

After the Midterm Exam.

Nov 8 (Monday)

Topics today: Modulation, Demodulation

Example: Road Map for the 2nd half of the Semester.

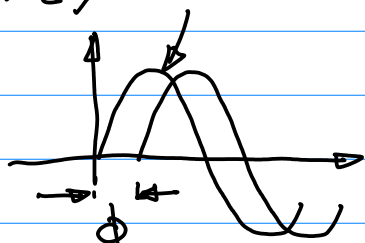
Mod/Demod Technique.

Handson PPT. (5 Blocks)

Industrial Grade JDT solution

PSK - Phase Shift Keying
CCK (Defined as IEEE 802.11b Standard)

Note: Phase, $A \sin(\omega_c t + \phi) \dots (1)$



phase "shift"

We can change phase value to make to carry information, e.g., "0" or "1".

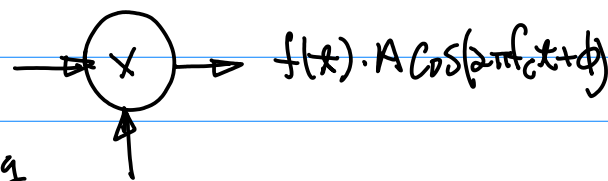
2. Background on Modulation.

What is modulation? A technique by multiplying a modulating function to a exist function to move the

modulating function to a higher frequency range.

Block Diagram to illustrate Modulation Technique

$f(t)$ "modulating Signal"



$A \cos(2\pi f_c t + \phi)$

"Carrier Signal"

Fig. 1

Why? (The objective) The objective of modulation is to move the Base Band Signal (e.g. modulating Signal) to higher Frequency Range.

Better/more Efficient Transmission
Better Random Noise Resistance, Robustness

To gain fast Transmission Bit Rate.

Ref on Theoretical Background, Fourier Transl. 2018F-117. on github

Properties in Fourier Transform provides foundation for good understanding of the Technique

Property 2: If $g(t) \leftrightarrow G(f)$ and $h(t) \leftrightarrow H(f)$
 then $g(t)h(t) \leftrightarrow G(f)*H(f) \dots (2)$
Property 3: If $g(t) \leftrightarrow G(f)$ and $h(t) \leftrightarrow H(f)$
 then $g(t)*h(t) \leftrightarrow G(f)H(f) \dots (3)$
Property 4: Sampling Property (Based on Eqn (2))

Ref: github, 2018F-118 ~

PSK Modulation & Demodulation
 HL

First, ASK, PSK, FSK modulation and Demodulation Formulation

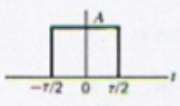
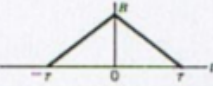
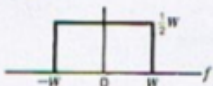
Table 1

ASK $S_1(t) = 0$
 $S_2(t) = A \cos 2\pi f_c t, t \in [0, T_b]$
 $\dots (1)$

Ref: from the class github. 2018F-111 ~

Theoretical Background. Review

$X(f) = \int_{-\infty}^{\infty} x(t) \exp(-j2\pi ft) dt$ $x(t) = \int_{-\infty}^{\infty} X(f) \exp(j2\pi ft) df$ $\int_{-\infty}^{\infty} x(t) ^2 dt = \int_{-\infty}^{\infty} X(f) ^2 df$		
Table C.1. Transform theorems.		
Name of theorem	Signal	Fourier transform
(1) Superposition	$a_1 x_1(t) + a_2 x_2(t)$	$a_1 X_1(f) + a_2 X_2(f)$
(2) Time delay	$x(t - t_0)$	$X(f) \exp(-j2\pi f t_0)$
(3) Scale change	$x(at)$	$ a ^{-1} X(f/a)$
(4) Frequency translation	$x(t) \exp(j2\pi f_0 t)$	$X(f - f_0)$
(5) Modulation	$x(t) \cos 2\pi f_0 t$	$\frac{1}{2} X(f - f_0) + \frac{1}{2} X(f + f_0)$
(6) Differentiation	$\frac{d^n x(t)}{dt^n}$	$(j2\pi f)^n X(f)$
(7) Integration	$\int_{-\infty}^t x(t') dt'$	$(j2\pi f)^{-1} X(f) + \frac{1}{2} X(0) \delta(f)$
(8) Convolution	$\int_{-\infty}^{\infty} x_1(t - \tau) x_2(\tau) d\tau$ $= \int_{-\infty}^{\infty} x_1(\tau) x_2(t - \tau) d\tau$	$X_1(f) X_2(f)$
(9) Multiplication	$x_1(t) x_2(t)$	$\int_{-\infty}^{\infty} X_1(f - f') X_2(f') df'$ $= \int_{-\infty}^{\infty} X_1(f') X_2(f - f') df'$

