

August 25 (Wed)

Introduction.

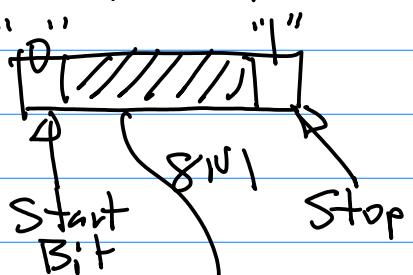
Today's Topics

Bill of Materials
Target platform
For Prototyping

Note: Your RF module(s)
is to be interfaced to GPIO
of your target Board.

Why? General Purpose \rightarrow No
Data Framing.

for UART, Data Frame



Payload, Data, 8 Bit

Note: CPU Target

Option to use NVDA Jetson
NANO

Guideline for Selection
of target Platform.

Bill of Material

1. Target CPU NXP LPC1769
OR NAND (NVDA)

2. RF modules, physical Layer only.

(1) ASK RF module, frequency $\sim 433\text{MHz}$
FCC Certified

Amplitude Switching

(2) Power $\leq 1000\text{mW. (1w)}$
Tx: Transmitter

(3) No MAC (media Access Control)
Needed



1. Register Level Control
of GPIO, SPI Controllers

For LPC1769 ✓

For NAND \rightarrow Devices
Drivers.

(1) Datasheet 400+ pages

(2) Software Dev.
Environment, tools.

Jetpack (OS +

(3) O.S. Distr. Libs)

August 25 (Wed)

2° Access to CPU pins, e.g.

GPIO pins, SPI pins.

Homework: Purchase ASK RF

Module By Sept. 8th (Wed)

OR ideally Sept 3rd (Fri)

Note: On your RF Board.

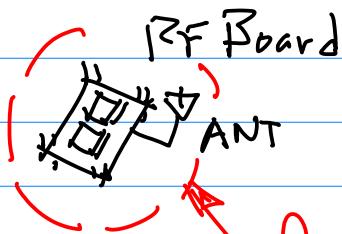


Fig. 3.

2 Blocks { RX
TX

Both Need to Be Powered.

Note: To provide hardware Debugging Act. on

the RF Board

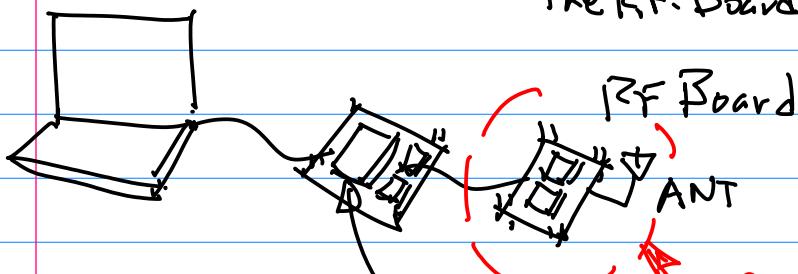


Fig. 2

Debugging Capability on the RF

Board:

① Objective: To visualize/observe
GPIO output.

Means: LED.

Material:

a LED (Red, Green), $I \approx 10\text{ mA}$

Connectors (to cable to RF Board)

b RJ45 Right Angle Connectors (2)

A piece of CAT5 Cable (Ethernet)

Components { Resistors
Capacitors

You may want to have the
DC PWR Delivered via
CAT5 Cable from your
Embedded Board.

RJ45 Pairs (Pin): 8

August 30th.

RF module to Build

RF Board.

1° ASK RF.

Amplitude Switch/Keying

2° Rx: Receiving

TX: Transmission

3° GPIO I/F

Regulator Data Pin

7805, 7812 OR

(1117?)

Homework: Identify/Bring Your
Wire Wrapping Board for RFIB
Design. 4x3 Inch ;

To Build RFIB

1° Board

2° 4 standoffs

3° Build I/O I/F Testing CKT.

To Light up LED when CPU Output "1"

To Turn off LED when CPU Output "0"

Output Testing

S_W Toggles to V_{cc} , when V_{cc} , CPU
Reads as "1"

S_W " to GND, CPU
Reads as "0"

Input Testing

4° CAT-5 Ethernet Cable

RJ45 Right Angle Connectors (2)

One for Embedded ;

One for RF Board ,

5. PWR Distribution to RF

Board :

= 5VDC is adequate

= But RF module can
be operated with

Bigger Power, 9VDC

or 7.5VDC may be

needed during Debugg
ing;

Sept 1. (wed)

Ref: IEEE802.6

1. github.com/alili/cmpe245/2018F
"2021F -"

2. Topics: Design R.F. Board for the
1st homework. 7 pts. (hardware)

Example:

From PP.2. System View

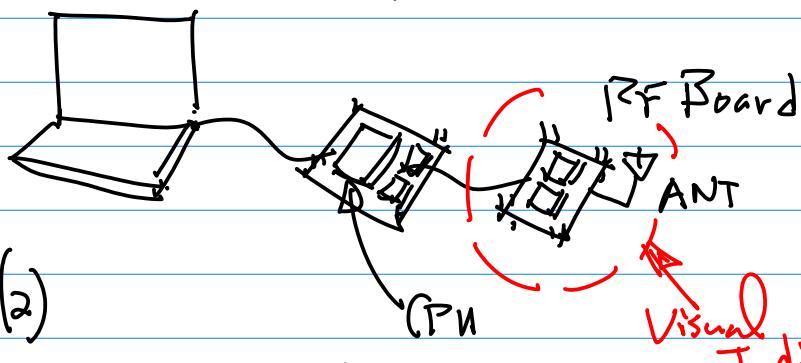
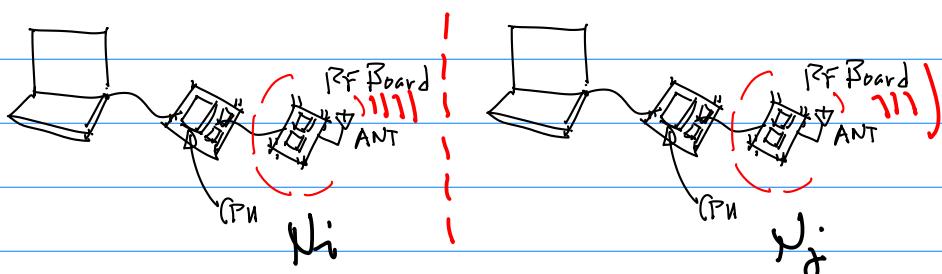


Fig.1 Node i, N_i



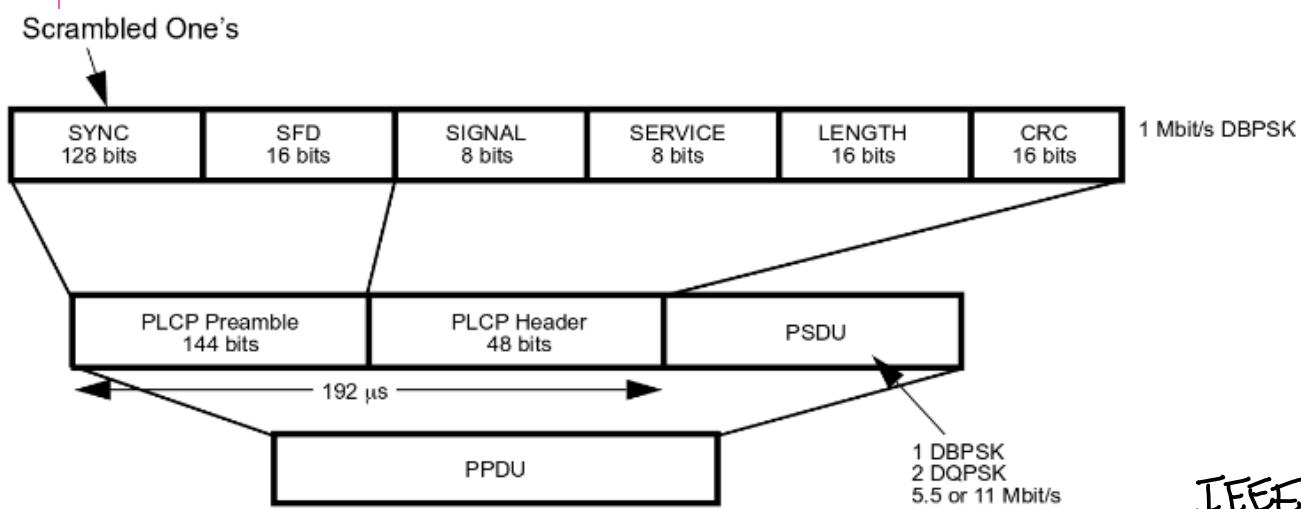
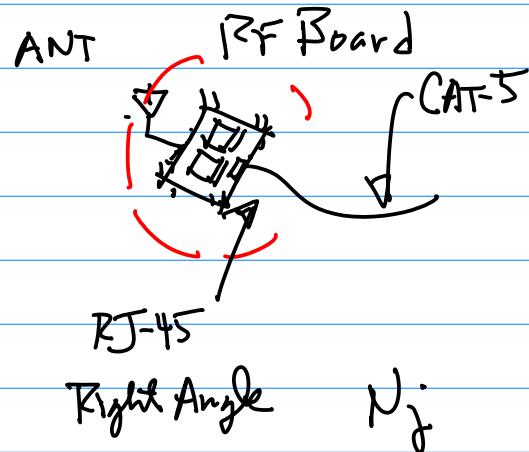
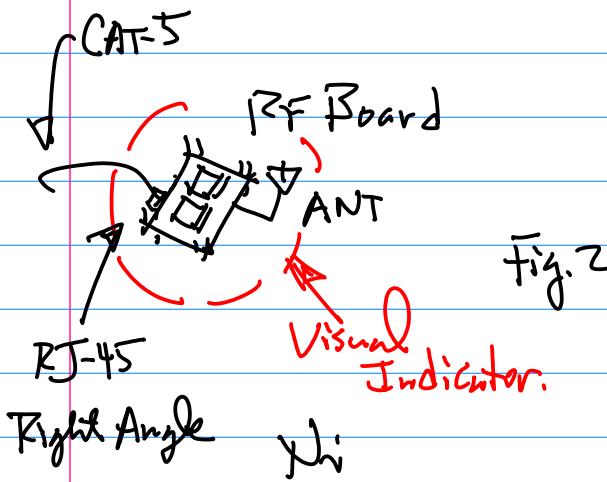


