Summary of Link Power Design (Chapter 4)
EE418: Satellite Communications
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- For an isotropic source, the flux density is $F = \frac{P_t}{4\pi R^2}$ W/m^2.
- **Antenna gain** is the increase in power in a given direction compared to isotropic antenna $G(\theta) = \frac{P(\theta)}{P_0 / 4\pi}$.
- **Effective isotropic radiated power**, $EIRP = P_t G_t$ watts
- The power available to a receive antenna of area A_r m^2 is , $P_r = F \text{ x } A_r = \frac{P_t G_t A_r}{4\pi R^2}$
- **Effective Aperture Area** A_e, , $A_e = A_{phy} \text{ x } \eta$
- Antennas have (maximum) gain ,G, related to the effective aperture area as $\boxed{Gain = \frac{4\pi A_e}{\lambda^2}}$.
- For a circular aperture, $A_{phy} = \pi r^2 = \pi \frac{D^2}{4}$. => $Gain = \left(\frac{\pi D}{\lambda}\right)^2 \times \eta$
- A rule of thumb to calculate a reflector **antenna beamwidth** in a given plane as a function of the antenna dimension in that plane is given by: $\boxed{\theta_{3dB} \cong \frac{75\lambda}{D}}$
- Assuming for instance a typical aperture efficiency of 0.55 gives: $Gain \cong \frac{30,000}{(\theta_{3dB})^2} = \frac{30,000}{\theta_{3dBH}\theta_{3dBE}}$
- So the received power is $P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$
- Free Space Loss or **Path Loss** $= L_p = \left(\frac{4\pi R}{\lambda}\right)^2$ ➔ $P_r = \frac{P_t G_t G_r}{L_p}$
- Other effects need to be accounted for in the transmission equation:
  - L_a = Losses due to attenuation in atmosphere
  - L_{ta} = Losses associated with transmitting antenna
  - L_{ra} = Losses associates with receiving antenna
  - L_{pol} = Losses due to polarization mismatch
  - L_{other} = (any other known loss - as much detail as available)
  - Lr = additional Losses at receiver (after receiving antenna)

$$\boxed{P_r = \frac{P_t G_t G_r}{L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r}}$$

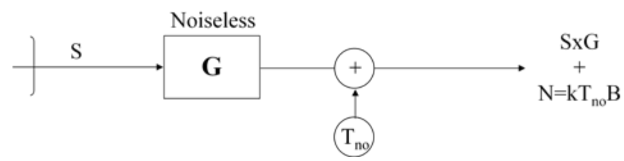
- If P_t = Power into antenna, and L_t = Loss between power source and antenna, then $P_t = P_{out} / L_t$.
- The transmission formula can be written in dB as:
  - $\boxed{P_r = EIRP - L_{ta} - L_p - L_a - L_{pol} - L_{ra} - L_{other} + G_r - L_r}$
- C/N: carrier/noise power
- C/N$_o$: carrier/noise p.s.d.
- **Noise Temperature** $\boxed{T[K] = T[^oC] + 273}$ $\boxed{T[K] = (T[^oF] - 32)\frac{5}{9} + 273}$
- The power available from thermal noise $\boxed{N = kT_s B \text{ (dBW)}}$,

where k = Boltzmann's constant = 1.38x10^{-23} J/K(-228.6 dBW/HzK),

- $N_0 = \frac{N}{B} = \frac{kT_s B}{B} = kT_s$ (dBW/Hz)
- Dealing with noise temperature is easy $\quad T_s = T_{transmitted} + T_{antenna} + T_{LNA} + T_{lineloss} + T_{RX}$
- But, we must:
  - Calculate the effective noise temperature of each contribution
  - Reference these noise temperatures to the same location

$$T_S = \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]$$

- $P_n = G_{IF} G_m G_{RF} kB \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]$
- **How can we make *N* as small as possible?**
- $T_S = \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right] \cong T_{RF} + T_{in}$



- **Modeling Lossy Elements**
  - All lossy elements reduce the amount of power transmitted through them:. They affect both:
    - Carrier or signal power
    - Noise power
  - The noise temperature contribution of a loss is: $T_{no} = T_p(1\text{-}G)$ in K $\qquad G = 1/\text{Loss}$
  - where G is the "gain" (smaller than unit) of the lossy element, also called transmissivity (P_{out} /P_{in}) and T_{no} is the physical temperature of the loss. Note the temperature is at the <u>output</u> of the loss.
- **Noise Figure** $\boxed{F_N = \frac{[S/N]_{in}}{[S/N]_{out}} = \frac{N_{out}}{kT_0 B_N G}}$
- **Noise Temperature**: $\boxed{T_d = T_0(F_n - 1)}$
- ***G/T Ratio of Earth Stations:***

  System Figure of Merit $\frac{C}{N} = \left(\frac{P_t G_t G_r}{kT_s B_n}\right)\left(\frac{\lambda}{4\pi R}\right)^2 = \left(\frac{P_t G_t}{kB_n}\right)\left(\frac{\lambda}{4\pi R}\right)^2 \left(\frac{G_r}{T_s}\right)$
- If the C/N ratios for each of the linear bent pipe transponder links are available:

$$\left(\frac{C}{N}\right)_{total} = \left[\left(\frac{C}{N}\right)_1^{-1} + \left(\frac{C}{N}\right)_2^{-1} + \ldots + \left(\frac{C}{N}\right)_n^{-1}\right]^{-1}$$

so long as the noise is uncorrelated between the links

- For baseband processing links: $\quad BER_{total} = BER_1 + BER_2 + \ldots + BER_n$

$$G = \left(\frac{\pi D}{\lambda}\right)^2 \times \eta$$

$$P_r = \frac{P_t G_t G_r}{L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r}$$

$$\frac{C}{N} = \frac{P_r}{KT_s B}$$

$$L_p = \left(\frac{4\pi R}{\lambda}\right)^2 \qquad L_a \propto F$$

$$T_S = \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]$$