สไลด์ที่แล้วเราเรียนเกี่ยวกับ

การส่งข้อมูล digital analog ไปยังช่องทาง digital

ANALOG TRANSMISSION

ความผิดพลาดการส่งข้อมูลแบบ analog สัญเสียอย่างไร

Digital Modulation

→ what is signal?
  ↳ voltage that's changing over the time.
→ analog signal
  ↳ analog signal should be smooth and continuous.

↳ may be limited to range with max and min value.
↳ there are still infinite number ∿∿∿

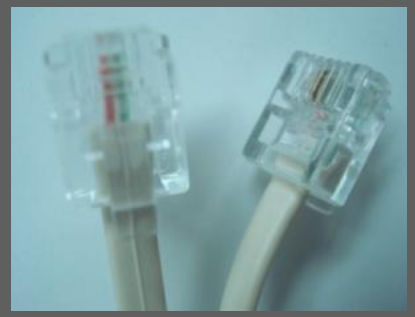
→ digital signal
↳ digital signal should have a finite set of possible value

ช่องทางการส่งสัญญาณแบบใดล่ะ ถือว่าเป็นช่องส่งสัญญาณ

ANALOG **Wire / Wireless**

ANALOG TRANSMISSION MEDIA

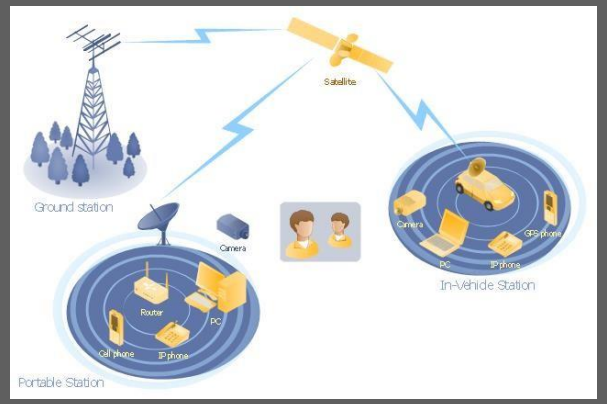
WIRE



สายโทรศัพท์
(ADSL,VDSL)

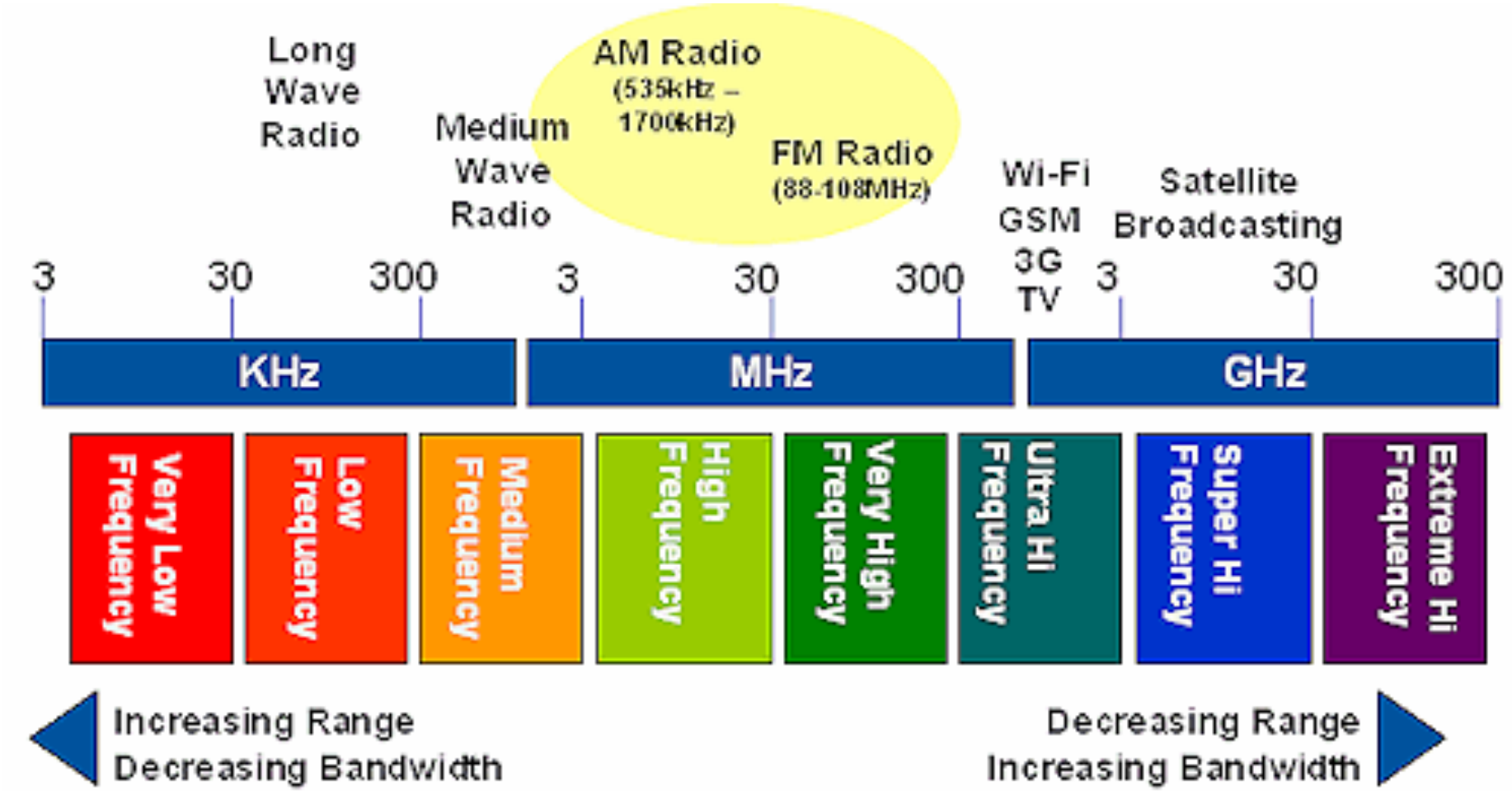
Coaxial Cable
(DOCSIS)

WIRELESS



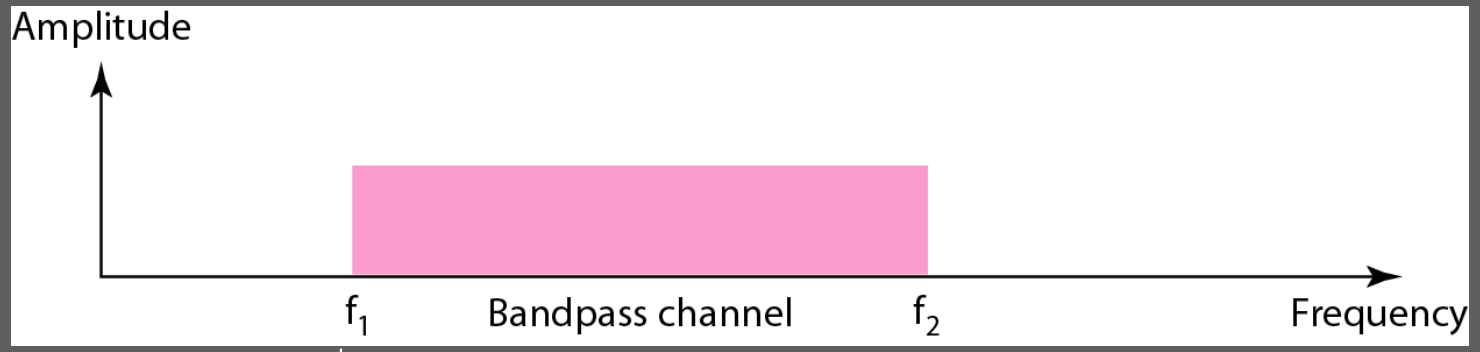
Frequency Utilization

Bandwidth Limitation



Transmitting
Direct
Digital Signal is not possible

ANALOG CHANNEL: BAND PASS CHANNEL



in —ᴖᴖᴖ—||— out

- Most of Analog Transmission Media is
  - Band Pass Channel
  - Cannot transmit Digital Signal
    - Low frequency data pattern will be all lost
    - Need Signal Conversion

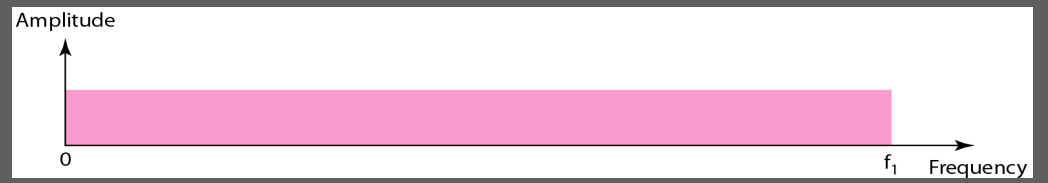
ใช้ L ต่ออนุกรมกับ C
L → กรองสัญญาณความถี่สูง
C → กรองสัญญาณความถี่ต่ำ

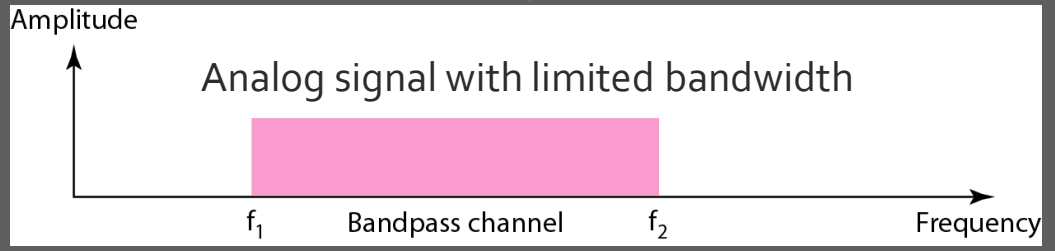
ตัวอย่างเช่น C ไม่ให้ผ่านออก

หรือใช้ L กรองออก อาจจะผ่านไป

Q ถ้าอยากส่งสัญญาณ DIGITAL ไปบนช่องสัญญาณ ANALOG

A
- ต้องทำ Signal Conversion





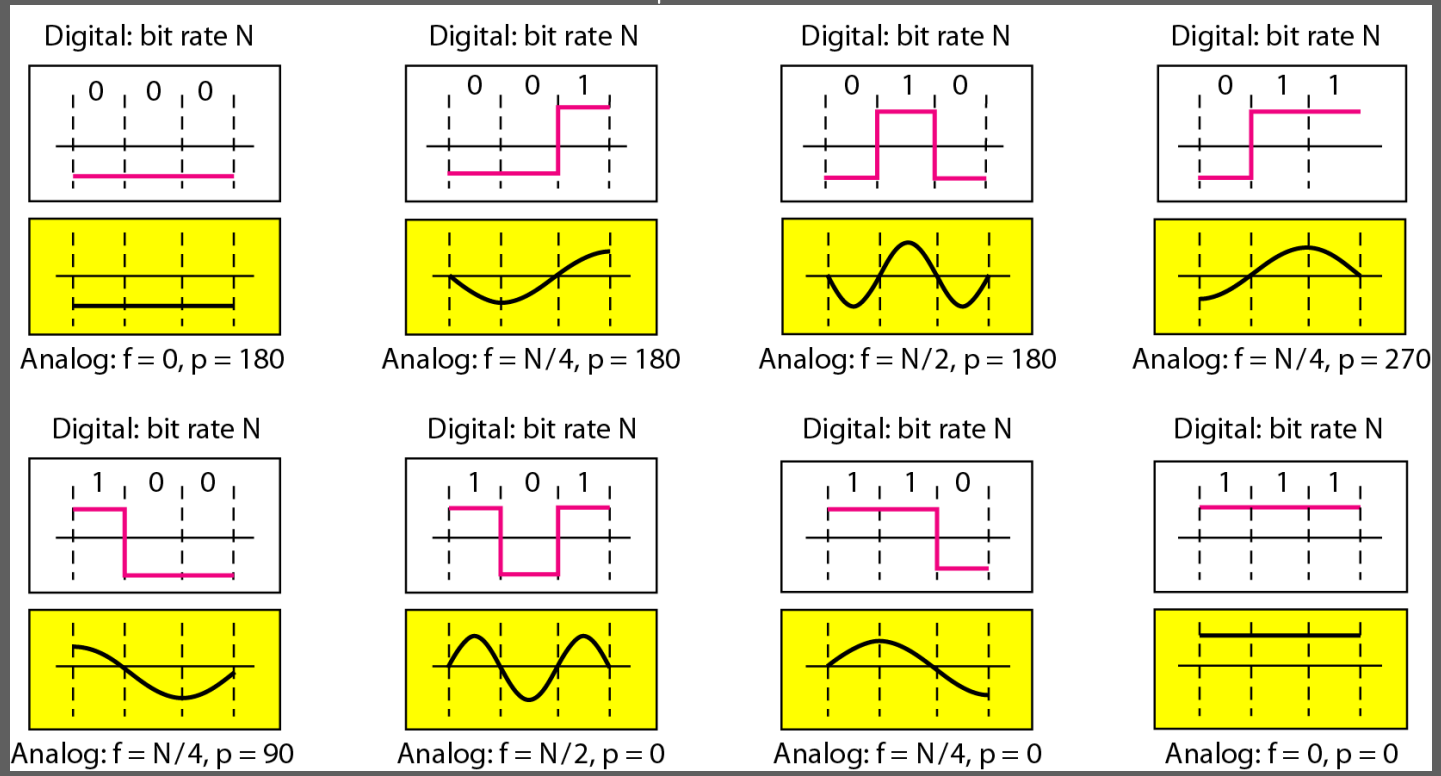
ANALOG CHANNEL: BAND PASS CHANNEL

$n = 5$

$\frac{5}{2} = 2.5 \Rightarrow f_{max}$

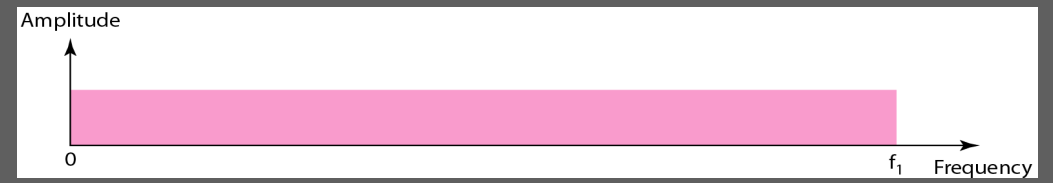
f_{max} เกิดเมื่อบิทสลับ 10101010 แบบนี้กี่ๆ

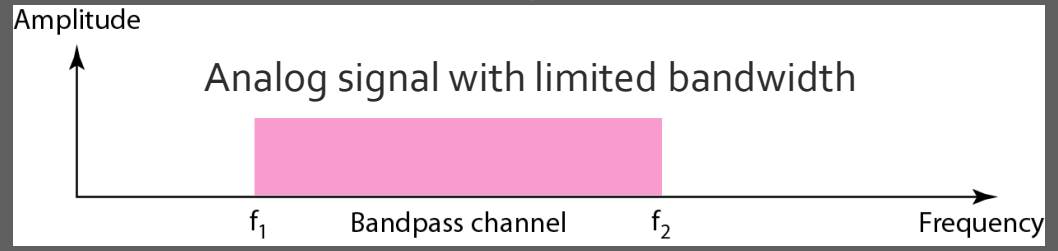
$$f_{max} = \frac{baud}{2}$$



Q ถ้าอยากส่งสัญญาณ DIGITAL ไปบนช่องสัญญาณ ANALOG

A
- ต้องทำ Signal Conversion





แล้วเราจะส่งสัญญาณไปได้อย่างไรนี่ ?? NONI.