Figure 127—Long PLCP PPDU format

IEEE802.11

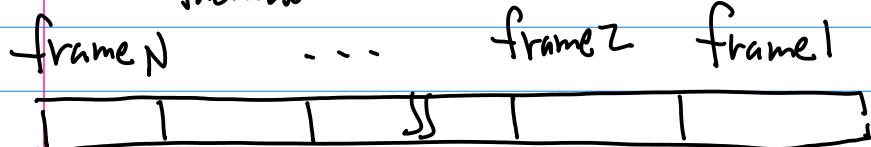
Fig. 3. TR.13

Node N_i , Node N_j , Each Node
is illustrated in Fig 1.

Sending Stream of Data from N_i to N_j



String of Bits Sent in "Framed" fashion.



time \rightarrow

Note: Consider the construction of each frame, frame i , $i = 1, 2, \dots, N_j$

What are the contents to be placed into a frame?

like start bit(s) \rightarrow
to mark the beginning of the communication.
 \rightarrow Timing/Sync.

C.R. (Cognitive Radio), SDR (Software Defined Radio)

multiple Bits in Sync. Design \rightarrow more Reliable \rightarrow "Robust" performance
Maybe

Question: What is the general guideline in terms of designing "Sync" Field?

multiple bits of what?

3 bits Example: b2 b1 b0

$2^3 = 8$	$\begin{array}{c} 0 \ 0 \ 0 \\ 0 \ 0 \ 1 \\ 0 \ 1 \ 0 \\ \vdots \\ , \ , \ , \end{array}$

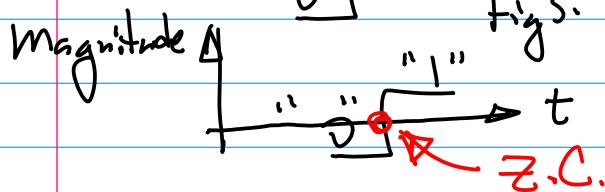
Transition \rightarrow Change of State

"Zero Crossing"

for Example "1"

$\cdot [D]$ OR

$\cdot [1]$



To provide best possible

"Transitions", e.g. Z.C.

Pick OX5 Binary: 101

The Objective for R.F.

Board Framework/Design:

To Allow N_i, N_j to Sync.

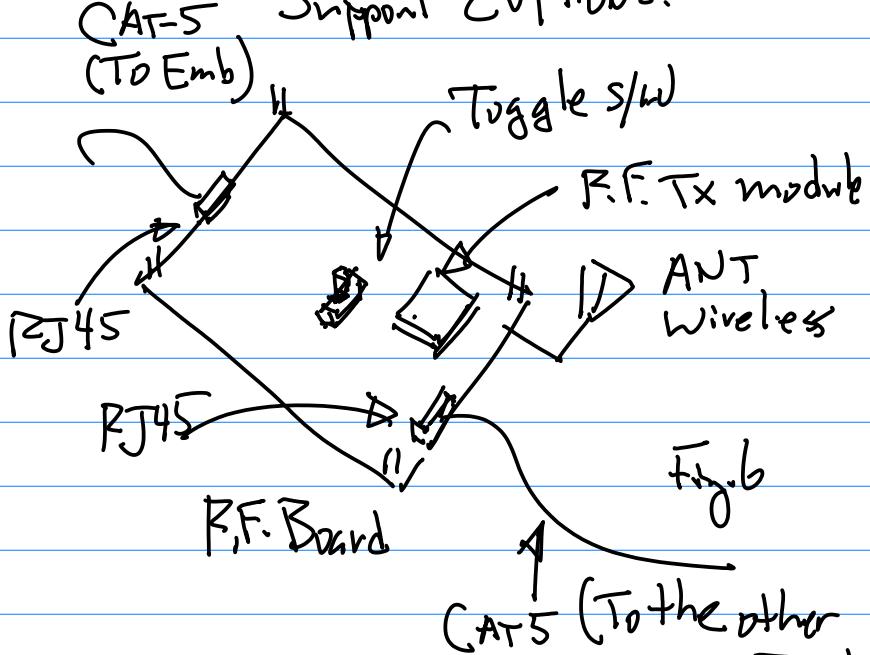
2-Step Approach:

Step 1. Based on Land Line;

Step 2. then R.F (Wireless)

Hence, R.F. Board will have to

Support 2 OPTIONS.



Sept 8 (W)

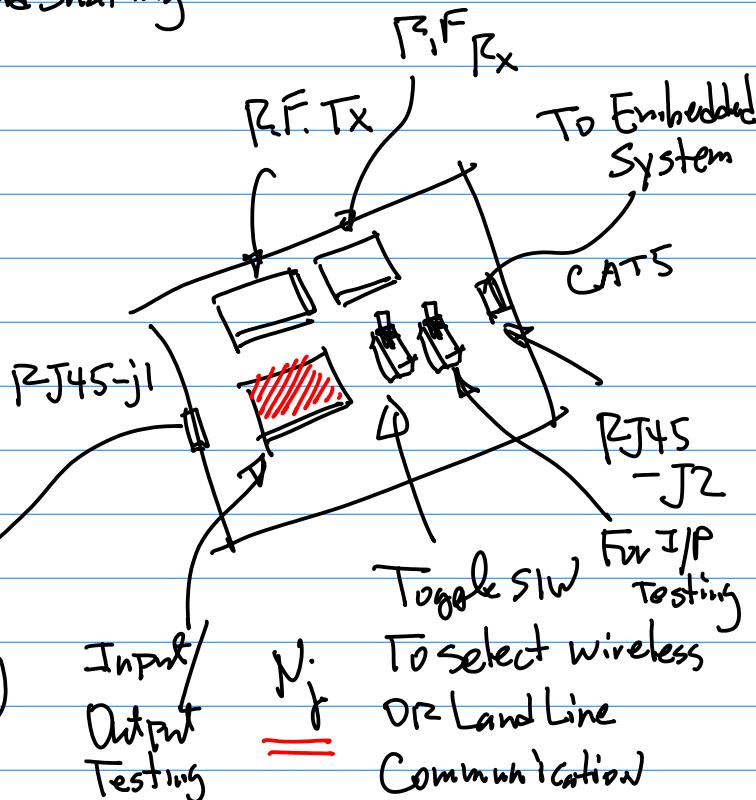
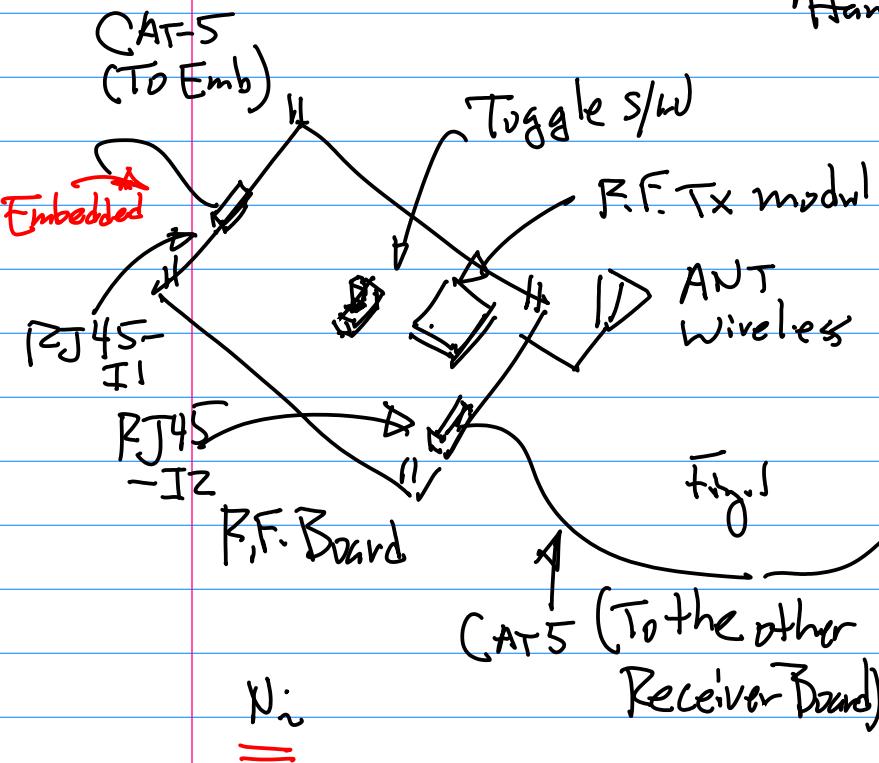
Topics: 1. Prototype for Handshaking
(For LPG17b9, NANO, OR your choice, such as Pie)

Note: NANO Boards are not delivered yet.
So, please find your solution.

