ACSE Labs12

Lab Report

姓名：廖冠勳
系級：電信
學號：0860306

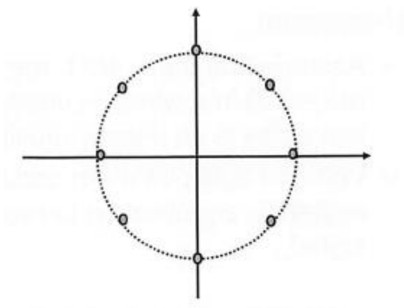
Lab 12 – Constant Envelop Modulation

A. Goal of Experiment :

- To Realize the Property of Communication System, including of QAM, PSK, MSK CPFSK, MSK, and GFSK.
- Use GFSK technique to modulate signal to make the modulated signal variaty increased.
- Use the Gaussian filter to make the signal transmitted in low demand of bandwidth.

B. Background of experiment :

■ Principle of PSK :



* Constant envelope

Signal can choose a digital modulated pattern like BPSK, QPSK, 8-PSK. The 8-PSK signal is showed above. We can formulate the formula of 8-PSK as below :

$$y = \cos\left(n * 2 * \frac{pi}{N}\right) + j * \sin\left(n * 2 * \frac{pi}{N}\right)$$

We can use N = 8 to generate a 8-PSK modulated signal. Therefore, The designed code for N-PSK can be written as :

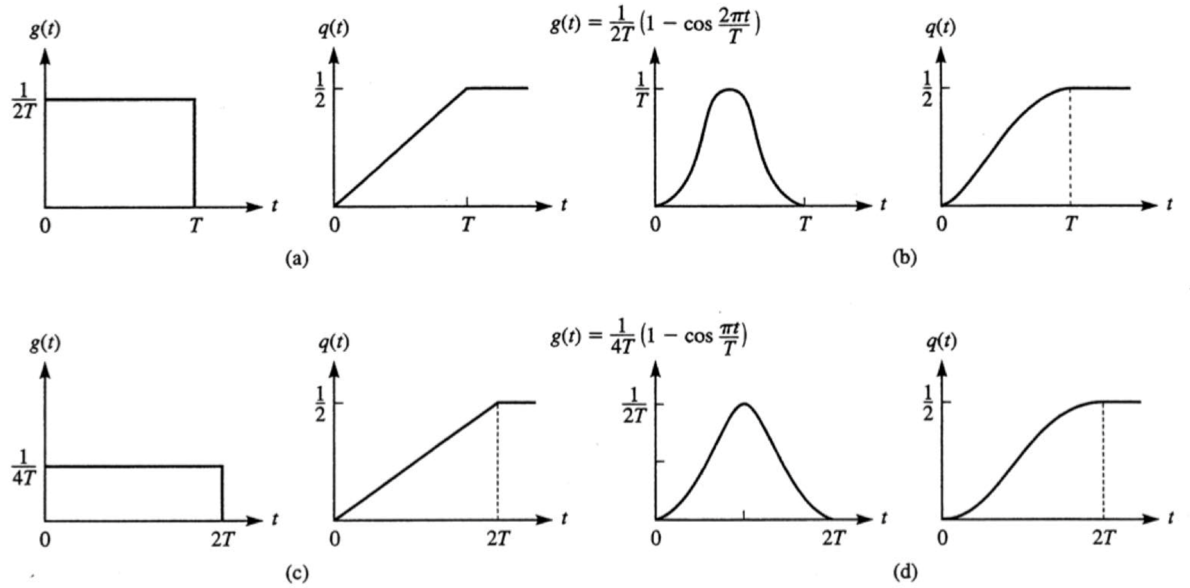
```
function mod_sig = Npsk(sig,N)
  for i = 1:length(sig)
      mod_sig(i) = cos(sig(i)*2*pi/N)+j*sin(sig(i)*2*pi/N);
  end
end
```

The n value in the notation above is the signal value itself. We can use this information to generate a N-PSK signal.