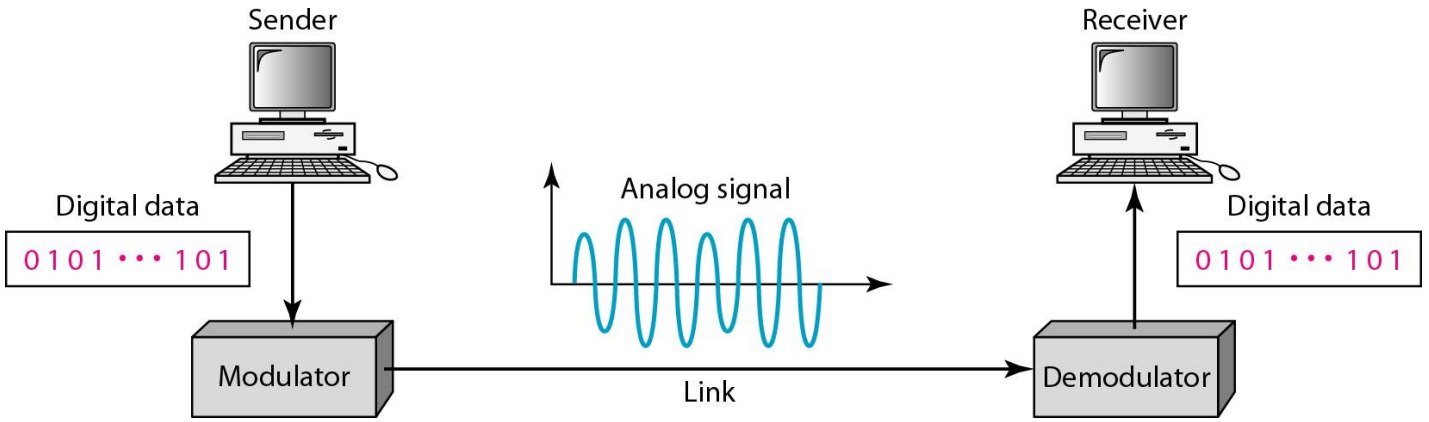
How would we represent **Bits** in the form of **Analog Signal**?

Bit-to-Analog Signal Conversion

Digital Modulation → การกล้ำสัญญาณ

การแล digital เกาะไปบน analog carrier

Digital Modulation



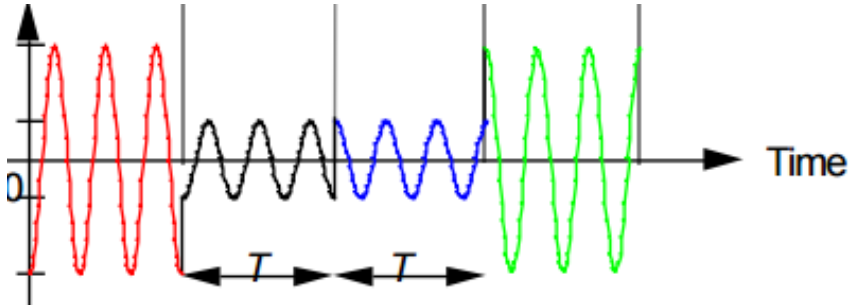
Analog Signal @ Selected Channel Frequency

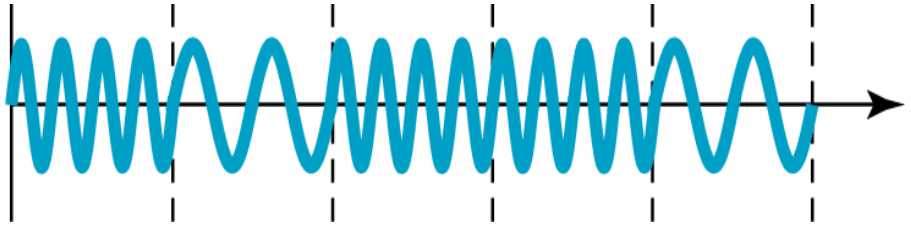
- Digital Modulatlion
  - Another technique for
    - Digital to Analog Conversion

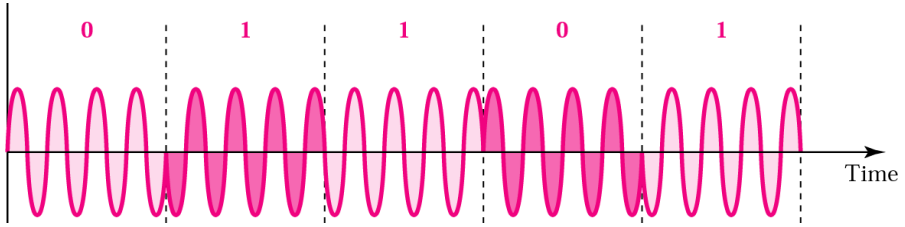
- Changing Analog Sinewave signal properties
  - to represent digital data

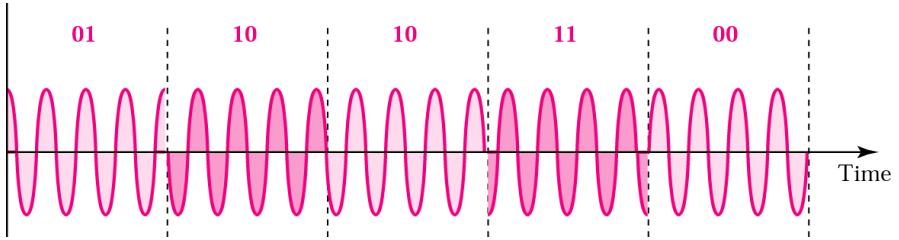
- What sinewave properties to be changed?
  - Amplitude
  - Frequency
  - Phase

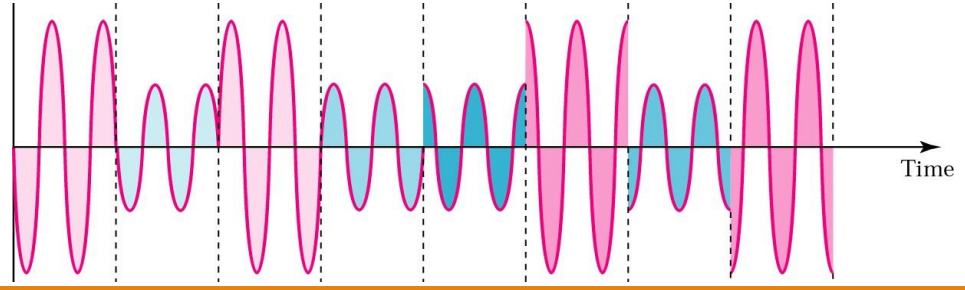
What property has been changed?



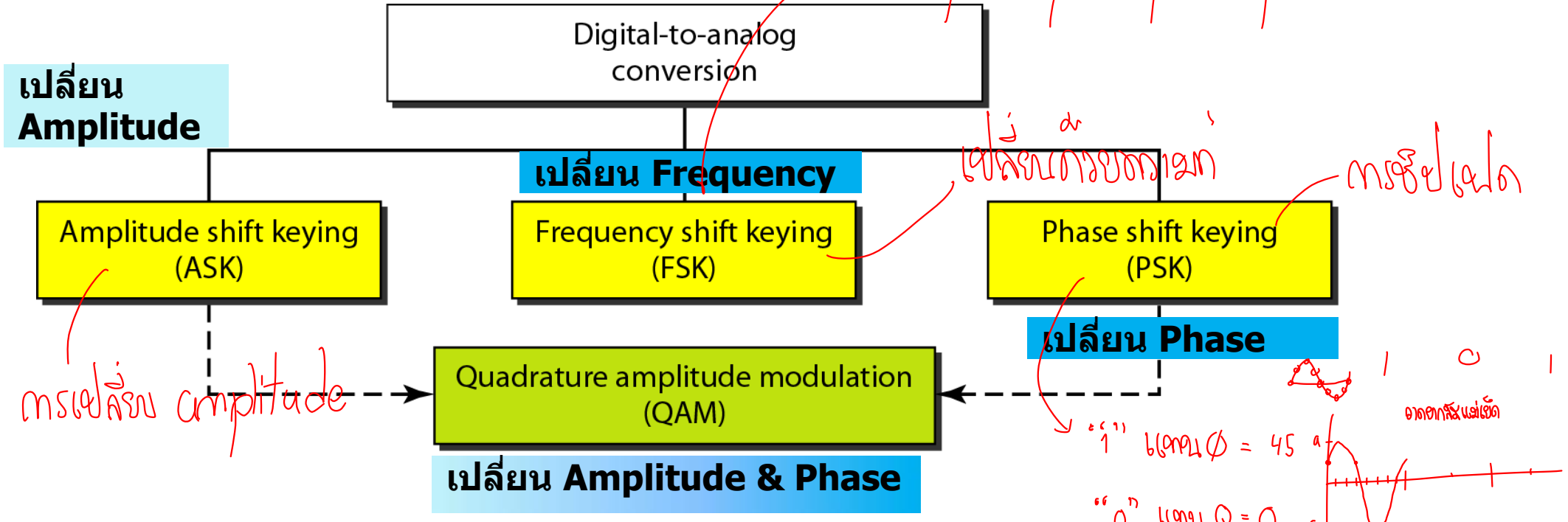


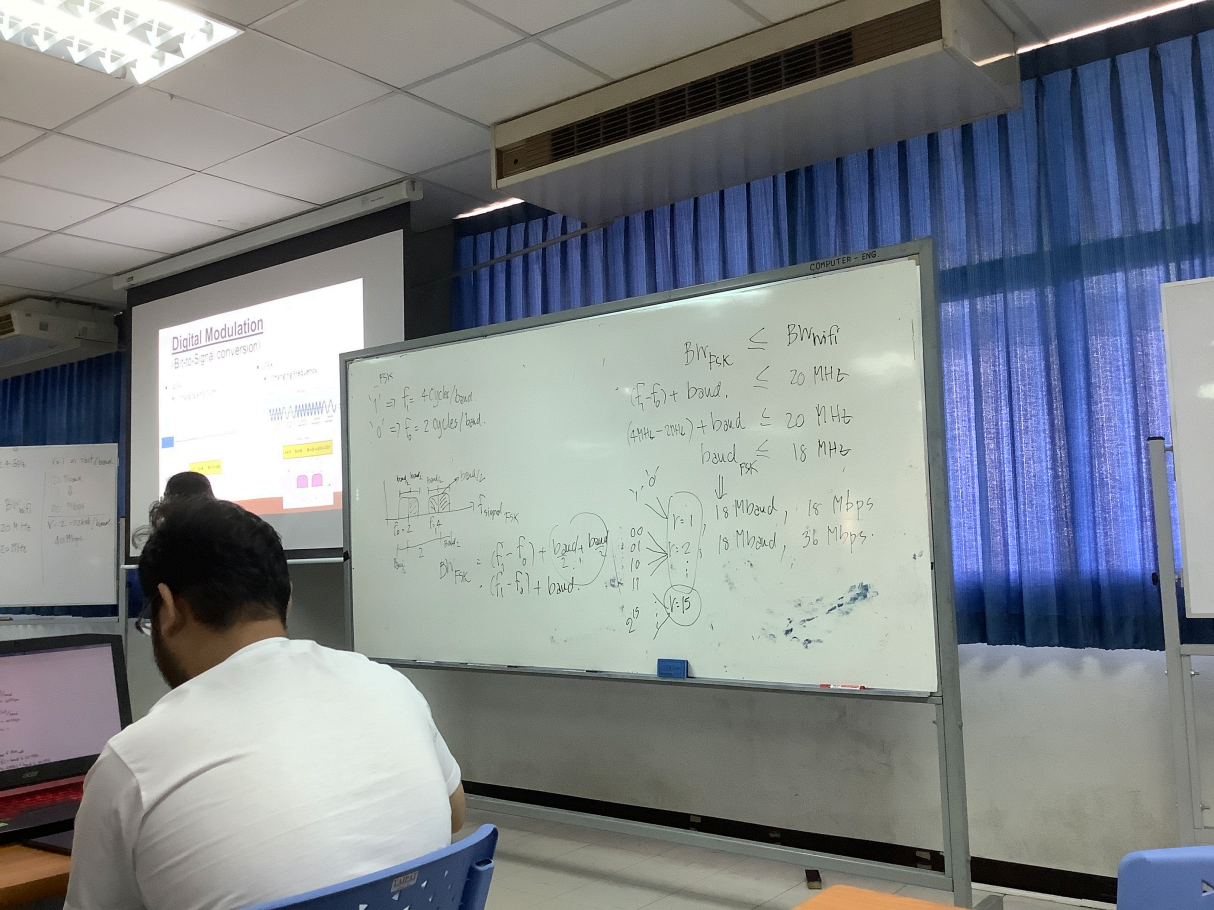






Digital Modulation Technique



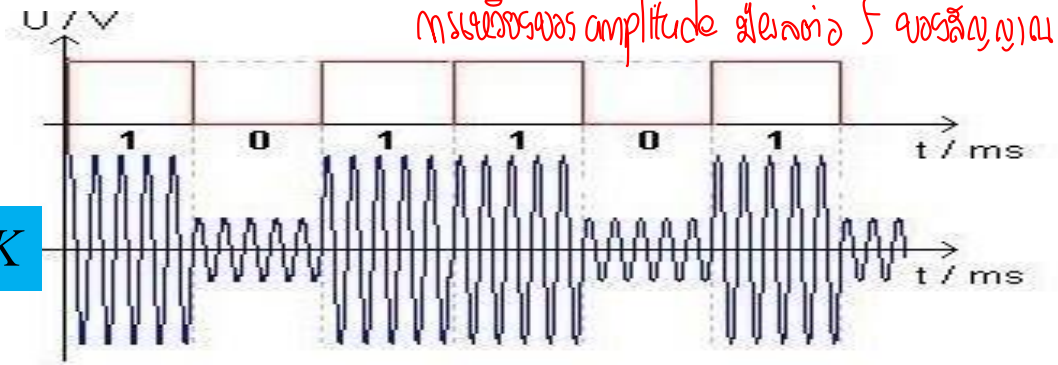

Digital Modulation
Bits-Signal conversion
COMPUTER - ENG
FSK
'1' ⇒ f_1 = 4 Cycles/baud
'0' ⇒ f_0 = 2 cycles/baud.
$BW_{FSK} = (f_1 - f_0) + baud + baud$
$(f_1 - f_0) + baud.$
$BW_{FSK} \leq BW_{wifi}$
$(f_1 - f_0) + baud \leq 20\ MHz$
$(4MHz - 2MHz) + baud \leq 20\ MHz$
$baud_{FSK} \leq 18\ MHz$
18 Mbaud, 18 Mbps
18 Mbaud, 36 Mbps.
00
01
10
11
V=1
V=2
V=15

Digital Modulation

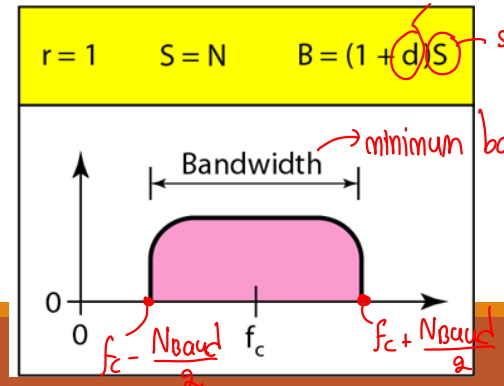
(Bit-to-Signal conversion)

