Digital Communication IC Design

Homework #1

(Due on 2024/10/2)

Please upload your codes and reports (with simulation results and explanations) to the NTUCool.

Total points: 140 points

1. Please randomly generate 16 binary bits by using your last two digits as the seed, and write down your own bits ($b_i, i = 0,1, \ldots 15$). These binary data will be used in all the questions of homework 1.

2. Use the binary bits generated in Question 1. For the following questions, the symbol period (T) is set to 200ns. The carrier frequency (f_c) is selected to be 20 MHz. The initial phase or previous value, if required, is zero. Note that to make the waveform smooth, at least 16 points are sampled in one sin/cos waveform period.
   (a) Use the white constellation mapping as in Fig. 1, where the binary data are indicated by (b_{2j}, b_{2j+1}) for $j = 0, \ldots, 7$. Plot O-QPSK passband waveform after modulation with carrier f_c. So, the length of the whole waveform is 1.6μs. (10%)
   (b) Use the white constellation mapping for the first symbol of even-numbered student and the black constellation mapping for the first symbol of odd-numbered students. Plot π/4-QPSK passband waveform after modulation with carrier f_c. So, the length of the whole waveform is 1.6μs. (10%)
   (c) Draw the spectrum of Q2(a) and Q2(b) (20%). Note that the y-axis must be in dB. Please limit the whole range of y-axis to be 60dB to see the desired properties.
   (d) Compare two spectrums in Q2(c) and write some of your observations regarding the properties in spectrum. (10%)

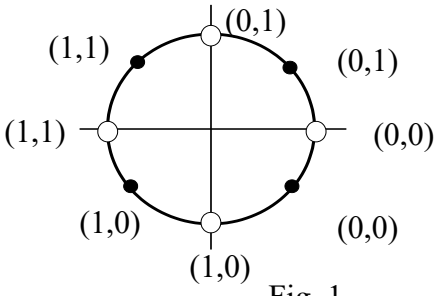

Fig. 1

3. Use the data from Q1. Plot OFDM **baseband** signals with **8** subcarriers by the

following step:

(a) With the symbol period of 500ns, calculate the subcarrier spacing f_{sub} and sampling interval T_s (10%). Please pay attention to the unit of your x-axis and y-axis.

(b) Use QPSK black constellation mapping for each subcarrier in Fig. 1. Draw the real part and imaginary part of the signals at subcarriers $X_k e^{j2\pi f_k t}$ for $k = 1,3,5,7$. Note that $f_k = k f_{sub}$. Also, in order to make the waveform smooth, at least 16 points are sampled in one sin/cos waveform period. (20%)

(c) Sum your waveform of 8 subcarriers and draw the real part and imaginary part of the output. $y(t) = \sum_{k=0}^{7} X_k e^{j2\pi f_k t}$ (10%)

(d) Calculate the time-domain waveform including real part and imaginary part by applying 8-point IFFT to the frequency-domain signals X_k for $k = 0,1,2, \ldots 7$. Draw the discrete real part and imaginary part outputs with proper sampling interval T_s from (a). (10%).

(e) First, scale the curve in (c) by 1/8. Then, on the same figure, use "stem" to draw the waveform of (d) with proper sampling interval T_s according to (a). Compare them and write your comments. (10%)

4. Now, we will try to generate OTFS baseband signals. Please use your binary data in Q1 by $b_i = \bar{b}_{i-16}$ for $i = 16,17, \ldots,31$, and use BPSK mapping for 32 binary data ($b_i = 0$: +1, $b_i = 1$: -1). Assume the number of subcarriers is 8 $(M = 8)$ and the number of time slots is 4 $(N = 4)$.

(a) Put your data in the delay-Doppler domain. For b_0 to b_7, they are put from subcarrier 0 to subcarrier 7 in the first time slot. And for b_8 to b_{15}, they are put from subcarrier 0 to subcarrier 7 in the second time slot and so on. Now, please use ISFFT and IFFT to draw the OTFS **baseband** transmitted signals in the time domain as indicated on Page 41. (10%)

(b) Put your data in the delay-Doppler domain. Then, apply IFFT to the two-dimensional data in the Doppler domain. Draw the OTFS **baseband** transmitted signals in the time domain. (10%)

(c) Compare Q4(a) and Q4(b). Write your comments. (10%)