To increase the option of phase, we use the Continuous Phase Shift Keying to generate signal by the method of intergration.

$$s(t) = \sum_n a_n g(t - nT_b)$$

a_n is the signal information. $g(t - nT_b)$ is the phase shapping function which can be written as many form like rectangular or Gaussian.This modulated for of phase genrate more modulation option.



The option of $g(t - nT_b)$ is showed as below. Then we can use the intergration of $g(t - nT_b)$ to get the below formula :

$$\theta(t) = 2\pi f_d T_b \sum_{n=-\infty}^{n-1} a_k + 2\pi 2 f_d T_b \frac{(t - nT_b)}{2T_b} a_n$$

Memory term Phase term

We define some property in the above form. Let $2f_d T_b = h$ which is called modulation index of CPFSK scheme.However when $h = 1/2$, we can make the formula above as the below :

$$\theta(t) = \pi \mathrm{h} \sum_{n=-\infty}^{n-1} a_k + 2\pi \mathrm{h} \frac{(t - nT_b)}{2T_b} a_n$$

Signal at tranmission side will encouter scattering and refraction, which will arise a multipath effect in the transmitting branch. The effect of the multipath can be modeled as below.

$$\theta(t)=\frac{1}{2}\pi\mathrm{h}\sum_{n=-\infty}^{n-1}a_k+\pi\mathrm{h}\frac{(t-nT_b)}{2T_b}a_n=\theta_{\mathrm{n}}+2\pi\mathrm{h}\frac{(t-nT_b)}{4T_b}a_n$$

Then we use this phase to get the signal :

$$S_{MSK}(t)=Acos\big(2\pi f_c t+\theta(t)\big)=Acos(2\pi\left(f_c+\frac{I_n}{4T}\right)t-\frac{n\pi I_n}{2}+\theta(\mathrm{n}))$$

Since $I_n\in\{\pm1\}$, $s_{MSK}(t)$ has two frequency components :

$$f_1=f_c-\frac{1}{4T}$$

$$f_2=f_c+\frac{1}{4T}$$

So $f_1-f_2=\frac{1}{2T}$ ，this result will gaurantee that we will make the CPSK signal orthogornal in the pass band. This special case is called minimum shift keying.

- Gaussian Filter Shift Keying :

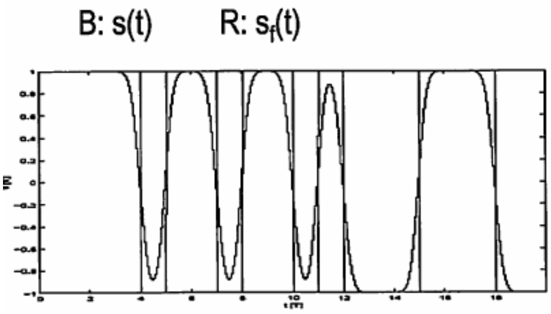
Let B be 3dB bandwidth of Gaussian filter. Its frequenct and impulse response can be represented as :

$$H(f)=\exp\left(-\frac{log2}{2}\left(\frac{f}{B}\right)^2\right)$$

$$\mathrm{h(t)}\ =\sqrt{\frac{2\pi}{log2}}\mathrm{B}\exp\left(-\frac{2\pi^2}{log2}B^2t^2\right)$$

$$\mathrm{h}(n)=h(nT)=C\exp\left(-\frac{2\pi^2}{log2}\frac{B}{Mf_b}^2n^2\right)$$

We can convolve the Gaussian filter to make the phase shapping as Gaussian type as below digram.



For a band spread signal, we will get a bandlimited in frequency domain. We will use less bandwidth by using this filter.

C. Experiment result and analysis :

- Practice Experiment Result :
  - Practice 1 :
    - Notation of Practice 2 :

      From background of this experiment, we can utilize the below formula to relize how the relationship between time doamin and frequncy domain of the Gaussian filter.

