└→ analog data to analog data

ทำไม ?? ⟶ $f_{data} \neq f_{channel}$

Analog Transmission

ANALOG MODULATION

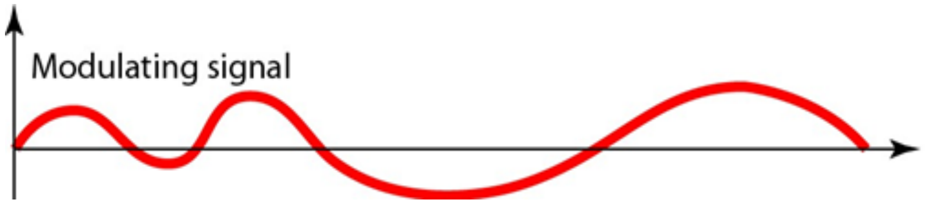
WHAT WOULD BE THE SIGNAL

For Analog Channel

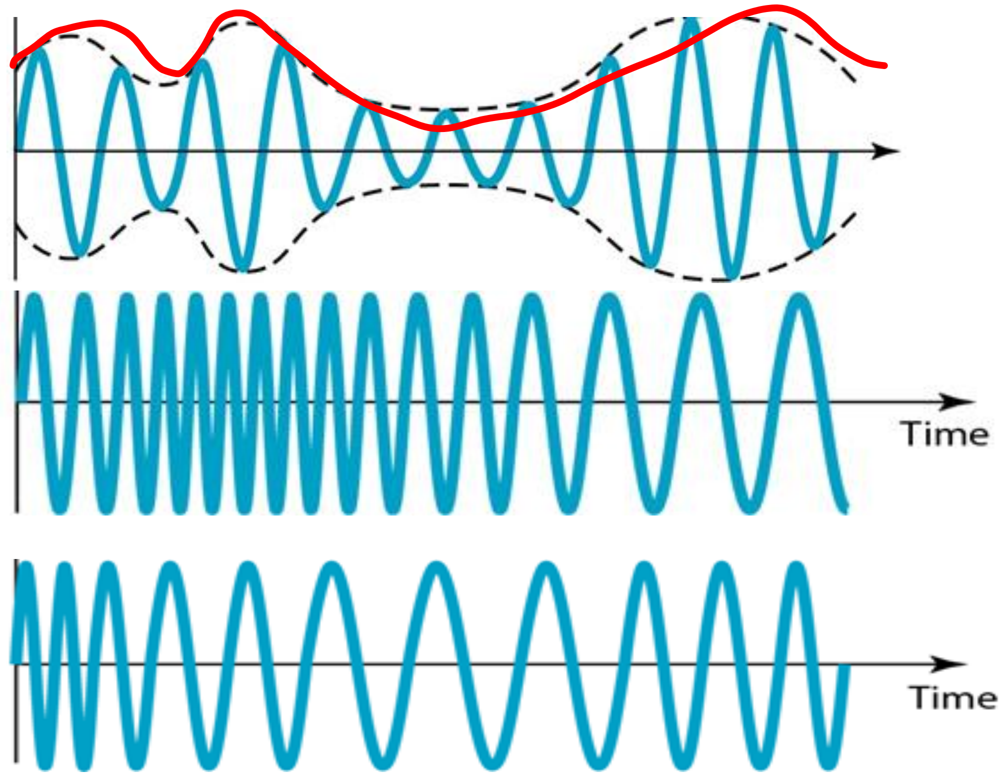
Signals on Analog Channel

ฝั่งนี้ถูกเปลี่ยน property

Analog Data



Analog signal on Analog Channel



HOW CAN WE GENERATE

Analog Signal

on Analog Channel?

