無線通訊積體電路 Homework 1

電機 4B 107501019 魏子翔

```
clear;
close all;
rng(19);
r = randi([0 1],1,8);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% 2-(a)
figure(1);      %2-a
A=1;           %振幅
fc=10*10^6;     %carrier frequency
f1=15*10^6;     %fc of bit 1
f0=5*10^6;      %fc of bit 0

T=400*10^-9;    %symbol time

Ts=0:T/10000:T; %symbol time
t=zeros(8,length(Ts));

for i=1:8
    t(i,:)=Ts+(i-1)*T;
end

ya=zeros(8,length(Ts)); %store modulated wave

for i=1:8   %modulating r
    ya(i,:)=r(i)*sin(2*pi*f1*t(i,:))+~r(i)*sin(2*pi*f0*t(i,:));
end

t=reshape(t',length(Ts)*8,1);
ya=reshape(ya',length(Ts)*8,1);

plot(t,ya);
title('2-(a) FSK waveform');
axis([0,8*400*10^-9,-2,2]);
axis normal;
xlabel('time(s)');
ylabel('Amplitude(V)');
```

```
hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% 2-(b)
figure(2);
A=1;          %振幅
fc=10*10^6;     %carrier frequency

T=400*10^-9;    %symbol time
I=zeros(4,2);
Q=zeros(4,2);

for i=1:4
    if r([2*i-1 2*i])==[0 0]           %signal 00
        I(i,:)=[T*(i-1) 1/sqrt(2)];
        Q(i,:)=[T*(i-1) -1/sqrt(2)];
    elseif r([2*i-1 2*i])==[0 1]       %signal 01
        I(i,:)=[T*(i-1) 1/sqrt(2)];
        Q(i,:)=[T*(i-1) 1/sqrt(2)];
    elseif r([2*i-1 2*i])==[1 0]       %signal 10
        I(i,:)=[T*(i-1) -1/sqrt(2)];
        Q(i,:)=[T*(i-1) -1/sqrt(2)];
    elseif r([2*i-1 2*i])==[1 1]       %signal 11
        I(i,:)=[T*(i-1) -1/sqrt(2)];
        Q(i,:)=[T*(i-1) 1/sqrt(2)];
    end

end
t=0:T/10000:4*T;
I_wave=pulstran(t-T/2,I,'rectpuls',T);
Q_wave=pulstran(t-T/2,Q,'rectpuls',T);

I_carrier=cos(2*pi*fc*t);
Q_carrier=sin(2*pi*fc*t);

yb=I_wave.*I_carrier-Q_wave.*Q_carrier;
plot(t,yb);
title('2-(b) QPSK waveform');
axis([0,4*400*10^-9,-2,2]);
```

```
axis normal;
xlabel('time(s)');
ylabel('Amplitude(V)');

hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% 2-(c)
figure(3);
A=1;          %振幅
fc=10*10^6;     %carrier frequency
p=0;           %phase

T=400*10^-9;    %symbol time
I=zeros(4,2);
Q=zeros(4,2);

WhiteBlack=1;   %bit 1 is white, bit 0 is black

for i=1:4
    if WhiteBlack==0
        if r([2*i-1 2*i])==[0 0]       %signal 00
            I(i,:)=[T*(i-1) 1/sqrt(2)];
            Q(i,:)=[T*(i-1) -1/sqrt(2)];
        elseif r([2*i-1 2*i])==[0 1]    %signal 01
            I(i,:)=[T*(i-1) 1/sqrt(2)];
            Q(i,:)=[T*(i-1) 1/sqrt(2)];
        elseif r([2*i-1 2*i])==[1 0]    %signal 10
            I(i,:)=[T*(i-1) -1/sqrt(2)];
            Q(i,:)=[T*(i-1) -1/sqrt(2)];
        elseif r([2*i-1 2*i])==[1 1]    %signal 11
            I(i,:)=[T*(i-1) -1/sqrt(2)];
            Q(i,:)=[T*(i-1) 1/sqrt(2)];
        end
        WhiteBlack=1;
    else
        if r([2*i-1 2*i])==[0 0]       %signal 00
            I(i,:)=[T*(i-1) 1];
            Q(i,:)=[T*(i-1) 0];
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```
        elseif r([2*i-1 2*i])==[0 1]    %signal 01
            I(i,:)=[T*(i-1) 0];
            Q(i,:)=[T*(i-1) 1];
        elseif r([2*i-1 2*i])==[1 0]    %signal 10
            I(i,:)=[T*(i-1) 0];