(1)		$A\tau \frac{\sin \pi f \tau}{\pi f \tau} \triangleq A\tau \text{sinc } f\tau$
(2)		$B\tau \frac{\sin^2 \pi f \tau}{(\pi f \tau)^2} \triangleq B\tau \text{sinc}^2 f\tau$
(3)	$e^{-\alpha t} u(t)$	$\frac{1}{\alpha + j2\pi f}$
(4)	$\exp(- t /\tau)$	$\frac{2\tau}{1 + (2\pi f \tau)^2}$
(5)	$\exp[-\pi(t/\tau)^2]$	$\tau \exp[-\pi(f\tau)^2]$
(6)	$\frac{\sin 2\pi W t}{2\pi W t} \triangleq \text{sinc } 2Wt$	
(7)	$\exp[j(2\pi f_0 t + \phi)]$	$\exp(j\phi) \delta(f - f_0)$
(8)	$\cos(2\pi f_0 t + \phi)$	$\frac{1}{2} [\delta(f - f_0) \exp(j\phi) + \delta(f + f_0) \exp(-j\phi)]$
(9)	$\delta(t - t_0)$	$\exp(-j2\pi f t_0)$
(10)	$\sum_{n=-\infty}^{\infty} \delta(t - nT_s)$	$\frac{1}{T_s} \sum_{n=-\infty}^{\infty} \delta(f - \frac{n}{T_s})$
(11)	$\text{sgn } t = \begin{cases} +1, & t > 0 \\ -1, & t < 0 \end{cases}$	$-\frac{j}{\pi f}$
(12)	$u(t) = \begin{cases} 1, & t > 0 \\ 0, & t < 0 \end{cases}$	$\frac{1}{j2\pi f} + \frac{1}{2} \delta(f)$

Example: From the class github, 2018F-111 ~

From Fig. 1. PP44

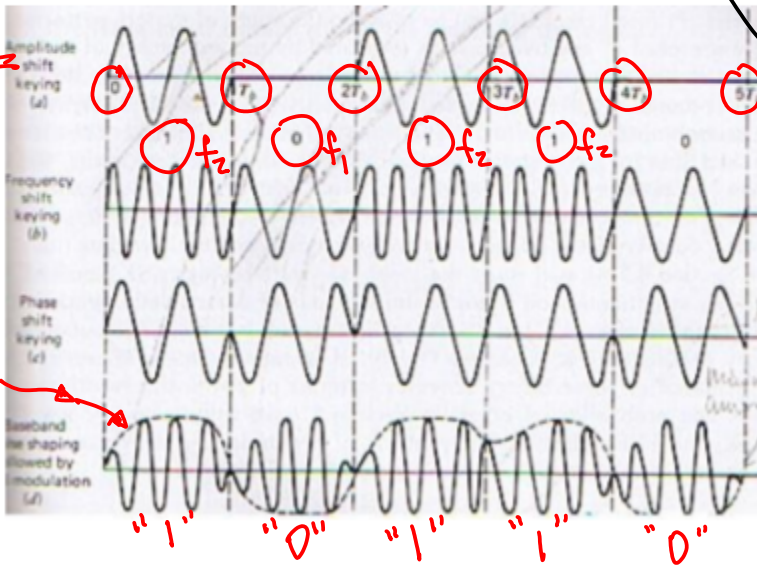
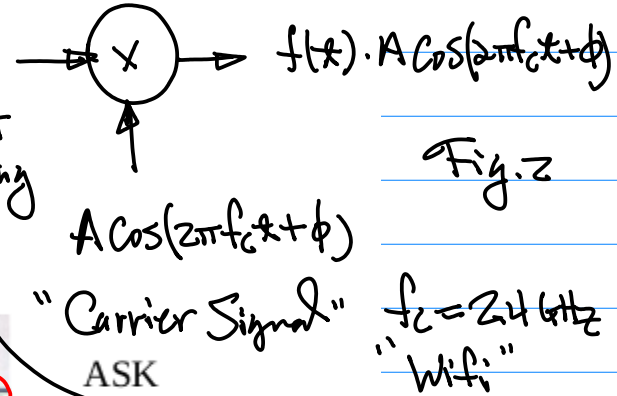
① Amplitude Signal → Base Band Signal $f(t)$ "modulating Signal"

ASK, FSK, PSK

Amplitude

Frequency Shift Keying

Phase Shift Keying



FSK

PSK

Base Band Shaping + Analog Modulation (DSB)

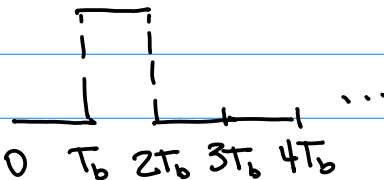
Suppose we have to transmit "SJSU CMPE245"

↓ JB, ASCII code

Decimal	Octal	Hex	Binary	Value
074	112	4A	0100 1010	J

0x4A
0100 1010 ...

Waveform.



Note from (2) (F.S.K.)

Base Band Signal 0x4A in

Binaries "0" → f_1
"1" → f_2

$f_1 < f_2$ for example.

0x4A

↓

0x4

↓ Binary

0100

$f_1 f_2 f_1 f_1$

0x4A
↓
0x4
↓
0100
P₁P₂P₁P₁

Modulated Signal
 $A \cos(2\pi f_c t + \phi_i)$
 $i=1, 2, \dots (1)$

$P_1 = \text{Phase 1} = 0 \text{ Degree}$
 $P_2 = \text{Phase 2} = 180 \text{ Degree}$
from Eqn(1).

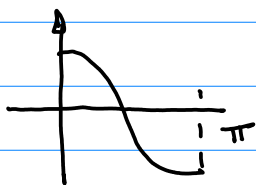
for Phase 1: $A \cos(2\pi f_c t + \phi_1)$

$$= A \cos(2\pi f_c t + 0)$$

$$= A \cos 2\pi f_c t$$

for Phase 2: $A \cos(2\pi f_c t + \phi_2)$

$$= A \cos(2\pi f_c t + \pi) = -A \cos 2\pi f_c t$$



Nov.10 (Wed)

Note: 1st References on PSK modulation
Demodulation on github ~ CMPE245;
(2021F-111~)

2nd

Project By End of the Semester.

