ECE 215 Spring 2025

Objective 3.5: Comms Distance using the Friis and LOS Equations

Objective 3.5

I can calculate the maximum communication distance between a transmitter and receiver using the Friis and Line-of-Sight equations.

Friis Equation

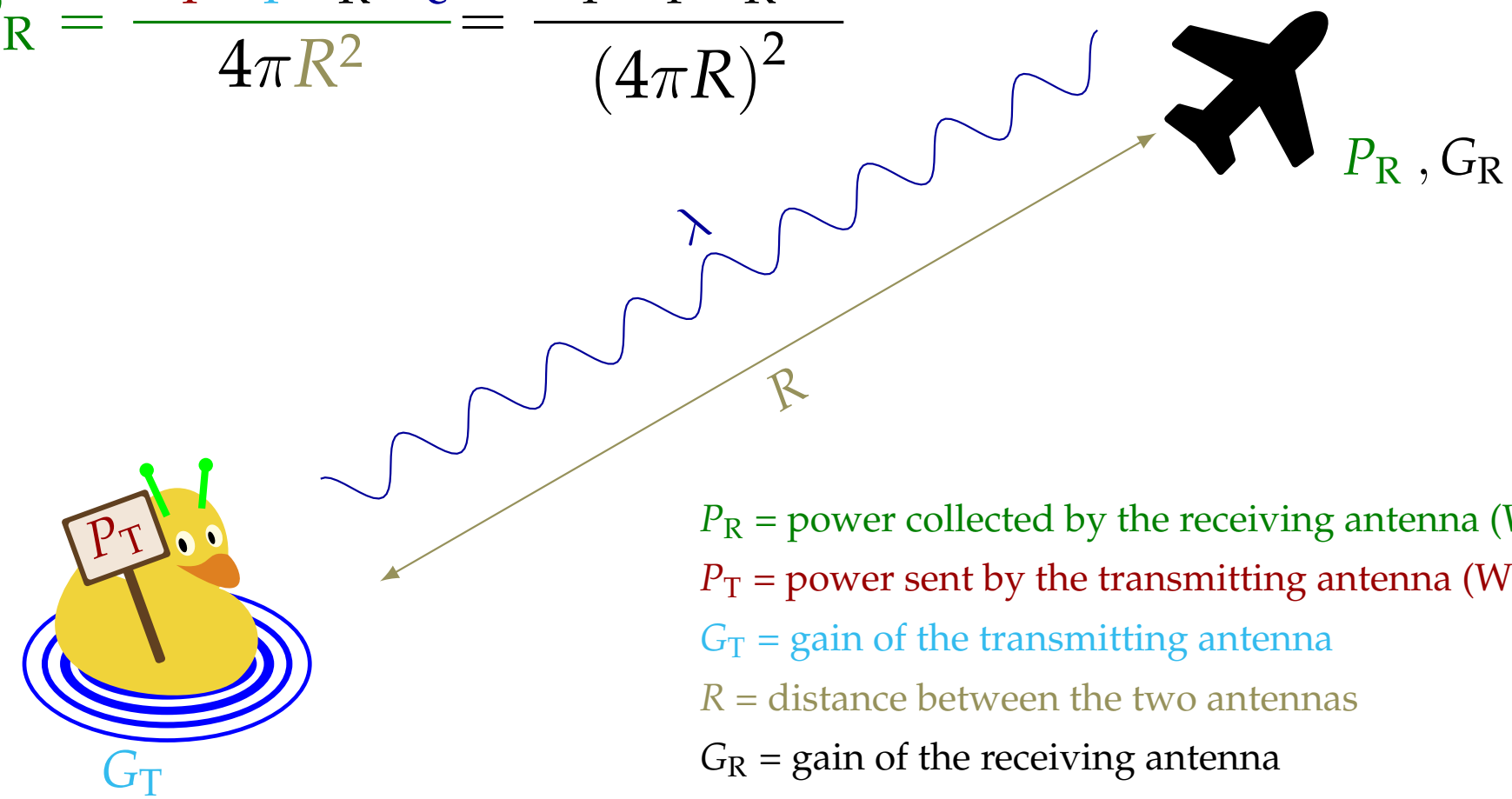
There's more to communications than LOS!

Other limiting factors are captured by *the Friis Equation*:

- Power Transmitted
- Gain of transmit antenna
- Gain of receive antenna
- Wavelength of signal
- Distance of communication

Friis Equation

$$P_R = \frac{P_T G_T G_R A_e}{4\pi R^2} = \frac{P_T G_T G_R \lambda^2}{(4\pi R)^2}$$



P_R = power collected by the receiving antenna (W)

P_T = power sent by the transmitting antenna (W)

G_T = gain of the transmitting antenna

R = distance between the two antennas

G_R = gain of the receiving antenna

A_e = effective receiving aperture = $\frac{\lambda^2}{4\pi}$

λ = wavelength of the signal (m)

Friis Equation - Implications

$$P_R = P_T G_T G_R \frac{\lambda^2}{(4\pi R)^2}$$

- Double power transmitted = double power received
- Double receiver or transmitter gain = double power received
- Double wavelength (lower frequency) = 4x power received
- Lower frequencies travel farther than higher ones
- Double distance between antennas = reduce the power received by 4

Radio Comm Problem Steps

- Read the problem, determine what you're looking for
- Determine if transmitter and receiver have LOS
- Determine if TX and RX radios have enough power to talk
  - Calculate received power
    OR
  - Calculate max distance

Bottom Line

Receive radio **must** have **both** LOS and enough power to communicate!