            Q(i,:)=[T*(i-1) -1];
        elseif r([2*i-1 2*i])==[1 1]    %signal 11
            I(i,:)=[T*(i-1) -1];
            Q(i,:)=[T*(i-1) 0];
        end
        WhiteBlack=0;
    end

end
t=0:T/10000:4*T;
I_wave=pulstran(t-T/2,I,'rectpuls',T);
Q_wave=pulstran(t-T/2,Q,'rectpuls',T);

I_carrier=cos(2*pi*fc*t);
Q_carrier=sin(2*pi*fc*t);

yb=I_wave.*I_carrier-Q_wave.*Q_carrier; %after modulation
plot(t,yb);
title('2-(c) \pi/4-QPSK waveform');
axis([0,4*400*10^-9,-2,2]);
axis normal;
xlabel('time(s)');
ylabel('Amplitude(V)');

hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% 2-(d-1)
figure(4);
A=1;          %振幅
fc=10*10^6;     %carrier frequency

T=400*10^-9;    %symbol time
I=zeros(4,2);
```

```
Q=zeros(5,2);
Q(1,:)=[-T/2 1/sqrt(2)];    %because of OQPSK

for i=1:4
    if r([2*i-1 2*i])==[0 0]
        I(i,:)=[T*(i-1) 1/sqrt(2)];
        Q(i+1,:)=[T*(i-1)+T/2 -1/sqrt(2)];
    elseif r([2*i-1 2*i])==[0 1]
        I(i,:)=[T*(i-1) 1/sqrt(2)];
        Q(i+1,:)=[T*(i-1)+T/2 1/sqrt(2)];
    elseif r([2*i-1 2*i])==[1 0]
        I(i,:)=[T*(i-1) -1/sqrt(2)];
        Q(i+1,:)=[T*(i-1)+T/2 -1/sqrt(2)];
    elseif r([2*i-1 2*i])==[1 1]
        I(i,:)=[T*(i-1) -1/sqrt(2)];
        Q(i+1,:)=[T*(i-1)+T/2 1/sqrt(2)];
    end

end
t=0:T/10000:4*T;
I_wave=pulstran(t-T/2,I,'rectpuls',T);
Q_wave=pulstran(t-T/2,Q,'rectpuls',T);

I_carrier=cos(2*pi*fc*t);
Q_carrier=sin(2*pi*fc*t);

yb=I_wave.*I_carrier-Q_wave.*Q_carrier;     %after modulation

subplot(3,1,1);plot(t,I_wave);
title('OQPSK baseband I');
axis([0,4*400*10^-9,-2,2]);
axis normal;
xlabel('time(s)');
ylabel('Amplitude(V)');

subplot(3,1,2);plot(t,Q_wave);
title('OQPSK baseband Q');
axis([0,4*400*10^-9,-2,2]);
```

```
axis normal;
xlabel('time(s)');
ylabel('Amplitude(V)');

subplot(3,1,3);plot(t,yb);
title('OQPSK waveform');
axis([0,4*400*10^-9,-2,2]);
axis normal;
xlabel('time(s)');
ylabel('Amplitude(V)');

sgtitle('2-(d) OQPSK waveform');
hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% 2-(d-2)
figure(5);
A=1;          %振幅
fc=10*10^6;     %carrier frequency

T=400*10^-9;    %symbol time
I=zeros(4,2);
Q=zeros(4,2);
p=pi/4;         %initail phase

for i=1:4
    if r([2*i-1 2*i])==[0 0]
        p=p+pi/4;
    elseif r([2*i-1 2*i])==[0 1]
        p=p-pi/4;
    elseif r([2*i-1 2*i])==[1 0]
        p=p-3*pi/4;
    elseif r([2*i-1 2*i])==[1 1]
        p=p+3*pi/4;
    end
    I(i,:)=[T*(i-1) real(exp(j*p))];
    Q(i,:)=[T*(i-1) imag(exp(j*p))];
end
t=0:T/10000:4*T;
```

```
I_wave=pulstran(t-T/2,I,'rectpuls',T);
Q_wave=pulstran(t-T/2,Q,'rectpuls',T);

I_carrier=cos(2*pi*fc*t);
Q_carrier=sin(2*pi*fc*t);

yb=I_wave.*I_carrier-Q_wave.*Q_carrier;

subplot(3,1,1);plot(t,I_wave);
title('\pi/4-QPSK baseband I');
axis([0,4*400*10^-9,-2,2]);
axis normal;
xlabel('time(s)');
ylabel('Amplitude(V)');

subplot(3,1,2);plot(t,Q_wave);
title('\pi/4-QPSK baseband Q');
axis([0,4*400*10^-9,-2,2]);
axis normal;
xlabel('time(s)');
ylabel('Amplitude(V)');

subplot(3,1,3);plot(t,yb);
title('\pi/4-QPSK waveform');