Modulation Basic

- digital modulation is similar to analog modulation, but rather than being able to continuously change the amplitude, phase or frequency
- analog modulation → เอาความถี่ต่ำส่งขึ้นความถี่สูง
- The process of varying any of the three characteristics as amp, freq or phase of a carrier signal is called as modulation

modulation signal (info) → $\boxed{\text{modulation}}$ → modulation signal

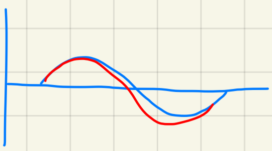
↑ carrier signal

(info) → analog, digital

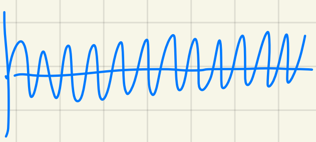
$\boxed{\text{modulation}}$

- analog modulation
  - amp
  - freq
  - phase
  } modulation
- digital modulation
  - Pulse Amplitude Modulation (PAM)
  - Pulse Width Modulation (PWM)
  - Pulse code modulation (PCM)

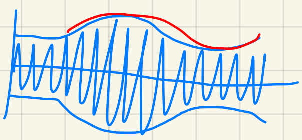
เรื่องที่ amplitude modulation



signal



carrier signal



modulated signal

amplitude : change

freq : same

phase : same

Bandwidth = 2Bandwidth

ข้อดี → ง่าย(ส่ง, รับ), ส่งได้ไกล, Bandwidth ต่ำ)

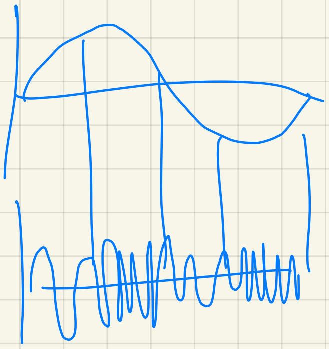
ข้อเสีย → power waste, noise

Frequency Modulation

↳ amplitude : same
freq : vary
phase : same

↳ Amplitude มากขึ้น, ความถี่มากขึ้น, คาบน้อยลง
(ของ info) (ของ carrier signal)

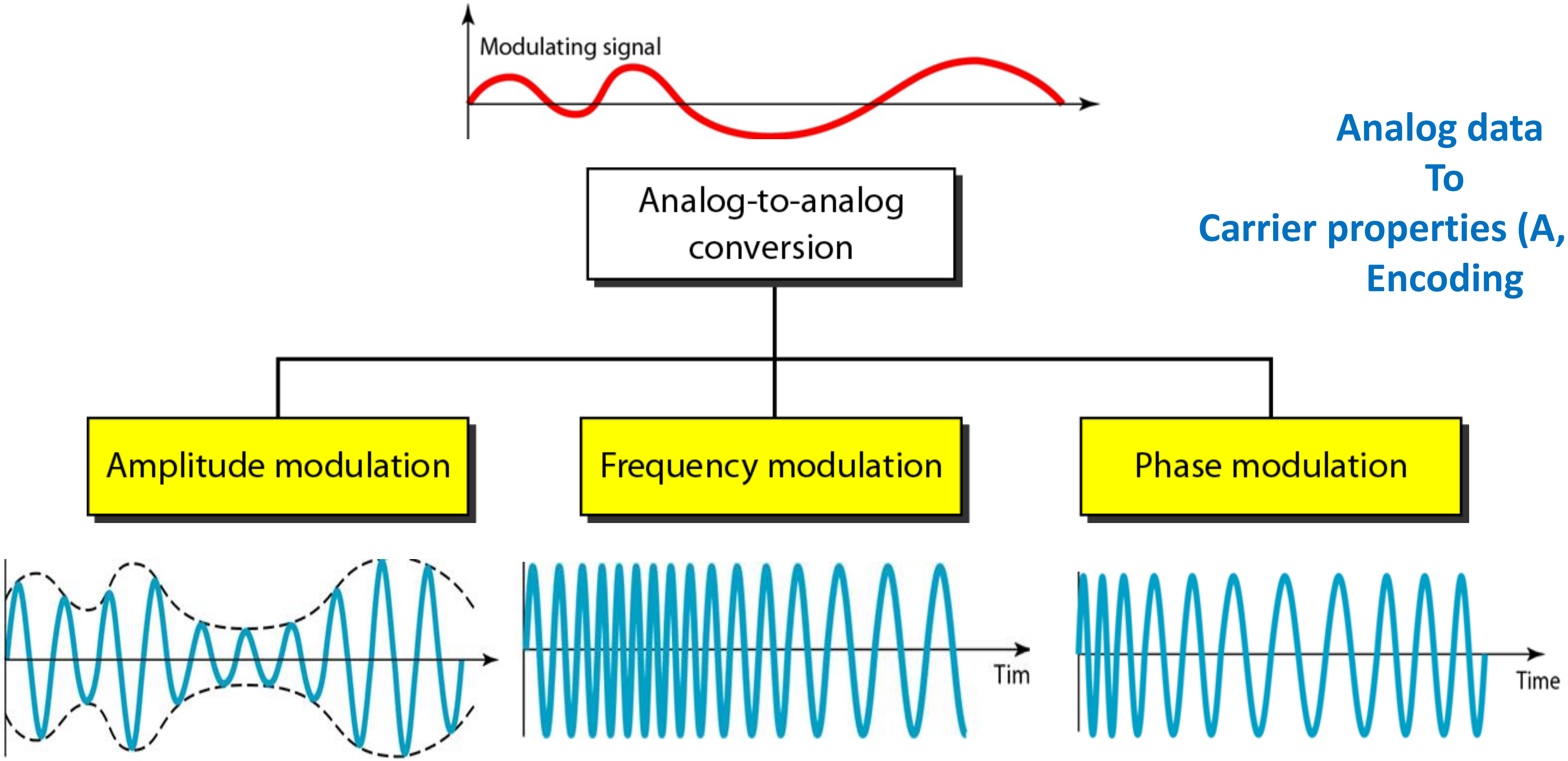
↳ Bandwidth = $2 \times f_m \times n$(sideband)