Note 2. Semester Long Project, please form

4 person team;

Example: "LAND-Line" Based Design for Handshaking



Homework: Next Monday, Show + Tell

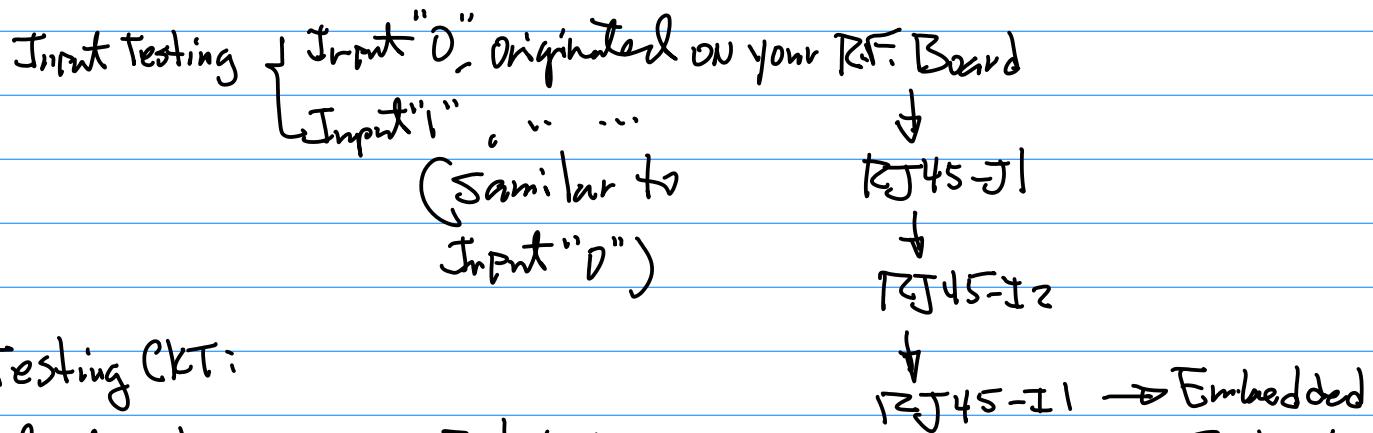
for each Person's R.F. Prototype Board.

Things to show for the next class:

1. 4×3 " Prototype Board; the Brick Through-Hole; metal coating of the through-holes only;
2. Stand-offs
3. RJ45 Connectors ($2 \times$), Right Angle; mounted on the Board;
4. Testing Circuit
 - \downarrow Output Testing
 - Output "1" from the Host/Embedd System
 - Output "0"
 - \downarrow Input Testing
 - Input "0" originated on your R.F. Board
 - Input "1"

\downarrow
RJ45-J1
 \downarrow
RJ45-I2

Continued,



Testing CKT:

Output Testing CKT → Red LED.

Embedded → RFB(N_i) → LED1 → RJ45-I2

via

RJ45-I1

On RFB($N_i \neq N_j$)

GPIOD output
from LFC/NAND

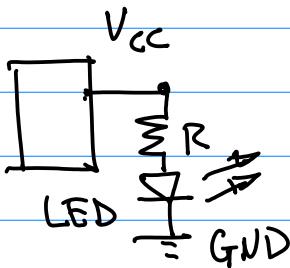


Fig. 2

$$V_{CC} = IR + V_{LED} \dots (1)$$

$$V_{CC} (\text{CMOS}) = 3.3 \text{ VDC}$$

$$V_{LED} = 1.8 \text{ VDC}; I = 10 \text{ mA};$$

Solve for $R \sim 250 \pm \Omega$ or higher;

Input Testing CKT.

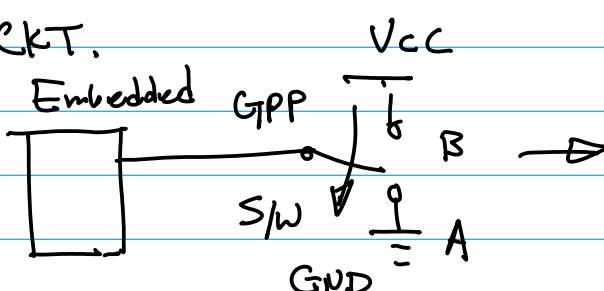
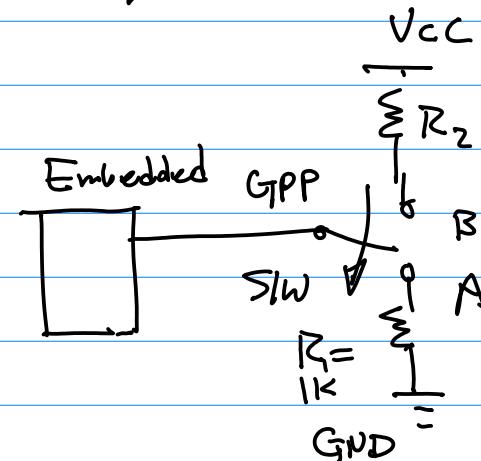


Fig. 3a



Sept 13 (Monday)

Todays Topics: 1° Hardware platform.

2° Sync Algorithm, LISA

(Linear Invariant Sync. Algorithm)

Ref: 1° ... github, ID: ~106...

2021F-106
for target RISC-V
(System On Chip)

2° github/finalisti/Cmpe245/...

2021F-105 ~ (NAND
Connector)

FPGA Solution (RISC-V), Igloo2.

a Board from Future Electronics

b IP-Core for CPU in Verilog
Can be downloaded ;

c TAP Plastic
NAND Board. Connector J-41

Identify GPIO

Example: Let's consider the design
of Sync Field in Wireless
Communication

Consider 1° Place to define sync.
Bits.



Suppose we have a letter
in a Hex Number

$0x4f$
 $0 \boxed{1} 00 : 1111$ Binary
Equivalent
"0"
↑
Due to Noise, the
corruption may lead
to a failure

$0 \boxed{1} 00 : 11110$...
↑
Correct
missing Sync. Bit

2° Sync is established
Based on "2 C"

The change of the state of
a signal, For Example

"0" → "1" OR "1" → "0"

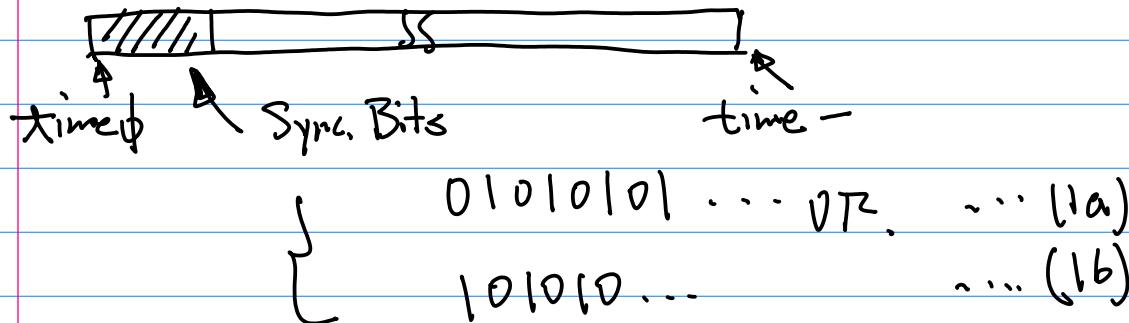
Preferred change is to
include "1".

Requirements:

1° Establish Sync with
Change of State

01010101 ...

OR
101010...



Consider Random Disturbances, alters one bit in the Sync field. (1a)

of the Sync Field,
e.g. the Beginning
of the Payload.