axis([0,4*400*10^-9,-2,2]);
axis normal;
xlabel('time(s)');
ylabel('Amplitude(V)');

sgtitle('2-(d) \pi/4-QPSK waveform');

hold on;
```

```
clear;
close all;
rng(19);
r = randi([0 1],1,8);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% 3-(b)
figure(1);
A=1;            %振幅
Ts=100*10^-9;   %sampling interval
N=8;            %amounts of subcarrier

fsub=1/(N*Ts);
Xk=zeros(8,1);

for i=1:8
    if r(i)==1
        Xk(i,:)=1;
    else
        Xk(i,:)=-1;
    end
end

t=0:Ts/10000:8*Ts;
Xk_wave=pulstran(t-Ts/2,Xk,'rectpuls',Ts);

%subcarrier=exp(j*2*pi*k*fsub*t);

x_subcarrier=zeros(8,length(t));

for k=0:7
    x_subcarrier(k+1,:)=Xk(k+1)*exp(j*2*pi*k*fsub*t);
end

for i=1:8
    subplot(4,2,i);
    plot(t,real(x_subcarrier(i,:)));
    title(['Subcarrier ',num2str(i),' waveform']);
    axis([0,N*Ts,-2,2]);
```

```
    axis normal;
    xlabel('time(s)');
    ylabel('Amplifier(V)');
end
sgtitle('3-(b) Real part of the signals at eight subcarriers');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% 3-(c)
figure(2)
y=zeros(1,length(t));

for i=1:8
    y(1,:)=y(1,:)+x_subcarrier(i,:);
end

subplot(2,1,1);
plot(t,real(y));
title(['Real part waveform of 8 subcarriers']);
axis([0,N*Ts,-5,5]);
axis normal;
xlabel('time(s)');
ylabel('Amplifier(V)');

subplot(2,1,2);
plot(t,imag(y));
title(['Image part waveform of 8 subcarriers']);
axis([0,N*Ts,-5,5]);
axis normal;
xlabel('time(s)');
ylabel('Amplifier(V)');

sgtitle('3-(c) Sum of eight subcarriers');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% 3-(d)
figure(3);

y_ifft=8*ifft(Xk',8);

nTs=0:Ts:7*Ts;
xn_subcarrier=zeros(8,length(nTs));
```

```
for k=0:7
    xn_subcarrier(k+1,:)=Xk(k+1)*exp(j*2*pi*k*fsub*(nTs));
end
y_discrete=zeros(1,length(nTs));
for i=1:8
    y_discrete(1,:)=y_discrete(1,:)+xn_subcarrier(i,:);
end

subplot(2,1,1);
stem(nTs,real(y_ifft),'filled');
title(['Real part waveform of 8 subcarriers']);
axis([0,N*Ts,-5,5]);
axis normal;
xlabel('time(s)');
ylabel('Amplifier(V)');

subplot(2,1,2);
stem(nTs,imag(y_ifft),'filled');
title(['Image part waveform of 8 subcarriers']);
axis([0,N*Ts,-5,5]);
axis normal;
xlabel('time(s)');
ylabel('Amplifier(V)');

sgtitle('3-(d) Discrete real part and image part');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% 3-(e)
figure(4);

y_scale=y/8;

nTs=0:Ts:8*Ts;
x_stem=zeros(8,length(nTs));
for k=0:7
    x_stem(k+1,:)=Xk(k+1)*exp(j*2*pi*k*fsub*(nTs))/8;
end
y_stem=zeros(1,length(nTs));
for i=1:8
    y_stem(1,:)=y_stem(1,:)+x_stem(i,:);
```

```
end

subplot(2,1,1);
plot(t,real(y_scale));
hold on;
stem(nTs,real(y_stem),'filled');
title(['Real part waveform of 8 subcarriers']);
axis([0,N*Ts,-5/8,5/8]);
axis normal;
xlabel('time(s)');
ylabel('Amplifier(V)');

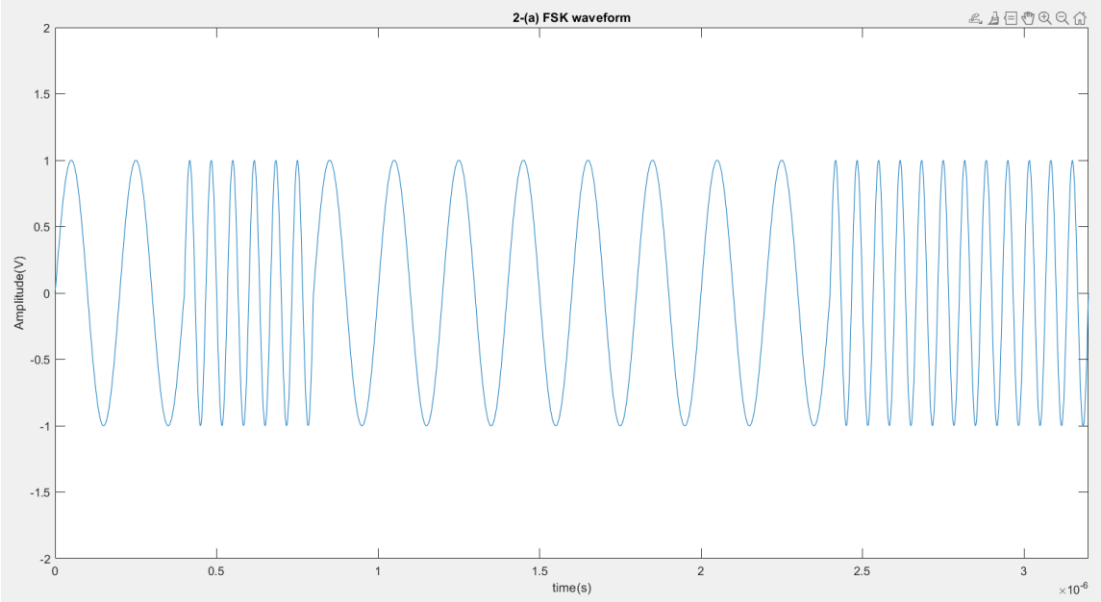
subplot(2,1,2);
plot(t,imag(y_scale));
hold on;
stem(nTs,imag(y_stem),'filled');
title(['Image part waveform of 8 subcarriers']);
axis([0,N*Ts,-5/8,5/8]);
axis normal;
xlabel('time(s)');
ylabel('Amplifier(V)');

sgtitle('3-(e) Scaling curve');
```

