Low-power radio design for the IoT
Exercise 6 (29.04.2021)

Christian Enz

Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland

Problem 1   Link budget

In this example we will look into a simplified link budget estimation for a Bluetooth transceiver. According to the Bluetooth specifications the maximum transmit power must not exceed $P_{Tx,max} = 20\,\text{dBm}$. The system operates in the $f_c = 2.4\,\text{Ghz}$ ISM band, where $B = 1\,\text{Mhz}$ bandwidth is available for each Bluetooth channel. This particular transceiver is using GMSK modulation that requires $SNR = 10\,\text{dB}$ to achieve the desired BER performance. Assume that we want to keep a margin of $10\,\text{dB}$ in order to make sure that we have a reliable link (received power must remain $10\,\text{dB}$ above the sensitivity level), and that antenna gain on the transmitter and the receiver side is $G_{Tx} = G_{Rx} = 0\,\text{dB}$. Consider a source of thermal noise at the input of the receiver with maximum availabe power $P_{n,i} = kTB$. The power attenuation (in dB) when transmitting a signal with wavelenght λ over a distance d is given by:

$$A_{dB} = 10log\left(\frac{(4\pi)^2 d^2}{\lambda^2}\right) \tag{1}$$

In all the calculations you can use $10log(kT) = -174\,\text{dBm}$.

- Find the receiver sensitivity if the transceiver needs to operate at a range of 1 km. Find the maximum Noise Figure (NF) of the receiver front-end in order to achieve the desired sensitivity.

- Recalculate the maximum noise figure if the range is now limited to 100 m.

- Now imagine that the receiver you use has the noise figure $NF = 10\,\text{dB}$. What is the available range in this case?

- Assume that you want to extend the range of the transceiver but you are not allowed to transmit above $20\,\text{dBm}$ and that no additional antenna gain is available. The only remaining system parameter is channel bandwidth. Calculate the available bandwidth if the desired range is 10 km.

Problem 2   Indirect conversion architecture

The sliding-IF architecture shown in Fig. 1 is designed for the 11a band (Fig. 2).

- Determine the required LO frequency range.

- Determine the image frequency range.

- Determine the interferer frequencies that can appear in the output baseband as a result of mixing with the third harmonic of the

  rst LO or the third harmonic of the second LO.

Problem 3   Direct conversion architecture

The simplified Hartley architecture shown in Fig.3 incorporates mixers having a voltage conversion gain of A_{mix} and an infinite input impedance.

- Taking into account only the noise of the two resistors, compute the noise
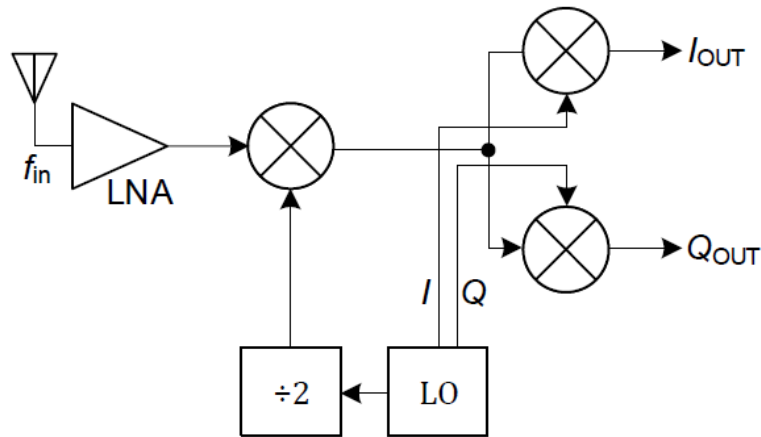 gure of the receiver with respect to a source resistance of R_S at an IF of $1/(R_1 C_1)$.
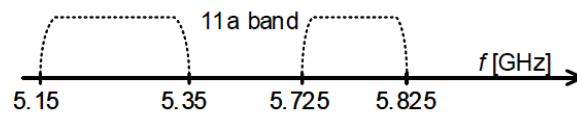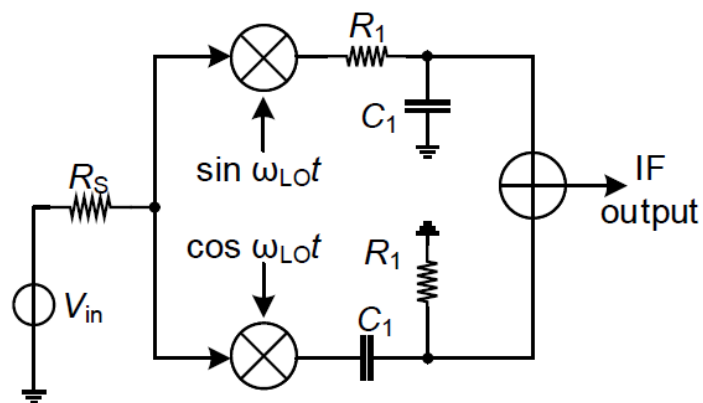

Figure 1: Sliding-IF RX for 11a.

Figure 2: 11a band.

Figure 3: Simplified Hartley RX.