Friis Problem 1

A CIA operative with SOF support is trying to upload data to a Cessna flying at 1000 feet AGL in the People's Republic of Pineland. He's using a radio with a parabolic dish to upload the data. The antenna is 1 meter in diameter, has an efficiency of 80%, and transmits 120 W at 3.7 GHz. The Cessna has a small parabolic dish that is 500mm in diameter with an efficiency of 75%. Assuming the Cessna is 80 km away and needs a signal of at least 200 nW, does the CIA operative have a valid comm channel? If so, what's the power received at the Cessna? Assume the CIA terminal is at 0 feet AGL.

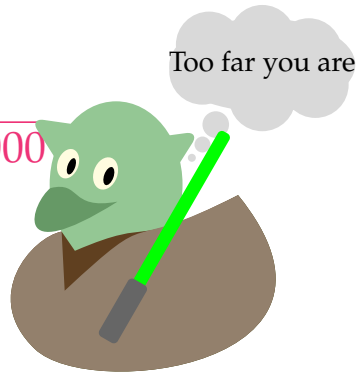
$$P_T = 120W \qquad P_{r,min} = 200\,nW$$
$$G_T = 1201.2\ (L32) \qquad G_R = 281.49\ (L32)$$
$$R = 80\,km \qquad f = 3.7\,GHz$$
$$h_{cessna} = 1000\ feet \qquad h_{CIA} = 0\ feet$$

Friis Problem 1

- Read the problem, determine what you're looking for → Can the CIA and Cessna talk?
- Determine if transmitter and receiver have LOS

$$r_{\max} = \sqrt{2h_{\text{CIA}}} + \sqrt{2h_{\text{cessna}}} = \sqrt{2 * 0} + \sqrt{2 * 1000}$$

$$= 44.72\text{miles} * \left(\frac{1.61\text{km}}{\text{mile}}\right) = 72\text{km}$$



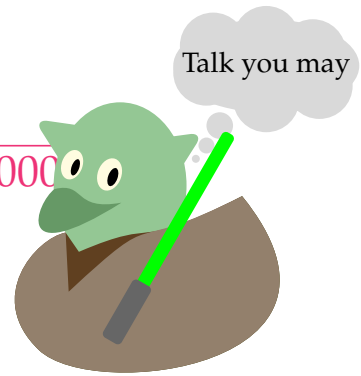
- Determine if tx and rx radios have enough power to talk

Friis Problem 1

- Read the problem, determine what you're looking for → Can the CIA operative climb something and *then* talk with the Cessna?
- Determine if transmitter and receiver have LOS

$$r_{\max} = \sqrt{2h_{\text{CIA}}} + \sqrt{2h_{\text{cessna}}} = \sqrt{2 * 30} + \sqrt{2 * 1000}$$

$$= 52.5\text{miles} * \left(\frac{1.61\text{km}}{\text{mile}}\right) = 84.5\text{km}$$



- Determine if tx and rx radios have enough power to talk
  - Calculate wavelength $\lambda = \frac{3\times10^8\text{m/s}}{3.7\times10^9\text{Hz}} = 81.08\text{mm}$
  - Calculate transmitter gain $G_{\text{T}} = \frac{(2\pi r)^2}{\lambda^2} * \eta = \frac{(2\pi * 0.5\text{m})^2}{(0.08108\text{m})^2} * 0.8 = 1201.2$
  - Calculate receiver gain $G_{\text{R}} = \frac{(2\pi r)^2}{\lambda^2} * \eta = \frac{(2\pi * 0.25\text{m})^2}{(0.08108\text{m})^2} * 0.75 = 281.49$
  - $P_{\text{R}} = (120\text{W})\,(1201)\,(281.5)\left(\frac{0.08108}{4\pi * 80\text{km}}\right)^2 = 269.9\text{nW}$

Friis Problem 2

A control station uses a $\frac{\lambda}{4}$ monopole antenna (gain of 3.28) on top of a 15 foot tower to control a UAS, which is orbiting at 3000 feet AGL. The station broadcasts an 800W control signal at 300MHz. The receiving antenna on the UAS has a gain of 4.77dB. If the aircraft needs 3.3 nW of power to process the signal, what is the maximum distance the aircraft can be from the ground station and still remain under positive control?