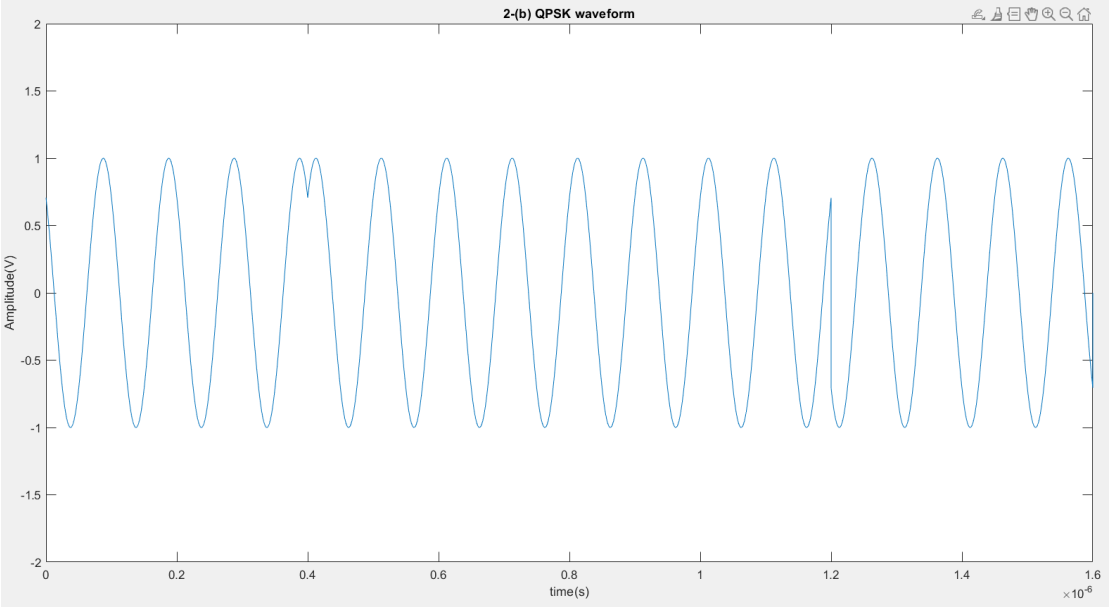
1. The 8-bit signal generated by MATLAB is: 0 1 0 0 0 0 1 1.