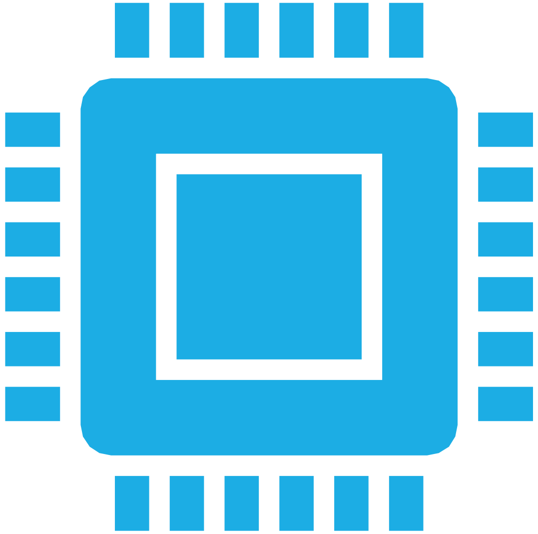
จดแบบจะชิดเพลาลกกล้า

↳ ข้อดี → noise immunity, entire signal usefull, less transmit power and remain constant
ข้อเสีย → large bandwidth, complex (ส่ง, รับ)

Analog Modulation



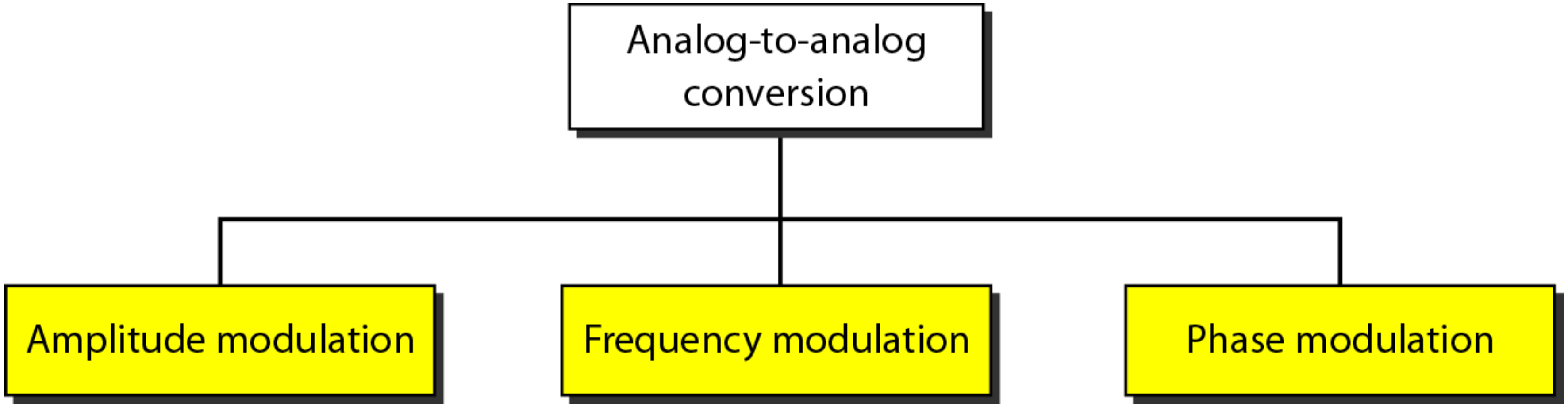
Analog data
To
Carrier properties (A, f, zeta)
Encoding