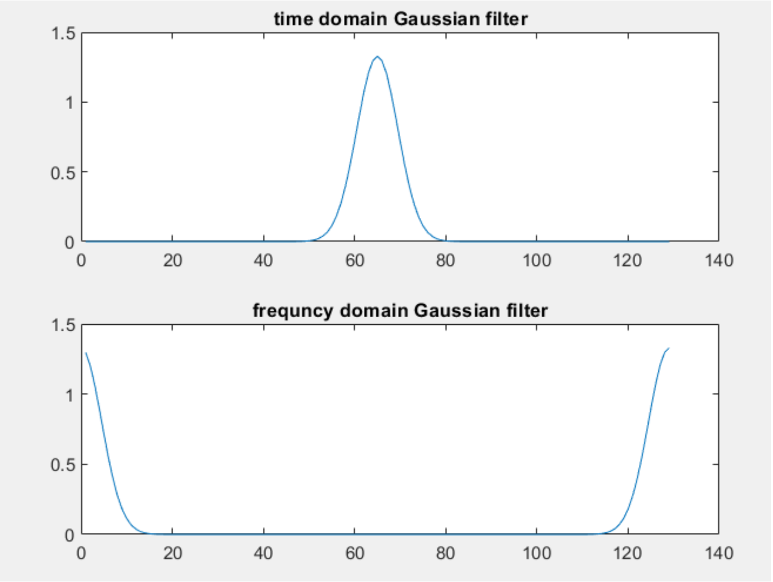
$$H(f) = \exp\left(-\frac{log2}{2}\left(\frac{f}{B}\right)^2\right)$$

$$\mathrm{h(t)} = \sqrt{\frac{2\pi}{log2}}\mathrm{B}\exp\left(-\frac{2\pi^2}{log2}B^2t^2\right)$$

      From this result we can conculde that both time domain and frequency filter will be gaussian distribution shape.

    - List of parameter utilize in the experiment :

f_b	2
$T_b = \frac{1}{f_b}$	1/2
BT	0.5
M	17



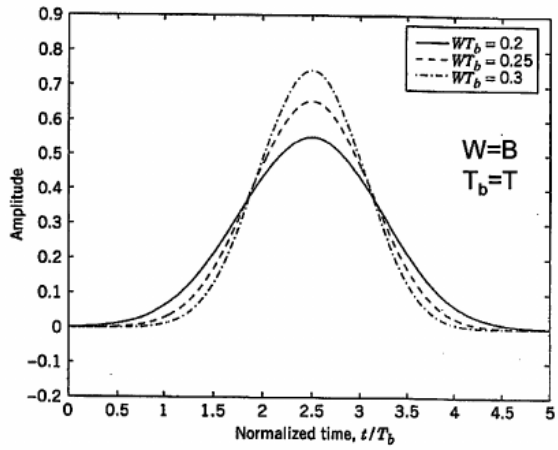
As we mentioned in the notation , we can get the gaussian shape like in the experiment.The Gaussian filter can be implemented as below code.

```
B = BT/Tb;
C = sqrt(2*pi/log(2)) * B;
g_filter = C*exp(-2*(pi^2)/log(2)*(BT/M)^2*(t.^2));
```