LORA R.F. to establish C.R.
(Cognitive Radio), Team Based

Project.

(1) LORA R.F. kit to Implement
SPI Based I/F to your target
platform;

One kit per team;

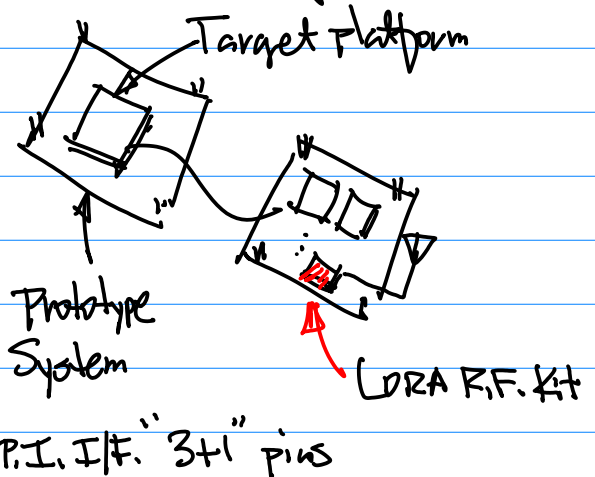
(2) Formal Presentation
With Demo, Requires Both
R.F. kit. Any Suggestions?

(3) Project Counts 20 pts.
Requires integration to your
target platform.

Sample code for LPC1114 platform
is provided as it is, Individual
responsibility to make it as
an integral part of your
final project.

Homework (Due A week from today)
Nov. 17.

1. Build Hardware Interface to
T.F. module (Lora).



S.P.I. { MOSI. (Master Out Slave In)
MISO
SCK (Serial clock)
"plus 1 pin": Enable/Select pin.

Discussion on Modulation Technique.
IEEE 802.11b.

2021F-101-IEEE-802.11b.pdf

potential number of octets is correct.

- a) 5.5 Mbit/s CCK Length = number of octets
b) 11 Mbit/s CCK Length = number of octets
(b7) bit shall indicate a "rounding took more than"

Copyright © 2000 IEEE. All rights reserved.

Submission:

1^o photo of the Setup should
R.F. module integrated with
your embedded wireless
System.

2^o Photo or Jpeg, or pdf Shows
the pin Connection/Connectivity
diagram.

3^o One Paragraph Description
for System Bring up. (LoRA R.F. Kit)
Be sure to provide URL.

4^o Elect a team Coordinator,
provide Coordinator's name and
all the team members name.

4^o Create one pdf file for all
the homework material, then zip it
Note: please indicate the
teammember who has the physical
R.F. Kit. In your first photo, please
provide this information.

Example: from pp.46. Illustration of
modulation in Time Domain.

"modulating Signal"
Base Band Signal

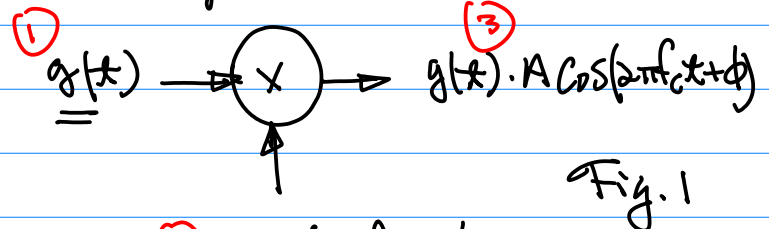


Fig. 1

(2) $A \cos(2\pi f_c t + \phi)$

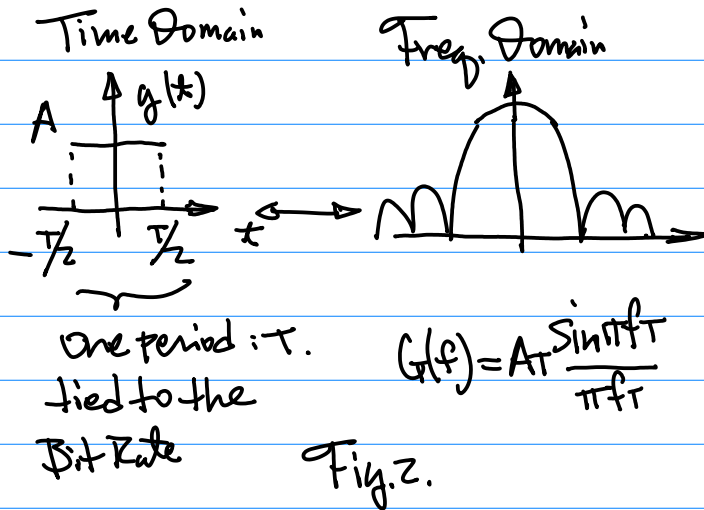
"Carrier Signal" $f_c = 2.4 \text{ GHz}$
"Wifi"

Let's take a look this
modulation in the Frequency Domain.