- ASK
  - Changing Amplitude

2-ASK



การเปลี่ยนของ amplitude มีผลต่อ f ของสัญญาณ

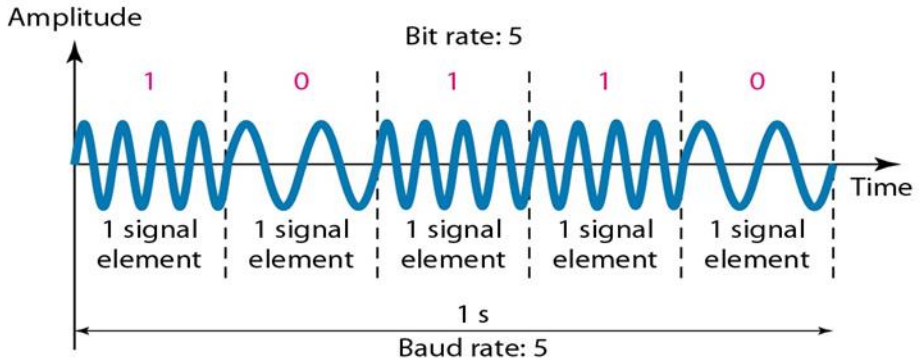


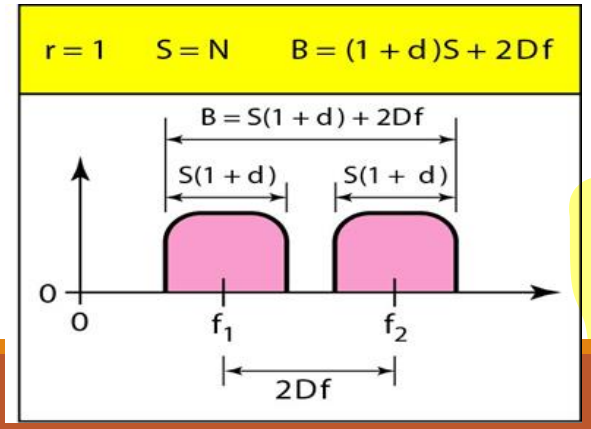
0,1 เลือกเอา

signal rate = Baud rate

minimum bandwidth = N_{Baud}

- FSK
  - Changing Frequency





$= (f_1 - f_0) + \frac{baud}{2} + \frac{baud}{2}$

$= (f_1 - f_0) + baud$

BW = (1+d)S + (1-12)Df

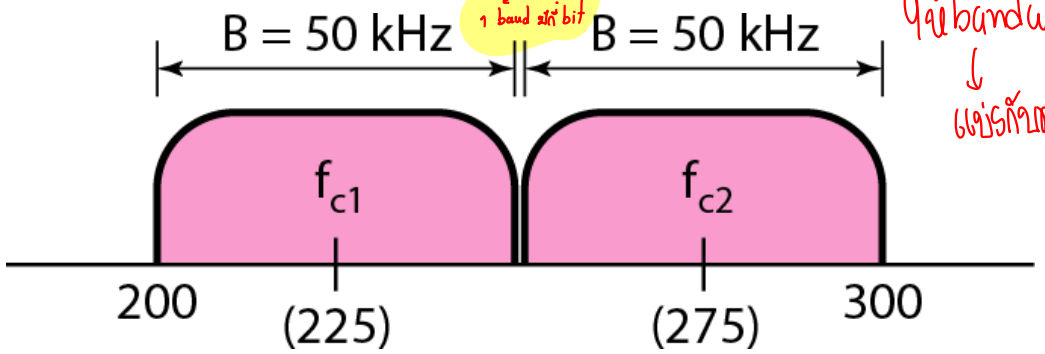
ดูหน้า

signal_rate = signal_unit / sec (baud_rate)

Relation between ASK baud rate and bandwidth

data_rate = bits/sec (bps) = bit/baud × baud/sec = r × S

1 baud มี กี่ bit



ถ้ามี bandwidth = 100 → แบ่งครึ่งตามจำนวนช่อง

Fullduplex channel

Fc1 = transmitting frequency (upload) = 225 Hz

Fc2 = receiving frequency (download) = 275 Hz

B = Bandwidth (BW) = 50 kHz

Baud rate$_{max}$ =

2-ASK: r = 1bit/baud -> bit rate $_{max}$ = 1 x 50 = 50 bps (level)

4-ASK: r = 2 bit/baud → r x baud_rate = 2x50 = 100 bps

8-ASK: r = 3 bit/baud → r x baud_rate = 3x50 = 150 bps

BW = (1+d) Baud rate = (1+d) S

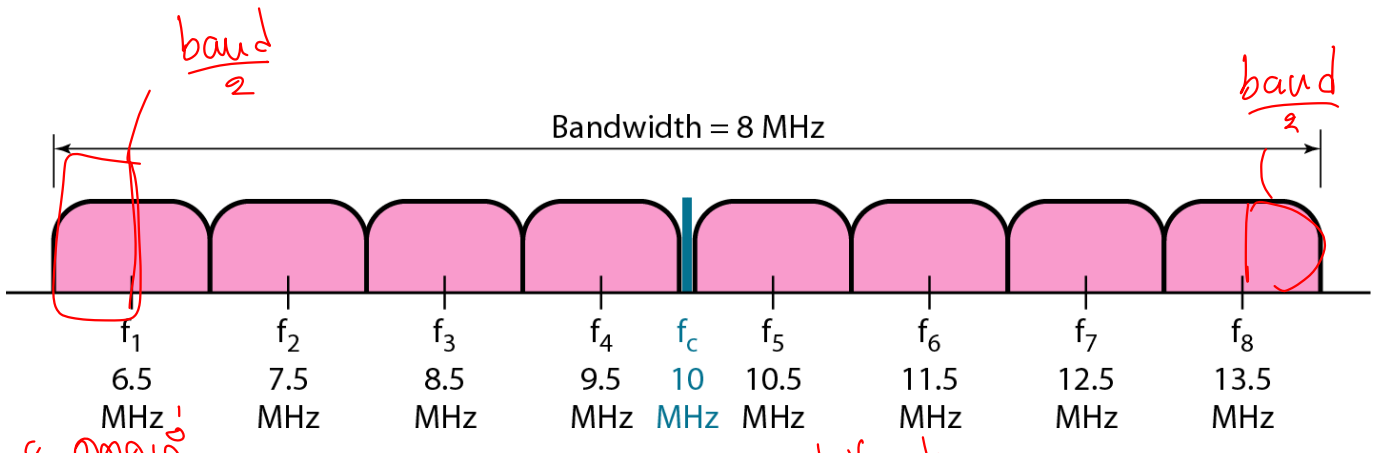
$r = \log_2 level$

$0 \le d < 1$

BW = (1+0) Baudrate

50 = Baudrate

Relation between FSK baud rate and bandwidth



Half-duplex channel Transmit

8-FSK: 3 bits/baud

frequencies:

Bchannel = Channel Bandwidth = 8MHz

Bsignal = Signal Bandwidth =

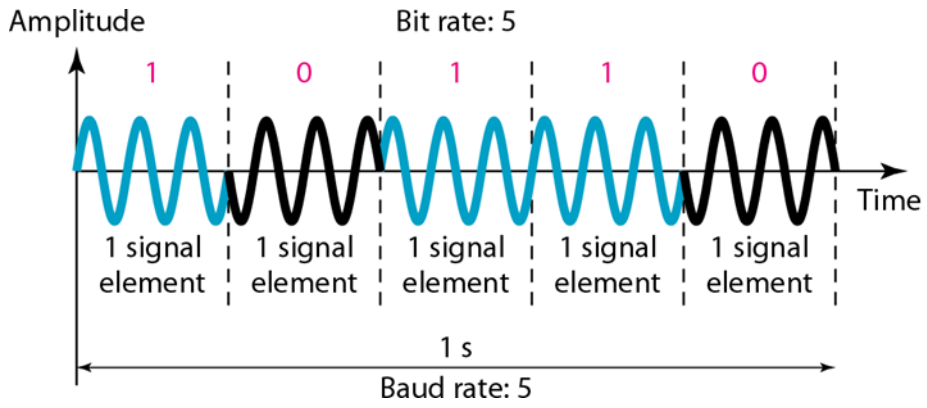
Baud rate$_{max}$ =

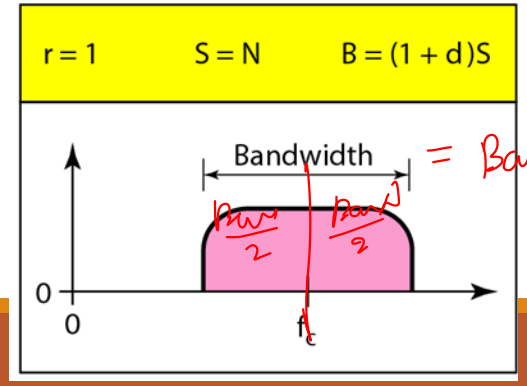
Bit rate$_{max}$ =

Digital Modulation

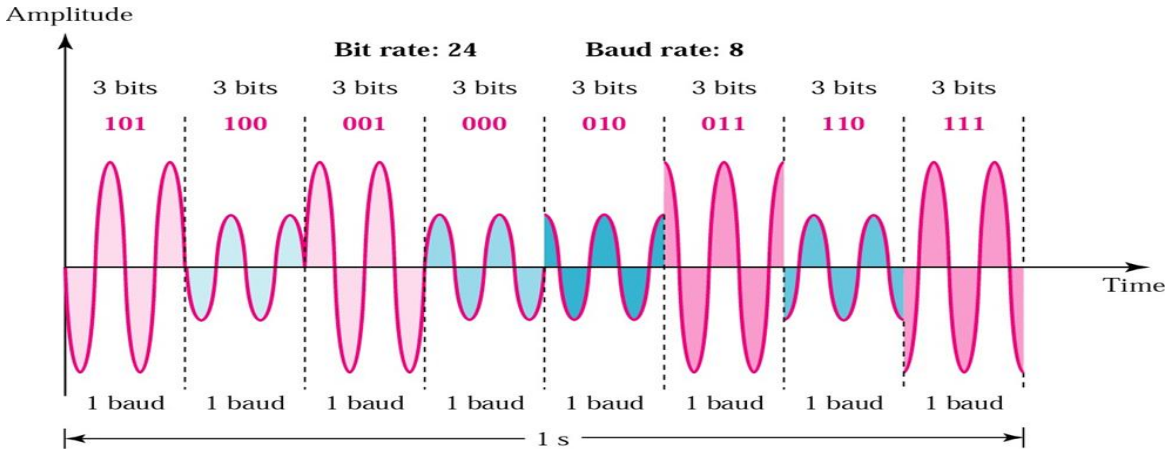
(Bit-to-Signal conversion)

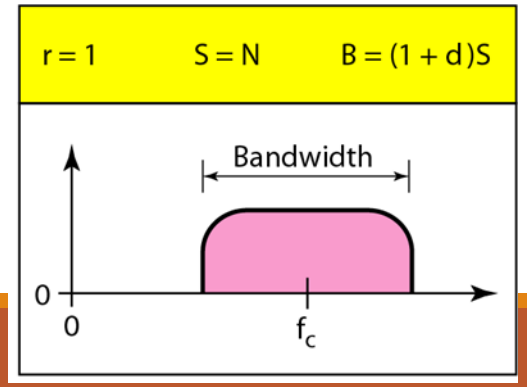
- PSK
  - Changing Phase



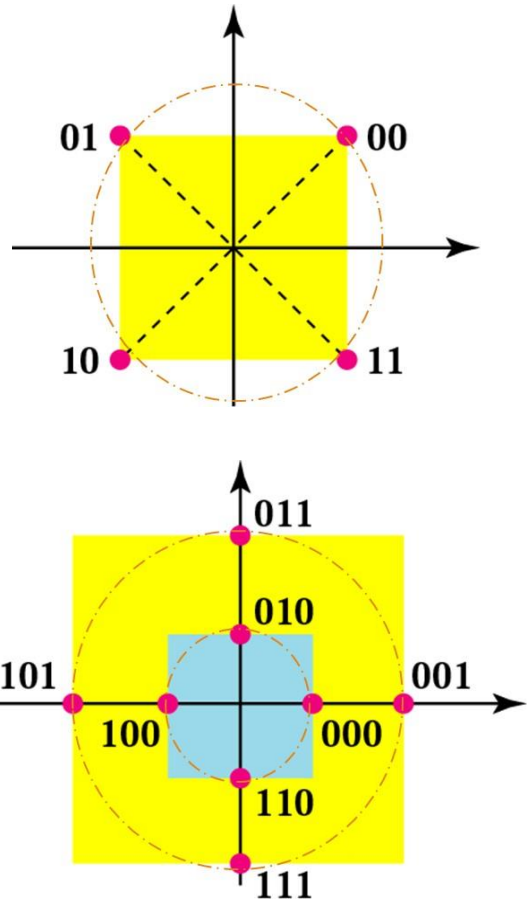


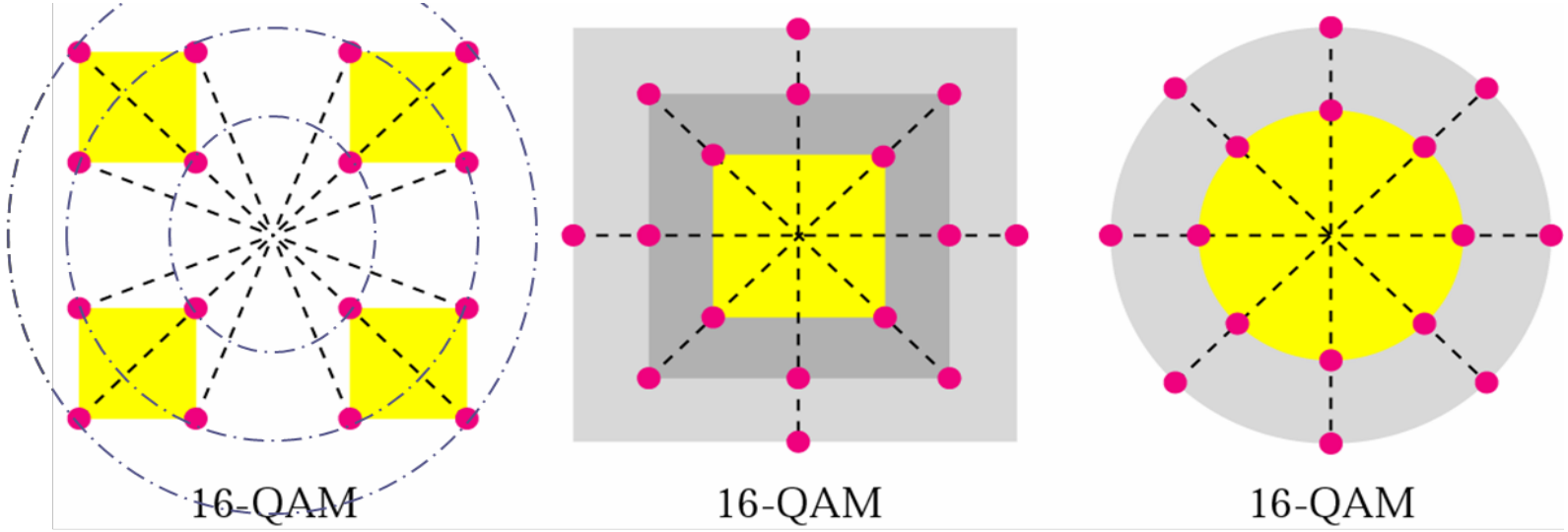
- QAM
  - Changing Amplitude & Phase





How many Amplitude and Phase in QAM?