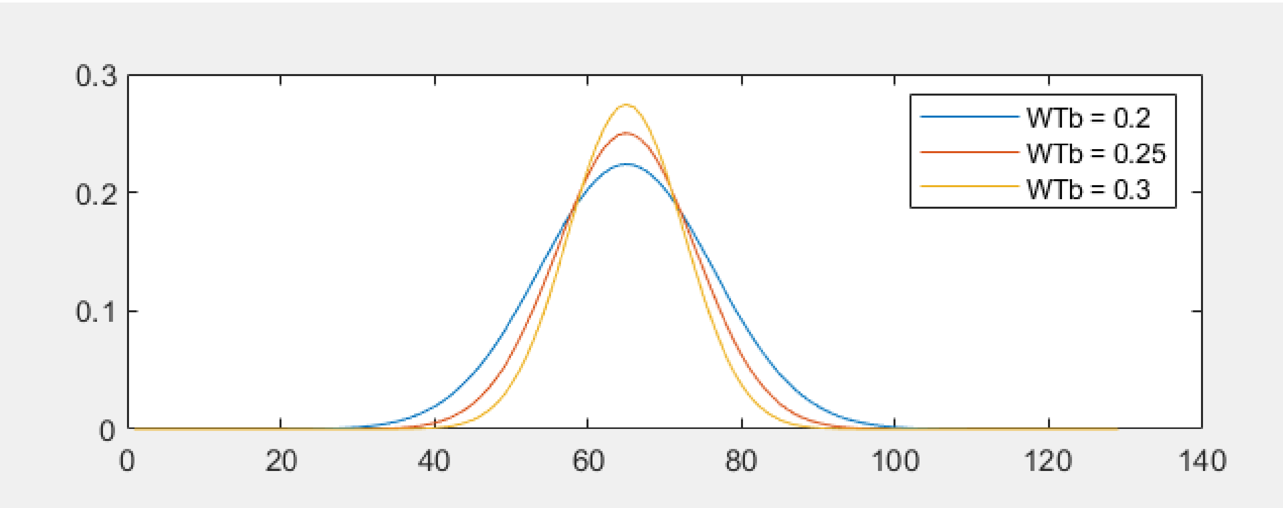
Notice :
This filter will cause a gain in both time and frequncy domain. To gaurantee a unit energy gain . We should Nomalize the filter by L_2 norm to get a unit energy gain response.

```
g_filter = g_filter ./ sqrt(sum(g_filter.^2));
```

For different BT of Gaussian filter, we can get the below graph :



To verify this result I also do the experiment like above diagram:



- Practice 3 :
  - Notation :

    From background of this experiment, we can utilize the below formula to make some analysis.

    CPFSK of transmitted signal :

$$A\cos\left(2\pi f_c t + \theta(t)\right)$$

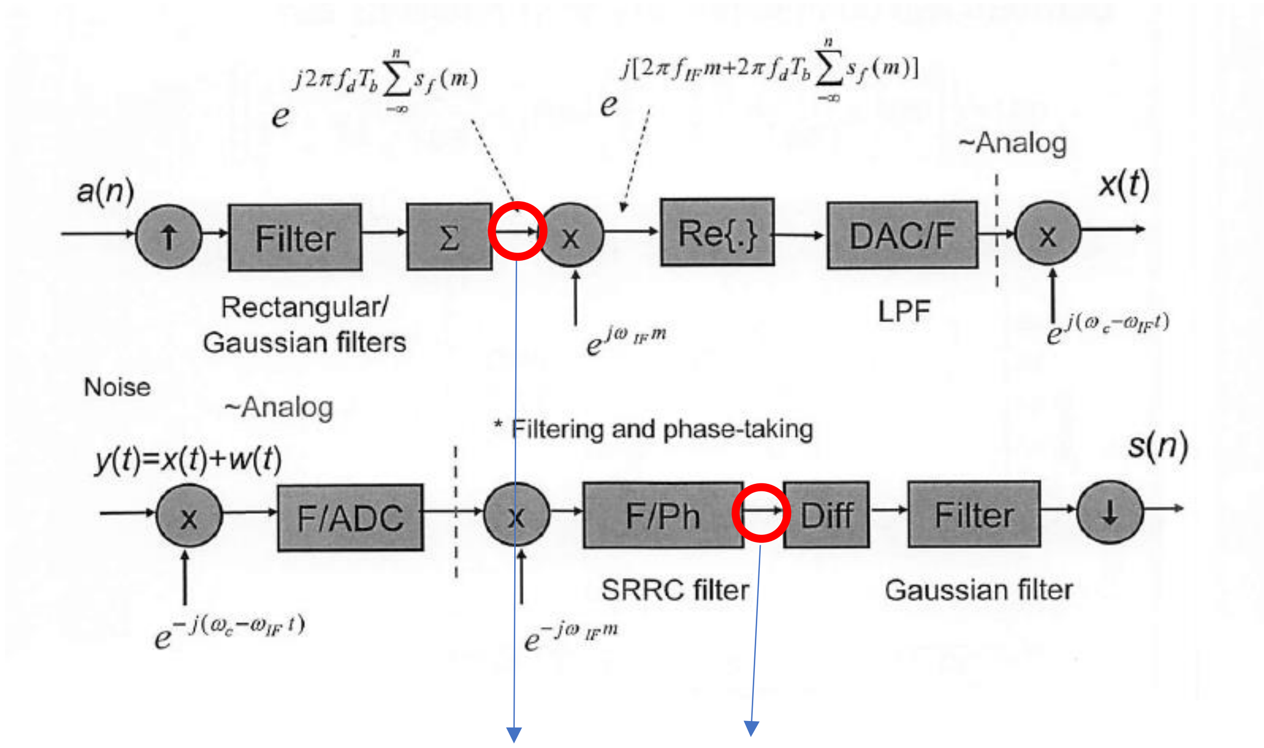
where :

