Communication Theory Lab Report

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Date: April 1, 2022
Communication Theory Lab
(EE304P, Spring-2022)

Lab Assignment # 4

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Digital Modulation Techniques

Abstract

In this experiment, we have tried to understand the concept of Amplitude shift keying, Frequency shift keying and Phaae shift keying in time domain by giving rectangular pulse as an input. We analysed these prominent digital modulation techniques by plotting their graphs in MATLAB. In all the techniques, we observed the modulated waveforms and have tried to explained them in this report.

1 Theory

Digital modulation techniques are widely used for communication because of its improved transmission, data security and information storage capacity, as compared to analog modulation techniques which we discussed in my last reports. We have a plethora of modulation techniques, but in this report, we have implemented only three that are as follows:

1. ASK - Amplitude Shift Keying
2. PSK - Phase Shift Keying
3. FSK - Frequency Shift Keying

ASK is a digital to analog conversion technique. In amplitude shift keying, the amplitude of the carrier signal is varying with that of the message signal.

Consider m(t) as the message signal and c(t) as carrier signal. So m(t) here is a digital signal (it will be having a string of 0s and 1s). Also c(t) = Ac*cos($_c$*t). So the ASK modulated signal is given by -

$$\phi_i(t) = m(t) * cos(\omega_c * t) \tag{1}$$

FSK is a digital to analog conversion technique. In frequency shift keying, the frequency of the carrier signal is varying with the amplitude of the message signal.

Consider m(t) as the message signal and c1(t) and c2(t) as carrier signals with frequencies f_1 and f_2. So m(t) here is a digital signal (it will be having a string of 0s and 1s). Also c(t) will be of the form Ac*cos($_c$*t). So the FSK modulated signal is given by -

$$\phi_i(t) = A * cos(\omega_c 1 * t)\text{when m(t) = 0} \quad (2)$$

$$\phi_i(t) = A * cos(\omega_c 2 * t)\text{when m(t) = 1} \quad (3)$$

PSK is a digital to analog conversion technique. In phase shift keying, the phase of the carrier signal is varying with the amplitude of the message signal.

Consider m(t) as the message signal and c(t) as carrier signal with frequency f_1. So m(t) here is a digital signal (it will be having a string of 0s and 1s). Also c(t) will be of the form Ac*cos($_c$*t). When the message signal goes from 1 to 0. phase reversal will take place. So the PSK modulated signal is given by

$$phase = 0° \text{ when m(t) = 1} \quad (4)$$

$$phase = 180° \text{ when m(t) = 0} \quad (5)$$

1.1 Block Diagram

The block diagram is only for ASK. You can see message signal (m(t)) getting multiplied with the carrier signal to form the modulated signal.

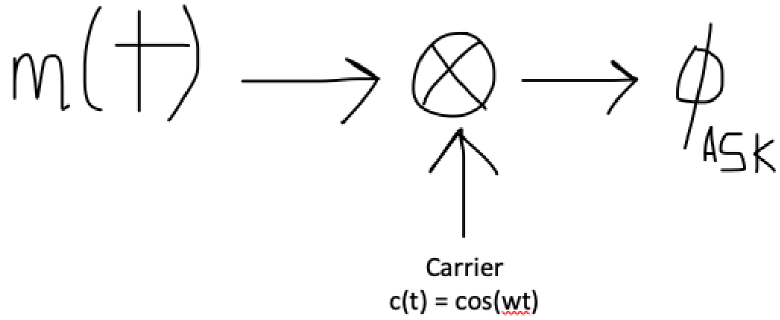

Figure 1: ASK block diagram

1.2 Expected Outcome

The figures below are not drawn to scale.

1.2.1 Answer 1

This question was taken directly from what was taught in the lectures.