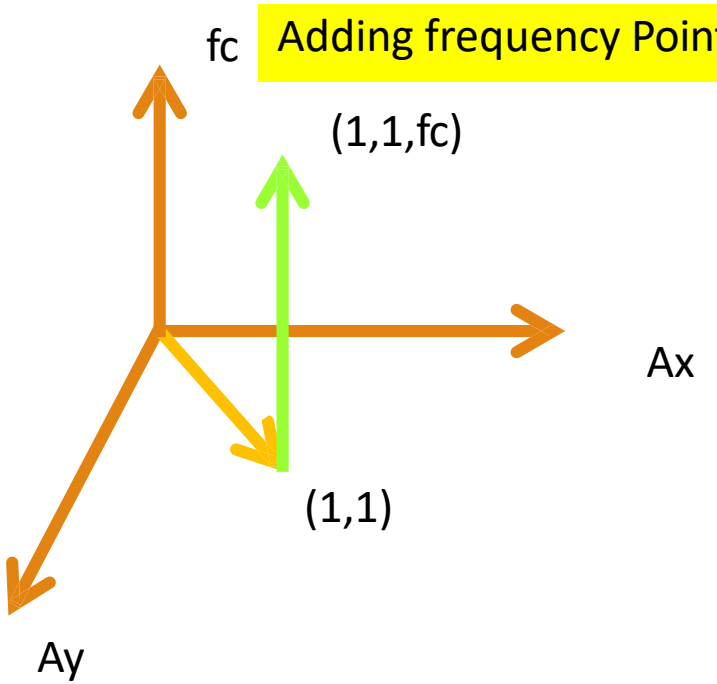




ITU-T recommendation

OSI recommendation

Constellation Diagram



3D Constellation diagram

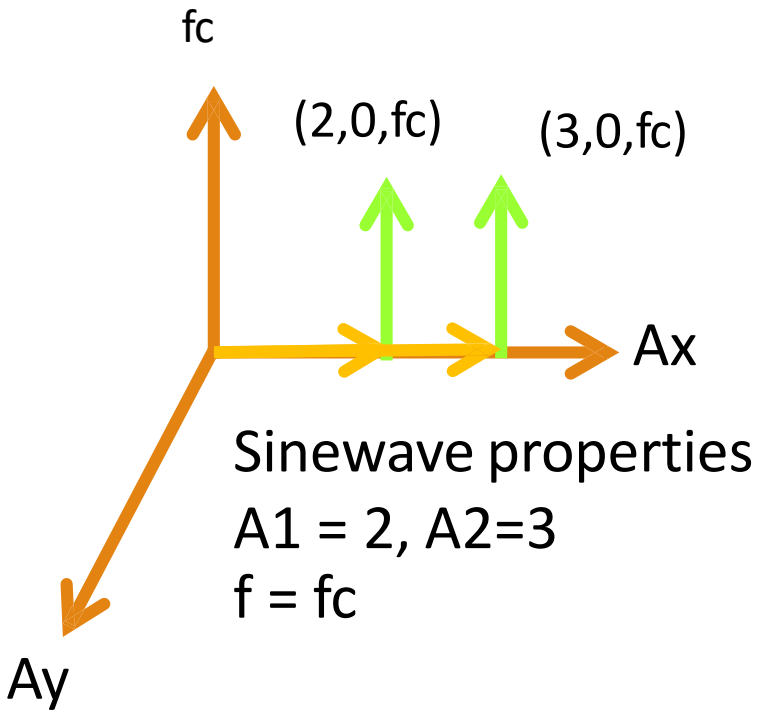
$$s(t) = \mathrm{A}\sin(2\pi f_c t + \theta)$$

คือ simple harmonic ที่สมบูรณ์ที่สุด

$$s(t) = A\sin(\omega t + \theta$$

$$= A\sin(2\pi f + \theta)$$

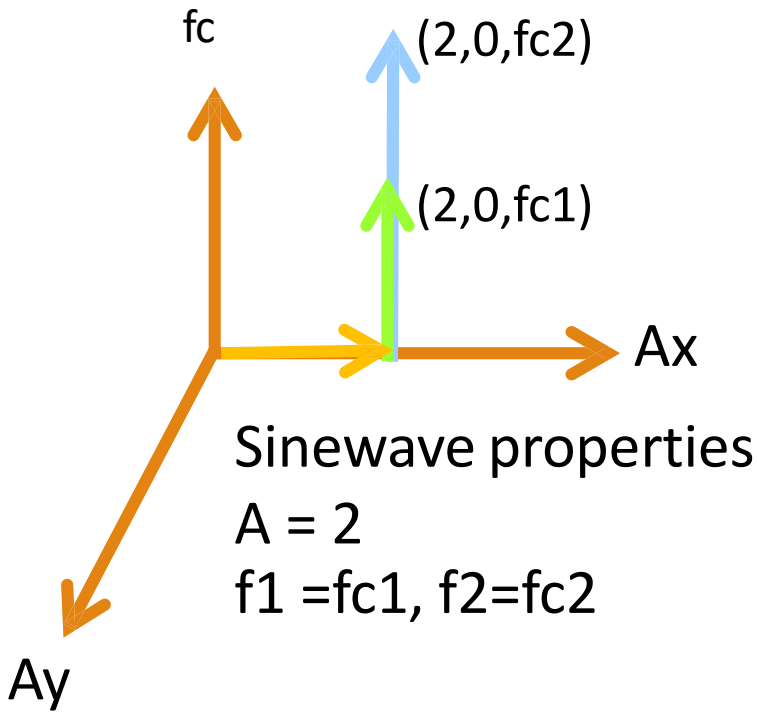
Ex: 2-ASK vs 2-FSK



Sinewave properties

A1 = 2, A2=3

f = fc

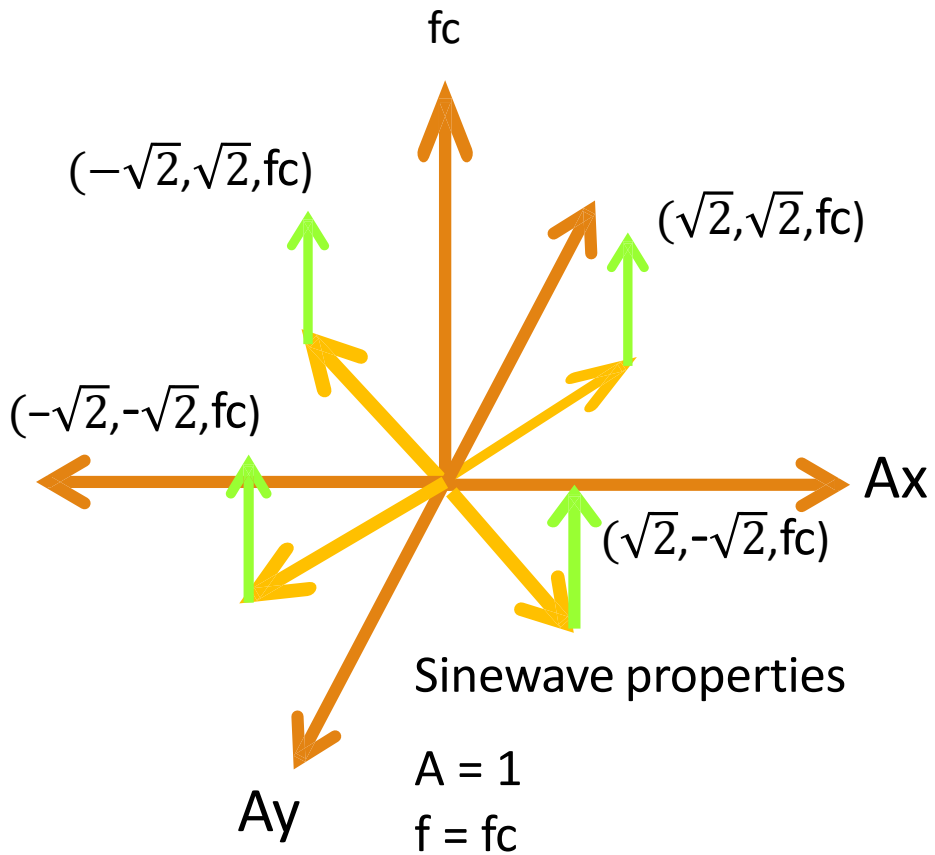


Sinewave properties

A = 2

f1 =fc1, f2=fc2

Ex: 4-PSK vs 8-QAM

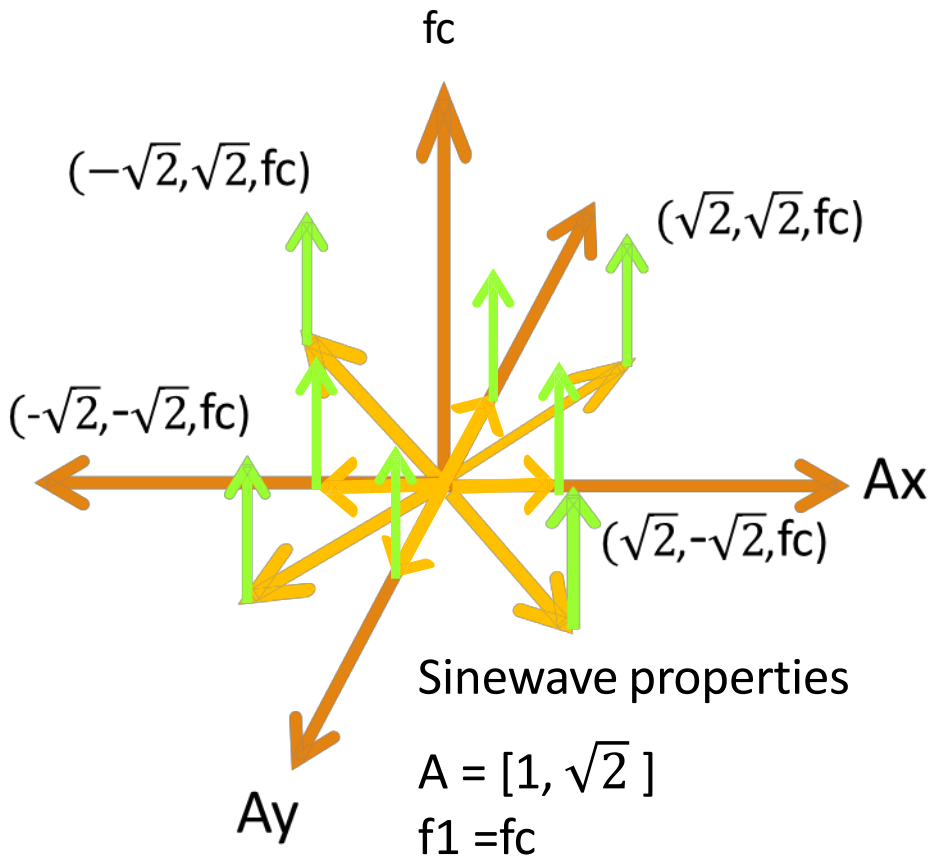


Sinewave properties

A = 1

f = fc

Zeta = [45 135 225 315]



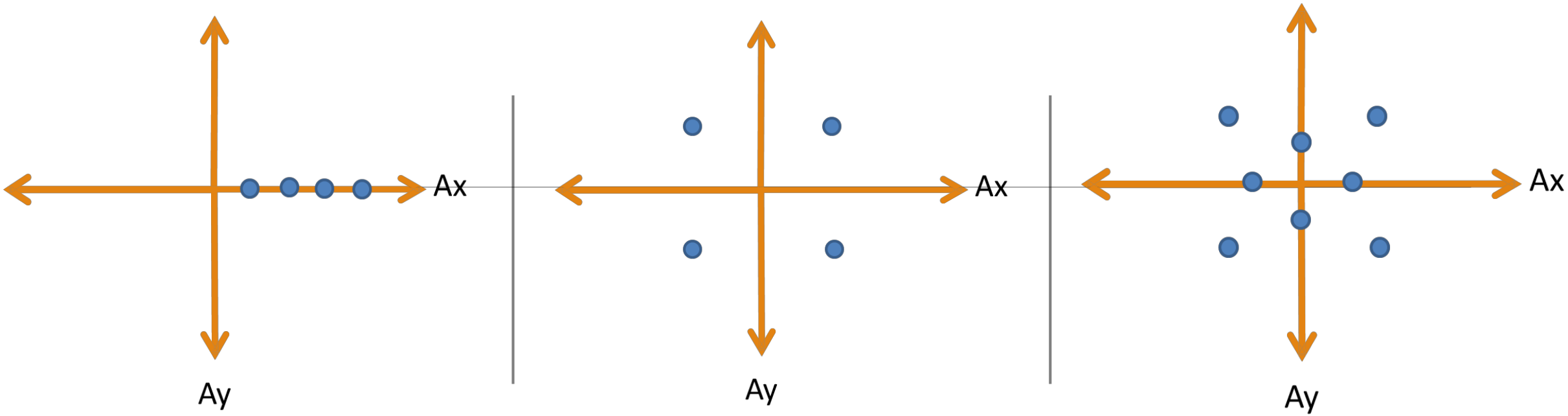
Sinewave properties

A = [1, $\sqrt{2}$]

f1 =fc

Zeta=[0 90 180 270],

[45 135 225 315]



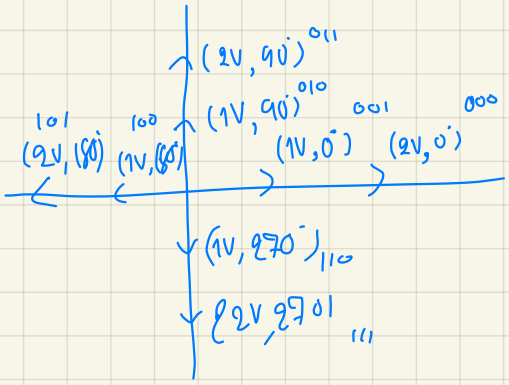
พระเจ้าช่วยลูกช้าช้าย~

Ex: 4-ASK / 4-PSK / 8-QAM

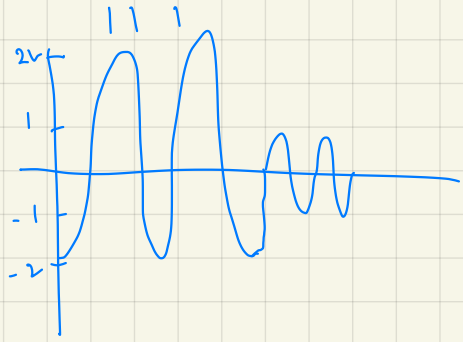
Activity #10.1

1) Random Bits = 8
2) Digital Modulation (Bit-to-Signal Encoding)
   วาด constellation diagram
   Encoded MOD signal
   2.1) 4-ASK
   2.2) 4-PSK
   2.3) 8-QAM