First. Take each of the Signals, 3 of them
in Fig. 1. then perform Fourier Transform
on each of them.

$$g(t) \leftrightarrow \text{F.T.}[g(t)] = G(f) \quad \dots 1)$$

$$g(t) \leftrightarrow G(f) = A_T \frac{\sin \pi f T}{\pi f T} \dots (2)$$



2017F-108-lec-BB-Sign... A

Now, for the 2nd Signal in Fig. 1
(Modulation Block Diagram)

$$(8) \cos(2\pi f_c t + \phi)$$

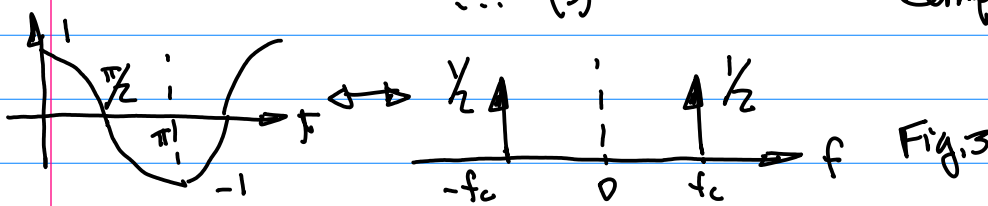
"Carrier Signal", f_c : Carrier frequency.

In Wi-Fi Communication, $f_c = 2.4 \text{ GHz}$

from this table,

$$\text{Assuming } \phi = 0 \quad \cos(2\pi f_c t + \phi) = \cos(2\pi f_c t)$$

$$\cos(2\pi f_c t) \leftrightarrow \frac{1}{2} [\delta(f - f_c) + \delta(f + f_c)] \dots (3)$$



Nov 15 (Monday)

Note: 1st midterm key is ready, to be
Posted on CANVAS.

2nd Resume Semester Long
Project.

Homework: Nov. 22nd (Monday)

Team Implementation of Hardware
Interface to LoRa module.

What to Submit to CANVAS:

1st Photo of Hardware Implementation

a. Embedded Target platform

b. R.F. Board/module

c. LoRa R.F. module

2nd Since it is a team
Project, team members
(Assuming $\phi = 0$)

To identify your team, And
team Coordinator's Name and
Contact information.

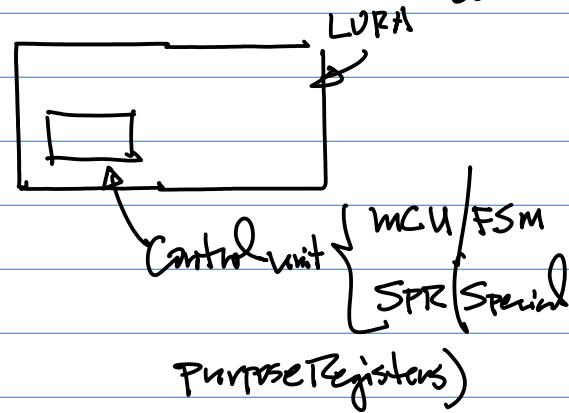
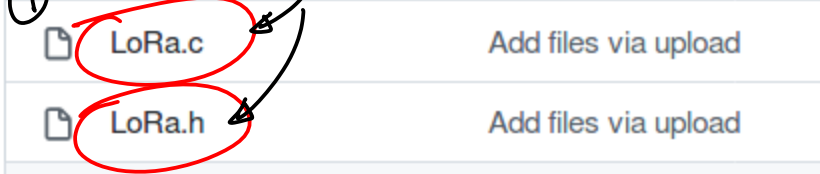
3rd Photo of Pin Connection
Diagram (from the vendor's
website), the information about your
4th provide target platform.

if you are using LPC1114,
provide URL link of the Code
Sample on the class github.

CMPE245

50

① Two modules.



```
1 /*
2  * LoRa.c
3  *
4  * Created on: Oct 29, 2017
5  * CTI One Corporation released for Dr
6  */
```

② Tested module

<https://github.com/hualili/CMPE245-Embedded-Wireless/blob/master/LoRa.c>

And LoRa.h file Below.

<https://github.com/hualili/CMPE245-Embedded-Wireless/blob/master/LoRa.h>

```
8 /*
9  * LoRa.cpp
10 *
11 * Created on: Oct 29, 2017
12 * CTI One Corporation released for Dr
13 */
```

```
16 #include <stdio.h>
17 #include <stdint.h>
18 #include "LoRa.h"
19 #include "ssp.h"
20 #include "extint.h"
```

③ header files needed for the testing of this code.

```
21 // registers
22 #define REG_FIFO 0x00
23 #define REG_OP_MODE 0x01
24 #define REG_FRF_MSB 0x06
25 #define REG_FRF_MID 0x07
26 #define REG_FRF_LSB 0x08
27 #define REG_PA_CONFIG 0x09
```

```
1 /*
2  * LoRa.h
3  *
4  * Created on: Oct 29, 2017
5  * CTI One Corporation released for Dr. Harry Li
6  */
```

```
8 #ifndef LORA_H_
9 #define LORA_H_
10
11 /*
12  * LoRa.h
13  *
14  * Created on: Oct 29, 2017
15  * CTI One Corporation released for Dr. Harry Li
16  */
```

Origin of SSP Code is from NXP.

```
19 #include <stdint.h>
20 #include "ssp.h"
```

⑤ SSP Code for SPI Interface.

```
22 // #define LORA_DEFAULT_SS_PIN 10
23 #define LORA_DEFAULT_RESET_PIN 2
24 #define LORA_DEFAULT_DIO0_PIN 3
```

⑥

Pin mappings. May be changed for different Vendors, Check your vendor's website, get

Top level (Conceptual level) Description of LoRA :

④ Special Purpose Registers of LORA module

the Latest pin Connection diagram.