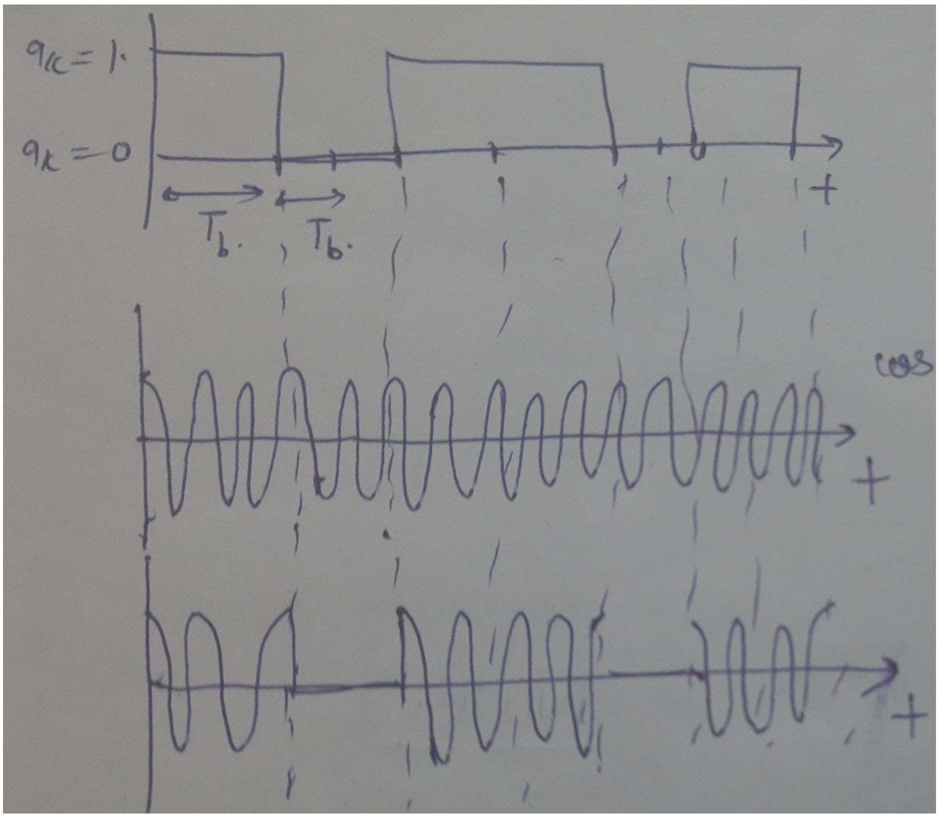

Figure 2: Figure for part A

1.2.2 Answer 2

This is directly taken from the lecture.

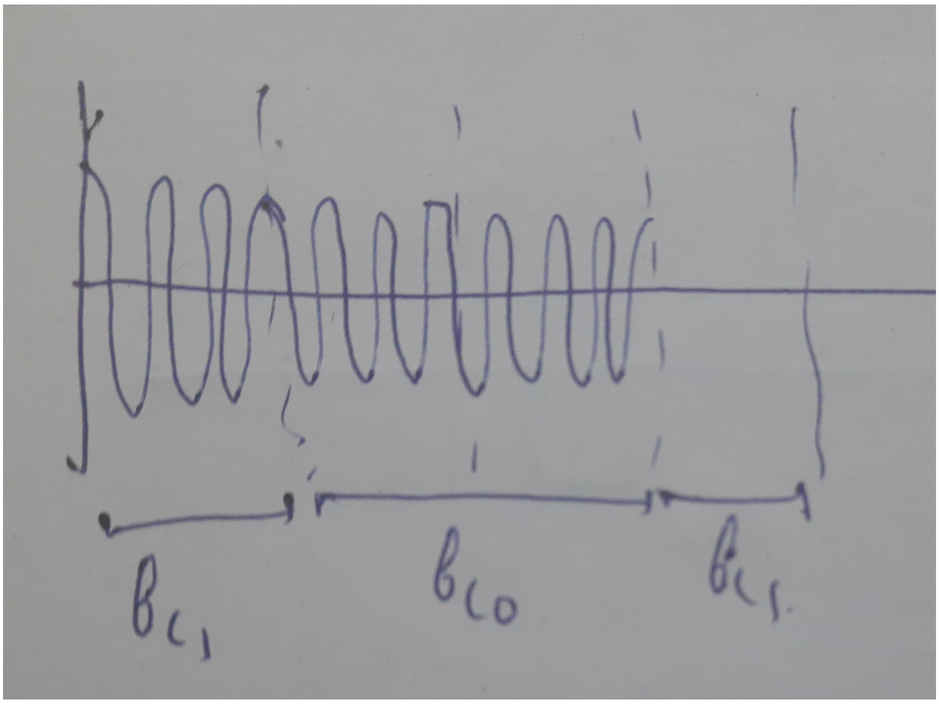

Figure 3: Figure for part B

1.2.3 Answer 3

This question was taking inference from what was taught in the lectures.