3) แลกใบ Activity กับเพื่อน โดยให้เพื่อน ถอด bits กลับ
4) ตรวจคำตอบกับเพื่อน


(2V, 90°) 011
(1V, 90°) 010
001
000
101
100
(2V, 180°)
(1V, 180°)
(1V, 0°)
(2V, 0°)
(1V, 270°) 110
(2V, 270°) 111

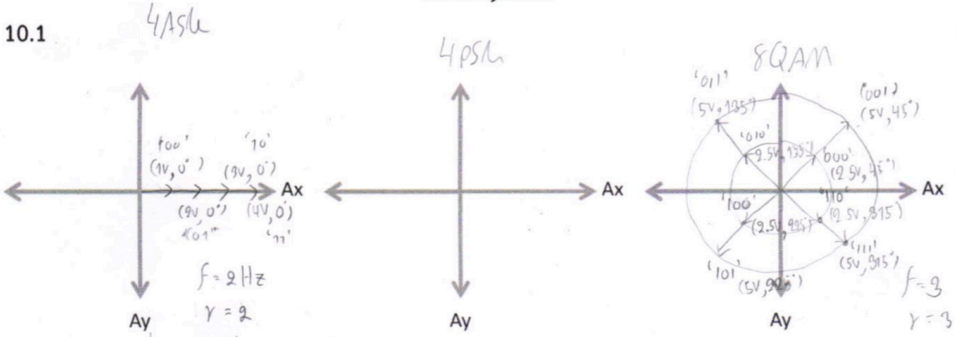
$f = 2$

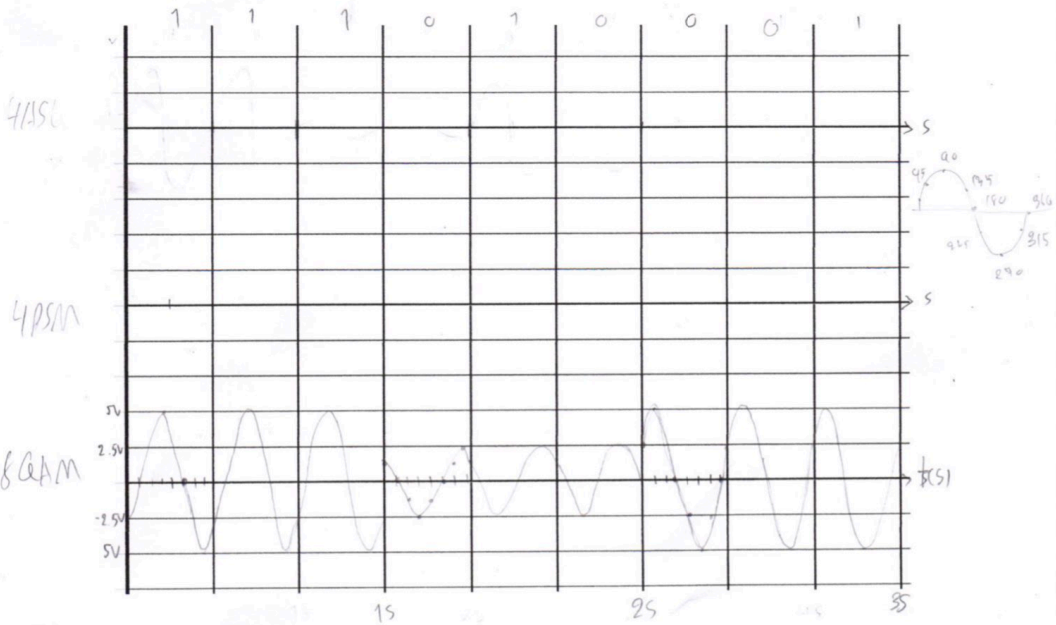

2V
1
-1
-2

ชื่อ-นามสกุล นาย ปฐมพงษ์ ศรีษะรมย์โยธา รหัส นศ. 61011433

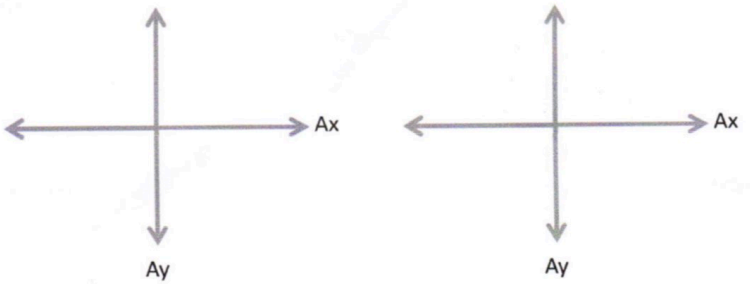
Activity #10

10.1





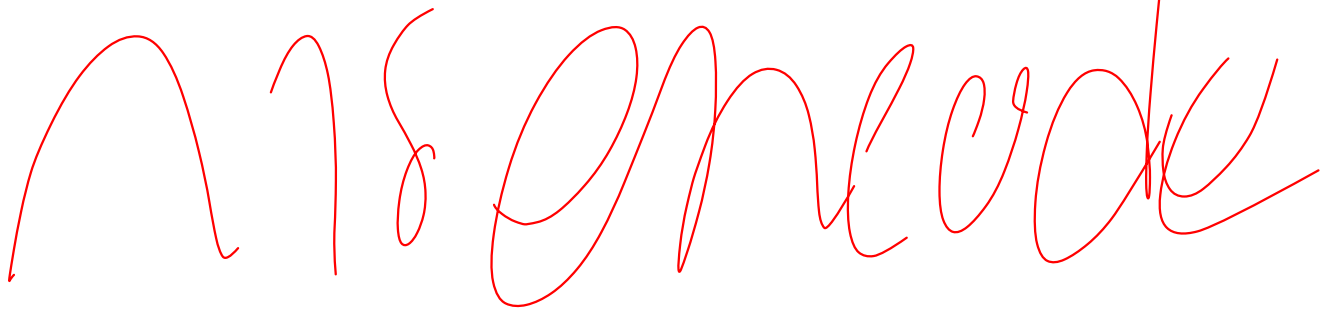
10.2



How can we create digital MODulation signal?

ASK MOD

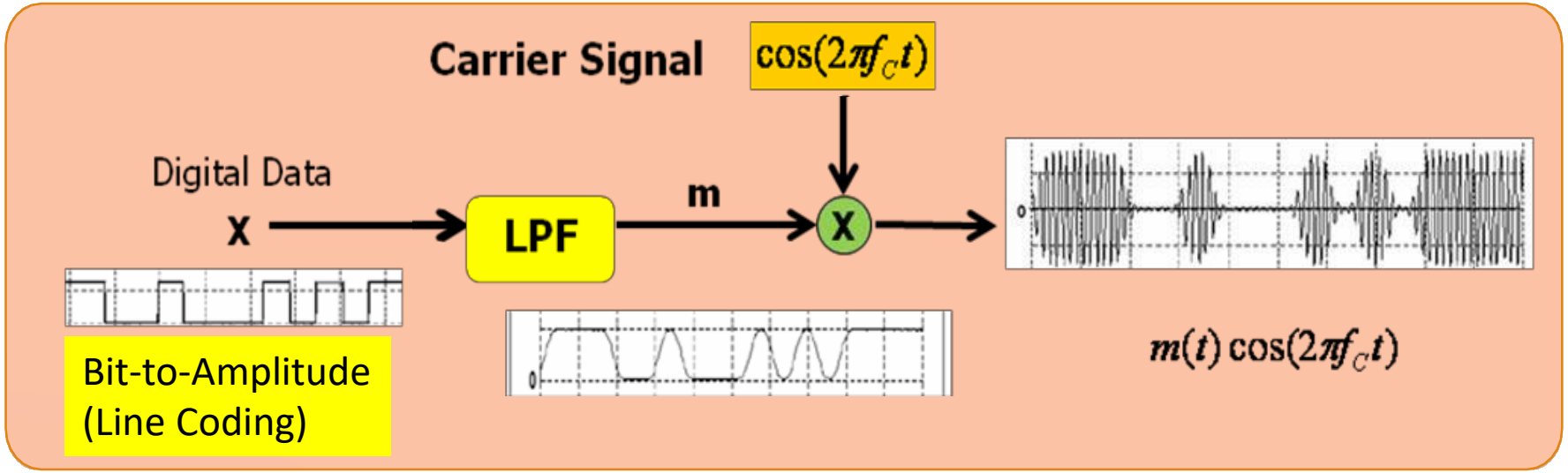
ENCODE Bit-to-ASK SIGNAL



OOK: On-Off Keying

ASK MOD

TX



ASK GENERATION STEP

- 4-ASK (Binary ASK)
  - '00' -> A0
  - '01' -> A1
  - '10' -> A2
  - '11' -> A3

1) Partition r Bits to be encoded

   Ex. 11000110 (r = 2)

   11 00 01 10

2) Bit-to-Signal property encoding (Selecting Amplitude)

   11 -> A_3 / 00 -> A_0 / 01 -> A_1 / 10 -> A_2

3) Creating 1 Signal Unit for ASK

   1 Signal Unit (SU) = #จำนวน carrier signal cycles / baud

   = f_c / baud

4) Doing Amplitude **MOD**

   A_3 **x** SU(0) / A_0 **x** SU(1) / A_1 **x** SU(2) / A_2 **x** SU(3)

What is the relation between buad_rate vs cycles/baud ?

$\frac{cycles}{baud} = \frac{fc}{baud\_rate}$

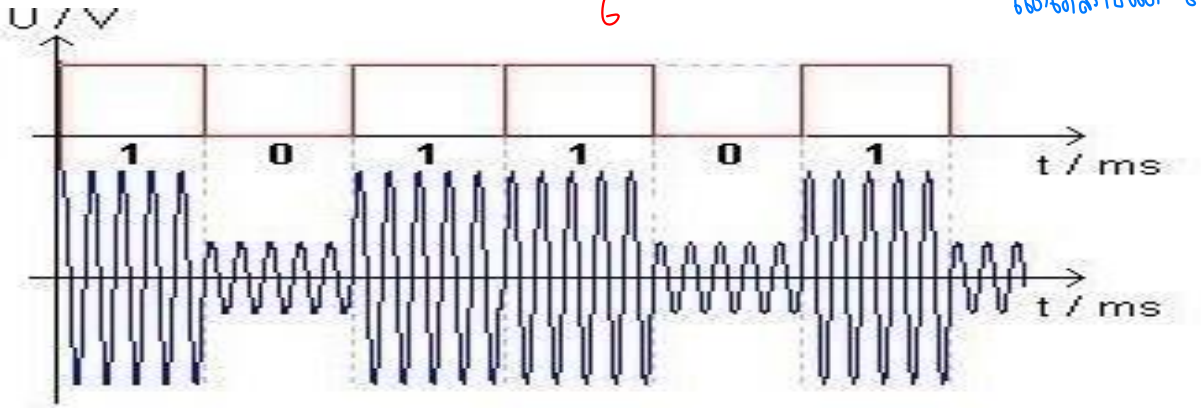
จำนวนรอบคลื่นทั้งหมดที่ส่งไปใน 1 วิ

ส่งไปได้กี่หน่วยต่อวินาที

$= \frac{30}{6}$ → ผลลัพธ์

ทั้งหมดมี 30 คลื่น

แต่ละรหัสแต่ละตัวมี 6 ชุด → 1 ชุดตัวอย่างมี 5 คลื่น → 5 cycle



Buad rate = signal elements/s (Hz, baud, baud/s)

fc = carrier frequency (Hz)

$\frac{cycle}{baud} = \frac{fc}{baud\_rate}$

Cycles/baud = fc / baud_rate

Ex. Baud rate = 6 Hz, T = 1/6 s

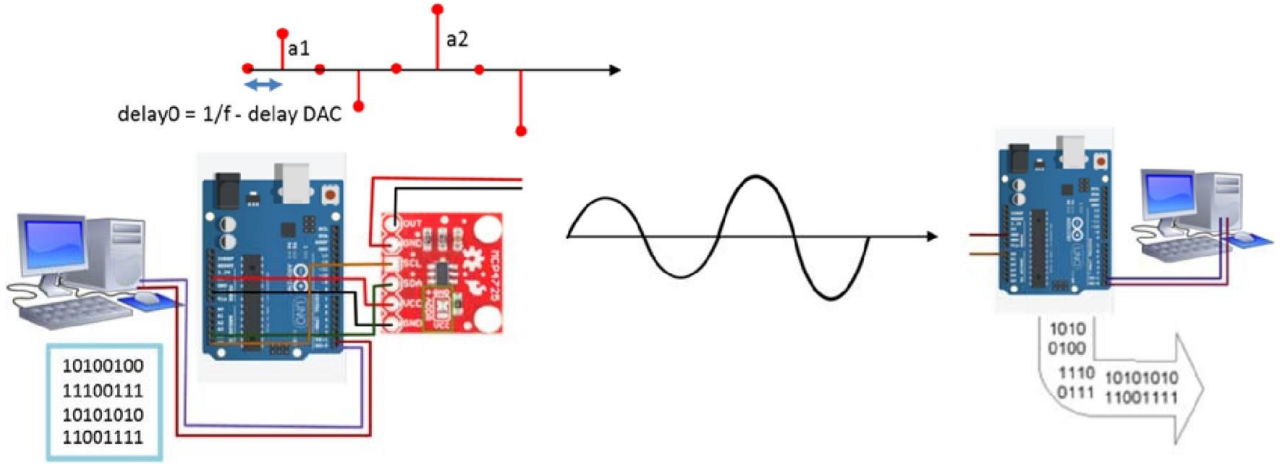
- fc = 30 Hz -> T = 1/30 s
- cycles/baud = (1/6) / (1/30) = 5
- = fc / baud = 30 / 6 = 5

Summarize: Amplitude Shift Keying

Bit representation
- Changing Amplitude of Carrier Signal

Benefit
- Simple (normally used for fiber optic / RFID)
- Require Less Bandwidth

Disadvantage
- Easily effected by noise



ภาคส่ง (Tx) : PC → Arduino → DAC → ASK Signal **ภาครับ (Rx)** : ASK Signal → Arduino(ADC) → PC

Digital data
'11000110'

Partition r bits/baud
'11' '00' '01' '10'

Select sinewave
Properties (Amplitude)

MOD with sinewave for each Signal unit (SU)

ASK MOD

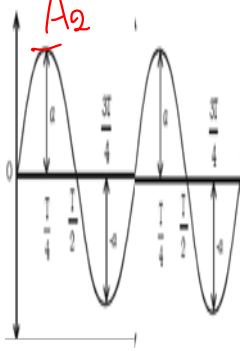
Digital data '11000110'

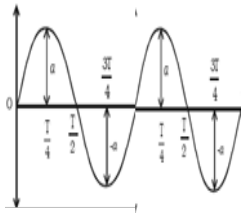
Partition r bits/baud '11' '00' '01' '10'

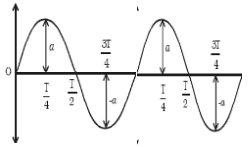
Select sinewave Properties (Amplitude)

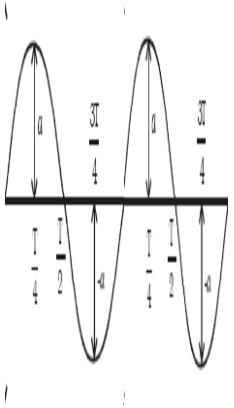
MOD with sinewave for each Signal unit (SU)

Set_r[0]	Set_r[1]	Set_r[2]	Set_r[3]
'11000110'	'00110001'	'00001100'	'00000011'
'00000010'	'00000001'	'00000000'	'00000011'
Select A_2	Select A_1	Select A_0	Select A_3
X	X	X	X
1 SU	1 SU	1 SU	1 SU
A_2 SU	A_1 SU	A_0 SU	A_3 SU









Example:
fc = 1000 Hz
Baud rate = 500 baud
r = 2
#cycles/baud =
Zeta = [0 90 180 270]

How can we create digital DeMODulation signal?

ASK DeMOD

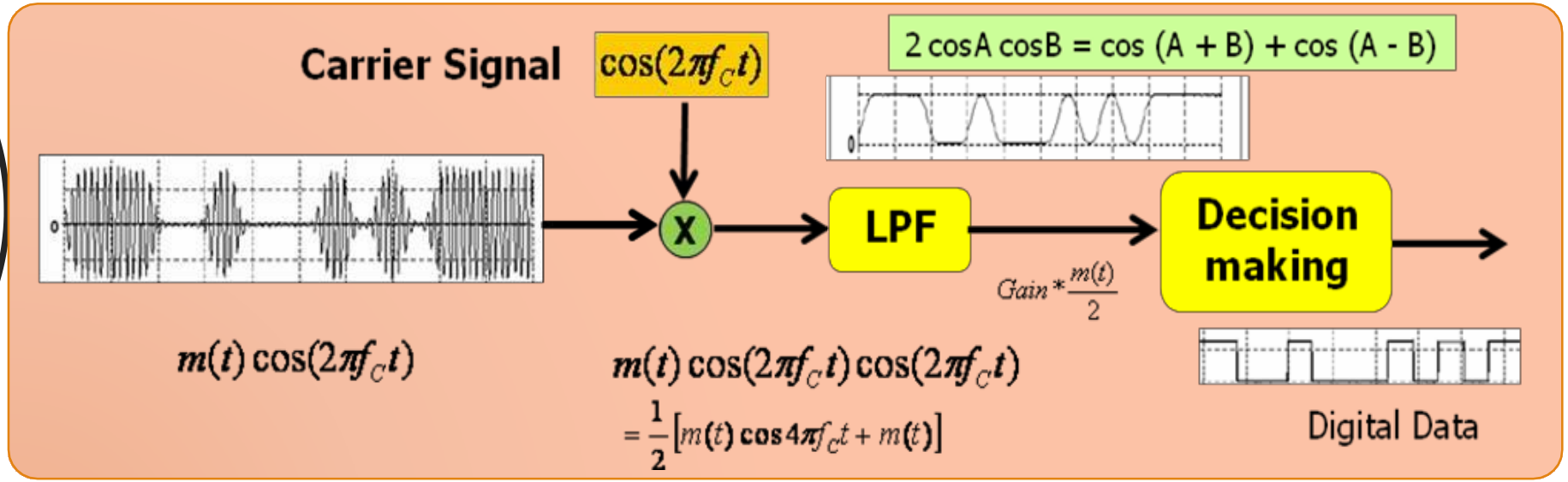
Decode ASK SIGNAL to Bits

OOK: On-Off Keying

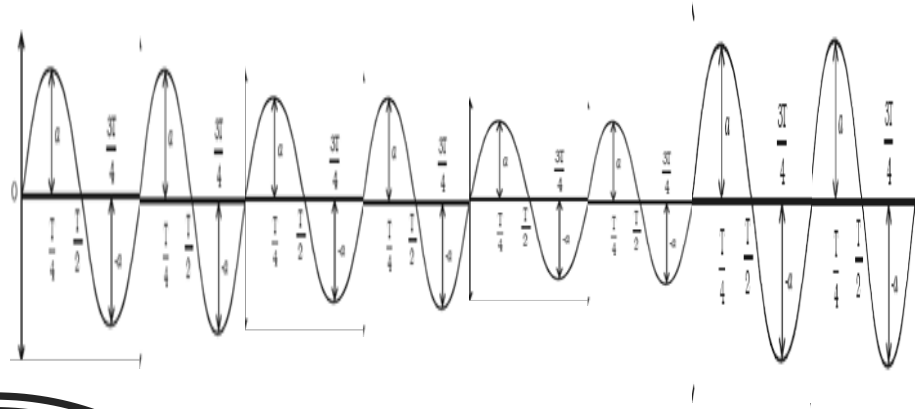
How would we get the bits back?

