After the Midterm Exam.

Nov 8 (Monday)

Topics today: Modulation, Demodulation

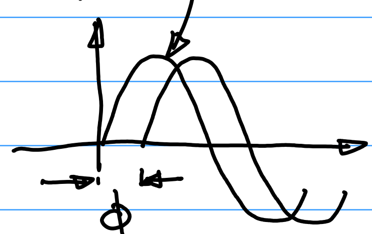
Example: Road Map for the 2nd half of the Semester.

- MOD/DEMOD Technique.
  - ↓ PPT. (5 Blocks)
- Hardson

Industrial Grade IOT solution

PSK — phase shift Keying
= CCK (Defined as IEEE 802.11b Standard)

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



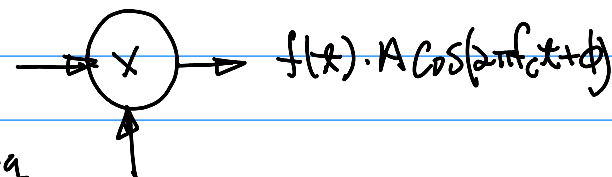

We can change phase value to make to carry information, e.g. "0" or "1".

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 Transform. 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 $g(t)h(t) \leftrightarrow G(f)*H(f)$ ...(2)

**Property 3**: If $g(t) \leftrightarrow G(f)$, and $h(t) \leftrightarrow H(f)$
then $g(t)*h(t) \leftrightarrow G(f)H(f)$ ...(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

$S_1(t) = 0$

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

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

# Theoretical Background. Review

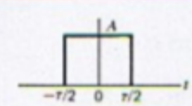
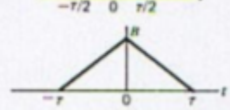
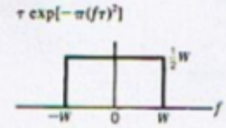
$$X(f) = \int_{-\infty}^{\infty} x(t)\exp(-j2\pi ft)\,dt$$

$$x(t) = \int_{-\infty}^{\infty} X(f)\exp(j2\pi ft)\,df$$

$$\int_{-\infty}^{\infty} |x(t)|^2\,dt = \int_{-\infty}^{\infty} |X(f)|^2\,df$$

**Table C.1. Transform theorems.**

| Name of theorem | Signal | Fourier transform |
|---|---|---|
| (1) Superposition | $a_1x_1(t) + a_2x_2(t)$ | $a_1X_1(f) + a_2X_2(f)$ |
| (2) Time delay | $x(t - t_0)$ | $X(f)\exp(-j2\pi ft_0)$ |
| (3) Scale change | $x(at)$ | $\lvert a\rvert^{-1}X(f/a)$ |
| (4) Frequency translation | $x(t)\exp(j2\pi f_0t)$ | $X(f - f_0)$ |
| (5) Modulation | $x(t)\cos 2\pi f_0t$ | $\frac{1}{2}X(f - f_0) + \frac{1}{2}X(f + f_0)$ |
| (6) Differentiation | $\frac{d^nx(t)}{dt^n}$ | $(j2\pi f)^nX(f)$ |
| (7) Integration | $\int_{-\infty}^{t} x(t')\,dt'$ | $(j2\pi f)^{-1}X(f) + \frac{1}{2}X(0)\delta(f)$ |
| (8) Convolution | $\int_{-\infty}^{\infty} x_1(t - t')x_2(t')\,dt' = \int_{-\infty}^{\infty} x_1(t')x_2(t - t')\,dt'$ | $X_1(f)X_2(f)$ |
| (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)  | $A\tau\frac{\sin \pi f\tau}{\pi f\tau} \triangleq A\tau\,\mathrm{sinc}\, f\tau$ |
| (2)  | $B\tau\frac{\sin^2 \pi f\tau}{(\pi f\tau)^2} \triangleq B\tau\,\mathrm{sinc}^2 f\tau$ |
| (3) $e^{-at}u(t)$ | $\frac{1}{a + j2\pi f}$ |
| (4) $\exp(-\lvert t\rvert/\tau)$ | $\frac{2\tau}{1 + (2\pi f\tau)^2}$ |
| (5) $\exp[-\pi(t/\tau)^2]$ | $\tau\exp[-\pi(f\tau)^2]$ |
| (6) $\frac{\sin 2\pi Wt}{2\pi Wt} \triangleq \mathrm{sinc}\, 2Wt$ |  |
| (7) $\exp[j(2\pi f_ct + \phi)]$ | $\exp(j\phi)\delta(f - f_c)$ |
| (8) $\cos(2\pi f_ct + \phi)$ | $\frac{1}{2}\delta(f - f_c)\exp(j\phi) + \frac{1}{2}\delta(f + f_c)\exp(-j\phi)$ |
| (9) $\delta(t - t_0)$ | $\exp(-j2\pi ft_0)$ |
| (10) $\sum_{m=-\infty}^{\infty} \delta(t - mT_s)$ | $\frac{1}{T_s}\sum_{n=-\infty}^{\infty} \delta\left(f - \frac{n}{T_s}\right)$ |
| (11) $\mathrm{sgn}\, t = \begin{cases} +1, & t > 0 \\ -1, & t < 0 \end{cases}$ | $-\frac{j}{\pi f}$ |
| (12) $u(t) = \begin{cases} 1, & t > 0 \\ \dots \end{cases}$ | $\frac{1}{2}\delta(f) + \frac{1}{\dots}$ |