1.3 Application

Applications of digital modulation:

1. `US Alert system:` FSK is also used for transmitting warning messages for the United States' Emergency Alert System.

2. `telephone-line modems :` Old television line modems used FSK for retrieving and sending data and it's speed was up to 1.2K MBPS.

3. `Low-frequency RF applications:` ASK is widely used in RF applications which deal with lower frequency range. It is also used in home automation devices.

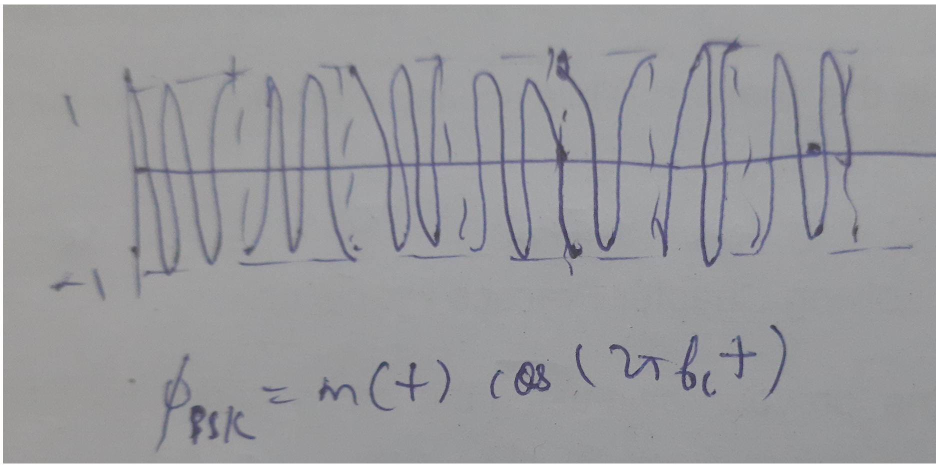

Figure 4: Figure for part C

4. `Wireless Lans:` PSK is widely used in applications of contactless operations, RFID, Bluetooth communications etc.

2 Results and Inferences

2.1 Answer 1

We have,

$$\phi(t) = m(t) * Ac * sin(2\pi f_c t) \tag{6}$$

We can see that it relates to ASK (Amplitude shift keying) modulation, a digital modulation technique discussed above.

Inferences are :

1. We can see that for the time interval where the amplitude of the message signal (m(t)) is high, here $a_k = +1$, the modulated signal is exactly same as that of the carrier wave. Also wherever the amplitude of message signal is low, here $a_k = 0$, the modulated signal is also zero. Thus we can say that amplitude of message signal is governing the amplitude of modulated signal.

