7 Propagation

We now know everything required to relate the power available at the transmitter to the power delivered to the receiver!

First we'll consider the case where the channel is (approximately) **free-space**, but then we will consider more realistic (and difficult) scenarios.

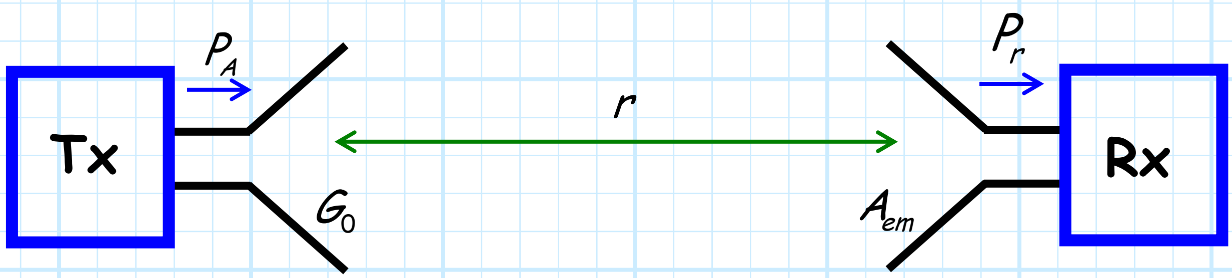
A. The Friis Transmission Equation

When the channel between the transmit and receive antenna is **free-space**, we can directly use our knowledge of transmit and receive antennas to determine the received power.

HO: The Friis Transmission Equation

The Friis Transmission Equation

Consider the following problem:



In other words, we find that:

* A transmitter delivers energy to the transmit antenna at a rate of P_A Watts.

* This **transmit** antenna has gain G_0.

* A receive antenna is located a **distance** r from the transmitter.

* The effective aperture of the **receive** antenna is A_{em}.

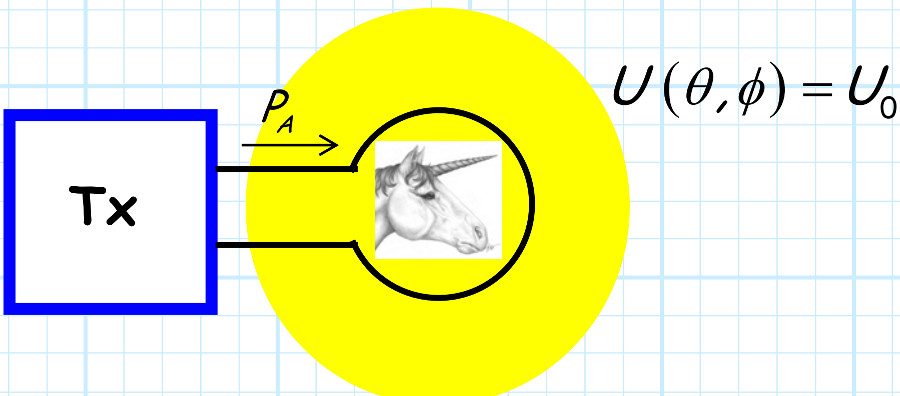
* The transmit antenna is **pointed** at the receiver (i.e. its mainlobe is directed at the receiver), and the receive antenna is **pointed** at the transmitter (i.e. its mainlobe is directed at the transmitter).

Q: *At what **rate** P_r is **energy** being delivered to the receiver?*

A: You now know every thing necessary to answer this question!!

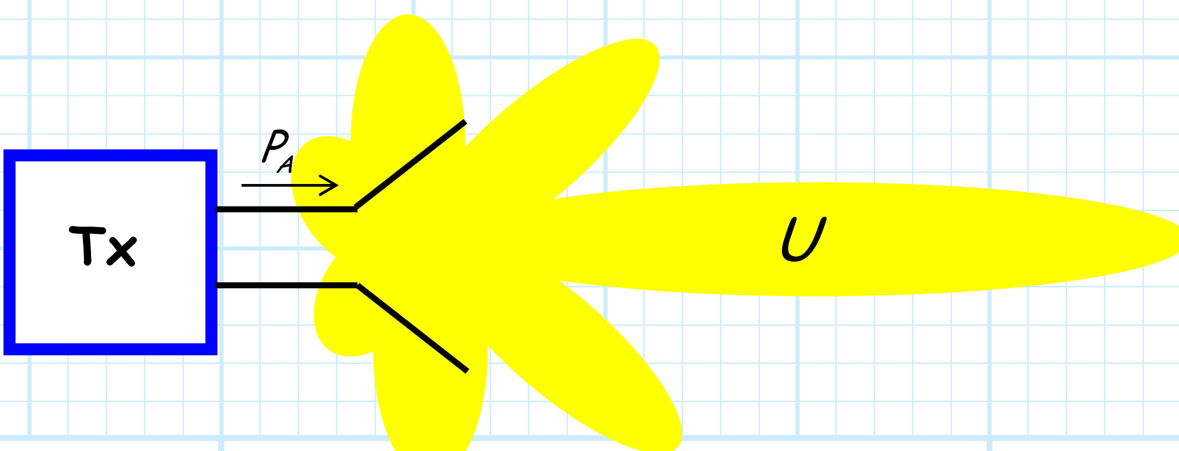
1. An **isotropic** antenna would radiate a uniform intensity U_0:

$$U_0 = \frac{P_A}{4\pi} \qquad \textit{Watts/steradian}$$



2. But, the **transmit** antenna has a gain G_0, so the intensity produced by the transmit antenna in the direction of the receive antenna is:

$$U = U_0 G_0 = \frac{P_A\, G_0}{4\pi} \qquad \textit{Watts/steradian}$$

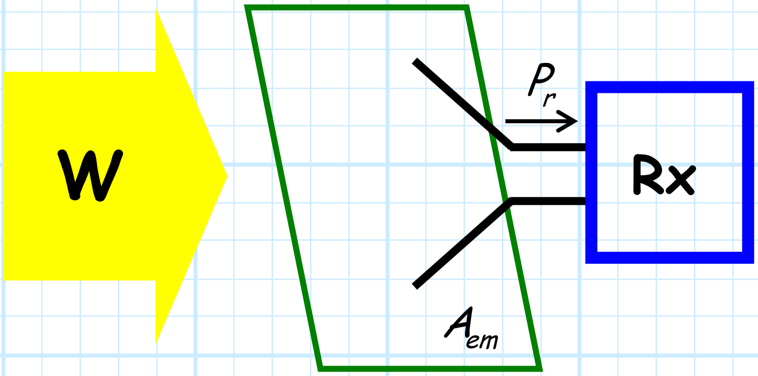


3. Thus, the power density of the e.m. wave incident on the **receive** antenna—at a distance r from the transmitter—is detemined to be:

$$\mathbf{W} = U\frac{\hat{\mathbf{r}}}{r^2} = U_0 G_0 \frac{\hat{\mathbf{r}}}{r^2} = \frac{P_A\, G_0}{4\pi r^2}\hat{\mathbf{r}} \qquad Watts/m^2$$

4. The **receive** antenna is therefore collects energy at a rate proportional to its effective aperture:

$$P_r = |\mathbf{W}|\, A_{em} = \frac{U}{r^2}A_{em} = \frac{U_0 G_0}{r^2}A_{em} = \frac{P_A\, G_0\, A_{em}}{4\pi r^2} \qquad Watts$$



The power P_r is then **delivered to the receiver**—it is the power of our receiver **input** signal (i.e., $P_r = P_{in}$)!

This result provides us with the **Friis Transmission Equation**:

$$P_r = P_A \frac{G_0\, A_{em}}{4\pi r^2}$$