50 Submit ^{Screen Capture of your} SPI interface

Program, together with the Source code to establish work in progress.

Note: Submission on CANVAS.

Example: Continuation of modulation Discussion.

Ref: [github/hualili/Cmpe245](https://github.com/hualili/Cmpe245)

2018F-111-lec5-BB-Signals-2018-10-1.pdf

Technique for Convolution.

Convolution Time Domain

$$\int_{-\infty}^{\infty} x_1(t-t')x_2(t') dt' = \int_{-\infty}^{\infty} x_1(t')x_2(t-t') dt'$$

Fourier Transform

$$X_1(f)X_2(f)$$

Notation for Convolution of 2 signals
 $x_1(t), x_2(t)$, or $g(t), h(t)$

1° Notation: $g(t) * h(t)$ Convolution.

"*" Symbol for the operator of Convolution;

2° Definition:

$$g(t) * h(t) = \int_{-\infty}^{+\infty} g(\tau)h(t-\tau)d\tau \quad \dots (1)$$

If discrete signal:

$$g(t) \rightarrow g(k), h(t) \rightarrow h(k)$$

$$\sum_{k=0}^{n-1} g(k)h(n-k) \dots (2)$$

Property (of convolution):

$$g(t) \xrightarrow{\text{FT}} G(f) = G(f)$$

$$h(t) \xrightarrow{\text{FT}} H(f) = H(f)$$

then

$$g(t) * h(t) \xrightarrow{\text{FT}} G(f)H(f) \dots (3)$$

$$P^f = g(t) * h(t) = \int_{-\infty}^{+\infty} g(\tau)h(t-\tau)d\tau$$

then,

$$\text{Freq. } \mathcal{F}\{g(t) * h(t)\} = \int_{-\infty}^{+\infty} g(t) * h(t) e^{-j2\pi f t} dt$$

$$= \int_{-\infty}^{+\infty} \left[\int_{-\infty}^{+\infty} g(\tau)h(t-\tau)d\tau \right] e^{-j2\pi f t} dt$$

$$= \int_{-\infty}^{+\infty} g(\tau) e^{-j2\pi f \tau} e^{j2\pi f t} dt$$

$$\int_{-\infty}^{+\infty} h(t-\tau) e^{-j2\pi f (t-\tau)} d(t-\tau)$$

$$= \underbrace{\int_{-\infty}^{+\infty} g(\tau) e^{-j2\pi f \tau} d\tau}_{G(f)} \underbrace{\int_{-\infty}^{+\infty} h(t-\tau) e^{-j2\pi f (t-\tau)} d(t-\tau)}_{H(f)}$$

$$= G(f)H(f)$$

Symmetric Property to Eqn (3):

Property 2.

$$\text{If } g(t) \xrightarrow{\text{FT}} G(f) = G(f)$$

$$h(t) \xrightarrow{\text{FT}} H(f)$$

then,

$$g(t)h(t) \xrightarrow{\text{FT}} G(f) * H(f) \quad \dots (4)$$

Example: Convolution and Signal Sampling.

1° Sampling with Impulse function $\delta(t)$

First, Definition of $\delta(t)$

$$\delta(t) = \begin{cases} +\infty & t=0 \\ 0 & t \neq 0 \text{ and } \dots (5a) \end{cases}$$

$$\int_{-\infty}^{+\infty} \delta(t) dt = 1 \quad \dots (5b)$$

Nov. 17 (Wed)

Note: Homework on Lab-PC Module Hardware Integration is Due Today on CANVAS 11:59pm.

Example: Impulse Function & its Sampling Application.

So! Given a function $g(t)$ to Sample this function, we have

$$\int_{-\infty}^{+\infty} g(t) \delta(t) dt =$$

$$\int_{-\infty}^{-\epsilon} g(t) \delta(t) dt + \int_{-\epsilon}^{+\epsilon} g(t) \delta(t) dt + \int_{+\epsilon}^{+\infty} g(t) \delta(t) dt \quad \dots (6)$$

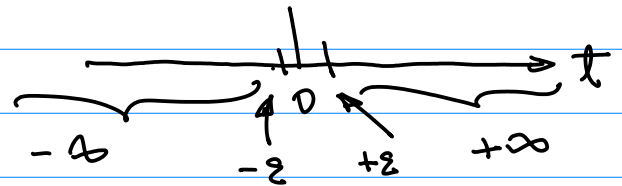


Fig 1.

$$\int_{-\infty}^{-\epsilon} g(t) \delta(t) dt = 0$$

$$\int_{+\epsilon}^{+\infty} g(t) \delta(t) dt = 0$$

hence,

$$\text{Eqn (6) Becomes } \int_{-\epsilon}^{+\epsilon} g(t) \delta(t) dt$$

$$\lim_{\epsilon \rightarrow 0} \int_{-\epsilon}^{+\epsilon} g(t) \delta(t) dt = g(0) \quad \dots (7)$$

$g(t)$ is Sampled at $t=0$ By $\delta(t)$.

Consider the following Applications.