2.

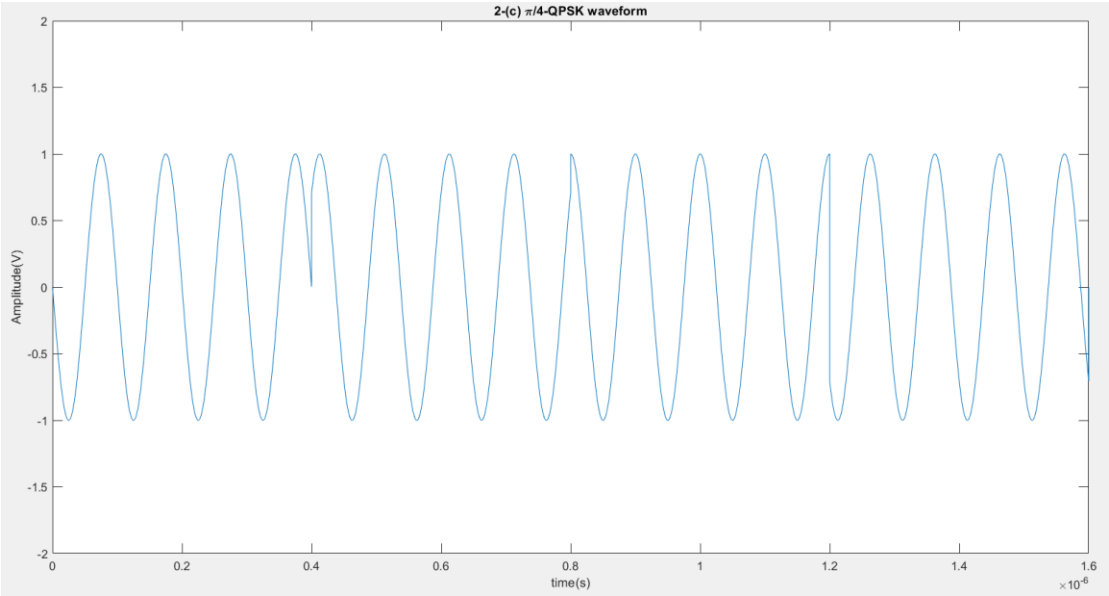
a.



b.