010101...
1 (Random Noise)

Suppose we know the Sync. field consists of 10 Bits. \rightarrow Discard the 1st 2 bits until we have 0101...

Pattern again, to satisfy the total Number of bits in the Sync. Definition.

Question: How to utilize the Sync Pattern even when this pattern is corrupted, And not to start over again?

- (1) The Need to Re-use the Sync Field Even if it is corrupted;
- (2) The Need to Known where is the end of

Sept 15 (W)

Homework: Due Next Wed.
Official (2pts) Sept. 22nd.

1° RF Board Prototype (finish this Prototype for Landline I/F).

2° Run a simple program C/C++ or Python to perform Testing of Input/Output function.

Input Testing : GPIO Reads Input "0" AND/OR "1", Note Toggle the Switch on the RF Board to produce "0", "1".

Output Testing: LED On when Output = "1"
LED Off = "0"

2° To Establish Timing
Even if Random disturbances
Corrupted Some bits in
Sync. Field, in addition to
pin point to where the
Corruption occurs.

What to Submit:

1° One description of your design implementation;

2° Photo of the System Set up

Host Laptop + Embedded Board + RF
LPC / NANO Board

3° Source (Soft Copy) LPC1769

Export your work as a project

NANO, Python or C/C++ Code

4° Video Clip 5~10 Sec.

~~On CANVAS OR~~ Submit the Zip
file via E-mail;

Embedding ID Index into
Sync Field.

From 101010 ...

Change it to the following.

g Take 8 bits

10101010 at a time

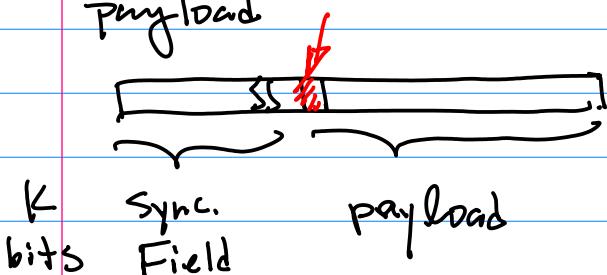
Taking the 1st 4 bits of this
Segment (1 byte), preserve
its pattern

prefix: 1010

Then, Taking the 2nd 4 bits
modify it to make it as
an index to reflect this

Byte position in the Sync

Field. e.g. 0 000 ... "0"
0 001 ... "1"
0 010 ... "2"
0 011 ... "3"



Cmpe245

11

0 0 0 0 ... "0"
 0 0 0 1 ... "1"
 0 0 1 0 ... "2"
 0 0 1 1 ... "3"
 ...

1 1 1 1 ... "f"

Assemble prefix and ID together

1 0 1 0 ; 0 0 0 0

1 0 1 0 ; 0 0 0 1

:

1 0 1 0 ; 1 1 1 1

a d i a l ; a z ; ... ; a f ... (1) 16 Bytes

Now, Change 1010 to 0101 = 0x5
 Therefore,

50;51;52 ... ;5f ... (z) 256 bit.

Integrate (1) & (z) together, 16 Bytes Let's define Confidence level η as follows,
 a d i a l ; a z ; ... ; a f ; 50, 51, ... , 5f

e.g.

0xa0, 0xa1, ... , ..., 0x5f ... (z)

32 Bytes (256 bits)

Design An Algorithm for Sync.
 Extraction @ Rx End

Question: What is the minimum Number of Bits in (z) do we need to establish Sync.?

Remark 1: Minimum 8 consecutive Bits with first 4 bits from alternating Bit Pattern, e.g. DXA, or 0x5 is Needed to Establish Sync. Given

Question: Sync. Based 8 bits v.s. Sync. Based on 16 bits, which one gives higher confidence? Ans: 16 bits,

Question: What is the number bits that gives the highest confidence level?

$$\eta = \left(\frac{\text{Sync. Establish with } K \text{ bits}}{\text{Total No. of bit in Sync. Field}} \right)^{(4)}$$

Sept. 20 (Mon)

Topics: 1^o LISA Conclusion

2^o Base Band Signals
with Defintional Modulation
Techniques, ASK, FSK, PSK.

3^o Project 1. Assignment

Software Defined Radio
Implementation of LISA.

The Oct. 8th (Fri), 11:59pm.

Written Requirements to Be

Posted on git & SJDE CANVAS.

Official (WRT5)

a. Land Line "LISA"

(Based on Homework
of Input/Output Testing)

b. RF. "LISA".

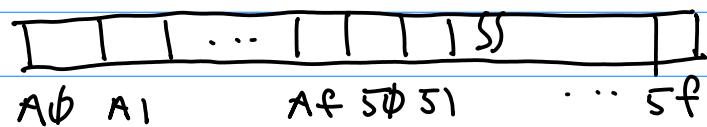
ASK RF Rx & Tx for the
implementation.

Example: Compute n (confidence
level, CL) for the sync
established Based 8 bits
data from the Sync. Field.

Sol. From Eqn(4),

$$\begin{aligned} n &= \frac{8}{\text{Total Bits}} = \frac{8}{256} = 2^3 \\ &\quad \text{in the Sync} \\ \text{Field} &= 2^{-5} = \frac{1}{32} \end{aligned}$$

Fig. 1



Linear: Index Arranged in a Linear
fashion;

Invariant: Capture 8 bit sync
pattern regardless of
its/their position(s);

Conclusion: LISA algorithm
Provides Robust, Versatile
Sync. Scheme to Allow N_i, N_j
to Establish Sync. (Handshaking).

Homework: Write C/C++ (or python)
for your hardware platform, to Realize
Baseline "LISA". (Due Sept. 27
Monday) 1 pt.

a. Prompt the user for his/her
Input for the Number of Bytes
to establish Sync.

1 Byte, 2 Bytes, ..., 32 Bytes

b. Implementation for "the Base
Line"

Baseline: Consecutive Bytes.

C. Creates A Test Pattern
as follows, "testsync.txt"

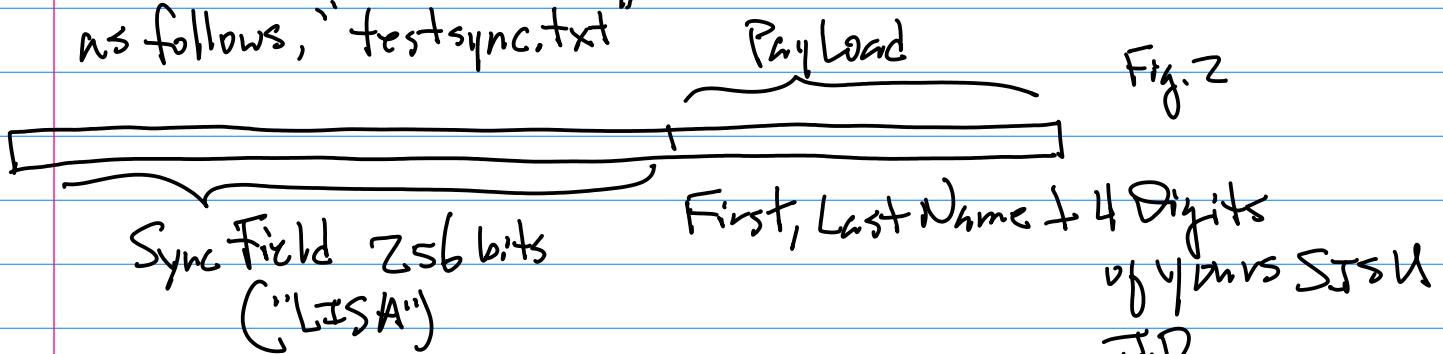


Fig. 2

Plaintext file.

d. Run your program to process
the testSync.txt, to extract
Sync. By Printing the payload.

Note, then future framework
will allow the Bytes from
Non-Consecutive order.

Note: Optional Requirements

Pseudo Code.

What to Submit:

a. Source Code (Indicate if
on Linux, or Windows, or
LPC, or NAND)

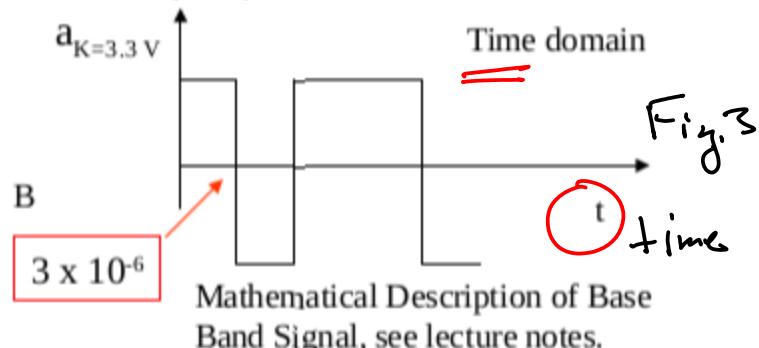
b. Binary Executable;

c. Optionally, Pseudo Code.