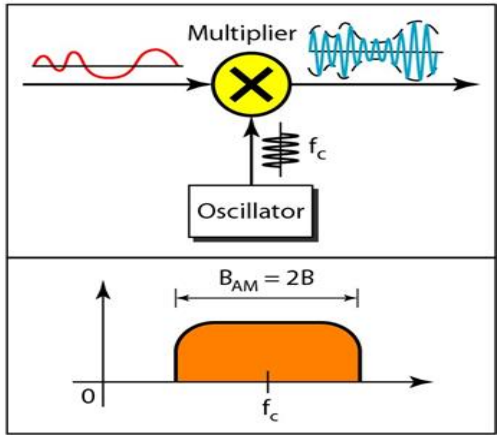


AMPLITUDE MODULATION (AM)

GENERATION THROUGH AMPLITUDE MULTIPLICATION

Figure 5.15 *Types of analog-to-analog modulation*





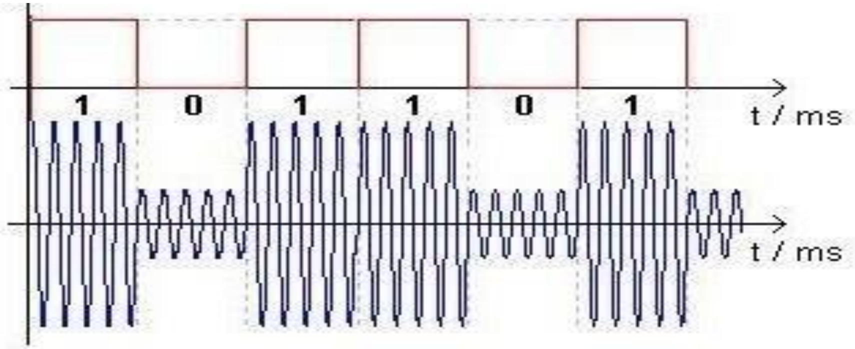
Encoding Analog data to Analog Amplitude

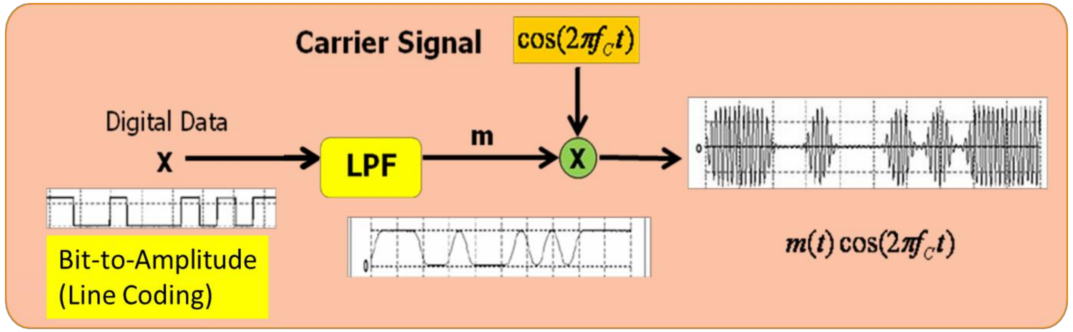
Will **AM** be different from **ASK**?