Sample $g(t)$ at any given time instance

$$t_0 \int_{-\infty}^{+\infty} g(t) \delta(t - t_0) dt = \int_{-\infty}^{t_0 - \epsilon} g(t) \delta(t - t_0) dt + \int_{t_0 - \epsilon}^{t_0 + \epsilon} g(t) \delta(t - t_0) dt + \int_{t_0 + \epsilon}^{+\infty} g(t) \delta(t - t_0) dt$$

$$= \int_{x_0 - \epsilon}^{x_0 + \epsilon} g(x) \delta(x - x_0) dx$$

$$= g(x_0)$$

Example: Given $G(f) = A_T \frac{\sin \pi f T}{\pi f T}$

(Spectrum of Base Band Signal)

Carrier Signal $h(x) = \cos 2\pi f_c x$

whose F.T.

$$H(f) = \frac{1}{2} [\delta(f - f_c) + \delta(f + f_c)] \quad \dots (6b)$$

Find: $G(f) * H(f) = ?$ And illustrate the result.

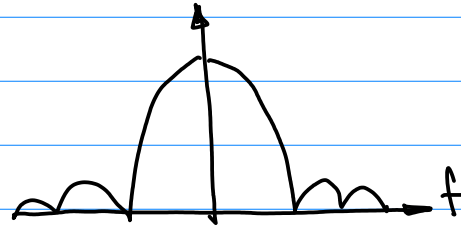


Fig. 2a

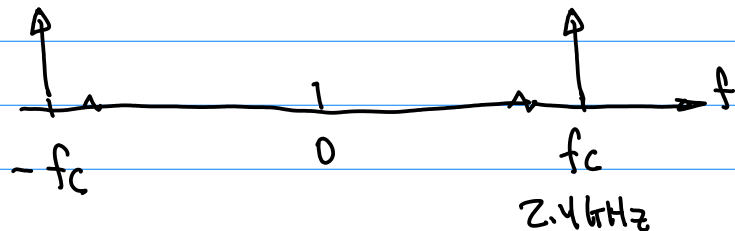


Fig. 2b

$$G(f) * H(f) = \int_{-\infty}^{+\infty} G(f-u) H(u) du$$

$$= \int_{-\infty}^{+\infty} A_T \frac{\sin \pi (f-u) T}{\pi (f-u) T} \cdot \frac{1}{2} [\delta(u - f_c) + \delta(u + f_c)] du$$

$$= \frac{A_T}{2} \frac{\sin \pi (f + f_c) T}{\pi (f + f_c) T} + \frac{A_T}{2} \frac{\sin \pi (f - f_c) T}{\pi (f - f_c) T} \quad \dots (7)$$

Note: please make sure how Eqn (7) is achieved.

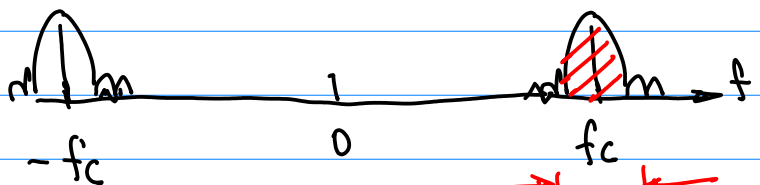


Fig. 2c
Bandwidth B.W.

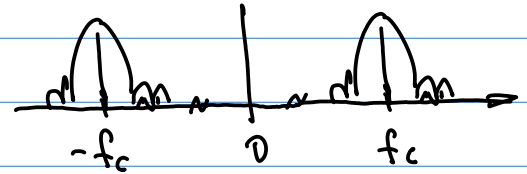
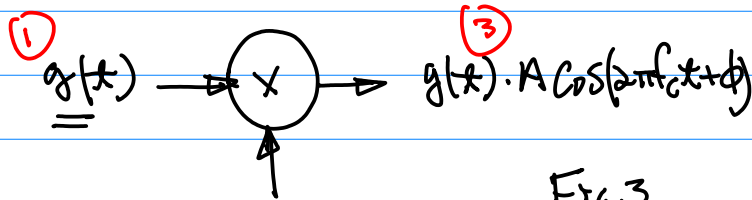
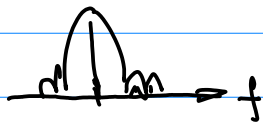
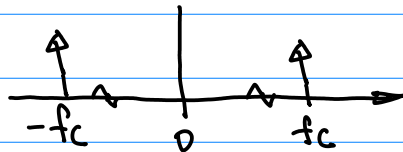


Fig. 3.

(2) $A \cos(2\pi f_c t + \phi)$



Ref: see class [github/huadili/cmpe245](https://github.com/huadili/cmpe245)...

2018F-117-Mod.pdf

2018F-118-DeMOD.jpg

Example Table

For One Bit (Period)

ASK	$S_1(t) = 0$ $S_2(t) = A \cos 2\pi f_c t, t \in [0, T_b]$... (1)
PSK	$S_1(t) = A \cos(2\pi f_c t + \phi_1)$ $S_2(t) = A \cos(2\pi f_c t + \phi_2)$... (2) $t \in [0, T_b], \phi_1 = 0, \phi_2 = \pi$
FSK	$S_1(t) = A \cos[2\pi(f_c - f_d)t]$ $S_2(t) = A \cos[2\pi(f_c + f_d)t]$... (3)

if Amplitude is equal to "1" (or A) then the output is

$$S_2(t) = A \cos 2\pi f_c t$$

ASK Technology is employed for the RF Kit in this class.