2. The maximum amplitude of modulated signal is same as that of the carrier signal.

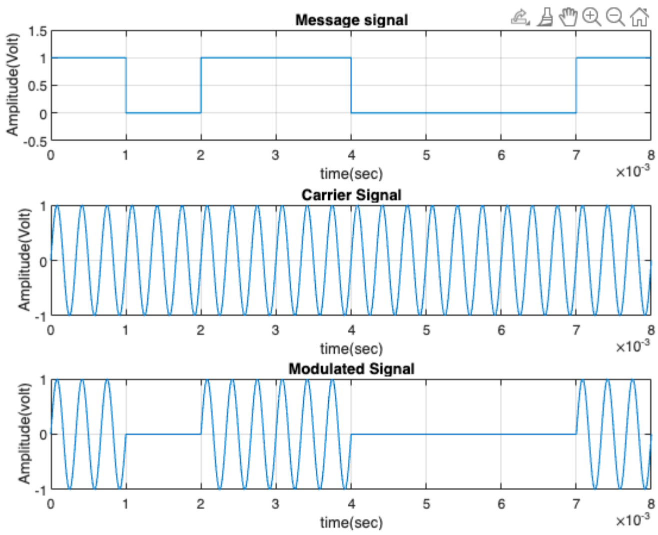

Figure 5: Figure for part A

2.2 Answer 2

We have,

$$\phi(t) = \Sigma(a_k * p(t - kT_b) * A_c * sin(2\pi f_c t)) + \Sigma((1 - a_k) * p(t - kT_b) * A_c * sin(2\pi f_{c0} t)) \tag{7}$$

It is given that :

1. ak = 10110001, So
2. 1-ak = 01001110

We can see that the frequency of the modulated signal is being changed as per the amplitude of the message signal, hence it is a FSK (Frequency shift keying) modulation.

Inferences are :

1. We have two carriers here, one with a frequency of 2KHz and other with 3KHz. Whenever ak = 1, the modulated signal follows the carrier wave that has the frequency of 2KHz. Whereas in the either case, it will be following the carrier wave with the frequency of 3KHz. It is also evident in the plots.
2. The amplitude of the modulated signal is same as the carrier signal.
3. The maximum amplitude of the modulated signal remains constant over the time.

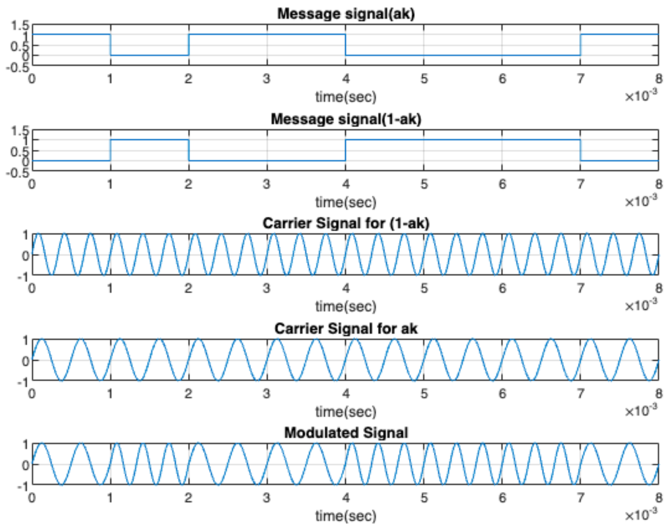

Figure 6: Figure for part B

2.3 Answer 3

We have,

$$\phi(t) = m(t) * Ac * sin(2\pi f_c t) \tag{8}$$

It is given that :

1. ak = 1 -1 1 1 -1 -1 -1 1

Inferences are :

1. We can see that whenever there is a shift in amplitude of message signal from +1 to -1 or vice-versa, there is an abrupt phase change in the modulated signal by 180 degrees; in other words, phase reversal. This behavior of phase changing as the amplitude of the message signal is PSK (Phase shift keying) modulation.
2. The amplitude of the modulated signal is same as the carrier signal.
3. For ak = 1, ϕ (t) = Ac* sin($2\pi f_c$ t). And for ak = -1, ϕ (t) = - Ac* sin($2\pi f_c$ t) = Ac* sin($2\pi f_c$ t + 180)

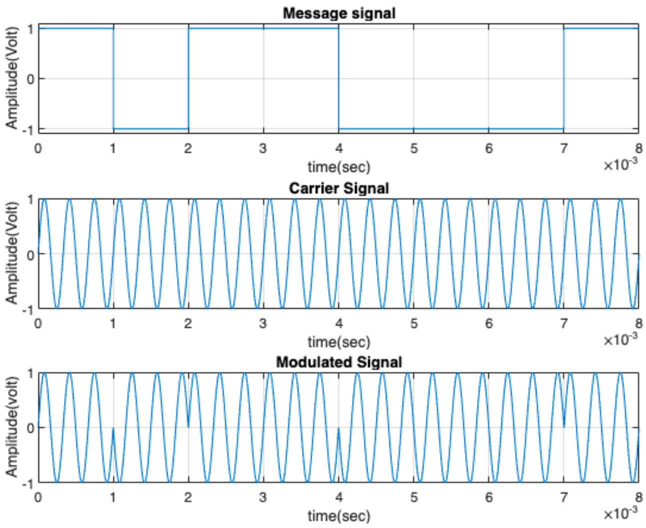

Figure 7: Figure for part C

Appendix

A Matlab Commands

Table 1: Matlab commands used in this lab.