(Amplitude MOD vs Amplitude Shift Keying)

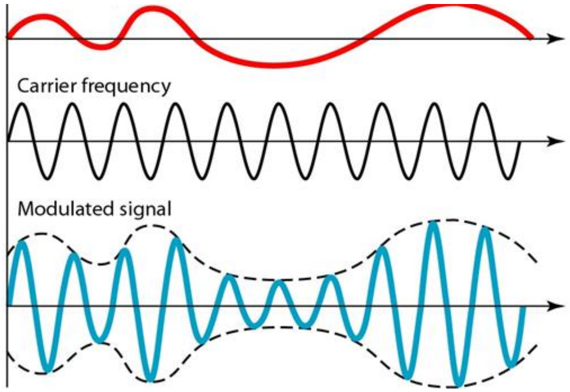
ASK vs AM

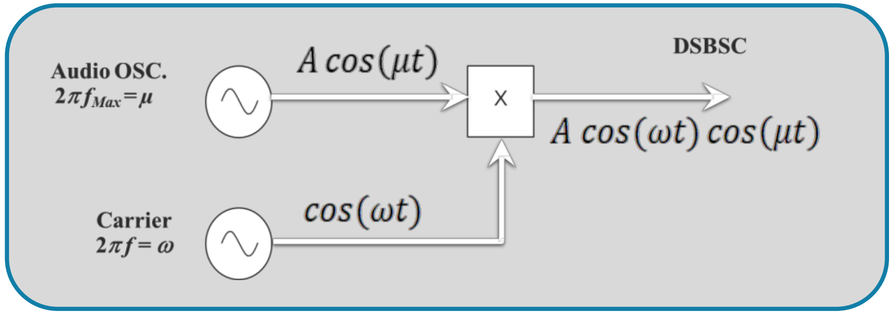
- Bits -> selected Asu -> m(t)
- Asu x $\cos(2\pi f_c t)$ -> m(t) $\cos(2\pi f_c t)$





- Analog data -> m(t)
- m(t) x $\cos(2\pi f_c t)$ -> m(t) $\cos(2\pi f_c t)$





Both implement through Amplitude Multiplication

ANALOG

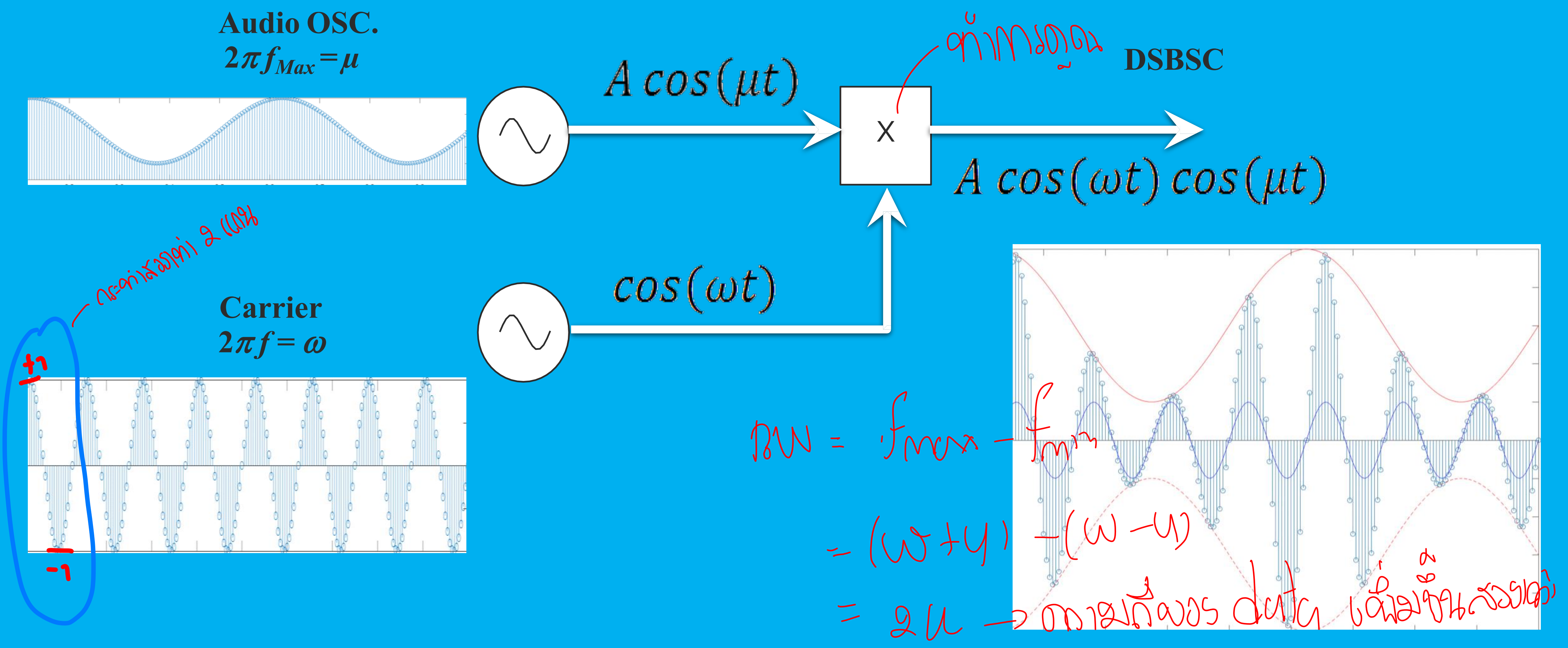
AMPLITUDE MODULALTION (AM)