Note 2: PSK (Phase Shift Keying)

Base Band Signal $g(t)$ is utilized to change phase value, ϕ_1, ϕ_2 for Example:

"1" $\rightarrow \phi_1$

"0" $\rightarrow \phi_2$

In addition, it is Binary Phase Shift Keying. (ϕ_1, ϕ_2)

Note 3: FSK: Frequency Shift Keying

Note 1. Eqn (1) ~ (3), $g(t)$ Base Band Signal is implied
if Amplitude in (1) is "0", then modulation produces the modulated signal $S_1(t) = 0$

"1" freq change, $f_c + f_d$
 "0" " " , $f_c - f_d$

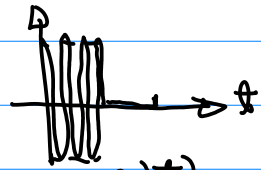
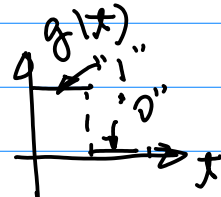
on Dec 6 (Monday)

Draw waveforms in Time Domain.

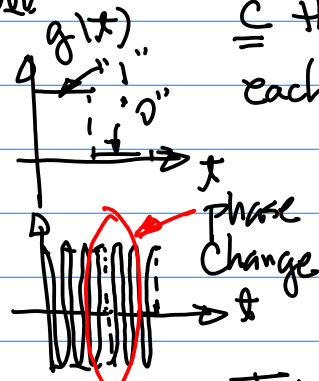
Base Band 10
 ASK

Amplitude $g(t)$

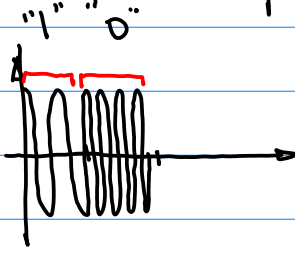
ASK



PSK } phase change induced by $g(t)$
 PSK waveform



FSK } freq. change induced by $g(t)$
 FSK



The presentation Requirements

(1) Implementation of LoRa RF on your chosen platform.

Demo: "Hello, First-Last-Name of the ^ateam coordinator^b, then First-Last Name of Each team member, c the work accomplished by each team member," Example:

		Task
John Doe	Coordinator	Hardware & Driver
Mr. A	member 1	..
Ms. B	member 2	Init & Config. R.F.
:		

(2) Short PPT. (3~5 slides)

(3) Report : IEEE Paper Template (github)

Nov. 22nd (Monday)

Note: 1° Homework has to be individual, e.g., photos, code, implementation have to be accomplished by Each individual;

2° Project (Semester Project on LoRa RF) formal presentation is scheduled

Sections — Contributor's Name

(First paragraph for Each Section indicates person(s) who contributed Lead the creation of the Section)

Submission:

1° Report; 2° PPT; 3° Photos & 5~10 Seconds Video clips.

Example: PSK \rightarrow BPSK (Binary PSK)

Bandwidth
Aspects.

$$A \cos(2\pi f_c t + \phi_i)$$

$$\phi_i, i=1, \text{ or } 2$$

$$\phi_1, \phi_2 \dots (1a)$$

\downarrow
QPSK (Quadrature PSK)

$$A \cos(2\pi f_c t + \phi_i)$$

$$\phi_i, i=1, 2, 3, 4.$$

$$\phi_1, \phi_2, \phi_3, \phi_4 \dots (1b)$$

From Eqn (7), pp 53

$$\cos 2\pi f_c t \leftrightarrow \frac{1}{2} [\delta(f-f_c) + \delta(f+f_c)]$$

$$H(f) = \frac{1}{2} [\delta(f-f_c) + \delta(f+f_c)] \dots (6b)$$

from pp 53.

Bandwidth for BPSK: From Eqn (7), pp 53.

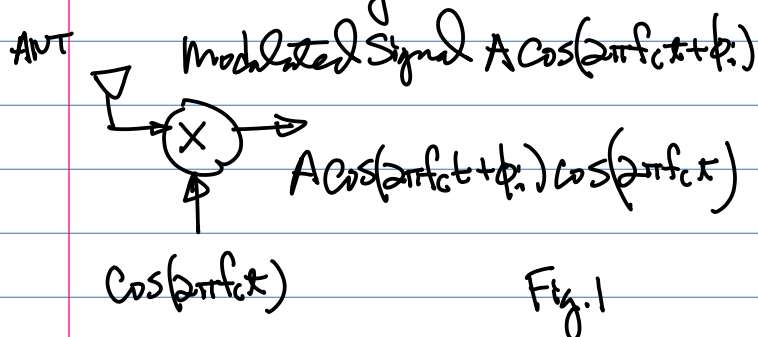
$$B.W. = 2 \cdot \frac{1}{T} \dots (2)$$

Bandwidth for QPSK: From Eqn (8), pp 53.

$$B.W. = 2 \cdot \frac{1}{T} \dots (2-b)$$

Example: Demodulation.

Theoretical Background:



From Property 2, Eqn (4), pp 52

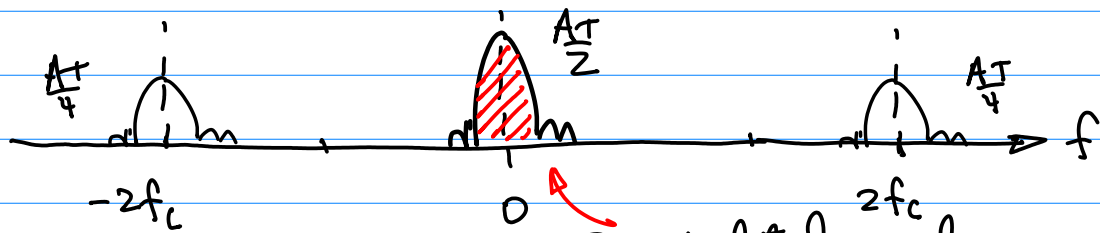
Since $A \cos(2\pi f_c t + \phi_i) \leftrightarrow$