ASK DeMOD

RX



$\cos \alpha \cos \beta = \frac{1}{2}(\cos(\alpha + \beta) + \cos(\alpha - \beta))$



ASK DeMOD

RX

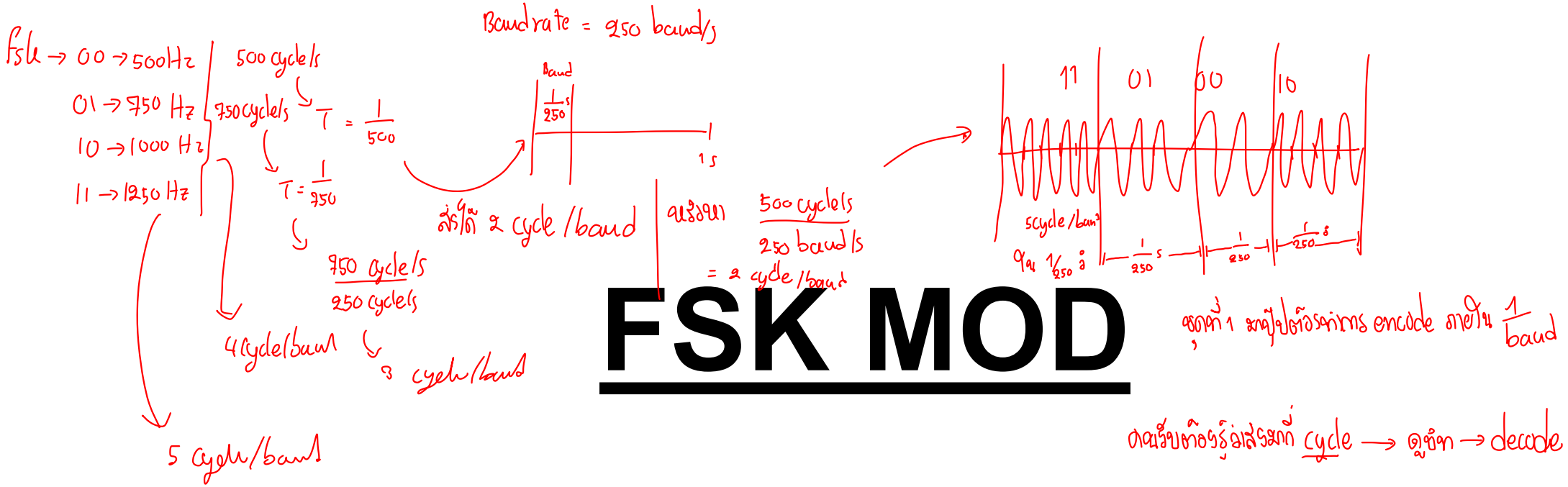
Reading (Sampling) to get Amax of each Signal unit (SU)

Amax = decoded Amplitude

Decode r bits/baud '11' '00' '01' '10'

Digital data '11000110'

```
void loop() {
  int tmp = analogRead(A0); // read signal from analog pin
  if(tmp-prev> r_slope && check ==false){
    max = 0;
    check = true;    // change check status is true
  }
  if(tmp>max){       // update max value
    max=tmp;
  }
  if(max-tmp > r_slope){  // check for falling signal
    if(check == true){
      if(a0min<max && max<a0max){
        Serial.print("0 0 ");
        count++;
      }
      else if(a1min<max && max<a1max){
        Serial.print("0 1 ");
        count++;
      }
      else if(a2min<max && max<a2max){
          Serial.print("1 0 ");
          count++;
       }
       else if(a3min<max && max<a3max){
          Serial.print("1 1 ");
          count++;
       }
       if(count == 5){
          Serial.println();
          count = 0;
       }
     }
     check = false;  // change check status is false
   }
   prev = tmp;    // assign temp value to previous
  }
```



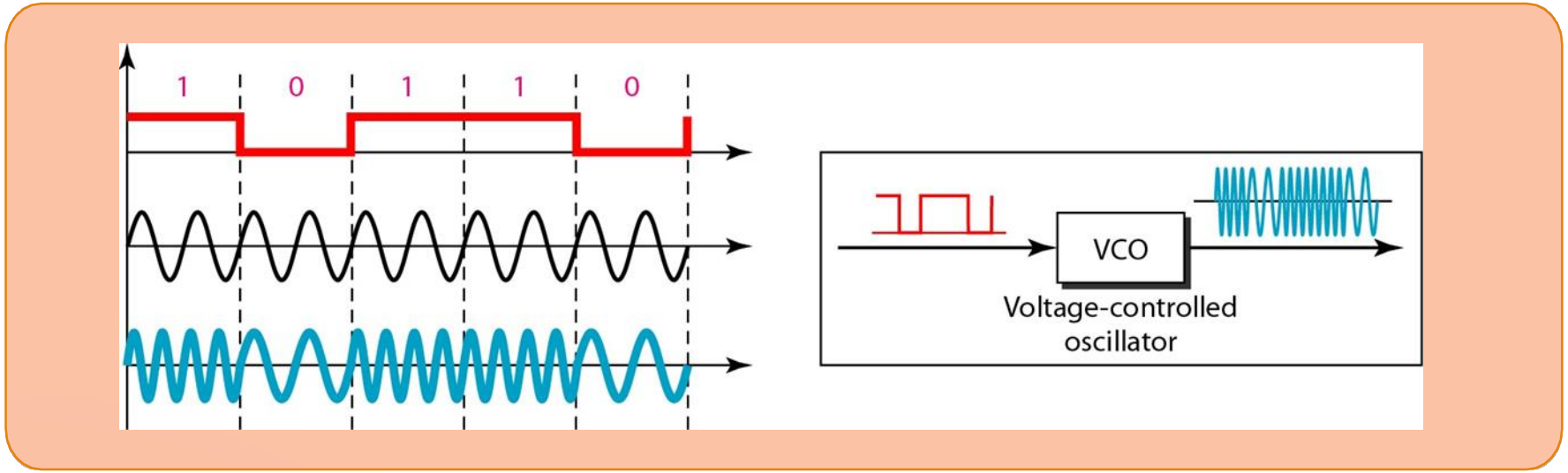
FSK MOD

ENCODE Bit-to-FSK SIGNAL

2-FSK

FSK MOD

TX



FSK MOD

Digital data
‘11000110’

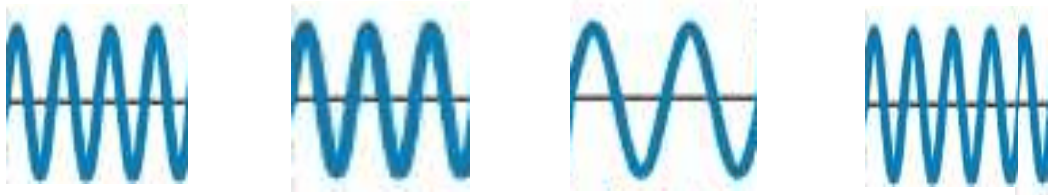
Partition r bits/baud
'11’ ’00’ ’01’ ’10’

Select sinewave
Properties (Frequency)

MOD with sinewave for
each Signal unit (SU)

fc = [500, 750, 1000, 1250]
Baud rate = 250 baud
r = 2
#cycles/baud =
Zeta = [0 90 180 270]

Set_r[0]	Set_r[1]	Set_r[2]	Set_r[3]
‘11000110’	‘00110001’	‘00001100’	‘00000011’
‘00000010’	‘00000001’	‘00000000’	‘00000011’
Select f_2	Select f_1	Select f_0	Select f_3
f_2 SU	f_1 SU	f_0 SU	f_3 SU

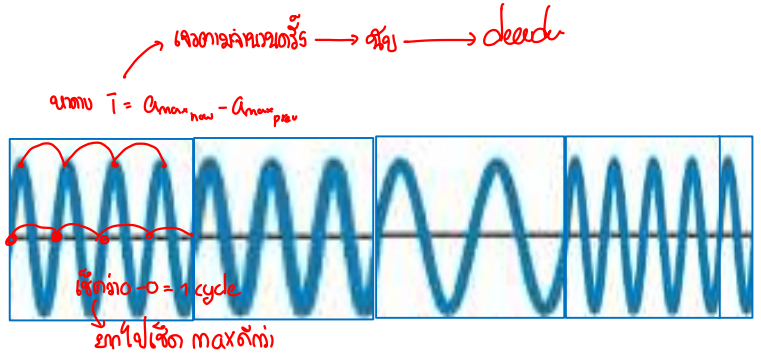


FSK DeMOD

Decode FSK SIGNAL to Bits

FSK DeMOD

RX

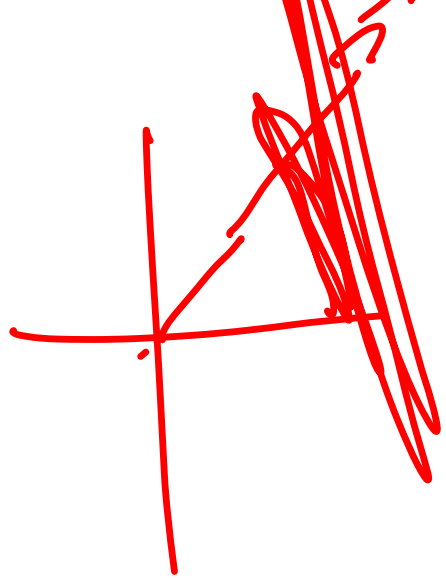


Reading (Sampling) to get Period (T) of each Signal unit (SU)

T = decoded Period
f = 1/ T

Decode r bits/baud
'11' '00' '01' '10'

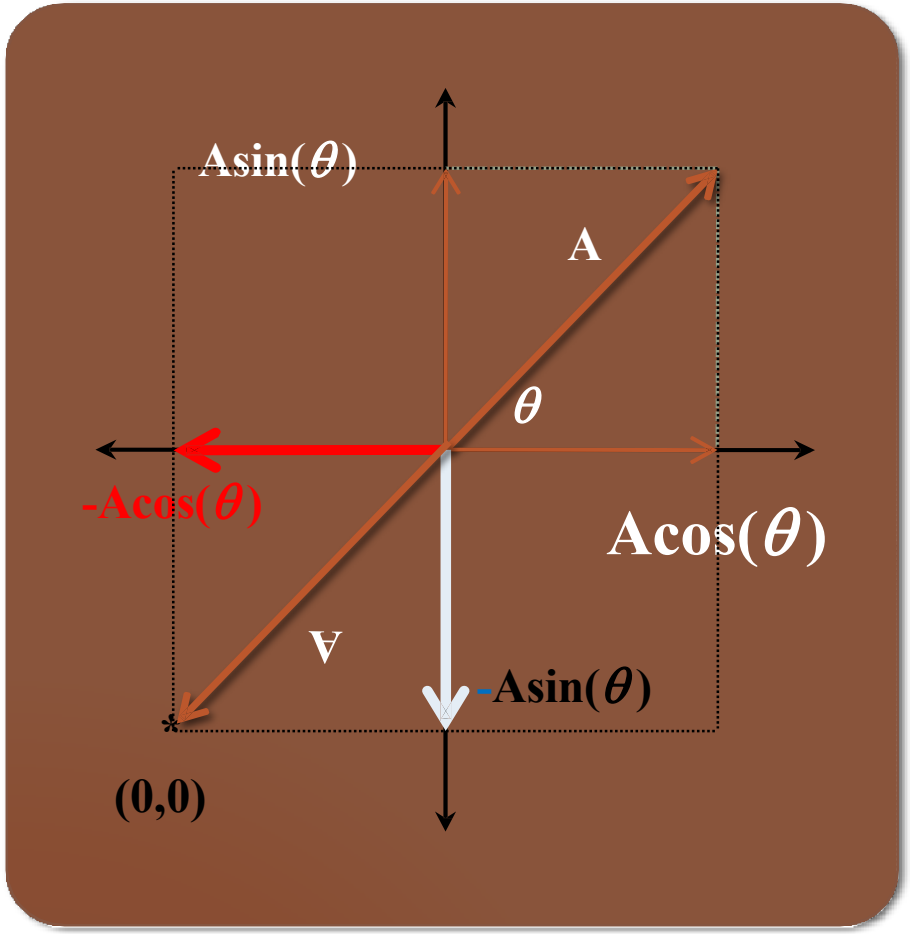
Digital data
'11000110'



PSK MOD

ENCODE Bit-to-PSK SIGNAL

Encode Zeta with combination of cosine & sine



PSK MOD

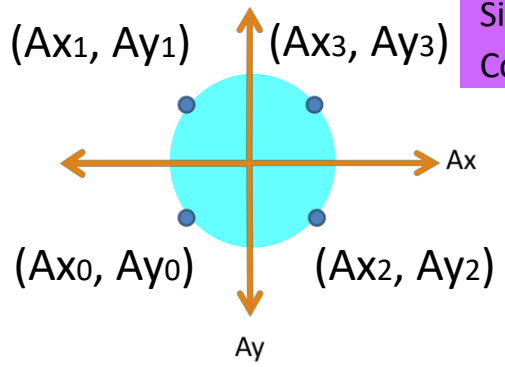
fc = 1000 Hz
Baud rate = 500 baud
r = 2
#cycles/baud =
Amplitude = A
Zeta = [45 135 225 315]
Ax =
Ay =

Digital data
'11000110'

Partition r bits/baud
'11' '00' '01' '10'

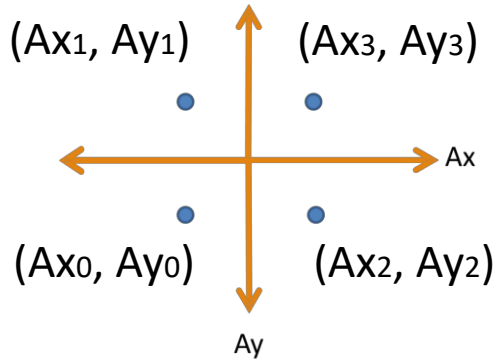
Select sinewave
Properties (Ax, Ay)

MOD with sinewave for
each Signal unit (SU)

