Werkcollege 2: huiswerkopgaven

Hieronder volgen de huiswerkopgaven voor het 2e werkcollege Telecommunicatietechniek. Bij het werkcollege wordt verwacht dat je de stof tot dan toe goed hebt bestudeerd en deze opgaven vooraf thuis hebt voorbereid.

Tijdens het werkcollege is er nog enige tijd om aan de lastige onderdelen, waar je thuis niet uit bent gekomen, met collega-studenten verder te werken. Daarna worden een aantal opgaven op het bord voorgemaakt.

Question 1.

An amplifier with a gain of G = 20 dB has a noise figure F = 6 dB and an equivalent noise bandwidth of B_{eq} = 10 MHz. The input of this amplifier is connected via a resistor of R = 100Ω to ground (where R is equal to the input resistance of the amplifier). Resistor and amplifier are at a temperature of T = 290K.

a. Calculate the effective input noise temperature of the amplifier.

b. Determine the total input noise temperature of the amplifier when connected to the input resistor R and the resulting input noise power spectral density in dBm/Hz.

c. Determine the total available noise power at the output of the amplifier for the situation under b.

Question 2.

The owner of a small satellite receiver likes to watch the DISCOVERY program that is transmitted at a frequency f_c = 11.0 GHz via the geo-stationary satellite ASTRA. The transmission power of the satellite is P_{tx} = +23 dBW and the distance to the receive station is 40.000 km. The gain of the transmit antenna of the satellite is $G_{sa} = 40\ \text{dB}$.

The receive station consists of a parabolic antenna followed by a combined low-noise amplifier/frequency converter, which amplifies the signal and converts it to a frequency of 750 MHz. This amplifier/frequency converter is connected via a cable with the television set.

From the receiver station the following facts are given:

- the parabolic antenna has a diameter of 1.2 m, and efficiency factor η = 0.5 ($A_e = \eta A$),

- the antenna noise temperature is T_a = 150 K,
- the combined low-noise amplifier/frequency converter has a gain of G_{ac} = 6 dB and a noise figure F_{ac} = 2.5 dB,
- the cable has a length of 15 meter and attenuation of 0.8 dB/m,
- the television set has a gain G_{tv} = 65 dB, a noise figure F_{tv} = 13 dB and an equivalent noise bandwidth B_N = 5.5 MHz.

a) Give a detailed block diagram of this satellite system including all relevant parameters.

b) Calculate the available signal power P_{rx} (in dBm) at the input of the television set.

c) Calculate the equivalent system noise temperature T_{syst} at the output of the receive antenna.

d) Determine the signal-to-noise ratio (SNR) in dB at the output of the television set.

Question 3.

A TV-signal is transmitted over a distance of 5 km using either of the two following systems:
1. a radio-relay system,
2. a cable system.

1. The radio-relay system consists of the following components:
   - a transmitter with output power $P_{tx} = 23\ \mathrm{dBm}$ operating at a frequency $f_c = 5\ \mathrm{GHz}$,
   - transmitter and receiver use identical parabolic antennas with a diameter of 1m and efficiency $\eta = 0.5$,
   - at the receiver, the antenna noise temperature $T_a = 160\ \mathrm{K}$; the antenna is connected via a first cable with an attenuation of

$L_{c1} = 3\ \text{dB}$ to an amplifier with a gain of $G_{amp} = 25\ \text{dB}$ and a noise figure of $F_{amp} = 4\ \text{dB}$. This amplifier is followed by a second cable with attenuation $L_{c2} = 15\ \text{dB}$ to the receiver This receiver has a gain of $G_{rx} = 55\ \text{dB}$, a noise figure $F_{rx} = 12\ \text{dB}$ and equivalent noise bandwidth $B_{rx\_eq} = 5.5\ \text{MHz}$.

a. Draw a detailed diagram of the radio-relay transmission system.

b. Calculate the available received signal power P_{rx} [in dBm] at the output of the receive antenna in case free-space propagation is assumed.

c. Calculate the signal-to-noise ratio (SNR) in dB at the receiver output.

2. In the cable system, the transmitter has an output power of $P_{tx} = 23\ \text{dBm}$ and operates at a frequency $f_c = 5\ \text{GHz}$. The cable connection has a length of 5 km and the attenuation at 5 GHz is $L_{c3} = 15\ \text{dB/km}$. The cable is directly connected to the receiver, which has the same parameters as for the radio-relay system: gain $G_{rx} = 55\ \text{dB}$, noise figure $F_{rx} = 12\ \text{dB}$ and equivalent noise bandwidth $B_{rx\_eq} = 5.5\ \text{MHz}$.

d. Draw a detailed diagram of the cable transmission system.

e. Calculate the signal-to-noise ratio (SNR) in dB at the receiver output of the cable system.

Question 4.

A TV-radioamateur wants to receive a very weak signal transmitted at a frequency of 435 MHz by another amateur. He uses an antenna which is connected via a 30 m long coaxial cable to the tuner. The cable loss is:

- L_1 = 50 dB/100m for f > 400 MHz
- L_2 = 5 dB/100m for f < 50 MHz

The tuner used is an electronic tuner (G_t = 40 dB, F_t =6 dB) with output frequency 35 MHz and equivalent noise bandwidth B_{eq} = 5.5 MHz. The signal of his radio-amateur friend is received with a signal power P_r = -60 dBm at the antenna output connectors, the antenna noise temperature is T_a = 180 K.

a. Provide a detailed sketch of the receiving system and calculate:
   1. the total equivalent noise temperature at the antenna output connectors;
   2. the signal-to-noise ratio SNR_{out} at the tuner output.

b. As an experiment, the tuner is directly connected to the antenna, followed by 30 m of coaxial cable. This is possible because the tuner can be tuned electronically. Calculate again the SNR_{out} but now at the output of the cable.

Question 5.

A DC-coupled broadband amplifier is characterized as:

$$v_{out} = K_1 v_{in} + K_2 v_{in}^2 + K_3 v_{in}^3$$

with K_1 = 10, K_2 = 1 and K_3 = 0.8. The input signal v_{in} of the amplifier consists of two sinewave signals with frequencies f_1 and f_2.

a. Determine the number of different frequency components of the output signal.

b. Calculated the 3rd order intercept point IP3 (in dBm) when the input impedance of the amplifier is 75Ω.

c. Given the input signal $v_{in}(t) = A_0 \sin 2\pi f_1 t$, derive an expression for the total harmonic distortion THD and determine (numerically) the value A_0 for which the THD = 5%.