Satellite Link Design

Basic Transmission Theory

Link Budget parameters

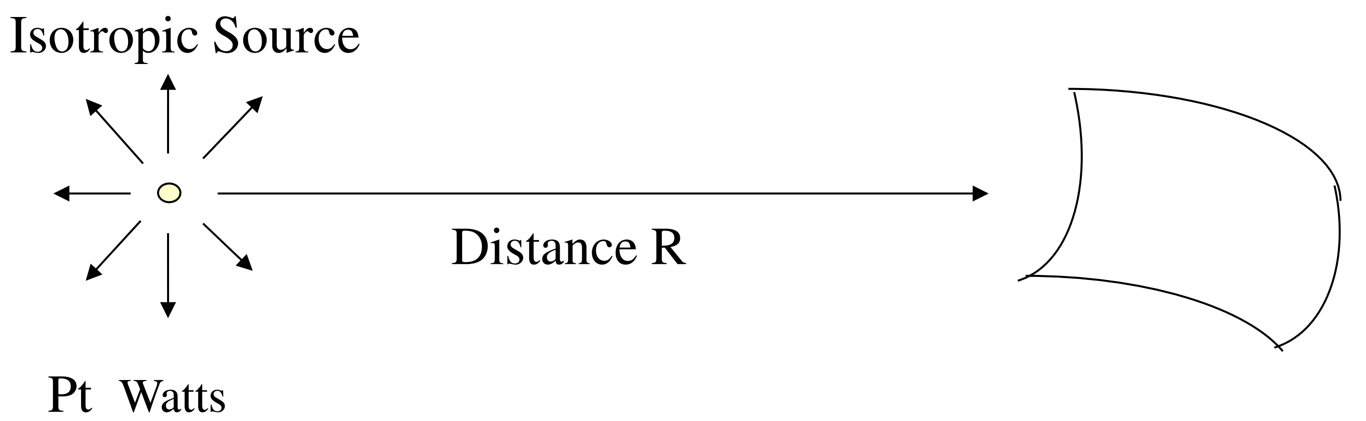
- Transmitter power at the antenna
- Antenna gain compared to isotropic radiator
- EIRP
- Flux density at receiver
- Free space path loss
- System noise temperature
- Figure of merit for receiving system
- Carrier to thermal noise ratio
- Carrier to noise density ratio
- Carrier to noise ratio

Isotropic Radiator

- Consider an Isotropic Source (punctual radiator) radiating Pt Watts uniformly into free space.
- At distance R, the area of the spherical shell with center at the source is $4pR^2$
- Flux density at distance R is given by Eq. 4.1

$$F = \frac{P_t}{4\pi R^2} \quad \text{W/m}^2$$

Isotropic Radiator 2



Surface Area of sphere = $4\pi R^2$ encloses Pt.

Power Flux Density:

$$F = \frac{P_t}{4\pi R^2} \quad \text{W/m}^2$$

Antenna Gain

- We need directive antennas to get power to go in wanted direction.
- Define Gain of antenna as increase in power in a given direction compared to isotropic antenna.

$$G(\theta) = \frac{P(\theta)}{P_0 / 4\pi} \quad \text{(Eqn 4.2)}$$

- $P(\theta)$ is variation of power with angle.
- $G(\theta)$ is gain at the direction θ.
- P_0 is total power transmitted.
- sphere = 4π solid radians

Antenna Gain 2

- Antenna has gain in every direction! Term gain may be confusing sometimes.
- Usually "Gain" denotes the <u>maximum</u> gain of the antenna.
- The direction of maximum gain is called "boresight".

Antenna Gain 3

- Gain is a ratio:
- It is usually expressed in ***Decibels*** (dB)

  G [dB] = 10 $\log_{10}$ (G ratio)

The world's most misused unit ??
(we will see more on dBs later)

EIRP - 1

- An isotropic radiator is an antenna which radiates in all directions equally
- Antenna gain is relative to this standard
- Antennas are fundamentally passive
  - No additional power is generated
  - Gain is realized by focusing power
  - Similar to the difference between a lantern and a flashlight
- Effective Isotropic Radiated Power (EIRP) is the amount of power the transmitter would have to produce if it was radiating to all directions equally
- Note that EIRP may vary as a function of direction because of changes in the antenna gain vs. angle

EIRP - 2

- The output power of a transmitter HPA is:

P_{out} watts

- Some power is lost before the antenna:

$P_t = P_{out} / L_t$ watts reaches the antenna

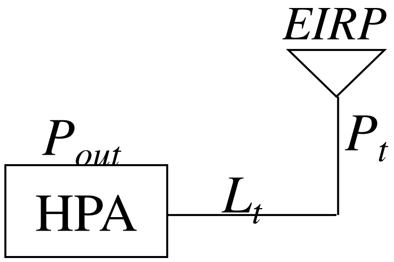
P_t = Power into antenna

- The antenna has a gain of:

G_t relative to an isotropic radiator

- This gives an effective isotropic radiated power of:

$EIRP = P_t G_t$ watts relative to a 1 watt isotropic radiator



Power Flux Density - 1

- We now want to find the power density at the receiver
- We know that power is conserved in a lossless medium
- The power radiated from a transmitter must pass through a spherical shell on the surface of which is the receiver
- The area of this spherical shell is $4pR^2$
- Therefore spherical spreading loss is $1/4pR^2$

Power Flux Density - 2

- Power flux density (p.f.d.) is a measure of the power per unit area
- This is a regulated parameter of the system
  - CCIR regulations limit the p.f.d. of any satellite system
  - CCIR regulations are enforced by signatory nations
  - Allowable p.f.d. varies w.r.t. elevation angle
  - Allows control of interference
  - Increasing importance with proliferation of LEO systems

Received Power

- We can rewrite the power flux density now considering the transmit antenna gain:

$$F = \frac{EIRP}{4\pi R^2} = \frac{P_t G_t}{4\pi R^2} \ \text{W/m}^2$$

- The power available to a receive antenna of area A_r m^2 we get:

$$P_r = F \text{ x } A_r = \frac{P_t G_t A_r}{4\pi R^2}$$

Effective Aperture

- Real antennas have effective flux collecting areas which are LESS than the physical aperture area.
- Define Effective Aperture Area Ae:

$$A_e = A_{phy} \text{ x } \eta$$

Where A_{phy} is actual (physical) aperture area.

η = aperture efficiency

- Very good: 75%
- Typical: 55%

System Noise Power - 2

- System noise is caused by thermal noise sources
  - External to RX system
    - Transmitted noise on link
    - Scene noise observed by antenna
  - Internal to RX system
- The power available from thermal noise is:

$$N = kT_sB \text{ (dBW)}$$

where k = Boltzmann's constant
= 1.38×10^{-23} J/K(-228.6 dBW/HzK),
T_s is the effective system noise temperature, and
B is the effective system bandwidth