Base Band Signal:

Without

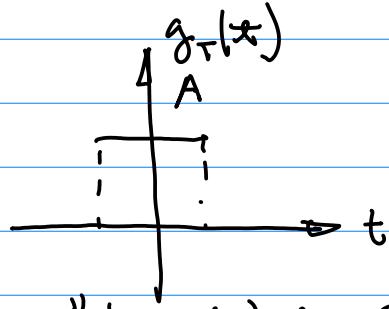
A Definition: Signal transmitted near zero frequency modulation.



Signd from GPIO, PWM, etc.
for example.

Suppose the Signal is periodic
Signal. Concentrate on a Single
Bit.

Fig.4



Subscript "T" in $g_T(t)$ for One bit

CmpE245

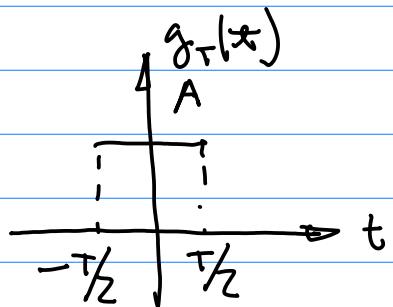
14

$$g_T(t) = \begin{cases} 1 & \text{for } t \in [-T/2, T/2] \\ 0 & \text{Otherwise} \end{cases} \quad \dots (1)$$

(bps - Bit per send)

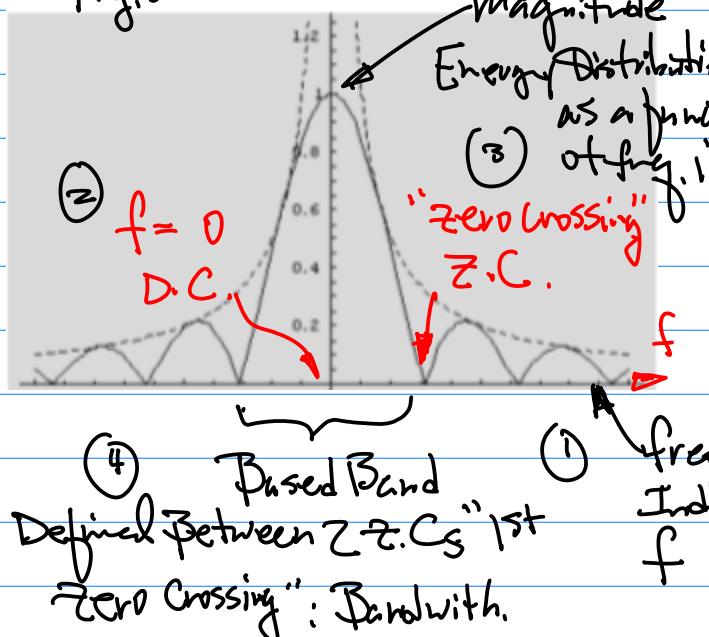
Sol:

Fig. b



Frequency Characteristics of the B.B. Signals:

Fig. 5



From the given bit rate,

$$f = 9600 \text{ Hz}$$

$$\text{Hence, } T = \frac{1}{f} = \frac{1}{9600}$$

$$= 1.04 \times 10^{-5} \text{ Sec}$$

$$= 1.04 \times 10^{-6} \text{ Sec (micro second)}$$

Consider Frequency Characteristics in Fig. 5,

Define Band width of the

$$g_T(t)$$

$$\bar{B}W =$$

(Between the 1st pair of Z.C.s)

Sept 22 (W)

Topics Today: Base Band Signal Analysis.

$g_T(t)$ from Eqn (1)

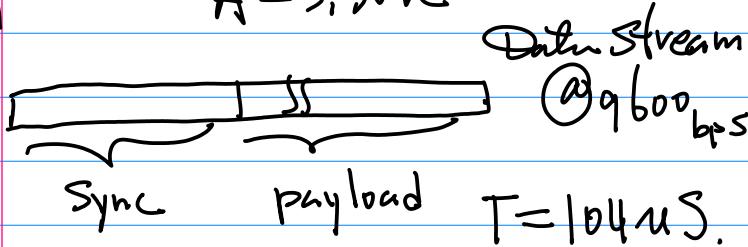
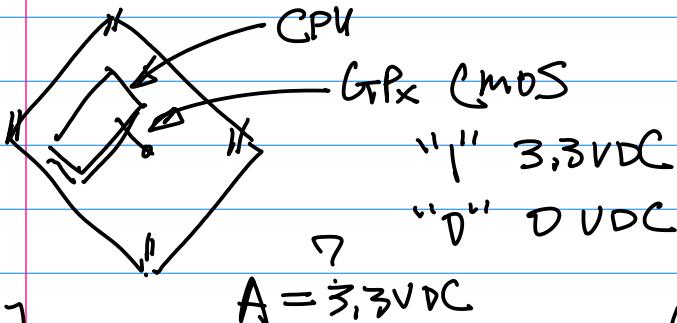
Example: Find $T = ?$ for a Base Band Signal @ 9600 bps

By Fourier Transform,

$$g_T(t) \xleftrightarrow{\text{F.T.}} \mathcal{F}[g_T(t)]$$

... (za)

$$\mathcal{F}[g_T(t)] = A_T \frac{\sin \pi f T}{\pi f T} \dots (zb)$$



Find Bandwidth from the 1st pair of Z.C. in Eqn(zb)

$$AT \frac{\sin \pi f T}{\pi f T} \text{ set } 0$$

then $\frac{\sin \pi f T}{\pi f T} = 0$, Hence

$$\sin \pi f T = 0$$

$$\pi f T = n\pi$$

$$n = 0, 1, 2, \dots$$

$f T = n$, where $n = 1$ 1st pair Z.C.

$$f T = 1, \therefore f = \frac{1}{T}$$

$$\text{Therefore, } B.W. = 2 \frac{1}{T} = 2 \frac{1}{f} \dots (3)$$

Example: Suppose a Baseband Signal is operating @ 9600 bps.

1. Find its Bandwidth?
2. If we double the Bit rate, find its new Bandwidth?

Sol.: For B.W., from eqn(3)

$$B.W. = 2 \frac{1}{f}$$

$$\text{and } T = \frac{1}{f}, \text{ or } f = 1/T$$

$$\text{hence: } B.W. = 2f = 19200 \text{ Hz}$$

When the bit rate is doubled, so is the B.W.

And T_{new} is the half of its original value.

PP60 IEEE 802.11b

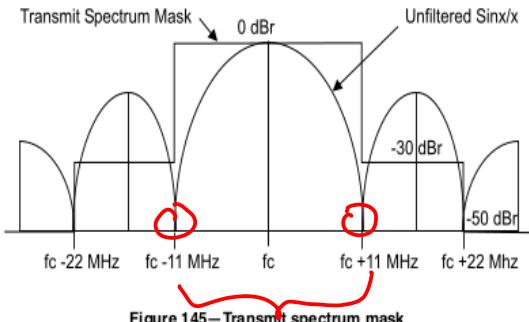
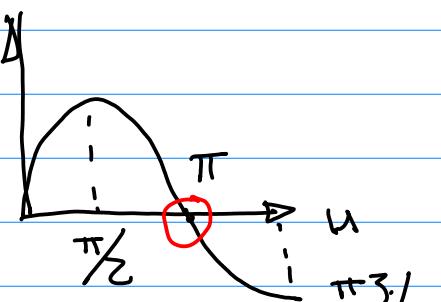


Figure 145 - Transmit spectrum mask

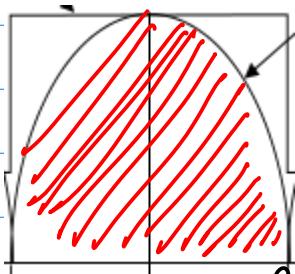
18.4.7.4 Transmit center frequency tolerance

$$\begin{aligned} B.W. &= f_c + 11 \text{ MHz} - (f_c - 11 \text{ MHz}) \\ &= 11 \text{ MHz} + 11 \text{ MHz} = 22 \text{ MHz} \end{aligned}$$

f_c = Carrier frequency ≈ 2.4 GHz
from the modulation
Carrier Signal (R_c) is modulated

by a Base Band Signal.

80% of the total energy of the R.F. Signal (Base Band + Carrier) has to be captured within the Base Band



80% of the Energy.

This 80% Requirements has to Be Satisfied by F.C.C.

$$\left(\frac{\text{Energy of the Base Band}}{\text{Energy of the total Signal}} \right)^2 = 80\%$$

or higher.

Question: How to Pack more energy into a Base Band (1st Part of the Z.C.)

Discrete Fourier Analysis Tool for the Design.

