Exercises for SDR

1- A digital radio has a RF front-end represented by the block diagram of figure 1. This system moves a bandwidth of interest to the base-band. Then, the system represented by the block diagram of figure 2 performs the analog to digital conversion of the I and Q components. The digital components can be once more translated in the frequency and then are decimated by a factor M. The digital filter $H(z)$, is an anti-aliasing low-pass filter.

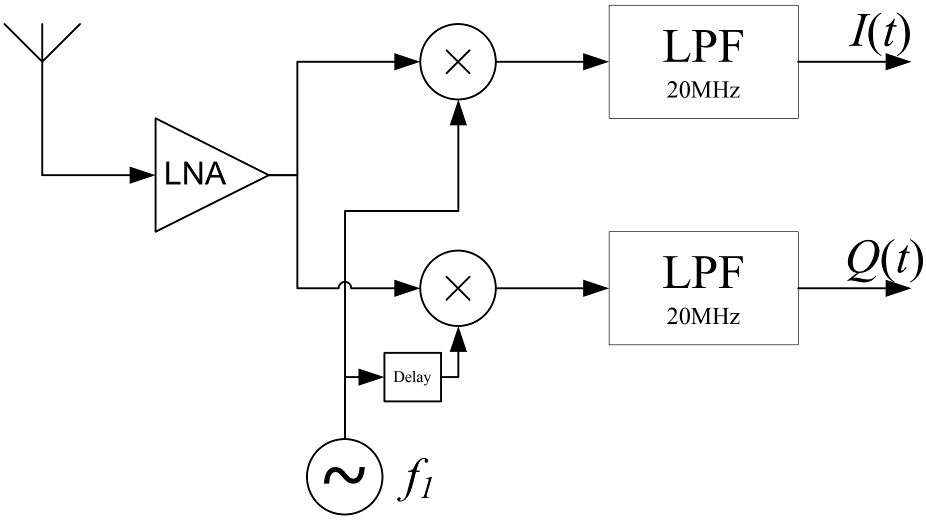

Figure 1 – RF front-end of a radio.

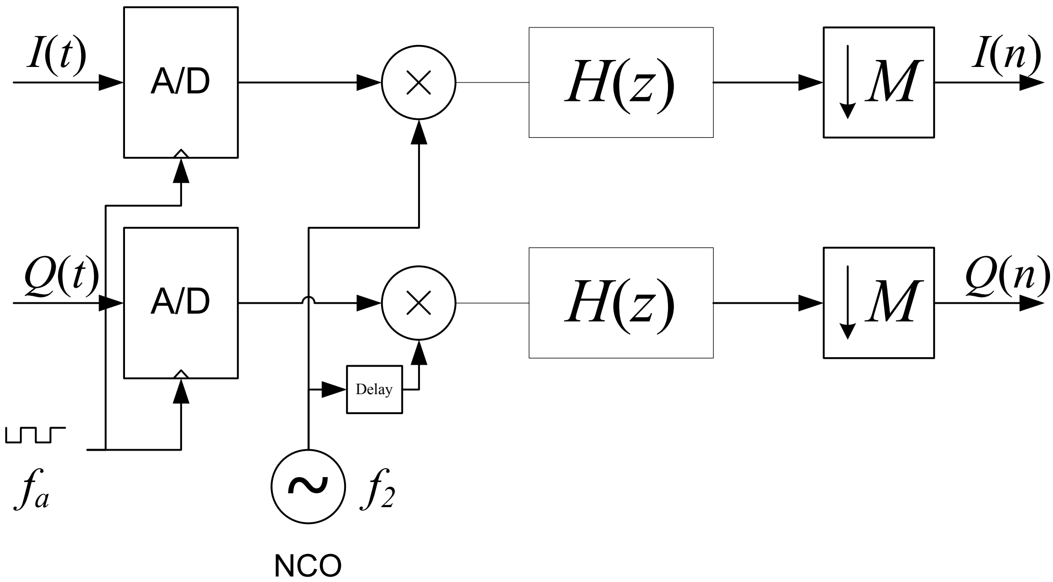

Figure 2 – Analog to digital convertors and decimators.

Answer the following questions:

a) What is the largest input signal bandwidth that can be represented by the RF-front-end of figure 1. Please consider the bandwidth of 20MHz of the low-pass filters at the output.
b) Suppose that the analog front-end of figure 1 has moved to the baseband a RF signal with 30MHz of bandwidth and centered at 100MHz. Assuming a sampling frequency of 64Msps on each ADC, set the frequency f_2, the cut-off frequency of the low-pass digital filters $H(z)$ and the decimation factor M, in order to get at the outputs $I(n)$ and $Q(n)$ the input signal bandwidth between 105 and 110MHz.

2- Sub-sampling is a useful technique to convert a band-pass signal from analog to digital. However, there are some constraints on the relation between the sampling frequency and the bandwidths that can be correctly converted to the baseband. Use an example to illustrate this restriction.

3- The Cascaded and Integrator-Comb (CIC) Filters are a clever implementation of a "Moving Average Filter". What is the transfer function of this type of filters? Sketch a block diagram of a CIC filter explaining the reason for their efficiency. Explain the advantages of these filters over the traditional FIR implementations, which make them useful for real time implementations of decimators.

4- One of the possible methods to generate a sinusoid is by Direct Digital Synthesis (DDS). A sine wave is a periodic signal because we always have

$$\sin(2\pi f_0 t) = \sin(2\pi f_0 (t + T_0))$$

with $T_0 = 1/f_0$ the sinusoid period. However, if the sampling period is not properly chosen the generated digital sinusoid it is not a periodic signal. Explain this property with an example and show the condition that must be observed in order to get a periodic signal.

5- Suppose that you need to design a sinusoid generator using the phase accumulator method with a frequency resolution of 100Hz and a center frequency of 10MHz. What would be the size of the LUT? What would be the minimum frequency that you can generate? What technique can you use to reduce the size of the LUT? Consider a sampling frequency of 100MHz.

6- Why the DSPs have a Harvard architecture? Which signal processing algorithm takes advantage of this architecture? Explain.

7- Suppose you need to process a digital signal with a sampling rate of 100Msps. What would be more appropriate, a DSP working at 2GHz or a 300MHz FPGA? What would be the largest FIR filter that you could implement at this sampling frequency?

8- Describe the Welch algorithm for power spectrum estimation. What is the advantage of using this algorithm over a simple FFT? When the number of averages in the Welch algorithm is increased what have you observed during the lab work of spectrum estimation?