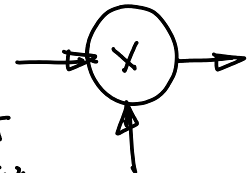
Example: From the class github, 2018F-111 ~ From Fig1. pp44

Amplitude Signal → Base Band Signal $\underline{\underline{f(t)}}$ "modulating Signal"

(1) (2) (3)

# ASK, FSK, PSK

Amplitude, Frequency Shift Keying, Phase Shift Keying

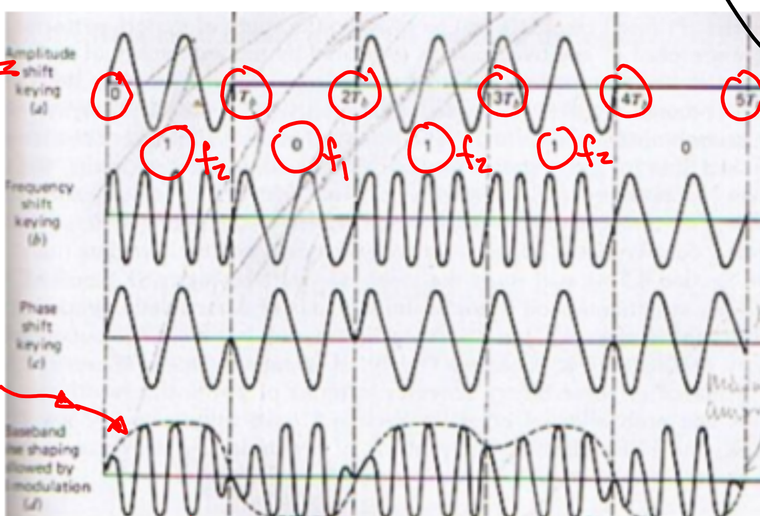



$f(t) \cdot A\cos(2\pi f_c t + \phi)$

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

Fig.2

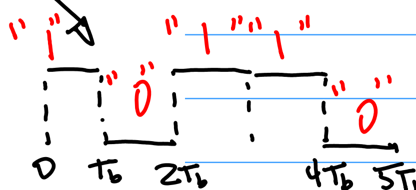
$f_c = 2.4\,GHz$ "Wifi"




ASK

FSK

PSK




Envelop has phase change

Fig.3

Base Band Shaping + Analog Modulation (DSB)

Suppose We have to transmit "SJSU CMPE245"

↓ By ASCII code

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

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

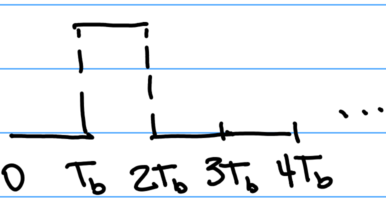
0100

$f_1 f_2 f_1 f_1$

0x4A

0100 1 ....

→ Waveform.



0X4'A

↓

0X4

↓

0 1 0 0

$P_1 P_2 P_1 P_1$

Modulated Signal

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

$i = 1, 2. \quad \ldots (1)$

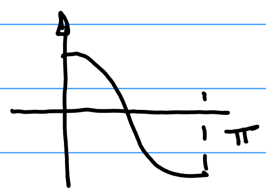
for Phase 1: $A\cos(2\pi f_c t + \phi_1)$

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

$= A\cos 2\pi f_c t$

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: 1° References on PSK modulation Demodulation on github ~ Cmpe245; (2021F-111 ~)

2° 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;

$P_1$ = Phase 1 = 0 Degree

$P_2$ = phase 2 = 180 Degree

from Eqn (1).

