Appendix: noise

Riccardo Miccini[1] Eren Can [1]

[1]Technical University of Denmark
Digital Communication

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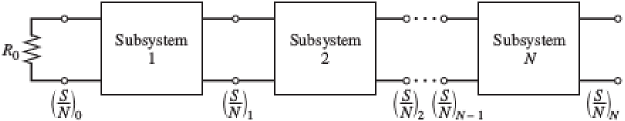
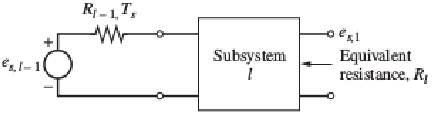
Characterization of noise in systems

- Noise can be modeled and characterized on a subsystem-basis
- Each subsystem can be analyzed separately and optimized for low noise performances



(a)



(b)

Noise Figure of a System

- Noise figure F_l: ratio between SNR at subsystem input and output: $\left(\frac{S}{N}\right)_l = \frac{1}{F_l}\left(\frac{S}{N}\right)_{l-1}$
- Ideally, $F_l = 1$ (no additional noise introduced), tipically between 2 and 8 dB
- Without having to calculate the signal power: $F_l = 1 + \frac{P_{int,l}}{G_a k T_0 B}$

  $P_{int,l}$ Available, internally-generated noise power
  G_a Available power gain
  k Boltzmann's constant
  T_0 Standardized temperature, $290K$
  B Frequency band
- For high gains, F_l approaches 1

Noise Temperature

- Power produced by a noisy resistor: $P_{a,R} = kTB$

  k Boltzmann's constant, $1.38 \times 10^{-23} J/K$
  T Temperature of the resistor, in Kelvin
  B Frequency band, in Hertz
  Noise power independent on the resistor value

- Equivalent noise temperature: $T_n = \frac{P_{n,max}}{kB}$

Free Space Propagation Example

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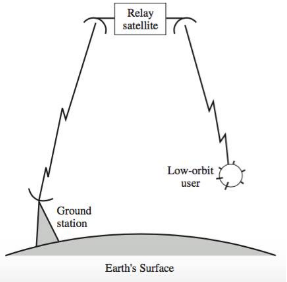

Investigating the Free-Space Propagation Example

- We made some assumptions in regard to the example.
  1. We have assumed that relay satellite transmitted signal power P_t
  2. It radiated isotropically
- Power density at a distance will be given by; $P_t = \frac{P_t}{4\pi d^2} W/m^2$
- If the satellite antenna has directivity, with the radiated power being directed toward low-orbit vehicle, antenna can be explained by the antenna power gain G_T over the isotropic radiation level.

Aperture-Type Antennas with Aperture Area A_t

- For aperture-type antennas with aperture area A_T large compared with the square of the transmitted wavelength λ^2.
- We can show that maximum gain will become:
  1. $G_T = \frac{4\pi A_T}{\lambda^2}$
  2. Also the power P_R intercepted by the receiving antenna is given by the product of the receiving aperture area A_R and the power density at the aperture. Thi will give us: $p_R = p_t A_R = \frac{P_T G_T}{4\pi d^2} A_R$
- If we also include other loses and use maximum gain G_R, it will yield into this formula: $P_R = (\frac{\lambda}{4\pi d})^2 \frac{P_T G_T G_R}{L_0}$
- The factor $(\frac{4\pi d}{\lambda})^2$ is referred as the "free-space loss"

Receiver Power

- It is easier to work with decibels when we calculate the receiver power.
- If we take the $10\log_{10} P_R$, than we obtain :
  $10\log_{10} P_R = 20\log_{10}(\frac{\lambda}{4\pi d}) + 10\log_{10} P_T + 10\log_{10} G_T + 10\log_{10} G_R - 10\log_{10} L_0$
- $10\log_{10} P_R$ can be interpreted as receiver power in decibels referenced to 1 W
- Also $10\log_{10} P_T$ is referred as the transmitted signal in dbW