thus, the general expression for the power density radiated by an arbitrary transmit antenna is

$$S_{avg} = G_t P_t \,/\, 4\pi R^2 \ \ W/m^2$$

If this power density is incident on the receive antenna, we can use the concept of effective aperture area, to find the received power:

$$P_r = A_e S_{avg} = G_t P_t A_e \,/\, 4\pi R^2 \ W.$$

Again, the possibility of losses in the receive antenna can be accounted for by using the gain (rather than the directivity) of the receive antenna. Then the result for the received power is

$$Pr = G_t G_r \lambda^2 \,/\, (4\pi R)^2 \ \ Pt \ W.$$

This result is known as the Friis radio link formula, and it addresses the fundamental question of how much power is received by a radio antenna. These include impedance mismatch at either antenna, polarization mismatch between the antennas, propagation effects leading to attenuation or depolarization, and multipath effects that may cause partial cancellation of the received field.

The Friis formula, received power is proportional to the product $P_t G_t$. These two factors—the transmit power and transmit antenna gain—characterize the transmitter, and in the main beam of the antenna the product $P_t G_t$ can be interpreted equivalently as the power radiated by an isotropic antenna with input power $P_t G_t$. Thus, this product is defined as the effective isotropic radiated power (EIRP):

$$\boldsymbol{EIRP: PtGtW}$$

For a given frequency, range, and receiver antenna gain, the received power is proportional to the EIRP of the transmitter and can only be increased by increasing the EIRP. This can be done by increasing the transmit power, or the transmit antenna gain, or both.