Matlab Command	Function
`plot(`x, y`)`	plots values of the simulation series y along the y-axis, with values of the simulation series x along the x-axis.
`figure()`	creates a new figure in MATLAB.
`title(x)`	adds a title x to the plot
`xlabel(x)`	adds a horizontal label x (along x axis) to the plot
`ylabel(x)`	adds a vertical label x (along y axis) to the plot
`grid on`	adds a grid to the plot.
`clc`	clears everything from the matlab command line window.
`linspace(x1,x2,p)`	generates p equally distant points between x1 and x2.
`subplot(abc)`	generates a subplot of size a x b, and the current image is of index c
`ones(length)`	creates an array of 1s.
`size`	gives length of an array

B Matlab Code

Matlab codes for each part.

B.1 Q1(a)

```
clc;
close all;
```

```
% defining time for message signal
Tb = .001;
t1 = 0:Tb/999:Tb;
t2 = Tb:Tb/999:2*Tb;
t3 = 2*Tb:Tb/999:3*Tb;
t4 = 3*Tb:Tb/999:4*Tb;
t5 = 4*Tb:Tb/999:5*Tb;
t6 = 5*Tb:Tb/999:6*Tb;
t7 = 6*Tb:Tb/999:7*Tb;
t8 = 7*Tb:Tb/999:8*Tb;

%defining time array
t = [t1 t2 t3 t4 t5 t6 t7 t8];

% defining ak
y1 = ones(size(t1));
y2 = zeros(size(t2));
y3 = ones(size(t3));
y4 = ones(size(t4));
y5 = zeros(size(t5));
y6 = zeros(size(t6));
y7 = zeros(size(t7));
y8 = ones(size(t8));

%defining message signal
ym = [y1 y2 y3 y4 y5 y6 y7 y8];

%plot ym
figure();
subplot(3,1,1);
plot(t ,ym);
ylim([-0.5 1.5]);
title("Message signal");
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
grid on;

% defining a carrier signal
Ac=1;
fc=3000;
Tc = 1/fc;
```

```
t1 = 0:Tc/333.33:(Tc*24);
yc=Ac*sin(2*pi*fc*t);
subplot(3,1,2);
plot(t1,yc);
title("Carrier Signal");
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
grid on;

% defining a modulated signal
y = (ym.*yc);
subplot(3,1,3);
plot(t,y);
title("Modulated Signal");
xlabel("time(sec)");
ylabel("Amplitude(volt)");
grid on;
```

