

# FRIIS TRANSMISSION EQUATION

**ANTENNA & RADIO WAVE PROPAGATION**

**Friday, 10 April 2026**

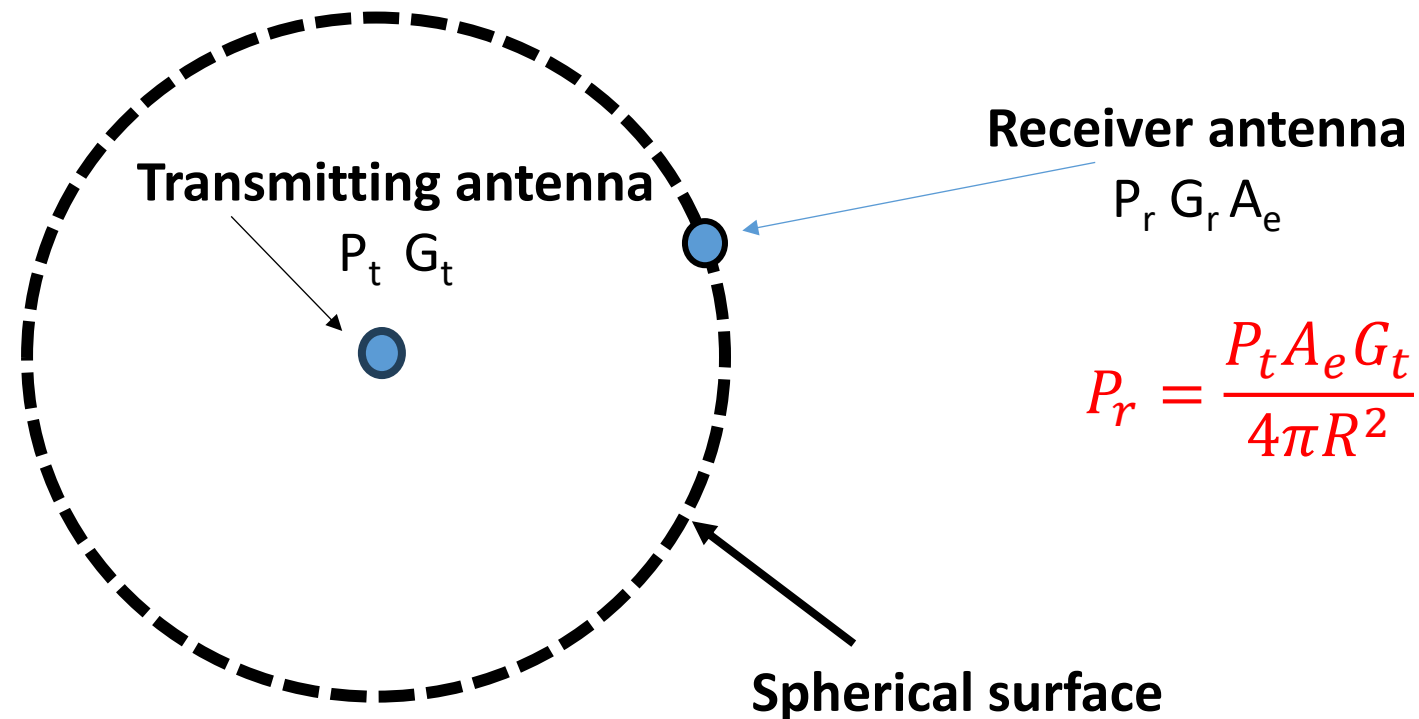
# ORIGIN AND USE OF FRIIS EQUATION

1. The Friis transmission equation was first derived in 1945 by Harald T. Friis at Bell Labs.
2. It is used in antenna engineering to calculate 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



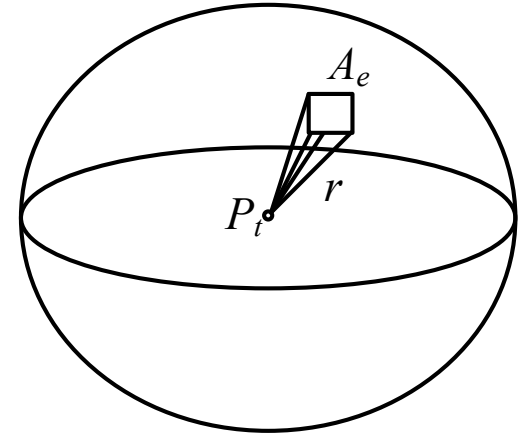
# FRIIS EQUATION

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

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,  $G_r$  is related to  $A_e$  and  $\lambda$  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

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

Or in decibels as

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

## 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 dipoles, 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<sup>nd</sup> loss of information will occur.

The gain of the ideal dipole is  $G_t = G_r = 1.642$

From the Friis equation,

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

After increasing the gain, we get

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

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

Solving, we get:

$$R_2 = 7804R_1$$