Passband Communication - General modulation and demodulation schemes

In this labsheet you will again study digital communication over passband channels. However, you will use general modulation and demodulation schemes under the assumption of ideal channels and perfect carrier, frame, and symbol synchronization.
Please try to modularize your code as much as possible by separating out different tasks into functions which can be reused. All plots should have clearly labelled axes. Modify and extend the starter code provided to complete the tasks.
Also note the following:

1. For all the tasks in this labsheet you can assume that the bit sequence generated by the source is IID and uniformly distributed.
2. You can assume that the symbol time is 1 sec. and the carrier frequency is 20 Hz for these examples.
3. The null to null bandwidth is a one-sided bandwidth defined for a passband PSD. It is equal to the width of the main lobe of a sinc^2-like spectrum and as the name suggests is the frequency extent around the carrier frequency upto the first nulls on either side.
4. Note that for obtaining the null to null bandwidth the average PSD across multiple runs should be used.

Generation of passband waveforms for different modulation schemes

1. For a sequence of 200 bits obtain the waveform corresponding to QPSK. The symbol time can be chosen to be 1 second. Record the bit rate. Obtain the PSD of the QPSK waveform and record the null to null bandwidth. Obtain the signal constellation for this transmission scheme.
2. For a sequence of 400 bits obtain the waveform corresponding to 16-QAM. Again record the bit rate and the null to null bandwidth. Obtain the signal constellation for this transmission scheme.
3. For a sequence of 300 bits obtain the waveform corresponding to 8-PSK. Again record the bit rate and the null to null bandwidth. Obtain the signal constellation for this transmission scheme.
4. For a sequence of 200 bits obtain the waveform corresponding to 4-FSK. Again record the bit rate and the null to null bandwidth.
5. Compare the bit rate, null to null bandwidth, and signal constellation for the four schemes discussed above.

Correlation receivers for different modulation schemes
Under the assumption of perfect frame and timing synchronization, implement correlation receivers for each of the four schemes discussed above. Please use the starter code to get an idea about how to do this.

1. Fix a sequence of 40 bits.
2. For this fixed sequence of bits generate QPSK, 16-QAM, 8-PSK, and 4-FSK passband waveforms.
3. Use the correlation receiver that you have implemented to receive and convert the above waveforms into bits.
4. Show the TA that the received sequence of bits is the same as the transmitted sequence of bits (since we are not modelling channel noise).

Passband Communication - SER and BER for general modulation and demodulation schemes

In this labsheet you will use the code from the previous lab to study the symbol error rate (SER) and bit error rate (BER) for general modulation and demodulation schemes.
Please try to modularize your code as much as possible by separating out different tasks into functions which can be reused. All plots should have clearly labelled axes. Each intermediate result has to be shown to the TAs/instructor for full credit. For this labsheet please make a copy of the code used for the previous lab and modify it for the tasks given below.
Also note the following:

1. For all the tasks in this labsheet you can assume that the bit sequence generated by the source is IID and uniformly distributed.
2. You can assume that the symbol time is 1 sec. and the carrier frequency is 20 Hz for these examples.
3. Note that for obtaining the SER and BER you have to consider a large number of symbols, for example 5000 or so, and obtain the fraction of symbols or bits in error.

1. Using the code from last lab, generate QPSK, 16-QAM, 8-PSK, and 4-FSK waveforms for 5000 symbols (please note that the number of bits would vary according to the number of bits/symbol for each of these modulation schemes.
2. Under the assumption of perfect frame and timing synchronization, implement correlation receivers for each of the four schemes discussed above. (Any equivalent form of the correlation receiver can be implemented - for example, the minimum distance receiver can also be implemented).
3. Model a channel introducing sampled AWGN noise - the modulated waveforms (sampled) are summed with sampled AWGN noise of mean zero and variance σ^2. Obtain the channel output (which is the received signal) for each of the four modulation schemes.
4. Visualize the received signal constellation with noise for 3 different values of σ^2 for all the four schemes (these values should be chosen with respect to the received signal constellation point when there is no noise so as to correspond approximately to regimes where there is little noise, there is noise std. deviation of approximately the same magnitude as signal, and noise std. deviation which is larger compared to the signal magnitude.). This has to be shown to the TA (12 figures in total).
5. Obtain the SER and BER as a function of σ^2 for each of the four modulation schemes discussed above. Plot the SER curve as a function of σ^2 for all four schemes on the same plot. Similarly plot the BER curve as a function of σ^2 for all four schemes on the same plot. Report this to the TA.