QPSK Modulator/Demodulator Example

This documents describes/implements the QPSK modulation and demodulation of a song signal.

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Program Initialization

```
%Clear Variables and Close All Figure Windows

% Clear all previous variables
clear
% Close all previous figure windows
close all
```

Read and Display an Example Image

cameraman.tif is an example gray-level image provided my matlab
Load the Cameraman Image

```
Im = imread('cameraman.tif');
% Extract part of the image
Im=Im(51:100,101:150);
```

Display the image

```
imshow(Im);
```

Convert Image to a Binary Vector

We need to convert the image to a binary bit sequence

Convert 256x256 image matrix to an image (column) vector (of size 256^2x1) by concatenating columns

```
Imv=Im(:);
```

Convert each the number in each row to a binary vector

```
Imvb=de2bi(Imv);
```

Note that **Imvb** has size 256^2x8
Now generate a row vector containing all bits

```
Imvbt=Imvb';

s=Imvbt(:)';
```

Generate Modulated Signal

QPSK Modulated Signal

From the single bit sequence generate a vector sequence

```
sv=[s(1:2:end);

    s(2:2:end)];
```

QPSK Constellation Mapper [0;0]-> -1-i [0;1]-> -1+i [1;0]-> 1-i [1;1]-> 1+i

```
for k=1:size(sv,2)
    switch num2str(sv(:,k)')
        case '0  0'
            c(k)=1-i;
        case '1  0'
            c(k)=-1-i;
        case '0  1'
            c(k)=1+i;
        otherwise
            c(k)=-1+i;
        end
end
```

```
% Normalize the power to 1
c=c/sqrt(2);
```

Rectangle Modulation

```
% Sample Rate
Fsampling=2^19;
% Sample Intervale
Tsampling=1/Fsampling;
% Symbol Rate
Fsymbol=2^13;
% Symbol Period
Tsymbol=1/Fsymbol;
% Number of Samples per Symbol Period
Ns=Tsymbol/Tsampling;
```

Baseband Signal (samples)

```
xb=kron(c,ones(1,Ns));
```

Carrier frequency:

$$f_c = 60kHz$$

```
fc=60e3; % 60 kHz;

%define theta
theta=(0:pi/10:2*pi);
```

to keep BER values for different SNR values

```
BER10=(0:length(theta)-1);

BER1=(0:length(theta)-1);

for a=1:2
 for i=1:length(theta)
% Carrier signal:  _
```

$$c(t) = cos(2\pi f_c t)$$

```
t=(0:1:(length(xb)-1))*Tsampling;

cost=cos(2*pi*fc*t);

sint=sin(2*pi*fc*t);
```

Transmitter output

$$x(t) = Re(xb(t))cos(2\pi f_c t) - Im(xb(t))sin(2\pi f_c t)$$

```
x=real(xb).*cost-imag(xb).*sint;
```

Channel Effect

We add some noise

First calculate average signal energy (per sample)

```
sigpow=mean(x.^2);
```

Define SNR level in (dB)

```
if a==1
    SNR=10;
else a==2
    SNR=1;
end
```

Noise Level

```
NoiseAmp=sqrt(10^(-SNR/10)*sigpow);
```

Generate Noise signal as Gaussian Noise

```
noise=NoiseAmp*randn(1,length(x));
```

Noisy received signal

$$y(t) = x(t) + n(t)$$

```
y=x+noise;
```

The QPSK Receiver Processing

Coherent QPSK Receiver operation

First extract real component baseband signal

$$u_r(t) = 2x(t)cos(2\pi f_c t)$$

```
ur=2*y.*cos((2*pi*fc*t)+theta(i));
```

Then low pass filter this signal

$$z_r(t) = u_r(t) * h_{LP}(t)$$

```
zr = lowpass(ur,30e3,Fsampling);
```

Then extract the imaginary component baseband signal

$$u_i(t) = 2x(t)sin(2\pi f_c t)$$

```
ui=-2*y.*sin((2*pi*fc*t)+theta(i));
```

Then low pass filter this signal

$$z_i(t) = u_i(t) * h_{LP}(t)$$

```
zi = lowpass(ui,30e3,Fsampling);
```

Basband signal

```
z=zr+i*zi;
```

Constellation Estimates

We sample the baseband received signal to get noisy estimates of transmitted constellation point. This is not the best way though. Any other suggestions for improvement?

```
ce=z(ceil(Ns/2):Ns:length(z));
```