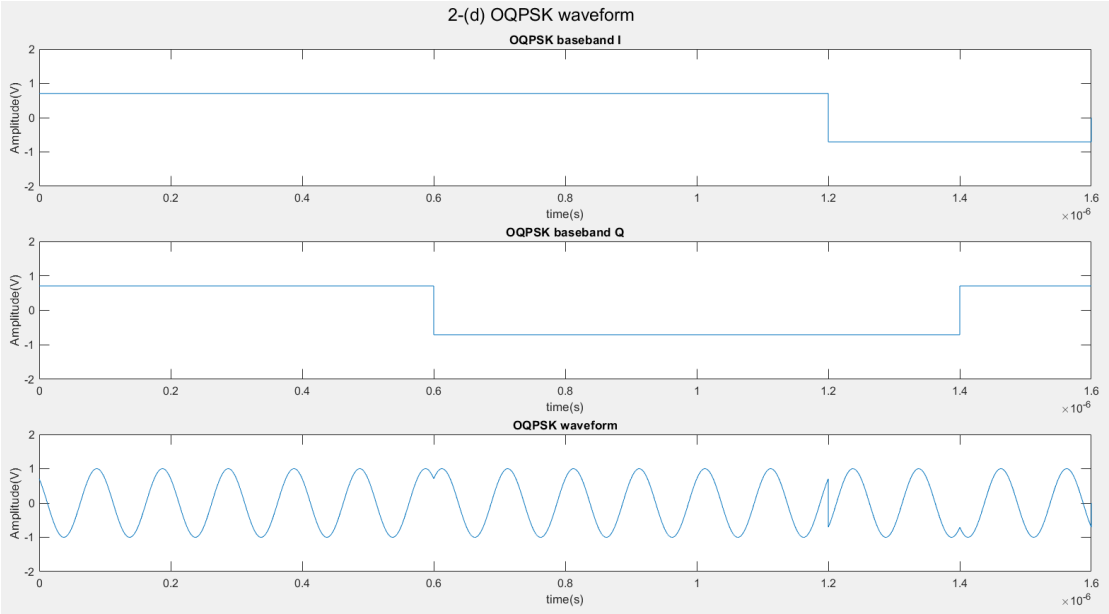


c.

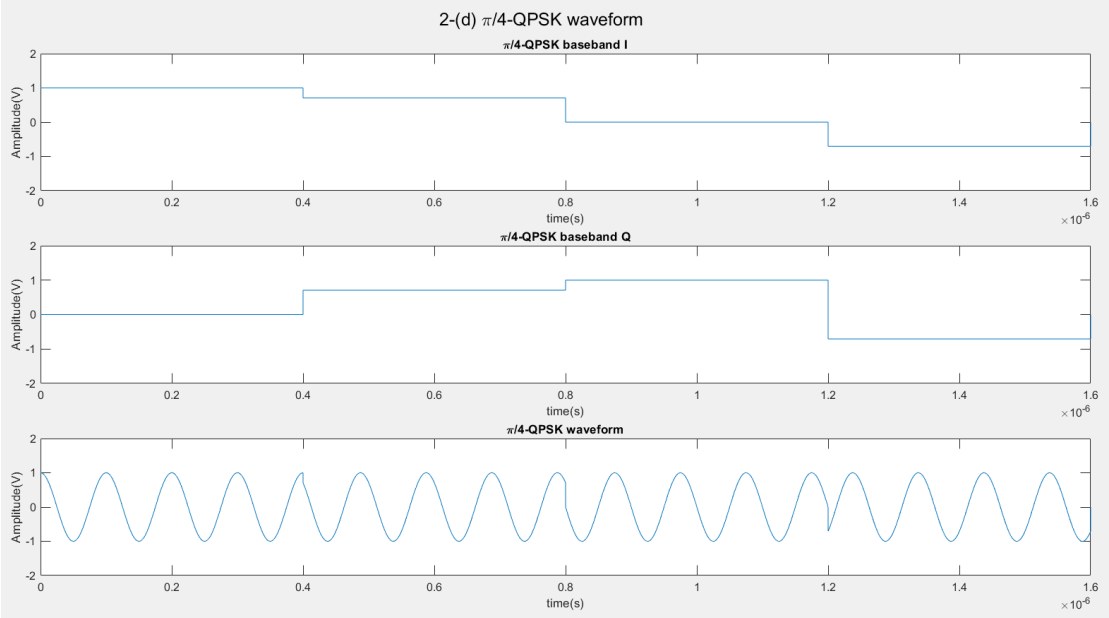

2-(c) π/4-QPSK waveform
Amplitude(V)
time(s)
×10^-6

d.