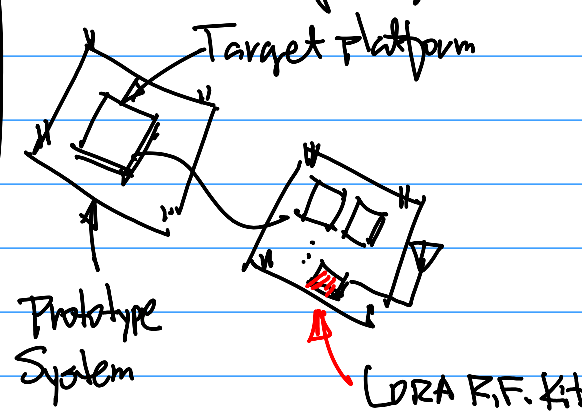
(2) Formal Presentation With Demo, Requires Both R.F. Kit. Any Suggestions?

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

Sample code for LPC1769 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 R.F module (Lora).




S.P.I. I/F. "3+1" pins

S.P.I. | MOSI. (Master Out Slave In)
MISO
SCK (Serial clock)

"plus 1 pin" : Enable/or Select pin.

Submission:

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

2° photo or Jpeg, or pdf Shows the pin Connection/connectivity diagram.

3° One paragraph Description for System Bring up. (LORA R.F. Kit) Be sure to provide URL.

4° Elect a team Coordinator, provide Coordinator's name and all the team members Name.

4° 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.

Discussion on modulation Technique.

IEEE802.11b.

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



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

"modulating Signal"
Base Band Signal

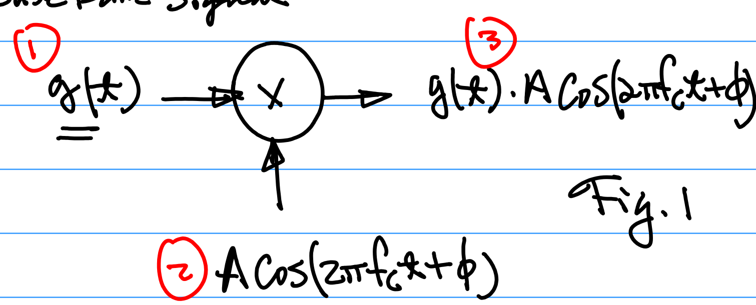



Fig. 1

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

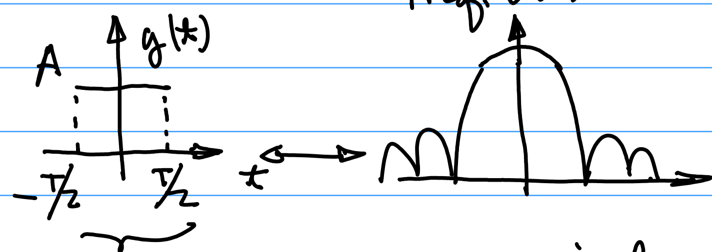
Let's take a look this modulation in the Frequency Domain.

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

$$g(t) \longleftrightarrow F.T.[g(t)] = G(f) \quad \dots (1)$$

$g(t) \longleftrightarrow G(f) = A\tau \dfrac{\sin \pi f \tau}{\pi f \tau}$ ...(2)

Time Domain Freq. Domain




One period: T. tied to the Bit Rate

$G(f) = A\tau \dfrac{\sin \pi f \tau}{\pi f \tau}$

Fig.2.

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

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

| | |
|---|---|
| (8) $\cos(2\pi f_c t + \phi)$ | $\frac{1}{2}\delta(f - f_c)\exp(j\phi) + \frac{1}{2}\delta(f + f_c)\exp(-j\phi)$ |

$\frac{1}{2}[\delta(f-f_c) + \delta(f+f_c)]$ (Assuming $\phi = 0$)

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

"Carrier Signal", $f_c$: Carrier frequency.

