ICS905 - Fundamentals in AMS & RF Electronics (FARE)

M2 ICS - Scholar Year 2024-2025(S1)

ICS905 - Exam

Duration 1h30 - Documents and calculator are allowed

Exercises

Exercise Elements of communication theory and RF systems **1**

Exercise Noise temperature **2**

Exercise RF front-end **3**

Exercise Reciprocal Mixing in UMTS receiver **4**

All exercises are independent.

Direction de la Formation Initiale
Département Communications et Électronique
École Nationale Supérieure des Télécommunications

Exercise 1 - Elements of communication theory and RF systems

Basic concepts

Question 1.1 What is the purpose of the matched filter in a communication system ?

Question 1.2 Explain the (time-domain) Nyquist ISI condition for a pulse shaping filter : what is the primary criterion that needs to be satisfied to minimize inter-symbol interference in a communication system ? Your answer should include both a mathematical equation and a brief explanation of the terms involved.

Question 1.3 Now give the Nyquist ISI condition in the frequency domain. Your answer should include both the mathematical equation and a brief explanation of the terms involved.

Short problem

Consider a pulse $s(t) = \operatorname{sinc}(at) \operatorname{sinc}(bt)$, where $\operatorname{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$ and $a \geq b > 0$.

Question 1.4 Sketch the frequency domain response of :
— $\operatorname{sinc}(at)$
— $\operatorname{sinc}(bt)$
— $s(t)$
Please label the axes and indicate the main features of the spectrum.

Question 1.5 Suppose that the pulse is to be used over an ideal real baseband channel with one-sided bandwidth 400 Hz. Choose a and b so that the pulse is Nyquist for 4-PAM signaling at 1200 bit/s and exactly fills the channel bandwidth.

Exercise 2 - Noise temperature

Noise figure is the most common way to express the noise added by a device or device stage. However, it is not the only one. Another famous way is to use the **noise temperature** formulation. It consists in modeling the added noise of a given stage in terms of an equivalent temperature. It can be computed using the following expression :

$$NA = GKT_eB,$$

where NA is the stage added noise, G the stage gain, K Boltzmann constant, B the signal bandwidth and T_e the equivalent temperature.

Question 2.1 Prove that T_e can be expressed by :

$$T_e = (F - 1)T_0,$$

where F is the device noise factor, and T_0 the room temperature, i.e., 290 Kelvins.

Let us consider a chain with 2 stages in series with gains G_1 and G_2 and noise temperatures T_{e1} and T_{e2}.

Question 2.2 Starting from Friis equation, determine the general expression of the overall noise temperature of the cascaded two stages.

Question 2.3 Calculate the noise temperature for a 2-amplifier chain with the following specifications : G_1=10 dB, G_2=5 dB, and noise figure of NF_1 =3 dB and NF_2=10 dB.

Exercise 3 - RF front-end

Question 3.1 For a power amplifier (PA), explain the following :
- What is the 1 dB compression point ?
- What is the Adjacent Channel Power Ratio (ACPR) ?

Question 3.2 For a low noise amplifier (LNA), explain the following :
- Which is the role of a LNA at the receiver path of a transceiver ?
- What is the noise factor of a LNA ?

Question 3.3 Consider the transmitter topology shown in Fig. 1. The noise figure of the power amplifier (PA) is NF=2.5 dB, the gain of the PA is G=10 dB and the filter insertion loss is 3 dB. Calculate the following :
- Overall gain
- Overall noise figure

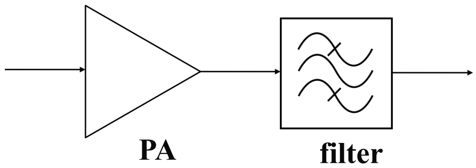

Figure 1 – Transmitter topology

Question 3.4 We need to design a power amplifier with an output power of 5 W, a power gain of 10 dB, a drain efficiency of 30 % and a supply voltage of 30 V at 1 GHz. Calculate the following :
- Required input power in dBm : P_{in}
- Power added efficiency : η_{PAE}

Exercise 4 - Reciprocal Mixing in UMTS receiver

Cellular base station receivers operate in the presence of high-level blockers/interferers while being required to detect weak signals of interest at the antenna. The reciprocal mixing of strong RF signals with LO noise degrades the receiver sensitivity. Specifying and evaluating the LO noise degradation in integrated mixers will allow a system designer to calculate the receiver sensitivity loss.

At the input of the first mixer stage, responsible for down-converting the RF signal to the IF band, there is a weak signal of interest at 2090.6 MHz in the presence of a high-level blocker located at 2093.6 MHz. The blocker signal bandwidth BW is 10 kHz. The blocker power P_B is X dB higher than the signal of interest power P_S.

The carrier frequency F_C and carrier power P_C along with the measured phase noise of the local oscillator are shown in Fig. 2.

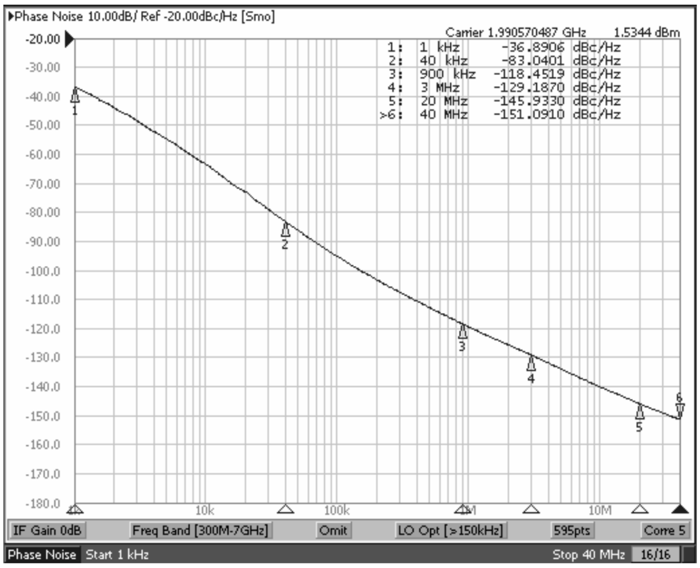

FIGURE 2 – Measured Phase Noise of the UMTS local oscillator

Question 4.1 What is the value of the intermediate frequency (IF) chosen ?

Question 4.2 Calculate in dBm the power P_N of the phase noise fraction that will mix with the blocker in the mixer block.

Question 4.3 Assuming that the reciprocal mixing is the only (or main) source of noise at the mixer output, calculate the maximum value of X in order to maintain a SNRmin of 30 dB after this first mixer.