OQPSK


2-(d) OQPSK waveform
OQPSK baseband I
OQPSK baseband Q
OQPSK waveform
Amplitude(V)
time(s)
×10^-6

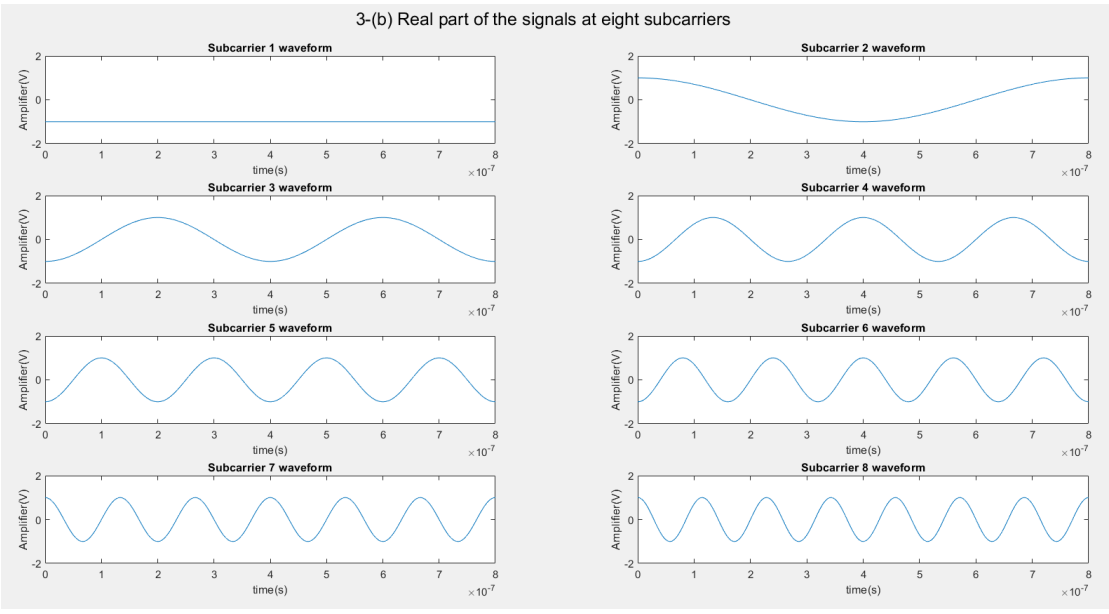
π/4-QPSK



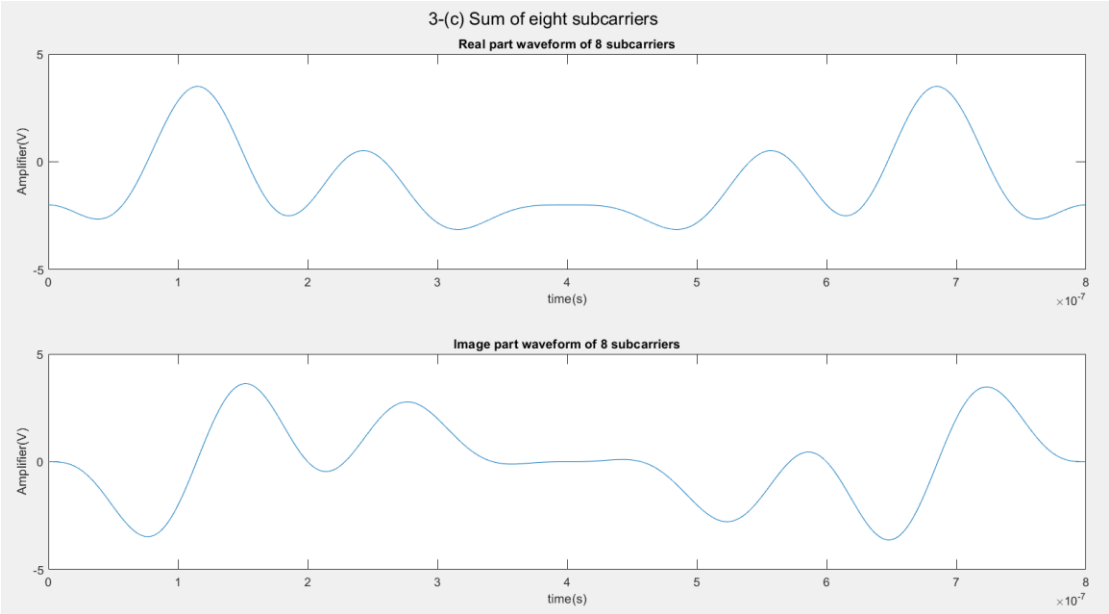
3.