B.2 Q1(b)

```
clc;
close all;

% defining time for message signal
Tb = .001;
t1 = 0:Tb/999:Tb;
t2 = Tb:Tb/999:2*Tb;
t3 = 2*Tb:Tb/999:3*Tb;
t4 = 3*Tb:Tb/999:4*Tb;
t5 = 4*Tb:Tb/999:5*Tb;
t6 = 5*Tb:Tb/999:6*Tb;
t7 = 6*Tb:Tb/999:7*Tb;
t8 = 7*Tb:Tb/999:8*Tb;

%defining time array
t = [t1 t2 t3 t4 t5 t6 t7 t8];

% defining ak
y11 = ones(size(t1));
y12 = zeros(size(t2));
```

```
y13 = ones(size(t3));
y14 = ones(size(t4));
y15 = zeros(size(t5));
y16 = zeros(size(t6));
y17 = zeros(size(t7));
y18 = ones(size(t8));

%defining message signal
ym1 = [y11 y12 y13 y14 y15 y16 y17 y18];

%plot ym1
figure();
subplot(5,1,1);
plot(t ,ym1);
ylim([-0.5 1.5]);
title("Message signal(ak)");
xlabel("time(sec)");
grid on;
%ylabel("Amplitude(Volt)");

%defining (1-ak)
y21 = zeros(size(t1));
y22 = ones(size(t2));
y23 = zeros(size(t3));
y24 = zeros(size(t4));
y25 = ones(size(t5));
y26 = ones(size(t6));
y27 = ones(size(t7));
y28 = zeros(size(t8));

%defining amplitudes of wave list
ym2 = [y21 y22 y23 y24 y25 y26 y27 y28];

%plot ym2
figure(1);
subplot(5,1,2);
plot(t ,ym2);
ylim([-0.5 1.5]);
title("Message signal(1-ak)");
xlabel("time(sec)");
grid on;
```

```
%ylabel("Amplitude(Volt)");

% plotting carrier signal
Ac=1;
fc0=3000;
Tc0 =  1/fc0;
t1 = 0:Tc0/333.33:(Tc0*24);
yc0=Ac*sin(2*pi*fc0*t);
subplot(5,1,3);
plot(t1,yc0);
title("Carrier Signal for (1-ak)");
xlabel("time(sec)");
grid on;
%ylabel("Amplitude(Volt)");

%plotting carrier signal 2
fc1=2000;
Tc1 =  1/fc1;
t1 = 0:Tc1/499.99:(Tc1*16);
yc1=Ac*sin(2*pi*fc1*t);
subplot(5,1,4);
plot(t1,yc1);
title("Carrier Signal for ak");
xlabel("time(sec)");
grid on;
%ylabel("Amplitude(Volt)");

% modulated signal
y = (ym1.*yc1)+(ym2.*yc0);
subplot(5,1,5);
plot(t1,y);
title("Modulated Signal");
xlabel("time(sec)");
%ylabel("Amplitude(volt)");
grid on;
```

B.3 Q1(c)

```
clc;
close all;
```

```
% defining time for message signal
Tb = .001;
t1 = 0:Tb/999:Tb;
t2 = Tb:Tb/999:2*Tb;
t3 = 2*Tb:Tb/999:3*Tb;
t4 = 3*Tb:Tb/999:4*Tb;
t5 = 4*Tb:Tb/999:5*Tb;
t6 = 5*Tb:Tb/999:6*Tb;
t7 = 6*Tb:Tb/999:7*Tb;
t8 = 7*Tb:Tb/999:8*Tb;

%defining time array
t = [t1 t2 t3 t4 t5 t6 t7 t8];

%new definition
y1 = ones(size(t1));
y2 = -1*ones(size(t2));
y3 = ones(size(t3));
y4 = ones(size(t4));
y5 = -1*ones(size(t5));
y6 = -1*ones(size(t6));
y7 = -1*ones(size(t7));
y8 = ones(size(t8));

%defining message signal
ym = [y1 y2 y3 y4 y5 y6 y7 y8];

%plot message signal
figure(1);
subplot(3,1,1);
plot(t ,ym);
ylim([-1.1 1.1]);
title("Message signal");
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
grid on;

%carrier signal
Ac=1;
fc=3000;
```

```
Tc =  1/fc;
t1 = 0:Tc/333.33:(Tc*24);
yc=Ac*sin(2*pi*fc*t);
subplot(3,1,2);
plot(t,yc);
title("Carrier Signal");
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
grid on;

% modulated signal
y = (ym.*yc);
subplot(3,1,3);
plot(t1,y);
title("Modulated Signal");
xlabel("time(sec)");
ylabel("Amplitude(volt)");
grid on;
```

References

[1] IIT Mandi lectures on EE304 offered by Dr Adarsh https://cloud.iitmandi.ac.in/d/4bb3a5f304334160ab67/

[2] Electronic notes lectures on PSK signal https://www.electronics-notes.com/articles/radio/modulation/frequency-modulation-fm.php

[3] Electronic notes lectures on ASK signal https://www.electronics-notes.com/articles/radio/modulation/frequency-modulation-fm.php

[4] Electronic notes lectures on FSK signal https://www.electronics-notes.com/articles/radio/modulation/frequency-modulation-fm.php

[5] Shift keying by Byjus https://byjus.com/jee/frequency-modulation/