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MSEE 336

Homework Assignment #2

Due Friday, September 20, 2024

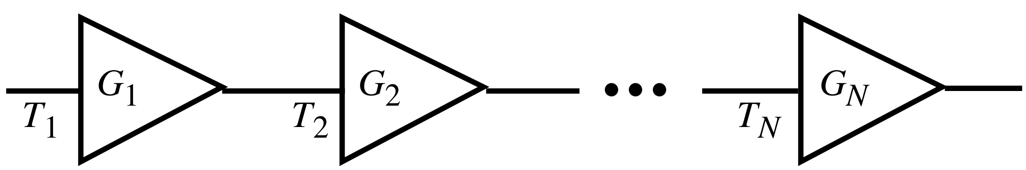
Reading Assignment: Chapter 3 of Draft text by Bell and Chang.

1. (Modified from Levanon Problem 2.1) Two metal spheres of radius a and $2a$ are placed an distance d much larger than a wavelength apart and act as a single target illuminated by a radar operating at wavelength $\lambda \ll a$. Find the minimum and maximum radar cross sections that can occur in this situation. Find the ratio $\sigma_{MAX}/\sigma_{MIN}$. (Ignore the effect of shadowing of one target by the other, and assume $a \gg \lambda$.)

2. (Levanon Problem 2.4) What will be the angular spacing between the incident and reflected rays if the corner of a dihedral reflector has an angle of $\pi/2 + \beta$?

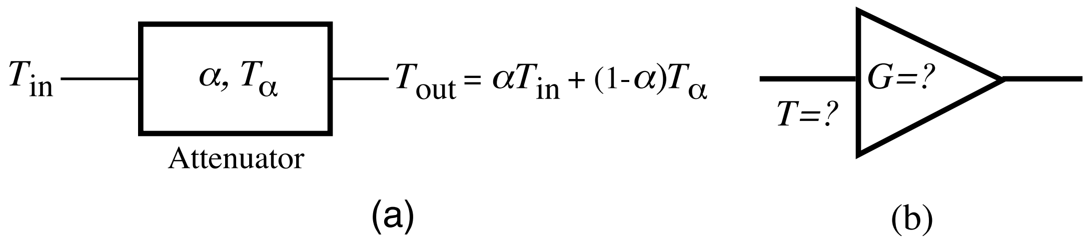
3. (Levanon 2.5) What is the angle of symmetry of a trihedral corner reflector? (This is of interest, because this is the angle at which the return from the trihedral corner reflector is maximized.)

4. Consider the following chain of microwave amplifiers in cascade. For each amplifier, the associated noise temperature is the equivalent noise temperature at its input. Find the equivalent system noise temperature for this cascade of amplifiers (that is, the source noise temperature required to obtain the same noise power at the cascade output if the cascade has amplifiers of the same GB product, but the amplifiers are noiseless). Assume all amplifiers have constant gain as specified over the same bandwidth $B = 40\,\text{MHz}$ and zero-gain outside of this bandwidth. From your answer, explain why such an emphasis is put on making the first amplifier stage a low-noise high-gain amplifier in many microwave systems.



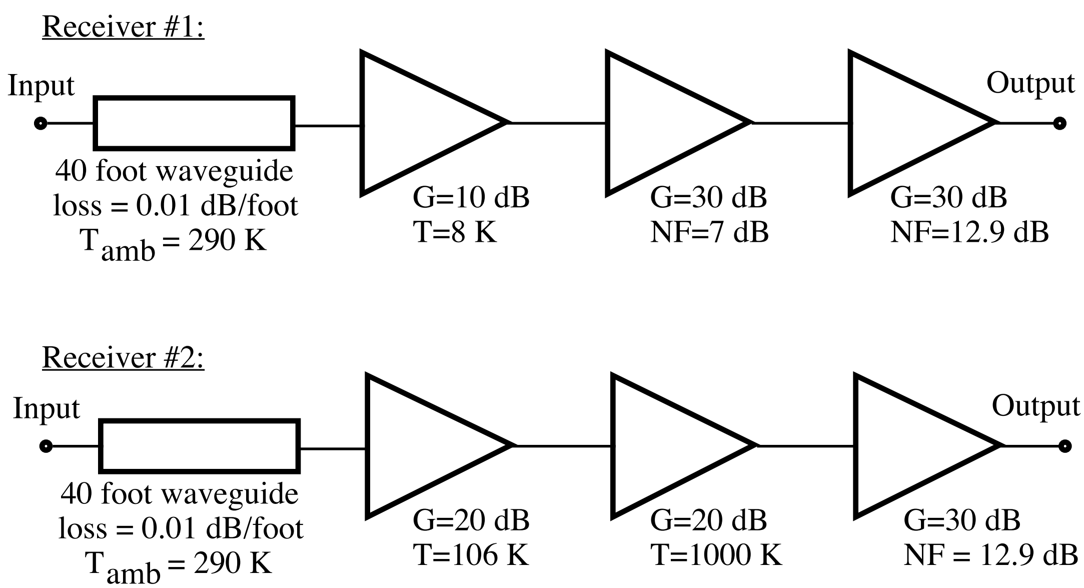
Problem 4: A Cascade of Amplifiers.

5. An attenuator with power "gain" α attenuates the power in a signal passing through it by a factor α. However, it will generally contribute thermal noise to the signal passing through it. An attenuator with attenuation α in thermal equilibrium with its environment at temperature T_α being fed by a source at noise temperature T_{in} will appear to the stage it feeds as a source with noise temperature $T_{\text{out}} = \alpha T_{\text{in}} + (1-\alpha)T_\alpha$, as shown in (a) of the figure below. We can view an attenuator as an amplifier with power gain less than one, as shown in (b). What is the gain and equivalent noise temperature of this amplifier?



Problem 5: (a) Attenuator at ambient temperature T_α, and (b) equivalent amplifier.

6. In the figure below, determine which receiver is better, and calculate the output signal to noise ratio. Assume that in both cases, the input noise has power 4.5×10^{-14} W, the input signal-to-noise ratio is 16.5 dB, and the system bandwidth is 40 MHz.



Problem 6: Two Competing Receiver Systems.

7. A microwave satellite receiver has a noise figure of 3 dB and a power gain of 10 dB, followed by a FET amplifier with a noise figure of 6 dB and a gain of 20 dB. What is the receiver temperature? What is the overall noise figure in dB? How does this depend on the gain of the FET stage?
8. The receiver in Problem 7 is attached to a parabolic reflector with a 1 m radius and perfect aperture efficiency. A transmitter on the ground with power P_T is attached to an identical antenna, and the antennas are pointing at each other. The transmitter frequency is 3 GHz. The distance between the antennas is 42180 km (altitude for geosynchronous orbit), and the earth, which completely fills the satellite antenna beam, appears as a source of temperature 300 K. Ignoring atmospheric attenuation (i.e., assuming free-space communication between antennas), what is the required transmitter power P_T if the satellite is to receive a signal with a 1 MHz bandwidth with a signal to noise ratio of 3 dB?
9. A radar target consists of a swarm of 5000 bees completely within the radar beam. Assume the geometric dimensions of the swarm are much larger than awavelength. Find a good model for the radar cross section of this "target".