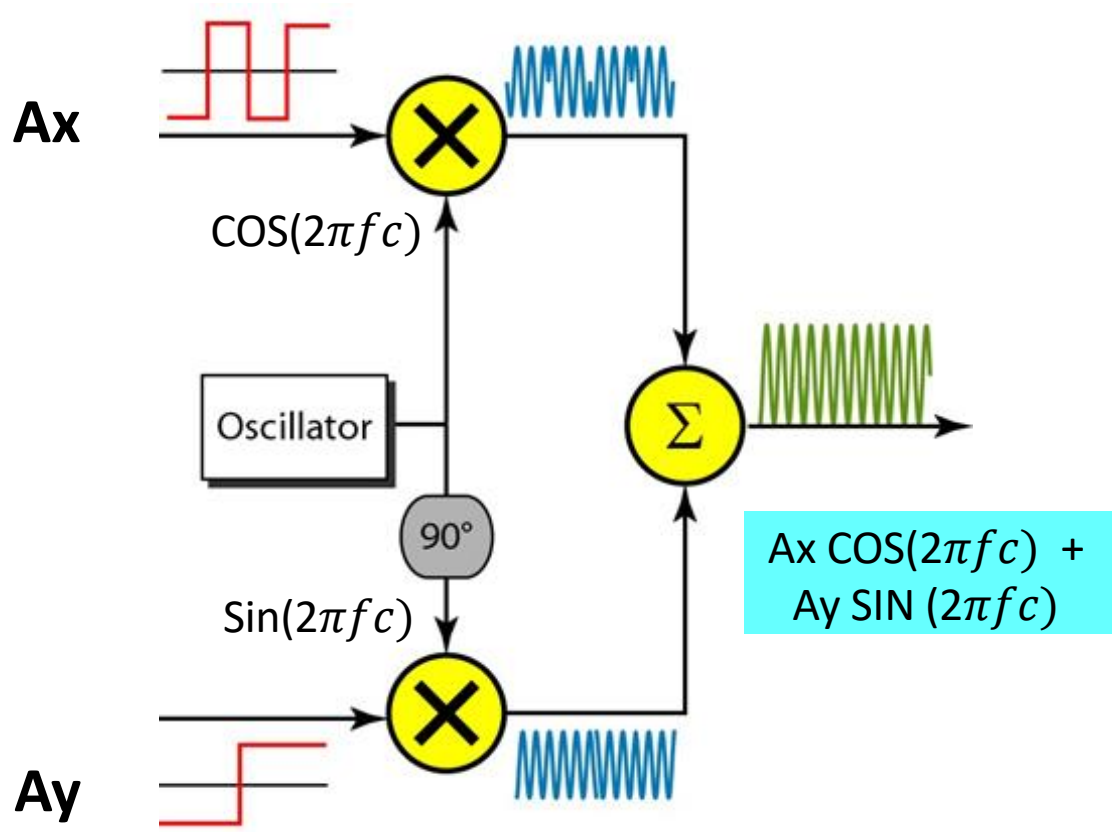


Set_r[0]	Set_r[1]	Set_r[2]	Set_r[3]
'11000110'	'00110001'	'00001100'	'00000011'
'00000010'	'00000001'	'00000000'	'00000011'
Select Ax2 Ay2	Select Ax1 Ay1	Select Ax0 Ay0	Select Ax3 Ax34
Sine SU Cos SU	Sine SU Cos SU	Sine SU Cos SU	Sine SU Cos SU
Ax2 CSU + Ay2 SSU	Ax1 CSU + Ay1 SSU	Ax0 CSU + Ay0 SSU	Ax3 CSU + Ay3 SSU
Zeta = 315	Zeta = 135	Zeta = 225	Zeta = 45
$[A\sqrt{2}, -A\sqrt{2}]$	$[-A\sqrt{2}, -A\sqrt{2}]$	$[-A\sqrt{2}, A\sqrt{2}]$	$[A\sqrt{2}, A\sqrt{2}]$

PSK MOD



Ax2 CSU + Ay2 SSU	Ax1 CSU + Ay1 SSU	Ax0 SU + Ay0 SU	Ax3 SU + Ay3 SU



Zeta = 45 [A√2 , A√2]	Zeta = 225 [-A√2 , A√2]	Zeta = 135 [-A√2 , -A√2]	Zeta = 315 [A√2 , -A√2]

SSU: Sine Signal Unit

CSU: Cosine Signal Unit

QAM MOD

ENCODE Bit-to-QAM SIGNAL

QAM MOD

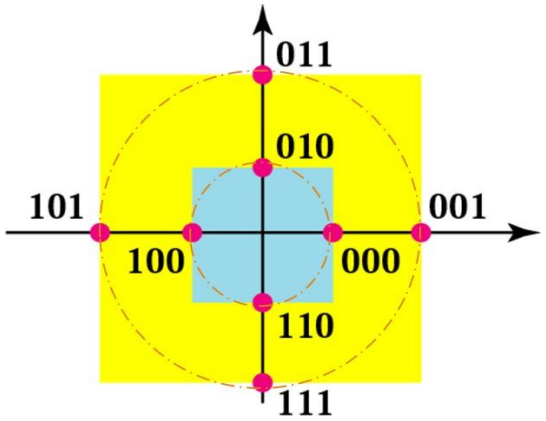
fc = 1000 Hz
Baud rate = 500 baud
r = 3
#cycles/baud =
Amplitude = [A_1 , A_2]
Zeta = [0 90 180 270]
Ax =
Ay =

Digital data
‘110001101’

Partition r bits/baud
‘110’ ’001’ ’101’

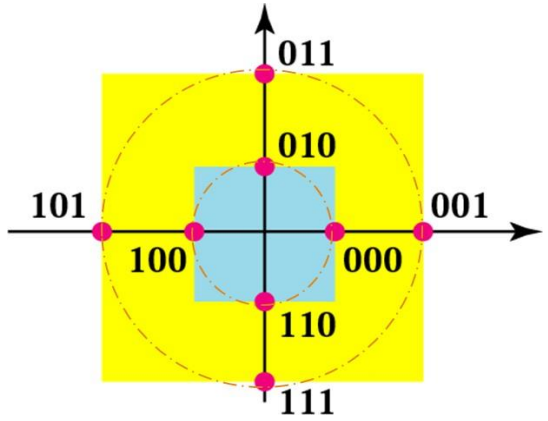
Select sinewave
Properties (Ax, Ay)

MOD with sinewave for
each Signal unit (SU)

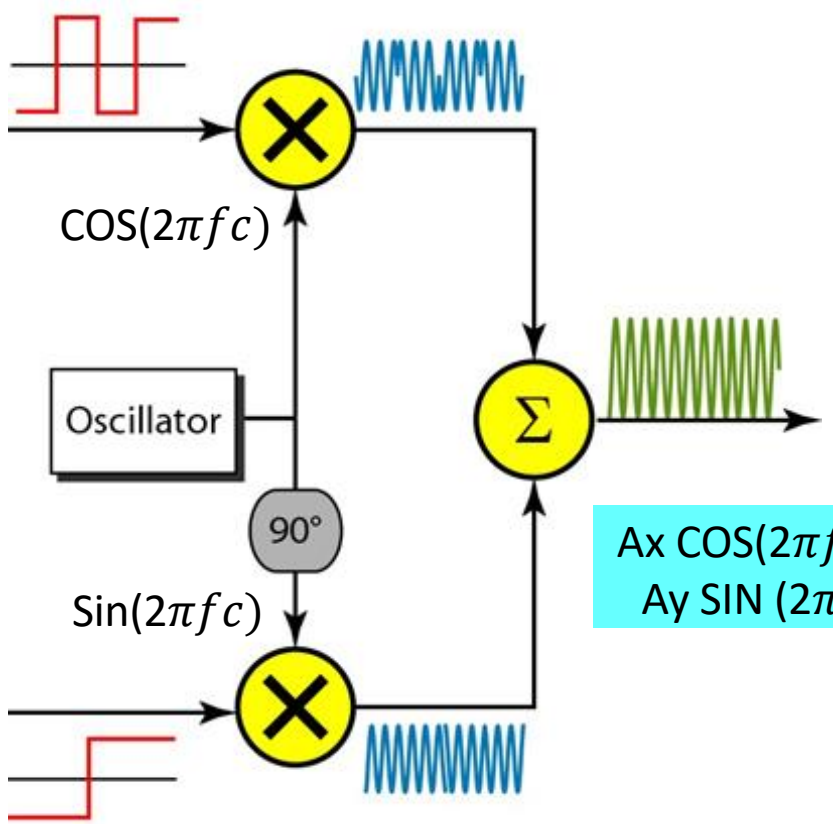


	Set_r[0]	Set_r[1]	Set_r[2]
	‘110001101’	‘000110001’	‘00000110’
	‘00000101’	‘00000001’	‘00000110’
	Select Ax_5 Ay_5	Select Ax_1 Ay_1	Select Ax_6 Ay_6
	Sine SU Cos SU	Sine SU Cos SU	Sine SU Cos SU
	Ax_5 CSU + Ay_5 SSU	Ax_1 CSU + Ay_1 SSU	Ax_6 CSU + Ay_6 SSU
	Zeta = 180 [$-A_2$, 0]	Zeta = 0 [A_2 , 0]	Zeta = 270 [0, $-A_1$]

QAM MOD



Ax5 CSU + Ay5 SSU	Ax1 CSU + Ay1 SSU	Ax0 SU + Ay0 SU



Zeta = 180 [-A2 , 0]	Zeta = 0 [A2 , 0]	Zeta = 90 [0, A1]

$$\cos(A - B) = \cos A \cos B + \sin A \sin B$$

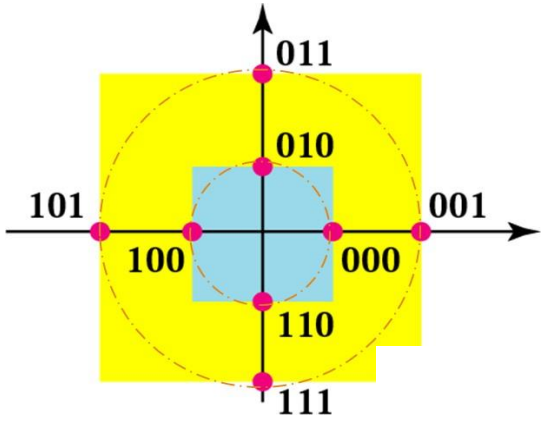
SSU: Sine Signal Unit

CSU: Cosine Signal Unit

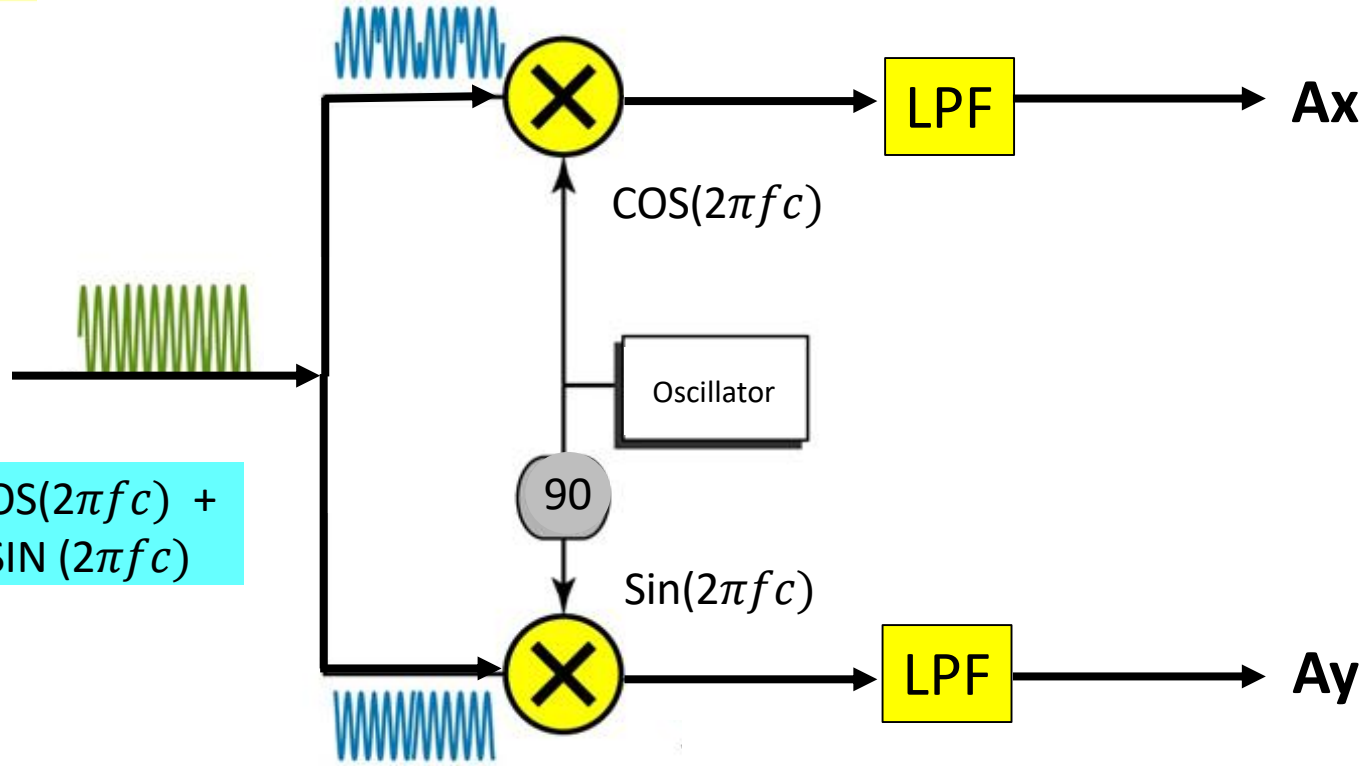
PSK & QAM DeMOD

DECODE PSK & QAM SIGNAL-to-Bit

PSK
QAM
DeMOD



Ax5 CSU + Ay5 SSU	Ax1 CSU + Ay1 SSU	Ax0 SU + Ay0 SU



Ax COS($2\pi fc$) + Ay SIN ($2\pi fc$)

$$\cos a \cos b = \tfrac{1}{2}(\cos(a+b) + \cos(a-b))$$
$$\sin a \sin b = \tfrac{1}{2}(\cos(a+b) - \cos(a-b))$$
$$\sin a \cos b = \tfrac{1}{2}(\sin(a+b) + \sin(a-b))$$

Zeta = 90	Zeta = 0	Zeta = 180

Activity #10.2

1) Draw Constellation Diagram
   - 8-PSK @
     - MOD signal amplitude: 2
     - zeta = [0, 45, 90, 135, 180, 225, 270, 315]
   - 8-QAM @
     - MOD signal amplitude: 2
     - zeta = [30, 150,-150, -30]
     - MOD signal amplitude: 4
     - zeta = [60, 120,-120, -60]

2) Encoded Amplitude (Ax, Ay) for
   - Data: ‘01101010001’

