Friis Transmission Equation

The Friis transmission equation is a fundamental principle in telecommunications and antenna theory used to calculate the power received by an antenna from another antenna that is transmitting a signal over a clear line-of-sight path. This equation is essential for designing and understanding wireless communication systems in free-space environments.

Equation

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

Where:

- **Pr**: Power received by the receiving antenna (in watts).
- **P_t**: Power transmitted by the transmitting antenna (in watts).
- **G_t**: Gain of the transmitting antenna (dimensionless or in dB).
- **G_r**: Gain of the receiving antenna (dimensionless or in dB).
- **λ**: Wavelength of the signal (in meters) [c/f]
- **d:** Distance between the transmitting and receiving antennas (in meters).

Key Concepts

- **Line-of-Sight Propagation**: Assumes a direct, unobstructed path between the antennas.
- **Antenna Gain**: Indicates how well an antenna directs or receives energy compared to an isotropic antenna (which radiates equally in all directions).
- **Wavelength and Frequency**: Inversely related; higher frequencies correspond to shorter wavelengths.
- **Free-Space Environment**: Assumes no obstacles, reflections, or interference.

Applications

- **Radio and Satellite Communications**: Estimating signal strength at various distances and designing link budgets.
- **Wireless Networking**: Designing and optimizing the placement of Wi-Fi access points.
- **Radar Systems**: Calculating the range and signal strength of radar waves.

Limitations

- **Ideal Conditions**: The equation assumes ideal free-space conditions, which may not hold true in real-world environments with obstacles and interference.

This repository includes examples and implementations to help understand and apply the Friis transmission equation in practical scenarios.