Sept. 27 (Mon)

Topics: 1^o Analytic Tool for Base Band Signal (Spectrum) Analysis;

2^o Semester Long Project (LoRaRF)

Team project (4 person)

Team, Each Team will have to Implement LoRaRF for C.R (Cognitive Radio)

Show+Tell "LISA" on NIAND

By Jonathan. Very Good

Note:

- 1^o Header: Name of the code;
- b. Coded by: c. Date
- d. Version, vX1.0;
- e. Status: Tested, Debugging
- f. Note, Such as version of the Python, or Compilation
- (u) & Bind for C/C++;

2^o Testing/Verification, to make sure the code works for All Possible Cases even when the Sync is corrupted;

Homework (1 pt). Continuation

of homework on pp. 12-13.

LAN Line Testing Between Ni & NJ Due A week from Today.

Oct. 4 (Monday) Before the Class.

Submission:

- 1^o Sub: CmpE245 homework Sync. LAN Line



WIRELESS, SENSING & TIMING



SX1276/77/78/79

DATASHEET

SX1276/77/78/79 - 137 MHz to 1020 MHz Low Power Long Range Transceiver

2. Sub. A photo of your testing result (Screen Capture); (where R.F. Tx module is connected to GPP of the target platform, LPC1769)

3. Submit A photo showing your testing environment. ($N_i \neq N_j$).

4. Source Code, and Binary;

Project 1. is Coming LISA
ON R.F. Board Communication

(10 pts) Due Oct 11th (Mon)

Before class, please have the R.F. Part Ready when Submission is done.

Note: Need Timer/Interrupt function on LPC1769.

Implementation: Timer \rightarrow

Interrupt on a desired

Time Interval for a chosen Bit Rate, \rightarrow Lead to R.F.

Tx module to send a bit

Announcement:

1. Due to Off-Campus Program, Change Office Hours to M, Tue, 3:40-4:40 pm.

2. Semester Long Project.

Kit, start prepare purchasing

Discussion On Spectrum Analysis Tool.

Discrete Fourier Transform \rightarrow

Compute Spectrum \rightarrow Evaluate the

Energy of the Signal \rightarrow To Modify

Improve the Energy (80%)

Distribution Requirements.

Example: Suppose A Base Band

Signal $y_r(t)$, As An Output from

GPP Port:

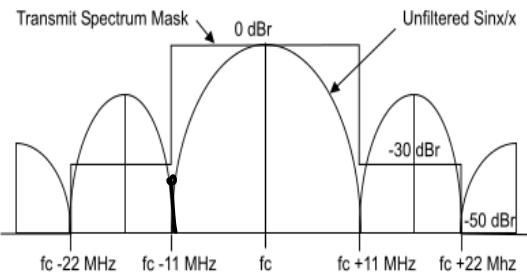
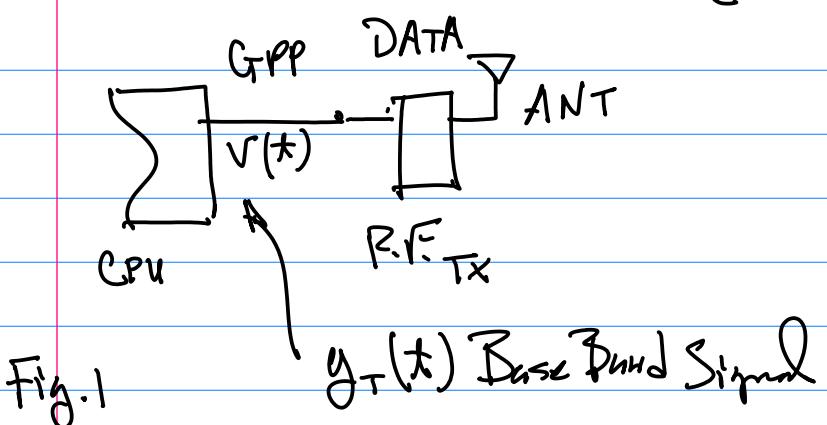
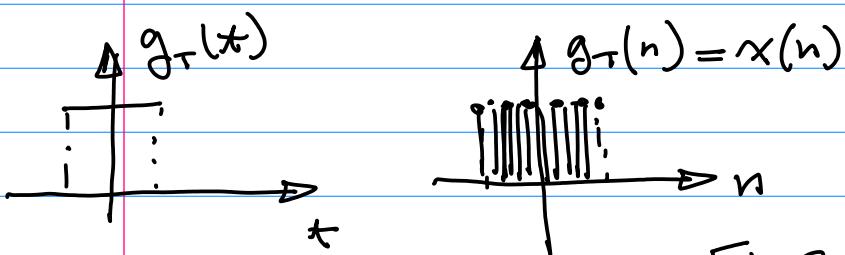


Figure 145—Transmit spectrum mask

Base Band Signal $y_T(t)$.

Digitize the Signal $y_T(n)$

n : Time Index



Find its Fourier Transform.

Discrete

$$X(m) = \frac{1}{N} \sum_{n=0}^{N-1} x(n) e^{-j \frac{2\pi m n}{N}}$$

... (1)

$X(m)$: Discrete Fourier

Transform;

m : A Frequency Index

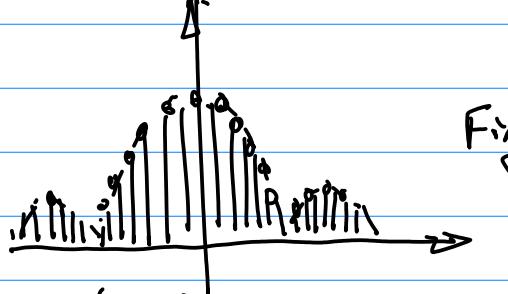
$$m = 0, 1, 2, \dots, N-1$$

$X(m)$ Digitized

$x(n)$: Discrete Signal in

Time Domain, Base Band Signal for Example. homework.

18.4.7.4 Transmit center frequency tolerance



Sept. 29 (Wed)

Announcement:

1. Project 1 (10 pts) Due 3 week
at 8th Before 12:30 PM.

Requirements

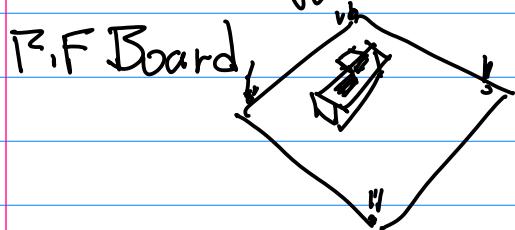
(1) Individual Project, However working as team is required.

Report, Prototype Board, Programs have to be individual, Team work including discussions, debugging as a team is encouraged.

(2) Implement LISA for R.F. Communication. Based

on LISA

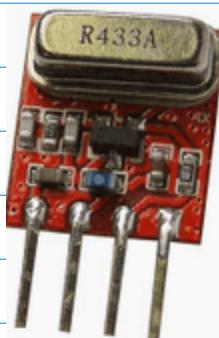
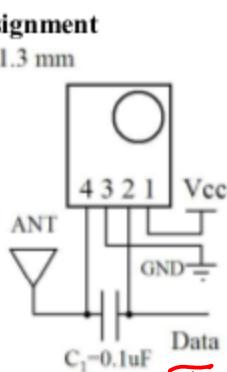
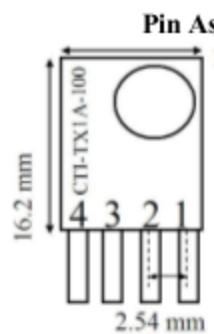
To have a toggle switch on R.F Board,



Position A: For Land Line

Position B: For R.F. Wireless

Note: ASK R.F. module, From [github/kalilic/Cmpe245](https://github.com/kalilic/Cmpe245) ~ 2017 f...TX



Data sheet
(Tech Spec)

$V_{cc} \in [3.3, 9]$

Pin Number	Label	
1	V_{cc}	Power
2	DATA	Data Input
3	GND	Ground
4	ANT	Antenna

Table 2. Pin Assignment

$330 \sim 450 \text{ MHz}$

$\sim 23 \text{ cm.}$

(3) On Receiver Side (R.F. Rx)

430.5 MHz

f_c Carrier frequency

A

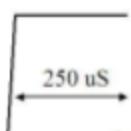
	Symbol	Test Condition	Parameter		
			Min	Typical	Max
Frequency	F_c		315 MHz	430.5 MHz	433.92 MHz
Modulation	ASK				

b R.F. Tx :

$$T = 1000 \mu\text{s} = 1 \text{ ms}, 1 \text{ kbps};$$

Logic "1"

When receiving signal high $< 500 \mu\text{s}$



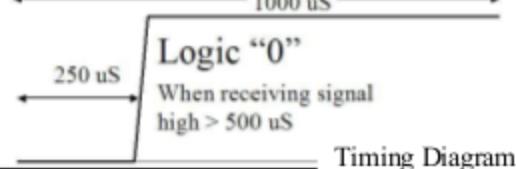
Over Sampling on Rx Side.

