CMPEN 462

Mini-Project #1: Basic OFDM Transmitter

Due: Feb 28, 2025 (8AM EST)

(worth 15 pts total)

This project is designed to help you get a better understanding of some of the theory we have been covering in class by having you build a part of the OFDM transmit chain as would be used in a wireless communication device. We can then build on this and related theory for later projects and ultimately get to the point where you can explore security aspects of wireless systems at various layers of the protocol stack.

You will be building pieces of the OFDM transmitter (5G cellular in this case) we covered in class in SP8 and SP9. You will be using some simplifications (e.g., skipping the DAC) to do the up-conversion (“RF carrier” and “Select in-phase component”) for generating the signal to be transmitted.

Project:

Build the following OFDM processing chain components (*An Introduction to 5G,* Christopher Cox) in Matlab or Python:

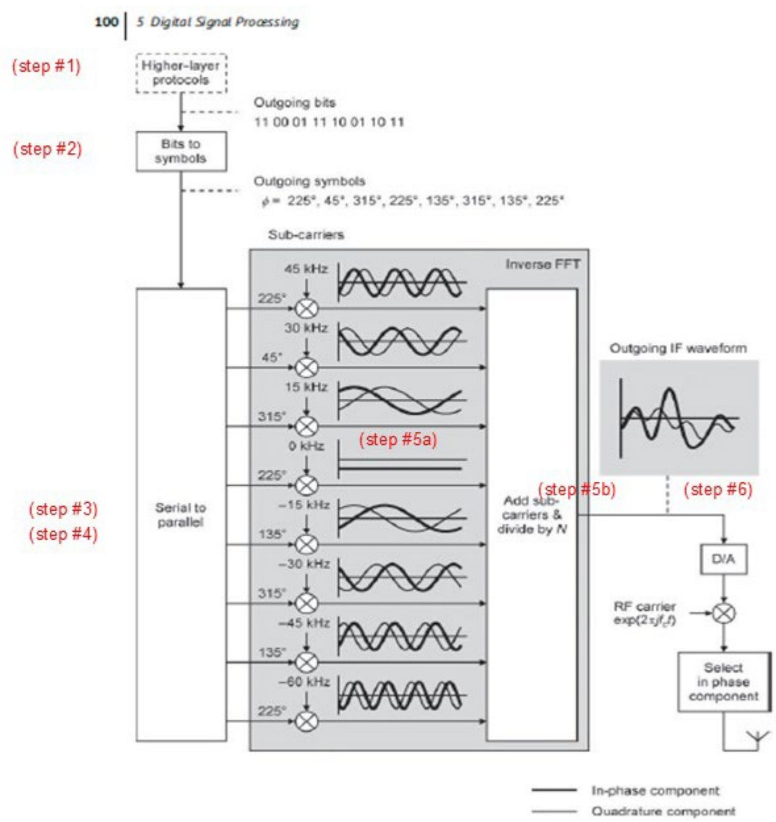

Figure 5.7 Processing steps in an OFDM transmitter.

Steps your code must perform:

1. Take the words “Wireless Communication Systems and Security” and concatenate it with your full name (without any spaces) and convert it to 8-bit ASCII. You will take this vector and repeat it as many times as required to create a source bit stream for the project (i.e., “Outgoing bits” from higher layer protocols in the picture). **Your simulated bit stream must be such that you will be generating at least one slot’s worth of OFDM transmit symbols for the 64QAM modulation scheme** (additional information is provided at the bottom of this document)**. All the other modulation schemes can use that same length bit stream regardless of how many output symbols they generate (hint: it will generate more than one subframe’s worth for the other modulation schemes)**. So, if your name is John Paul Jones, your beginning phrase is: “WirelessCommunicationSystemsandSecurityJohnPaulJones” and you will need to repeat this as many times as necessary to create a bit stream that is as long as you need to end up with 0.25 msec (one slot) worth of data that will be upconverted and ‘transmitted’.
2. Perform the ‘bits to symbols’ mapping using [3GPP TS 38.211 Section 5.1] as your source for the definition of the following modulation schemes:
    a. Pi/2 BPSK
    b. BPSK
    c. QPSK
    d. 64QAM
3. Perform the ‘Serial to Parallel’ conversion.
4. There is no “Resource Element Mapping” for a single data stream (i.e. single user in slide 7) so you will not be implementing that feature for this project, but you will in the future.
5. Perform 4096-point IFFT to generate each OFDM symbol.
6. Perform “Cyclic Prefix Insertion” as shown on **slides 10-16** of SP9. Add a cyclic prefix per **Table 7.12 on slides 23 and 24** of SP9. Note:: each [CP + OFDM symbol] pair creates a ‘transmit OFDM symbol’ and there are two different CP lengths for each frame with every OFDM symbol having one attached to it.
7. Collect the transmit OFDM symbols in an output buffer.
8. **Generate a time-scaled plot of two transmit OFDM symbols (i.e., symbol plus CP) for each modulation scheme to include in your report write up.**
9. We are ignoring the “DAC” functional block. That is, assume you have a system that creates an analog signal at this point in the processing chain.
10. Draw the direct up-conversion circuit (that is the structure) which takes the baseband signal (assume it would be analog at this point), shifts it up to an RF center frequency of your choice, sends it out an antenna, and justify it based on your understanding of the information in this document and any other source you wish. You will assume you are designing a downlink transmitter (i.e., base station (gNB) to user equipment (UE)). Don’t worry about any filters or amplifiers, etc., etc. Only what elements we have discussed in class.

You will be assuming a sample rate consistent with the disclosures on slides 23 and 24 and <u>sub-carrier bandwidth of 60kHz</u>. The above implementation approach I am having you take (i.e., excluding the Resource Element mapper function), leads to an overall system bandwidth of 135MHz (FR1). An actual 5GNR system would have a maximum system bandwidth 100MHz.

FYI: The "Analogue Transmitter" in Fig. 5.9 of Slide 15 of SP9 is equal to everything from the output of the D/A to the input to the antenna shown on the diagram in Fig. 5.7 of Slide 15.

<u>This isn't as complicated as it sounds</u> and working through the concepts will help you understand what we covered in class.

I will be posting a grading rubric. You will be submitting your code, the output buffer of OFDM symbols, and your drawing. We will demodulate what you have generated to assist in grading your project work. There will be points for your code design (meaning I don't want it to be sloppy and/or inefficient).