FRIIS TRANSMISSION EQUATION

ANTENNA & RADIO WAVE PROPAGATION

Monday, 14 December 2025

ORIGIN AND USE OF FRIIS EQUATION

1. **Friis transmission equation** was first derived in 1945 by Harald T. Friis at Bell Labs.

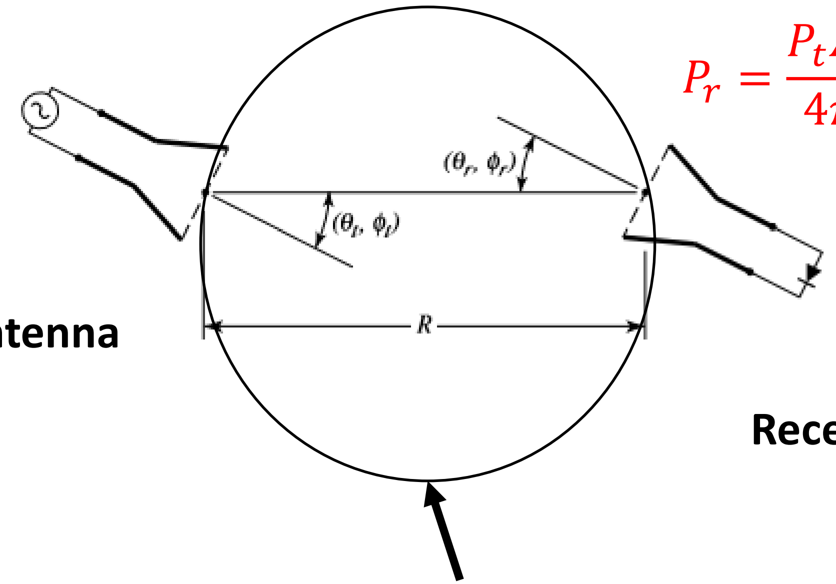
2. **Friis Equation is used in antenna engineering** to estimate the power received by one antenna from another under idealized conditions.

BASIS OF FRIIS EQUATION

The **Friis Transmission Equation** relates the power received to the power transmitted between two antennas separated by a distance,

R > $\frac{2D^2}{\lambda}$, where D is the largest dimension of either antenna

$$P_r = \frac{P_t A_e G_t}{4\pi R^2}$$



Transmitting antenna

P_t, G_t

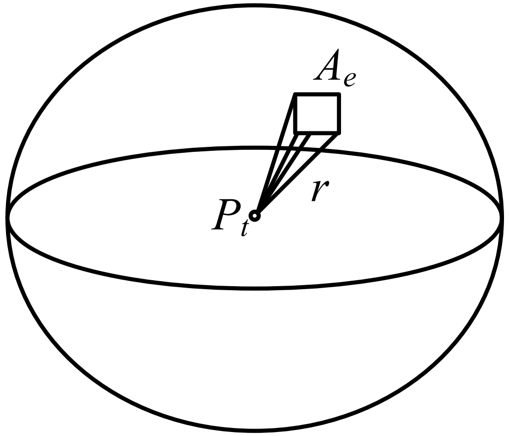
Receiver antenna

P_r, G_r

Cylindrical surface

FRIIS EQUATION

$$P_r = \frac{P_t A_e G_t}{4\pi R^2}$$



Where

A_e is the effective aperture of the receiving antenna

G_t is the gain of the lossless antenna

The gain of the receiver antenna, Gr is related to Ae and λ as follows:

$$G_r = \frac{4\pi A_e}{\lambda^2} \text{ or } A_e = \frac{G_r \lambda^2}{4\pi}$$

Substituting above, we get

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$$

FRISS EQUATION

Where P_t, P_r, G_t, G_r are measured in decibels, the Friis equation can be written as follows.

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$$

Or in decibels as

$$P_r = P_t + G_t + G_r + 20log_{10}\left(\frac{\lambda}{4\pi R}\right)$$

WORKED EXAMPLE

- A rocket is installed with a $\lambda/2$ dipole antenna. An identical antenna is used on the ground to communicate with it. After launch it is found that communication is lost after the rocket is at a certain distance from the ground. To regain communication, the ground-based transmitter is switched to an antenna with 80 dB gain. If the transmitter continues to transmit the same amount of power and assuming both antennas are ideal, what is the new distance at which communication will be lost again?

SOLUTION

Let R_1 be the distance at which the first loss of communication occurs.

Let R_2 be the distance at which the 2^{nd} loss of information will occur.

The gain of the $\lambda/2$ dipole is $G_t = G_r = 1.642$

From the Friis equation,

$$\frac{P_{r1}}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R_1}\right)^2 \quad G_t = G_r = 1.642$$

After increasing the gain, we get

$$\frac{P_{r2}}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R_2}\right)^2 \quad \text{where } G_t = 10^8 \text{ and } G_r = 1.642$$

The second loss in communication will occur when $P_{r2} = P_{r1}$

Solving, we get:

$$R_2 = 7804 R_1$$