Determine R.F. Tx module Bit Rate

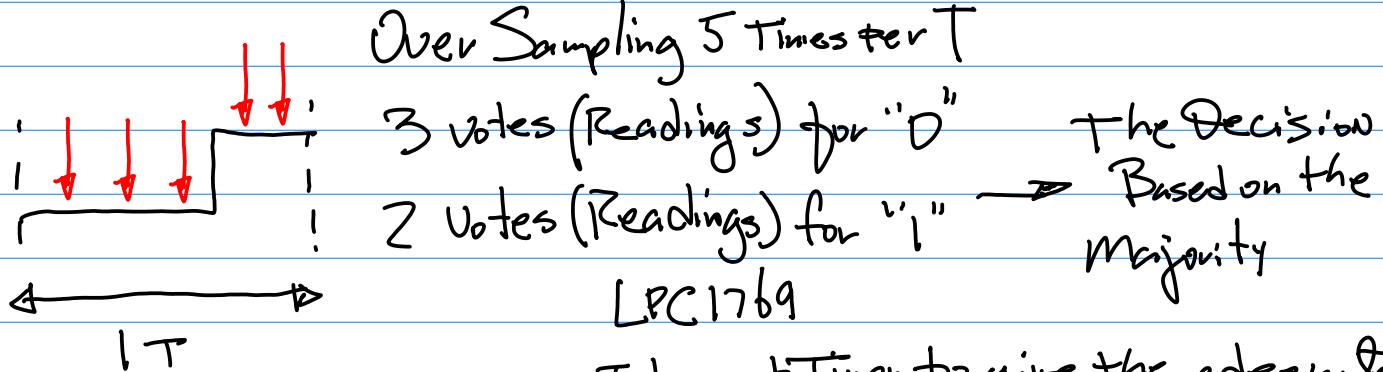
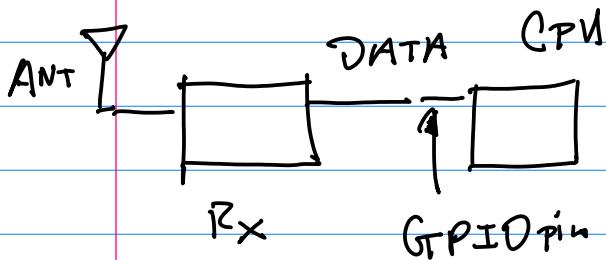
$$1 \text{ kbps} \rightarrow \text{Time per bit } T = \frac{1}{f} = 1 \times 10^{-3} \text{ s} \quad (f = 1 \text{ MHz})$$

Over Sampling +

In One Period T, Sample K Times



On Rx Side

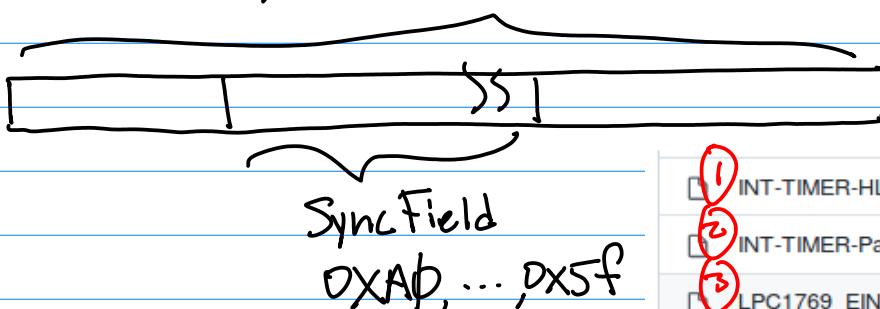


(4) Receiving Data from Rx, Read the Data

And place the Data into A Buffer, 1Kbits 1kbit

Ref: INT-TIMER-HL ~

(github)



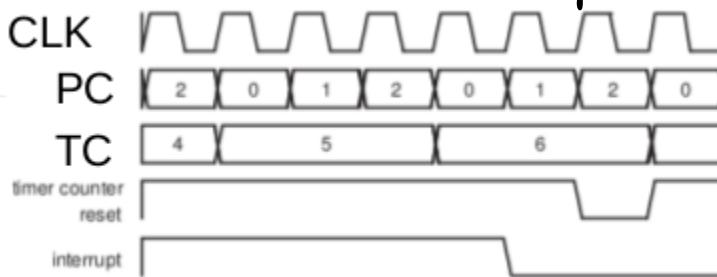
<input type="checkbox"/> 1	INT-TIMER-HL-2016--11-24.pdf	Add files via upload
<input type="checkbox"/> 2	INT-TIMER-Part2-HL-2016--12-4.pdf	Add files via upload
<input type="checkbox"/> 3	LPC1769_EINT_TIMER2016-4-19.zip	Add files via upload

Parse the Buffer to Extract Sync.

Objective: To Transmit Your Name (First, Last), plus 4 Digits

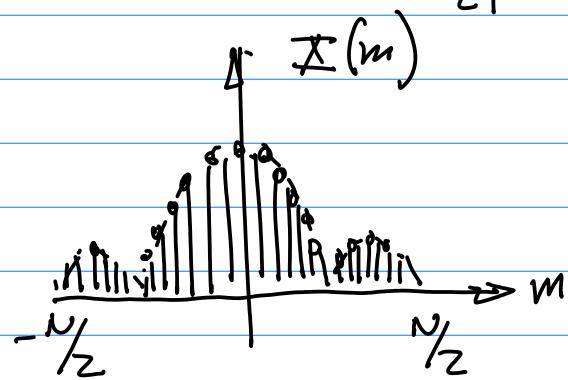
Student ID.

Timer Setup & Special Purpose Registers



Submission:

- 1º Report ($2 \sim 5$ pages in IEEE)
- 2º Same Code + Binary.
LPC1769 Zip. (Exported Project)
- 3º photos in Report
 \cong Entire System, Host + Embedded
+ R.F.
- 4º Video Clips < 10 Sec.
5 Sec. Better
Shows the Result.



Note: It is a plot of a Power Spectrum of $X(m)$.

Oct. 4 (Monday)

Today's Topic: Power Spectrum Analysis for Base Band Signal.

Continue the Discussion on Expr(1), pp.18

$$X(m) = \frac{1}{N} \sum_{n=0}^{N-1} x(n) e^{-j 2\pi \frac{mn}{N}} \quad \dots (1)$$

Q&A Session on Project 1.

1. Over-Sampling Implementation

① Bit Rate $\rightarrow T$ Time Interval for Period;

② Normal Sampling:

GPIO Read GPIO Pin
is connected
to Data Pin of
Rx

Properties & Physical meaning:

$$X(m) = X(m+kN) \dots \text{(z)}$$

where $K=0, 1, 2, \dots$

N No. of points per one period.

e.g. Period.

$X(m)$ is a periodical function.

Its period is equal to N .

Timing: Read once per T
Period

Timer (Interrupt)

Software Side: Create a Buffer with size of 1k, Assuming the Communication @ Low bit rate ($\sim 1024 \text{ bits/sec}$, ..., 9600 bits/sec)



Interrupt Timer is the key

Continuation for DFT in Eqn(1)
part. 2 Eqn(2)

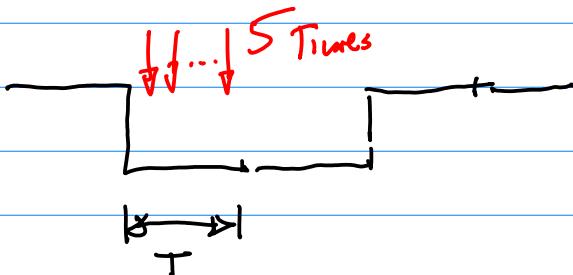
Define a Power Spectrum

$$P(m) \triangleq \sqrt{\operatorname{Re}[\tilde{x}(m)]^2 + \operatorname{Im}[\tilde{x}(m)]^2} \quad \dots (3)$$

Parse the Buffer, find/Extract Sync Bytes.

③ Over Sampling: Keep the Same Bit Rate, RF Rx Output is presented to GPIO pin, GPIO Read

5 Times per period.



Read into A Buffer, 5K

Buffer \rightarrow Buffer 1K

(After Preprocessing)

where

$$\begin{aligned} e^{-j\omega} &= \cos(-j\omega) + j\sin(-j\omega) \\ &= \cos(j\omega) - j\sin(j\omega) \end{aligned}$$

Hence,

$$= \frac{1}{N} \sum_{n=0}^{N-1} X(n) \cos\left(-j2\pi \frac{mn}{N}\right)$$

$$= \frac{1}{N} \sum_{n=0}^{N-1} X(n) \cos\left(j2\pi \frac{mn}{N}\right)$$

Preprocessing: Voting Algorithm. That is the real part

Note: for Eqn(3), with the understanding of the Power Spectrum Definition, we can drop Square-root Computation for Simplicity.