a. $\mathrm{N} = 8,\ T_s = 100ns,\ f_{sub} = \frac{1}{NT_s} = \frac{1}{8\times 100ns} = 1.25MHz$

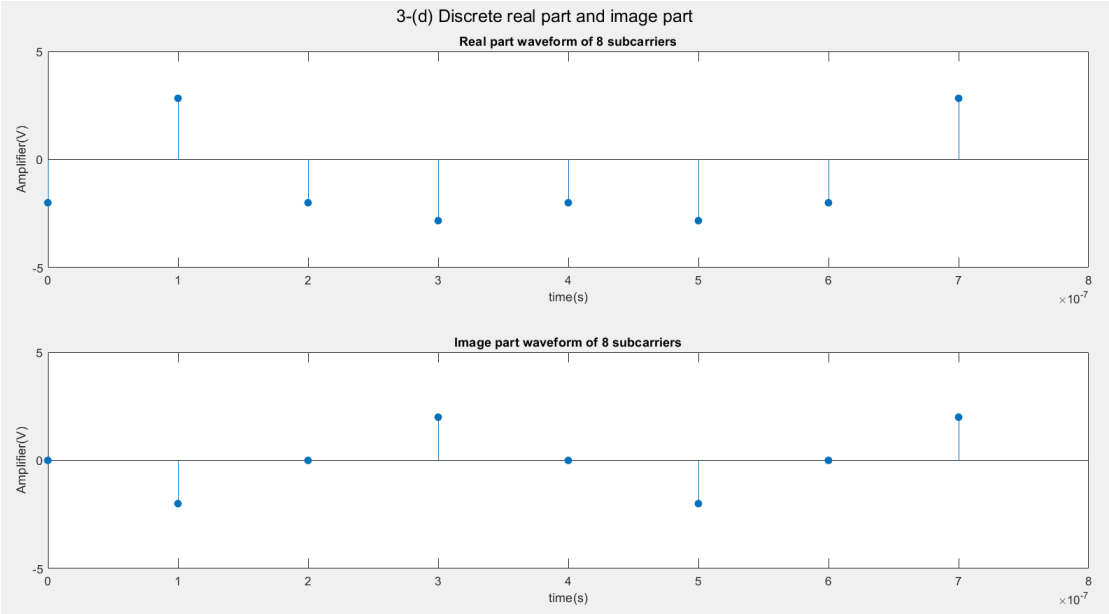
b. $b_i = \{0,1,0,0,0,0,1,1\} \xrightarrow{BPSKmapping} X_k = \{-1,+1,-1,-1,-1,-1,+1,+1\}$



c.


3-(c) Sum of eight subcarriers
Real part waveform of 8 subcarriers
Amplifier(V)
time(s)
×10^-7
Image part waveform of 8 subcarriers
Amplifier(V)
time(s)
×10^-7

d.


3-(d) Discrete real part and image part
Real part waveform of 8 subcarriers
Amplifier(V)
time(s)
×10^-7
Image part waveform of 8 subcarriers
Amplifier(V)
time(s)
×10^-7

e. After performing an inverse FFT (IFFT) on X_k to obtain the discrete-time signal, we overlay it with the continuous-time signal, resulting in the waveform shown below. The discrete-time signal perfectly aligns with the nT_s points of the continuous-time signal, satisfying $\mathrm{y}(t) = y(nT_s) = y[n]$.