$$\frac{A}{2} T \frac{\sin \pi (f+f_c) T}{\pi (f+f_c) T} + \frac{A}{2} T \frac{\sin \pi (f-f_c) T}{\pi (f-f_c) T}$$

$$\left[\frac{A}{2} T \frac{\sin \pi (f+f_c) T}{\pi (f+f_c) T} + \frac{A}{2} T \frac{\sin \pi (f-f_c) T}{\pi (f-f_c) T} \right] * \frac{1}{2} [\delta(f-f_c) + \delta(f+f_c)]$$

$$= \frac{A}{4} T \frac{\sin \pi f_c T}{\pi f_c T} + \frac{A}{4} T \frac{\sin \pi (f-2f_c) T}{\pi (f-2f_c) T} + \frac{A}{4} T \frac{\sin \pi (f+2f_c) T}{\pi (f+2f_c) T} + \frac{A}{4} T \frac{\sin \pi f_c T}{\pi f_c T}$$

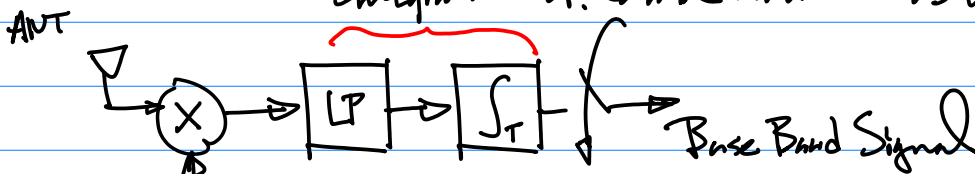
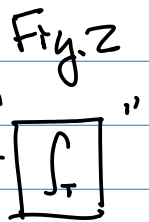
$$= \frac{A}{2} T \frac{\sin \pi f_c T}{\pi f_c T} + \frac{A}{4} T \frac{\sin \pi (f-2f_c) T}{\pi (f-2f_c) T} + \frac{A}{4} T \frac{\sin \pi (f+2f_c) T}{\pi (f+2f_c) T}$$



Use Low Pass Filter

to Recover the Base Band Signal

Integral with LP. can be illustrated as on Block



$$\cos(2\pi f_c t) \quad A \cos(2\pi f_c t + \phi_c) \cos(2\pi f_c t)$$

Demodulation for BPSK.

Example: Demodulation.

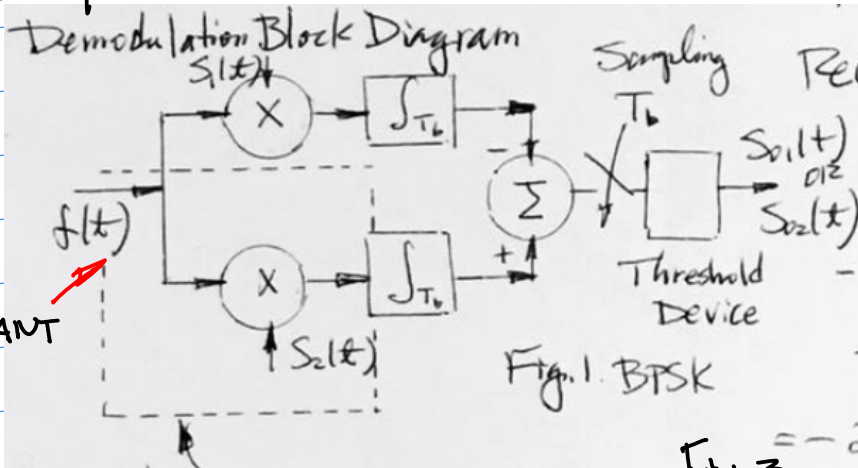


Fig. 1. BPSK

Fig. 3

First, In Time Domain, Modulated Signals Signal $f(t)$.

PSK

$$\begin{aligned} S_1(t) &= A \cos(2\pi f_c t + \phi_1) \\ S_2(t) &= A \cos(2\pi f_c t + \phi_2) \end{aligned} \quad (2)$$

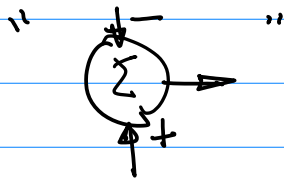
$t \in [0, T_b], \phi_1 = 0, \phi_2 = \pi$

if Output $= -A^2 T$, then $S_1(t)$, e.g. ϕ_1 is from the Base Band Signal

if Output $= A^2 T$, then $S_2(t)$, ϕ_2 is from the Base Band Signal.

2nd, Build Demod System with 2 Branches (multipliers) as shown in Fig. 3. PP 57.

3rd, Build A comparator,



" Threshold " unit will make Decision Based on the Compared difference.

From the handout, Fig 3, PP. 57

$$S_{01}(t) = \int_{(k-1)T_b}^{kT_b} f(t) [S_2(t) - S_1(t)] dt \quad \dots (4)$$

$\left\{ \begin{array}{l} -f(t)S_1(t) : \text{Upper Branch} \\ f(t)S_2(t) : \text{Lower Branch} \end{array} \right.$

Both going through " \int " operation.

$$\int_{(k-1)T_b}^{kT_b} [f(t)S_2(t) - f(t)S_1(t)] dt$$

4th Step, Evaluate Eqn(4) Based on what is given for Received modulated