Bit Estimates

We implement QPSK Demapper to extract bits from constellation estimates

Check which quadrant ce lies in

```
ser=real(ce)>0;

sei=imag(ce)>0;

se(1:2:(2*length(ser)))=ser;

se(2:2:(2*length(ser)))=sei;
```

Calculate Bit Error Rate

```
if a==1
    BER10(i)=sum(se~=s)/length(s)
else a==2
    BER1(i)=sum(se~=s)/length(s)
end
```

```
 end
```

disp theta vs ber graph

```
if a==1
    figure(2)
    plot(theta, BER10)
    title('impact of the Receiver s Phase Error with SNR = 10')
else a==2
    figure(3)
    plot(theta, BER1)
    title('impact of the Receiver s Phase Error with SNR = 1')
end

xlabel('Receiver oscillator s phase')
ylabel('BER values')

grid

if a==1
```

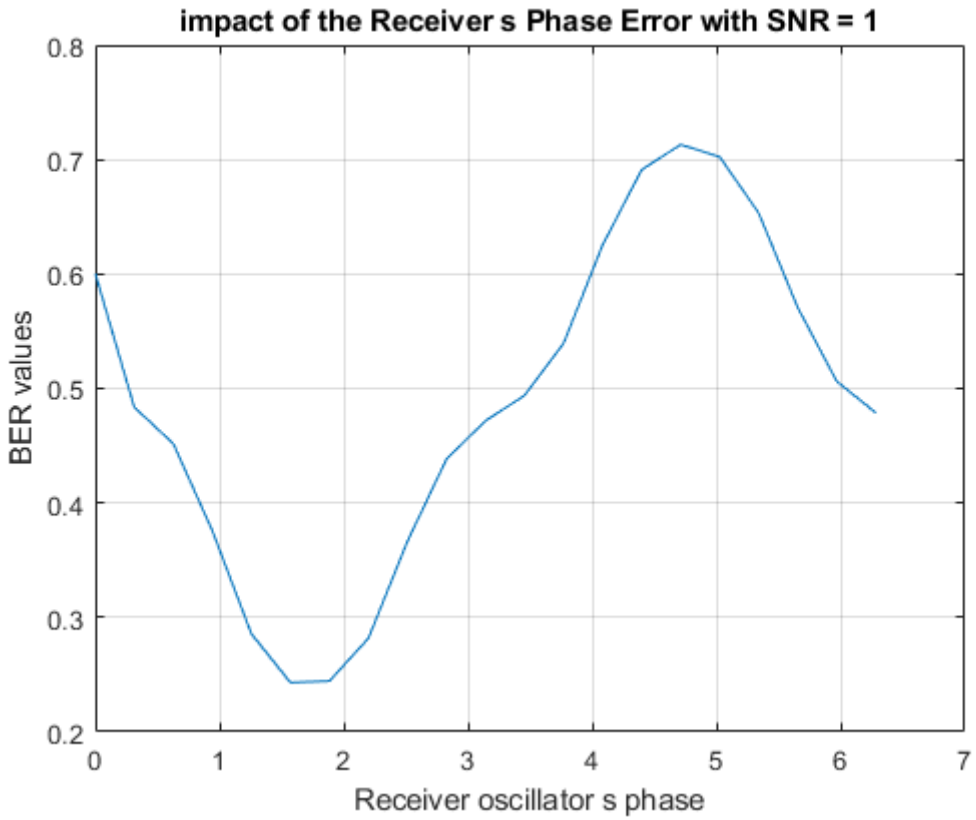
Reconstruct Image

From the bits we estimated, we reconstruct 8-bit gray level image

```
Imvbe=reshape(se,8,length(s)/8)';

% Vectorized image estimate in decimals
Imve=bi2de(Imvbe);
% Image estimate in matrix form
Ime=reshape(Imve,50,50);
figure(4)
subplot(1,2,1)
imshow(Im)
title('Transmitted')
subplot(1,2,2)

imshow(uint8(Ime))
title(['Received: BER=10'])
```




```
else a==2
```

Reconstruct Image

From the bits we estimated, we reconstruct 8-bit gray level image

```
Imvbe=reshape(se,8,length(s)/8)';

% Vectorized image estimate in decimals
Imve=bi2de(Imvbe);
% Image estimate in matrix form
Ime=reshape(Imve,50,50);
figure(5)
subplot(1,2,1)
imshow(Im)
title('Transmitted')
subplot(1,2,2)

imshow(uint8(Ime))
title(['Received: BER=1'])
```


```
end
```

```
end
```

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