In Wifi Communication, $f_c = 2.4\,GHz$

from this table,

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

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

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

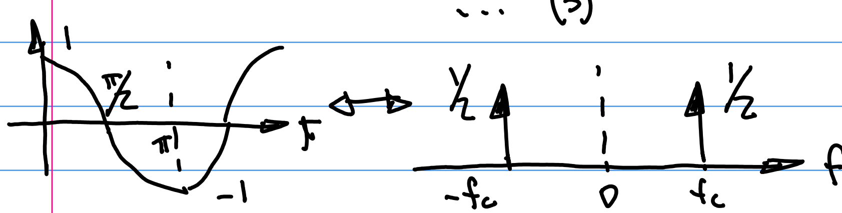



Fig.3

Nov 15 (Monday)

Note: 1° midterm key is ready, to Be Posted on CANVAS.

2° Resume Semester Long Project.

Homework: Nov. 22nd (Monday)

Team Implementation of Hardware Interface to LORA module.

What to Submit to CANVAS:

1° photo of Hardware Implementation

a. Embedded Target Platform

b. R.F. Board/module

c. LORA RF module

2° Since it is a team Project, team members To identify your team, And team Coordinator's Name and Contact information.

3° Photo of Pin Connection Diagram (from the vendor's website) the information about your

4° Provide target platform.

if you are using LPC1769, provide URL link of the code Sample on the class github.

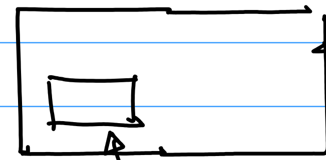
CMPE245

50

Two modules.

(1)

| | |
|---|---|
| LoRa.c | Add files via upload |
| LoRa.h | Add files via upload |



LORA

Control unit { MCU/FSM, SPR (Special Purpose Registers)

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

(2) Tested module

```
/*
 * LoRa.c
 *
 *  Created on: Oct 29, 2017
 *  CTI One Corporation released for Dr
 */

/*
 * LoRa.cpp
 *
 *  Created on: Oct 29, 2017
 *  CTI One Corporation released for Dr
 */


#include <stdio.h>
#include <stddef.h>
#include "LoRa.h"
#include "ssp.h"
#include "extint.h"
// registers
#define REG_FIFO                    0x00
#define REG_OP_MODE                 0x01
#define REG_FRF_MSB                 0x06
#define REG_FRF_MID                 0x07
#define REG_FRF_LSB                 0x08
#define REG_PA_CONFIG               0x09
         :
```

(3) header files needed for the testing of this code.

(4) Special Purpose Registers of LORA module

Top level (Conceptual level) Description of LORA :

```
/*
 * LoRa.h
 *
 *  Created on: Oct 29, 2017
 *  CTI One Corporation released for Dr. Harry Li
 */

#ifndef LORA_H_
#define LORA_H_

/*
 * LoRa.h
 *
 *  Created on: Oct 29, 2017
 *  CTI One Corporation released for Dr. Harry Li
 */


#include <stddef.h>
#include "ssp.h"

//#define LORA_DEFAULT_SS_PIN        10
#define LORA_DEFAULT_RESET_PIN     2
#define LORA_DEFAULT_DIO0_PIN      3
```

Origin of SSP code is from NXP.

(5) SSP code for SPI Interface.

(6) Pin mappings may be changed for different Vendors, Check your Vendor's website, get

the Latest pin connection diagram.

5° 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/~

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

Technique for Convolution. Convolution Time Domain — Fourier Transform Freq.

(7) integration

(8) Convolution $\int_{-\infty}^{\infty} x_1(t-t')x_2(t')\,dt' = \int_{-\infty}^{\infty} x_1(t')x_2(t-t')\,dt'$ $X_1(f)X_2(f)$

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:

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

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

Property (of convolution):

if $g(t) \leftrightarrow FT[g(t)] = G(f)$

$h(t) \leftrightarrow FT[h(t)] = H(f)$

then

$$g(t)*h(t) \leftrightarrow G(f)H(f) \quad \dots(3)$$

Pf

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

then,

$$FT[g(t)*h(t)] = \int_{-\infty}^{+\infty} g(t)*h(t)\,e^{-j2\pi f t}\,dt$$

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

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

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

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

Symmetric Property to Eqn (3):

Property 2.

If $g(t) \leftrightarrow FT[g(t)] = G(f)$

$h(t) \leftrightarrow FT[h(t)] = H(f)$

then,

$$g(t)\,h(t) \leftrightarrow G(f) * H(f) \quad \cdots (4)$$

Example: Convolution and Signal Sampling.

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

First, Definition of $\delta(t)$

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

$$\int_{-\infty}^{+\infty} \delta(\tau)\,d\tau = 1$$