

Low-power radio design for the IoT

Exercise 8 (14.04.2022)

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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 $P_{Tx,max} = 20$ dBm. The system operates in the $f_c = 2.4$ GHz ISM band, where $B = 1$ MHz bandwidth is available for each Bluetooth channel. This particular transceiver is using GMSK modulation that requires $SNR = 10$ dB to achieve the desired BER performance. Assume that we want to keep a margin of 10 dB in order to make sure that we have a reliable link (received power must remain 10 dB above the sensitivity level), and that antenna gain on the transmitter and the receiver side is $G_{Tx} = G_{Rx} = 0$ dB. Consider a source of thermal noise at the input of the receiver with maximum available power $P_{n,i} = kTB$. The power attenuation (in dB) when transmitting a signal with wavelength λ over a distance d is given by:

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

In all the calculations you can use $10 \log(kT) = -174$ 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 $NF = 10$ 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 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 first 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 figure of the receiver with respect to a source resistance of R_S at an IF of $1/(R_1C_1)$.

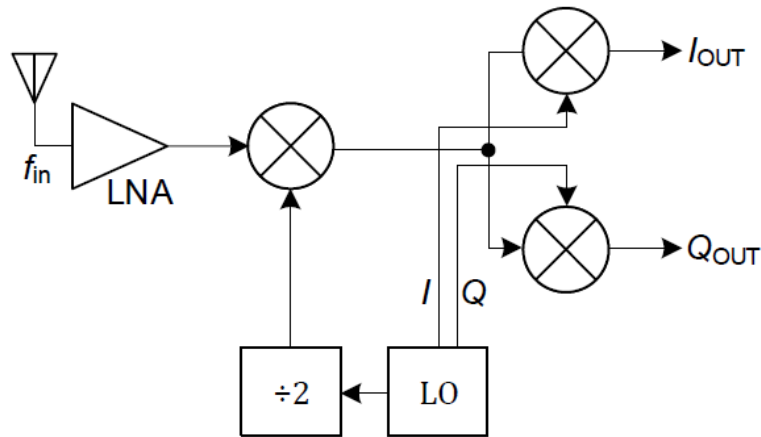


Figure 1: Sliding-IF RX for 11a.

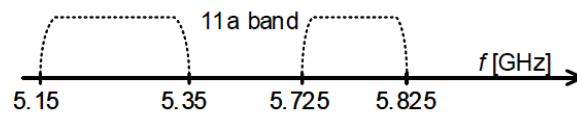


Figure 2: 11a band.

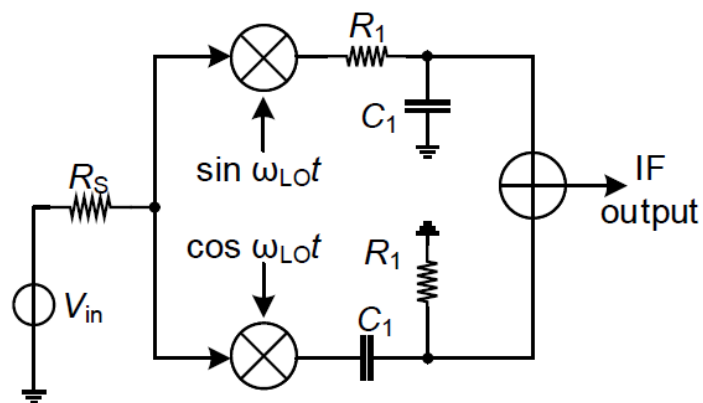


Figure 3: Simplified Hartley RX.