$$\theta(t) = 2\pi f_d T_b \sum_{n=-\infty}^{n-1} a_k + 2\pi 2 f_d T_b \frac{(t - nT_b)}{2T_b} a_n$$

  - List of parameter utilize in the experiment :

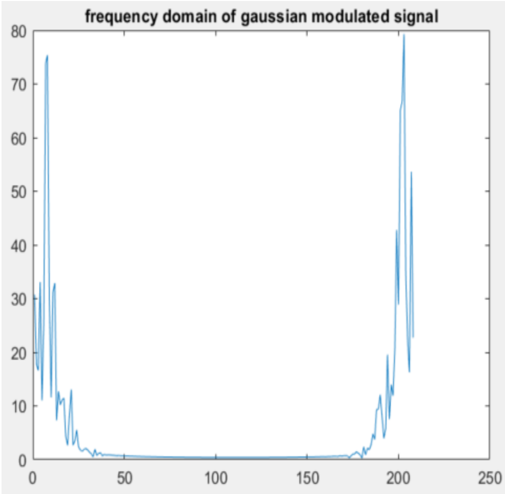
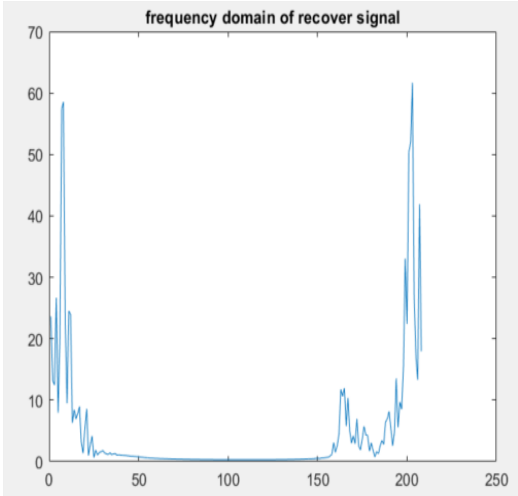
$f_b(10\text{^}6)$	1
$T_b = \frac{1}{f_b}$	1
f_d	0.15
Modulation index	0.3
AWGN_SNR_DB	10

  - Block diagram and some notation in the experiment :



Frequency response and phase plot

◆ Experiment result :