Data Communications through a telephone line

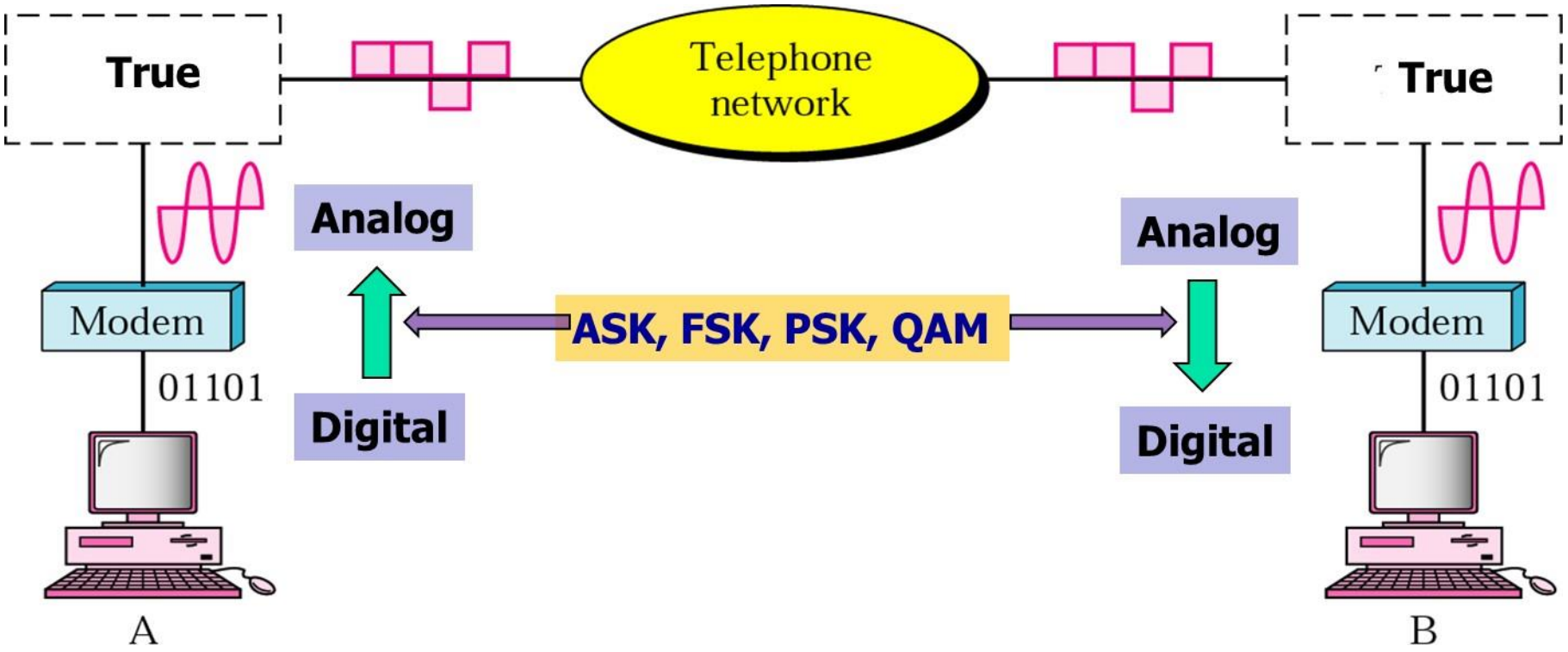
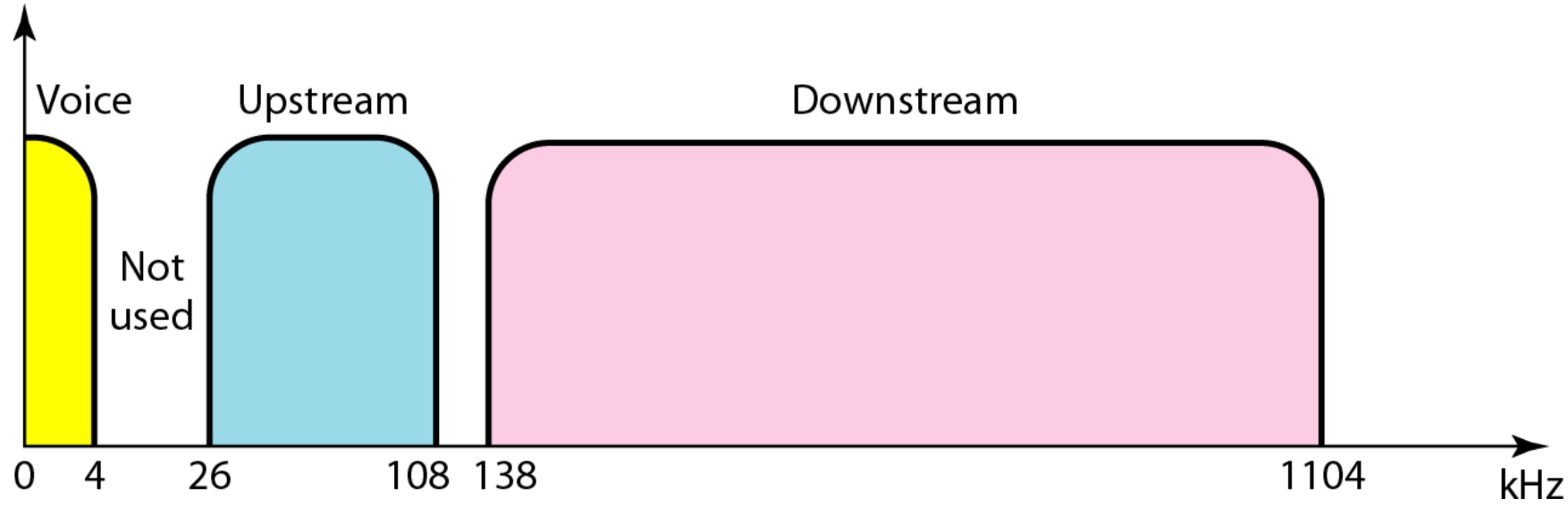
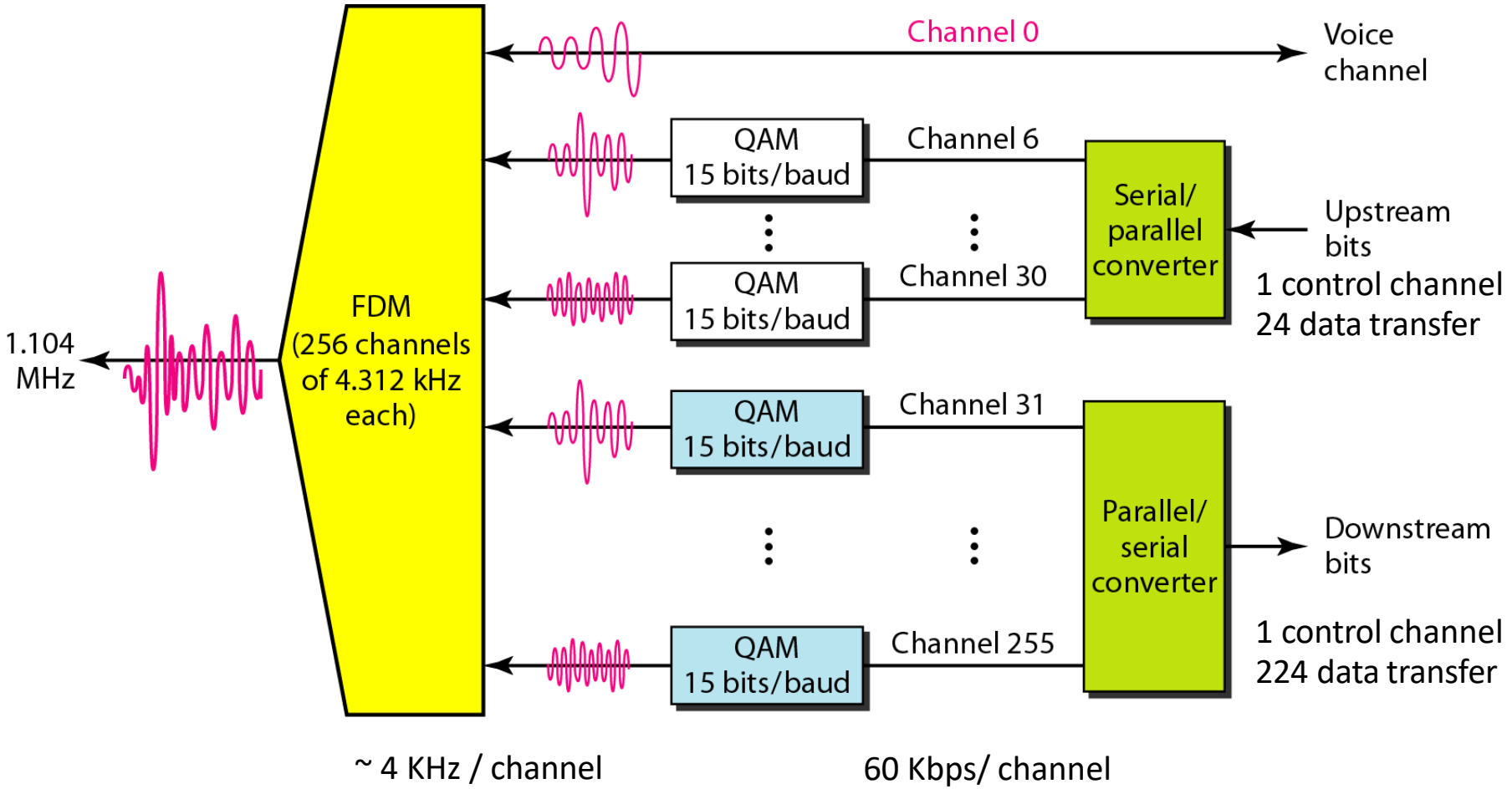


Figure 9.11 *Bandwidth division in ADSL*



- Transmission: twisted-pair (1 pair)
  - Divides 1.104 MHz bandwidth into three bands (256 channels; 4.312 KHz per channel)
    - POT (voice) (channel 0)
    - Upstream (channel 6-30; 25 channels),
    - Downstream (channel 31-255; 225 channels)

Figure 9.10 *Discrete Multitone Technique (DMT) : modulation technique standard for ADSL*



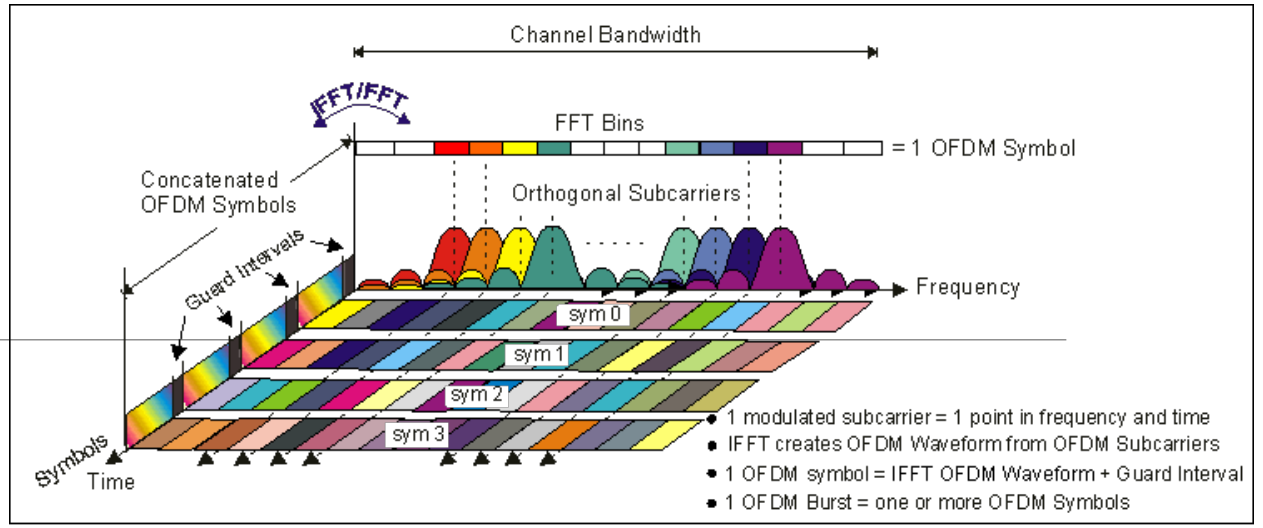
ANSI standard for ADSL

- Upstream (25-200 KHz -> 25 channels)
  - Each FDM sub channel: 4 KHz
  - Discrete Multitone Technique (DMT): 15 bits per baud
  - Data rate: 60 Kbps / channel
  - Upstream data rate (no noise): 25 x 60Kbps = 1.5 Mbps
  - data rate (with noise) : 64 Kbps – 1 Mbps

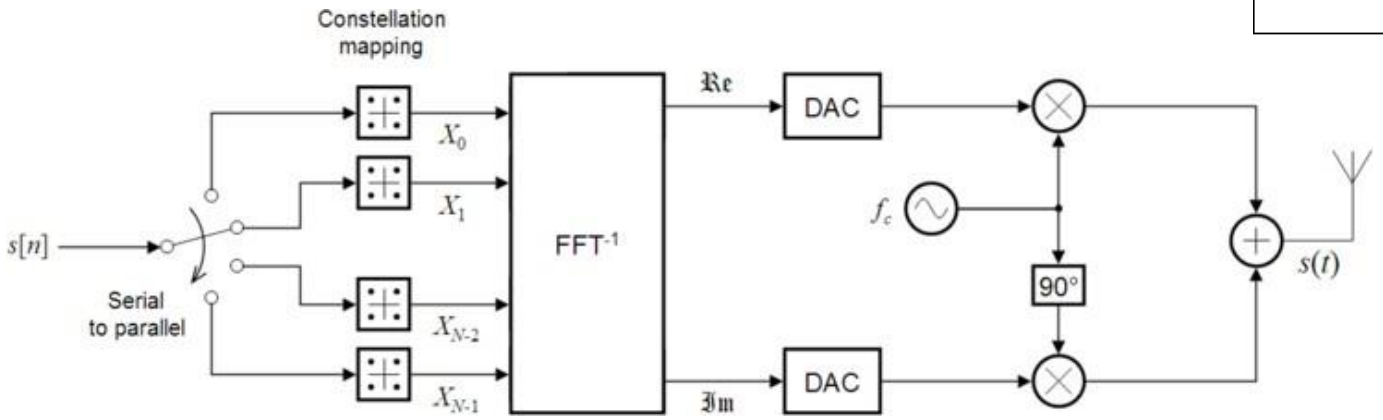
- Downstream (250-100 KHz -> 200 channels)
  - Downstream data rate: 200 x 60 Kbps = 12 Mbps
  - data rate (with noise): 500 Kbps – 8 Mbps

OFDM:

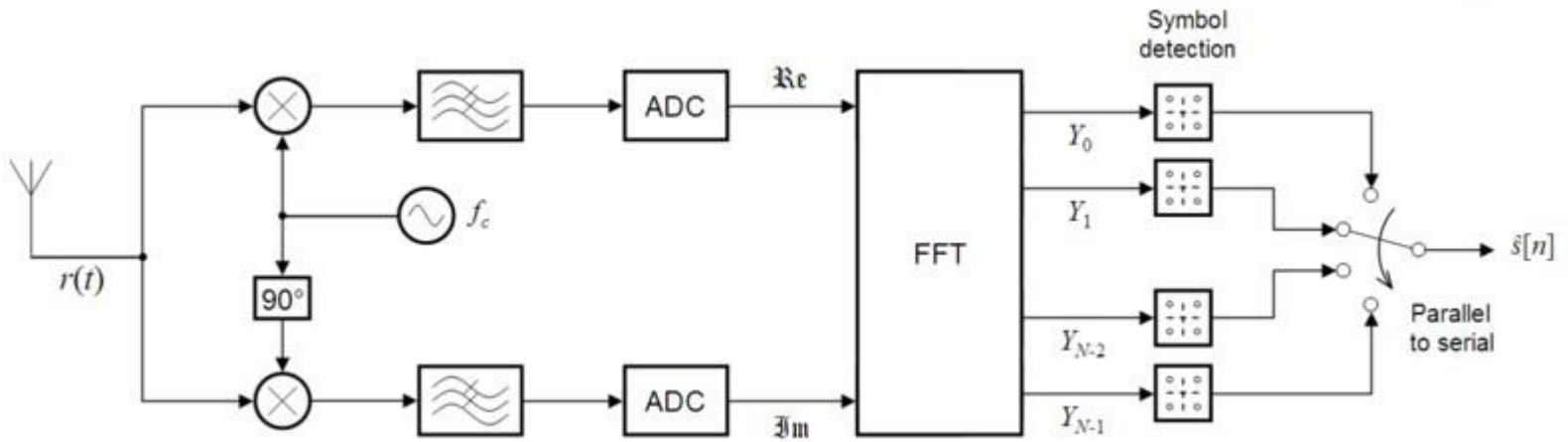
Orthogonal Frequency Division Multiplexing



Frequency-Time Representative of an OFDM signal



Mobile Data Modulation



Summary

Digital Modulation

- Transmitting Digital data on Analog (sinewave) Signal by
  - Changing sinewave property according to digital data
    - ASK: changing Amplitude
    - FSK: changing Arequency
    - PSK: changing Phase
    - QAM: changing Amplitude & Phase
- Objective: Transmitting Digital Data (Unlimited Bandwidth)
  - Onto Analog channel (Limited Bandwidth)