CIE-442 Digital Signal Processing Project

NB-IoT base station SDR receiver filter design

This is a **group project (3-5 members per team)** in which you are required to design an FIR digital filter for a NB-IoT software defined radio (SDR) base station Receiver.

You can use MATLAB LTE toolbox to generate the standard compliant NB-IoT uplink complex baseband waveforms representing the 180kHz narrowband carrier as shown in the following link:

https://se.mathworks.com/help/lte/ug/nb-iot-uplink-waveform-generation.html

In your simulation, you should assume 8 NB-IoT devices transmitting their UL signal to the NB-IoT base station. The NB-IoT mode is the Standalone mode in which the NB-IoT carrier is deployed outside the LTE spectrum, e.g., in the spectrum used for GSM or satellite communications.

The NB Physical Uplink Shared Channel (NPUSCH) is the physical channel carrying the uplink data and control information. You will be transmitting the NPUSCH format 1 for the 8 NB-IoT devices with different data from each device.

Please read the following requirements carefully.

Required Tasks

It is required to implement and document the following tasks:

1. Draw a block diagram of the uplink communication system including the 8 IoT devices transmitters and the base station receiver. In your diagram you should indicate the following:
   a) Transmit RF frequency that should match the NB-IoT standard.
   b) Receive RF and IF frequencies at the base station. Note that in the SDR, the 8 UL NB-IoT devices will be captured at IF using a single ADC as explained in the lecture.
   c) The digital down conversion, filtering, and downsampling stages per NB-IoT device in the base station receiver.
2. Generate using MATLAB the standard compliant NB-IoT uplink complex baseband waveform for one of the 8 NB-IoT devices. You should add a reference to the standard in your report. You will be transmitting the NPUSCH format 1. Plot the magnitude spectrum of the baseband signal.

3. Each NB-IoT signal should map to a suitable IF frequency at the base station receiver as explained in the lecture. Don't simulate the RF carrier, simulate only the IF stage. Select the frequency spacing between the NB-IoT carriers according to the standard in the standalone mode. Plot the magnitude spectrum of the composite IF signal at the base station receiver showing the spectrum of the 8 NB-IoT devices separated in frequency.
4. Write a clear and concise problem statement indicating the digital filtering problem you are trying to solve. Your digital FIR filter should properly select the desired NB-IoT signal from the composite IF signal and allow for downsampling after the filtering stage.
5. Determine the specifications and constraints of the digital FIR filter to be designed. The specifications and constraints should include at least the following: passband ripples, stopband attenuation, transition region width, and number of filter taps, i.e., filter complexity.
6. Start by designing multiple prototype FIR filters using the filter designer app in MATLAB
7. Evaluate (using a clear quantitative evaluation criteria) each design in step 6 against the specifications and complexity constraints defined in step 5.
8. Iterate your design by changing the filter design method and/or parameters until the specifications and constraints in step 5 are met.
9. The outcome of this design process should be the designed FIR filter coefficients, the filter frequency response, and a justification of this particular filter based on your iterative design process. You should also plot 3 spectra for one of the received NB-IoT waveforms after the following:
   a) Digital downconversion
   b) Digital downconversion and FIR filtering
   c) Digital downconversion, FIR filtering, and downsampling.
10. Discuss public health, safety, as well as social, environmental, and economic factors related to one or more NB-IoT application of your choice. Include the relevant references in your discussion.

Important Note:

A documentation of your filter designer is a mandatory requirement in this assignment (Assignments submitted without documentation will not be accepted). The documentation is required along with the code itself using MATLAB **Live Editor and transforming it also to PDF format**. In the documentation you should explain clearly all your used modules and their corresponding inputs, outputs, internal variables, etc., and how they map to the implemented task. You should also display the relevant outputs in your live editor according to the tasks described above.
This is a short video about the MATLAB live editor:
https://www.youtube.com/watch?v=bu4g8ID3aEk

<u>Grading criteria (Total grade of this project is worth 15% of the course grade)</u>

The **15** points are distributed as follows:

- **5** points: individual discussion at the end of the semester.
- **10** points distributed among the 10 tasks mentioned above, with 1 point per task. Note that the grade per task includes the documentation of the task. The task grading will be on a level from 0-4.
    - **Level 0:** Task not done
    - **Level 1:** Inadequate
    - **Level 2:** Needs improvement
    - **Level 3:** Meets Expectation
    - **Level 4:** Outstanding