<table>
<tr><td>Freqeuncy domain</td><td>
</td><td>
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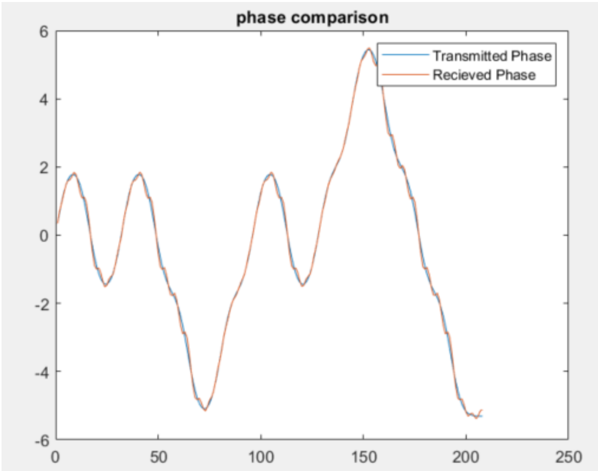
<tr><td>Phase comparison</td><td colspan="2">
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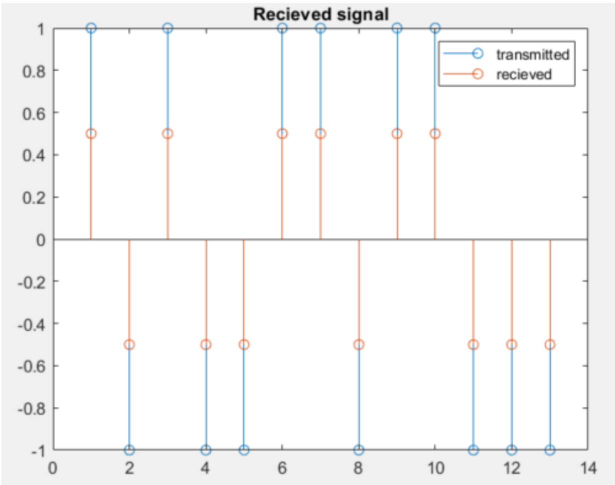
<tr><td>Received Signal</td><td colspan="2">
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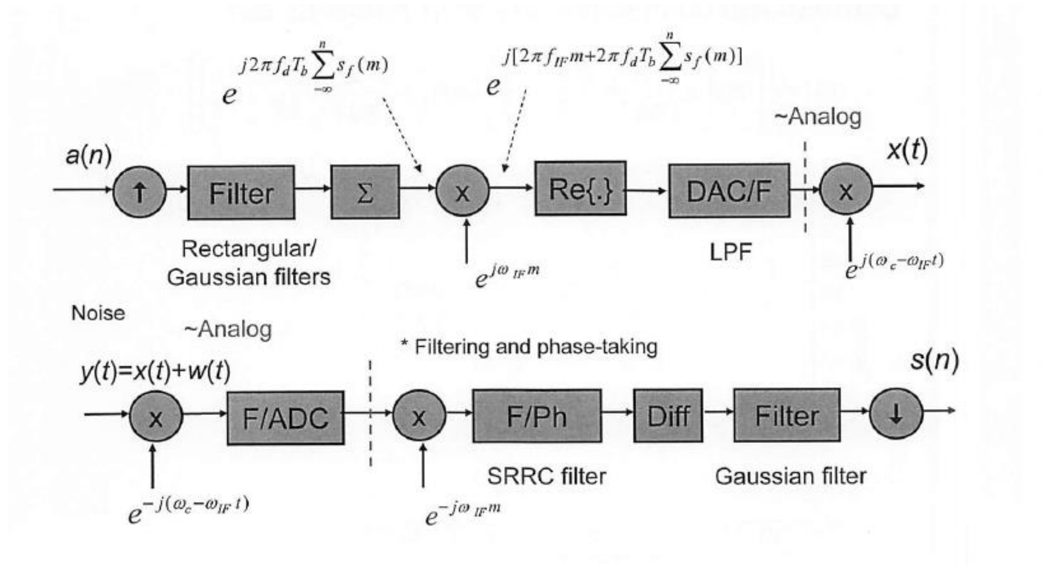
We can get almost the same phase, frequency, and time respone of the transmitted and received signal. We will explore more property of some combination of parametors in the Homework experiment.