Note:

$$P(m) = P(m + nN) \dots (4)$$

$$P_f^f = P(m) = \sqrt{R_e^2[\mathcal{X}(m)] + I_m^2[\mathcal{X}(m)]}$$

$$P(m + KN) = \sqrt{R_e^2[\mathcal{X}(m + KN)] + I_m^2[\mathcal{X}(m + KN)]}$$

where

$$\mathcal{X}(m) = \mathcal{X}(m + KN)$$

Therefore

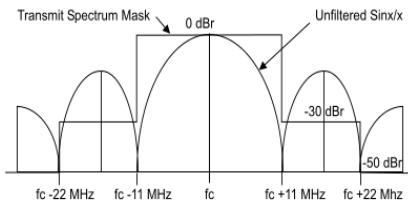
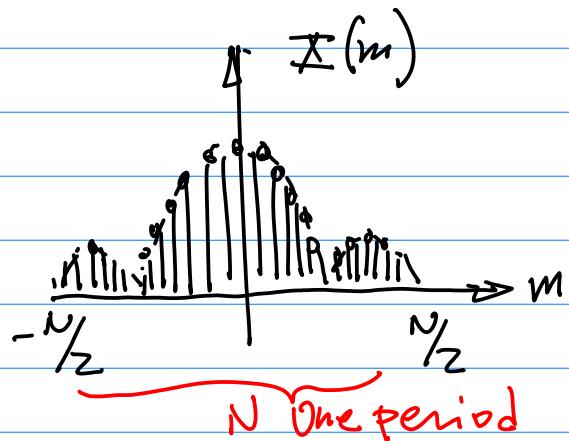
$$R_e^2[\mathcal{X}(m + KN)] + I_m^2[\mathcal{X}(m + KN)]$$

$$= R_e^2[\mathcal{X}(m)] + I_m^2[\mathcal{X}(m)]$$

So, we know this equal to $P(m)$ Any One Period (N -Points)

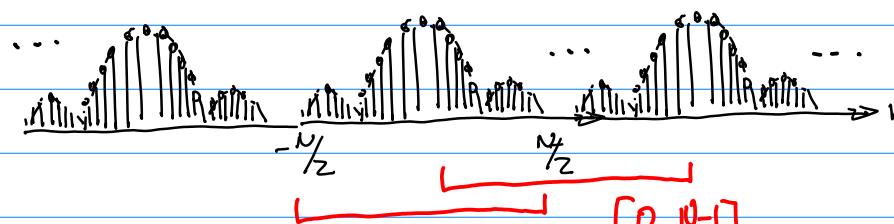
O.E.D.

Example:



18.4.7.4 Transmit center frequency tolerance

IEEE



$$[-\frac{N}{2}, \frac{N}{2}]$$

Fig.1a
periodical function

$$P(m)$$

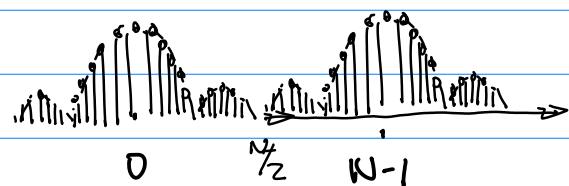


Fig.1b

$$[0, N-1]$$

Computation of $X(m)$ and its Power Spectrum.

Hand Compute DFT. Eqn (1).

$$\begin{aligned} X(m) &= \frac{1}{N} \sum_{n=0}^{N-1} x(n) e^{-j \frac{2\pi}{N} mn} \\ &= \frac{1}{N} \left(x(0) e^{-j \frac{2\pi}{N} \cdot 0} + x(1) e^{-j \frac{2\pi}{N} \cdot 1} \right. \\ &\quad \left. + x(2) e^{-j \frac{2\pi}{N} \cdot 2} + \dots + x(N-1) e^{-j \frac{2\pi}{N} \cdot (N-1)} \right) \end{aligned}$$

$$= \frac{1}{N} \left(e^{-j \frac{2\pi}{N} \cdot 0}, e^{-j \frac{2\pi}{N} \cdot 1}, e^{-j \frac{2\pi}{N} \cdot 2}, \dots, e^{-j \frac{2\pi}{N} \cdot (N-1)} \right) \begin{bmatrix} x(0) \\ x(1) \\ x(2) \\ \vdots \\ x(N-1) \end{bmatrix}$$

$$X(m) = \frac{1}{N} \left(e^{-j \frac{2\pi}{N} \cdot 0}, e^{-j \frac{2\pi}{N} \cdot 1}, e^{-j \frac{2\pi}{N} \cdot 2}, \dots, e^{-j \frac{2\pi}{N} \cdot (N-1)} \right) \begin{bmatrix} x(0) \\ x(1) \\ x(2) \\ \vdots \\ x(N-1) \end{bmatrix}$$

for $m=0$

$$X(0) = \frac{1}{N} \left(e^{-j \frac{2\pi}{N} \cdot 0}, e^{-j \frac{2\pi}{N} \cdot 0}, e^{-j \frac{2\pi}{N} \cdot 0}, \dots, e^{-j \frac{2\pi}{N} \cdot 0} \right) \begin{bmatrix} x(0) \\ x(1) \\ x(2) \\ \vdots \\ x(N-1) \end{bmatrix}$$

for $m=1$

$$\mathcal{X}(1) = \frac{1}{N} \left(e^{-j\frac{2\pi \cdot 0}{N}}, e^{-j\frac{2\pi \cdot 1}{N}}, e^{-j\frac{2\pi \cdot 1 \cdot 2}{N}}, \dots, e^{-j\frac{2\pi \cdot 1 \cdot (N-1)}{N}} \right) \begin{bmatrix} x(0) \\ x(1) \\ x(2) \\ \vdots \\ x(N-1) \end{bmatrix}$$

for $m=2$

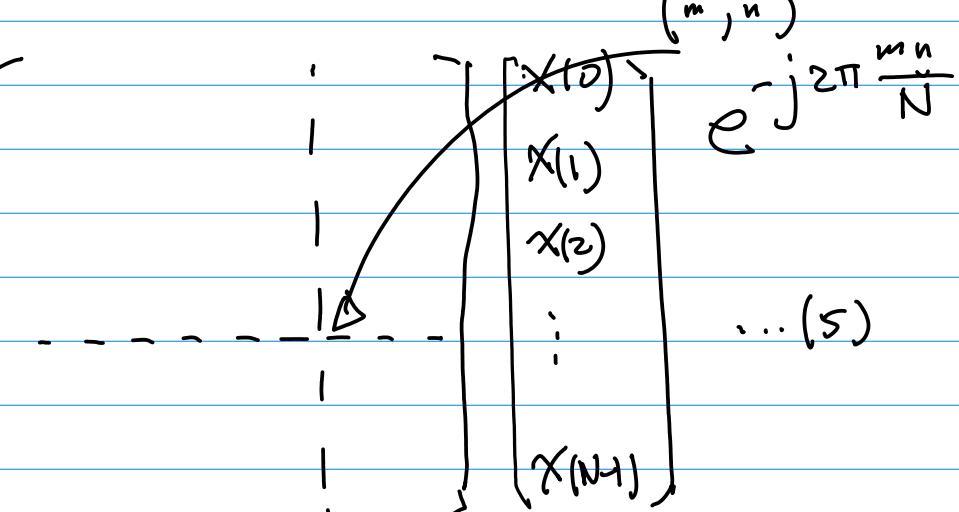
$$\mathcal{X}(2) = \frac{1}{N} \left(e^{-j\frac{2\pi \cdot 0}{N}}, e^{-j\frac{2\pi \cdot 2}{N}}, e^{-j\frac{2\pi \cdot 2 \cdot 2}{N}}, \dots, e^{-j\frac{2\pi \cdot 2 \cdot (N-1)}{N}} \right) \begin{bmatrix} x(0) \\ x(1) \\ x(2) \\ \vdots \\ x(N-1) \end{bmatrix}$$

 \vdots for $m=N-1$

$$\mathcal{X}(N-1) = \frac{1}{N} \left(e^{-j\frac{2\pi \cdot 0}{N}}, e^{-j\frac{2\pi \cdot N-1}{N}}, e^{-j\frac{2\pi \cdot (N-1) \cdot 2}{N}}, \dots, e^{-j\frac{2\pi \cdot (N-1) \cdot (N-1)}{N}} \right) \begin{bmatrix} x(0) \\ x(1) \\ x(2) \\ \vdots \\ x(N-1) \end{bmatrix}$$

Put these $\mathcal{X}(0), \mathcal{X}(1), \mathcal{X}(2), \dots, \mathcal{X}(N-1)$ together,
we have

$$\begin{bmatrix} \mathcal{X}(0) \\ \mathcal{X}(1) \\ \mathcal{X}(2) \\ \vdots \\ \mathcal{X}(N-1) \end{bmatrix} = \frac{1}{N} \begin{bmatrix} \mathcal{X}(0) \\ \mathcal{X}(1) \\ \mathcal{X}(2) \\ \vdots \\ \mathcal{X}(N-1) \end{bmatrix}$$

 $\dots (S)$