Exercise Sheet 5 : Noise in Communication Systems

Exercise 1

A resistor $R = 10\,k\Omega$ is placed in an environment at a temperature $T = 20°\text{C}$.

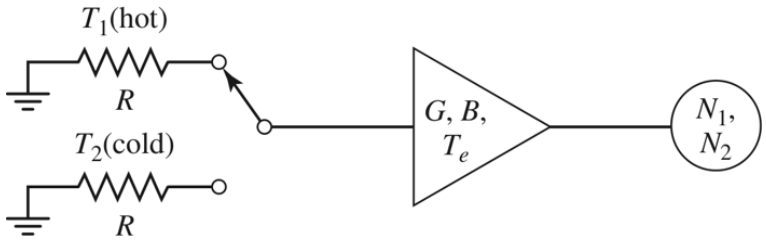
1. Calculate the thermal noise voltage produced by this resistor in a bandwidth $B = 100\,\text{kHz}$.

The resistor is connected to the input of a two port circuit with the following characteristics: Gain $G = 20\,\text{dB}$, Bandwidth B, Input resistance R and assumed noiseless.

2. Calculate the noise power at the output of the a two port circuit in dBm.
3. What is the nature of the noise at the a two port circuit output? Sketch its frequency spectrum.
4. In reality, this circuit is noisy, and the measured noise power at its output is $-130.8\,\text{dB}$. Calculate its equivalent noise temperature and noise factor in dB.

Exercise 2

We want to measure the equivalent temperature T_e of a quadripole with gain G. The following method is used:



(A) Hot Measurement: A matched resistor R at a temperature T_1 is connected to the input of the quadripole. The noise power N_1 is measured at the output.

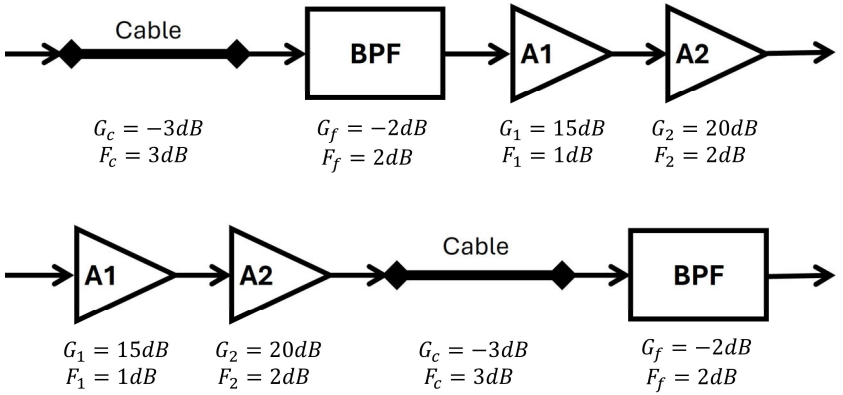
(B) Cold Measurement: R is replaced with an identical resistor at a lower temperature T_2. The noise power N_2 is measured at the output.

1. Express T_e as a function of N_1, N_2, T_1, and T_2.
2. An X-band amplifier has a gain of 20 dB and a 1 GHz bandwidth. Using the described method, the measured noise powers are:
   - $N_1 = -62\,\text{dBm}$ at $T_1 = 290\,\text{K}$,
   - $N_2 = -64.7\,\text{dBm}$ at $T_2 = 77\,\text{K}$.

   Calculate the equivalent noise temperature and noise factor (in dB) of this amplifier.
3. If the amplifier is used with a source having an equivalent noise temperature of $T = 450\,\text{K}$, what is the output noise power from the amplifier, in dBm?

Exercise 3

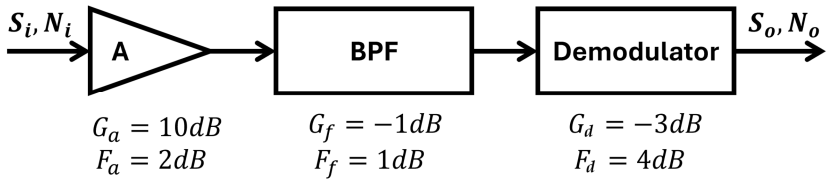
Consider the following two systems:



1. Calculate the gain and noise factor for each system.
2. Compare the results.

Exercise 4

The following system consists of an amplifier, a band-pass filter, and a demodulator. The system operates at a temperature $T = 290\,\text{K}$ with a bandwidth of 10 MHz. The input impedance is $50\,\Omega$.



1. Calculate the noise factor of the system.
2. The input of this system receives a noise signal from an antenna with an equivalent noise temperature $T_A = 150\,\text{K}$. Find the noise power at the output.
3. If a minimum SNR of 20 dB is required at the output, calculate the minimum signal voltage that must be applied at the input.

Exercise 5

Consider a communication link operating with the following parameters:

- The transmitted signal has an average power of $S = 10\,\text{mW}$.
- The noise power spectral density of $10^{-20}\,\text{W/Hz}$.
- The system has a bandwidth of $B = 1\,\text{MHz}$.

1. Compute the total noise power N in the system's bandwidth.
2. Calculate the Signal-to-Noise Ratio (SNR) at the receiver, both in linear scale and in decibels (dB).
3. If the system's bandwidth is doubled while keeping the transmitted signal power constant, what is the new SNR? Explain how bandwidth affects the SNR.
4. Suppose the communication link requires an SNR of at least 20 dB for reliable transmission. Determine the minimum signal power S_{min} required to achieve this SNR with the original bandwidth.