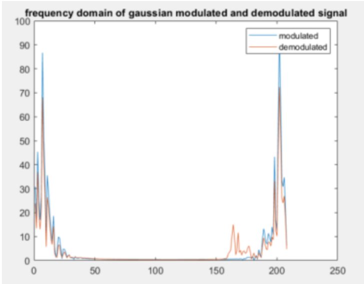
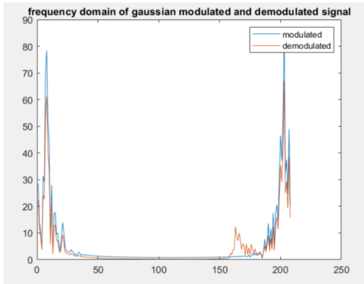
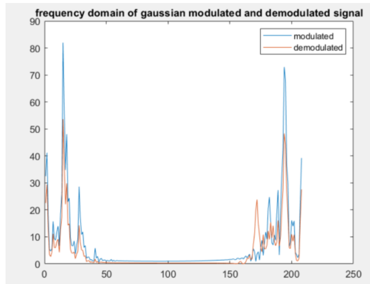
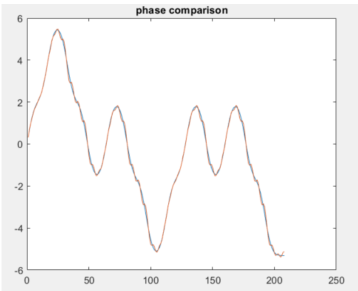
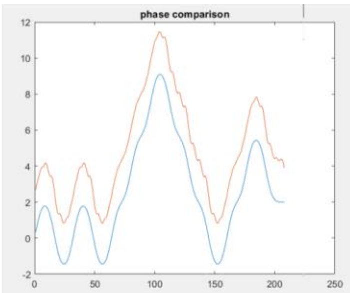
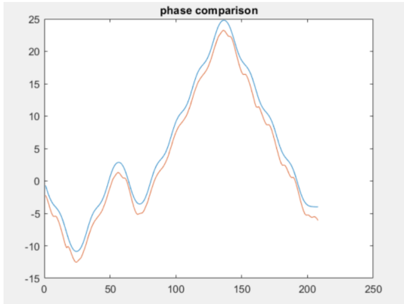
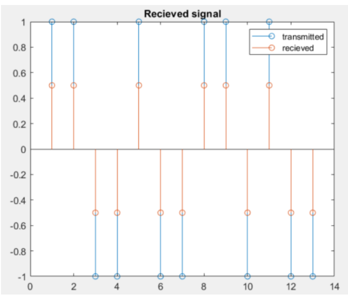
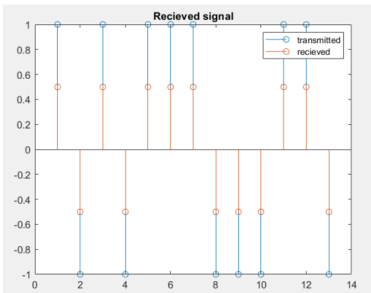
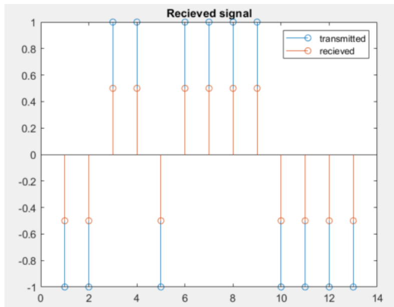
- Home work Experiment Result :

  - Experiment result :

Signal Type	BPSK
DAC UP factor	16 = sampling rate of the DAC / symbol rate
DMA UP factor	4 = sampling rate for DMA filter / sampling rate of the DAC
ADC Tap interval(T_{ADC})	64
System Architecture	

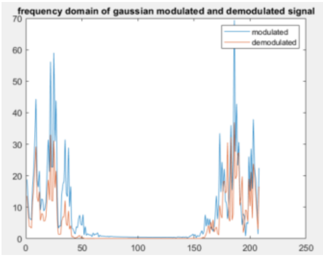
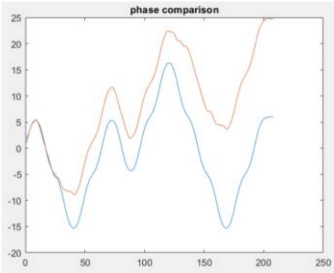
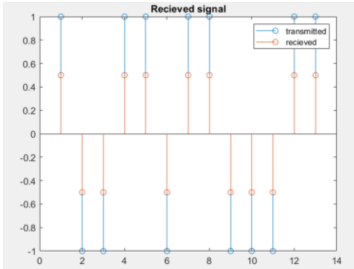
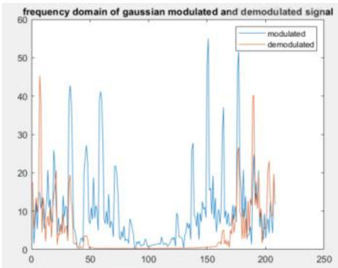
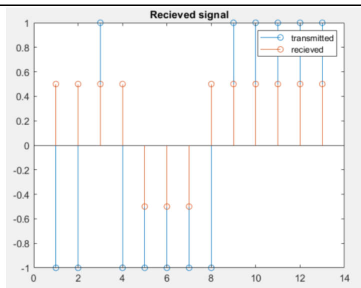
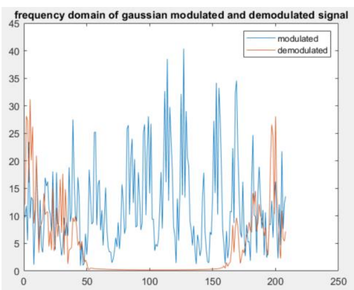
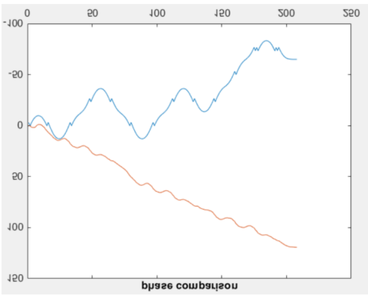
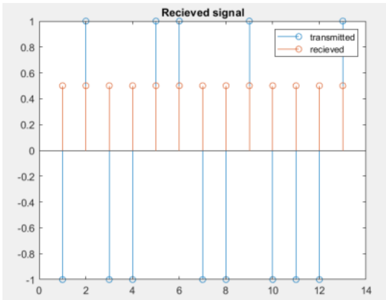
- List of parameter utilize in the experiment :

f_b	1	1	1
$T_b = \frac{1}{f_b}$	1	1	1
f_d	0.15	0.15	2*0.15
Modulation index	0.3	0.3	0.6
AWGN_SNR_DB	10	2	10
Notation of Experiment	A	B	C

	A	B	C
Freqeuncy domain			
Phase comparison			
Received Signal			

By the experiment A & B Group, We can observe that the AWGN is not so cirtical to the CPFSK modulation system. B will cause a little shift impact on the phase. However, in the C group. We can observe more phase shift and frequncy shift. Based on our observation, we can explore more experiment on the modification of parametor f_d .

Modulation index is abbreviated as Midx :

	Freqeuncy domain	Phase comparison	Received Signal
f_d : $3*0.15$ Midx : 0.9			
f_d : $6*0.15$ Midx : 1.8			
f_d : $9*0.15$ Midx : 2.7			

From the previous formula we can get the phase form that :

CPFSK of transmitted signal :

$$A\cos\left(2\pi f_c t+\theta(t)\right)$$

Where :

$$\theta(t)=\frac{1}{2}\pi \mathrm{h}\sum_{n=-\infty}^{n-1} a_k+\pi \mathrm{h}\frac{(t-nT_b)}{2T_b}a_n=\mathrm{h}^*(\frac{1}{2}\pi\sum_{n=-\infty}^{n-1} a_k+\pi\frac{(t-nT_b)}{2T_b}a_n)$$

h dominate the phase of the signal . As we increase the h , we will get a larger phase change which will cause a phase shift in this experiment result.