Technique

DOUBLE SIDEBAND SUPPRESSED CARRIER

(DSSC)

DSBSC (DOUBLE SIDEBAND SUPPRESSED CARRIER) (proof of bandwidth)



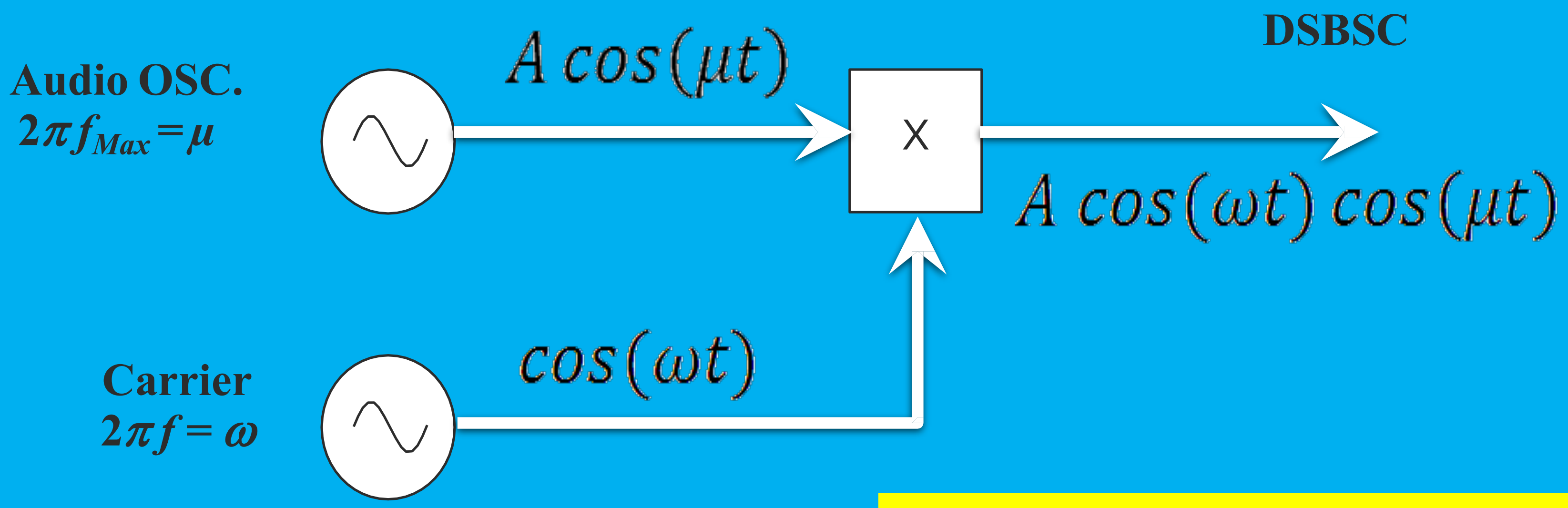
AMPLITUDE MODULALTION (AM)

Bandwidth

DOUBLE
SIDEBAND
SUPPRESSED
CARRIER

(DSSC)

DSBSC (DOUBLE SIDEBAND SUPPRESSED CARRIER) (proof of bandwidth)



cos ω cos μ = ½(cos (ω - μ) + cos (ω + μ))

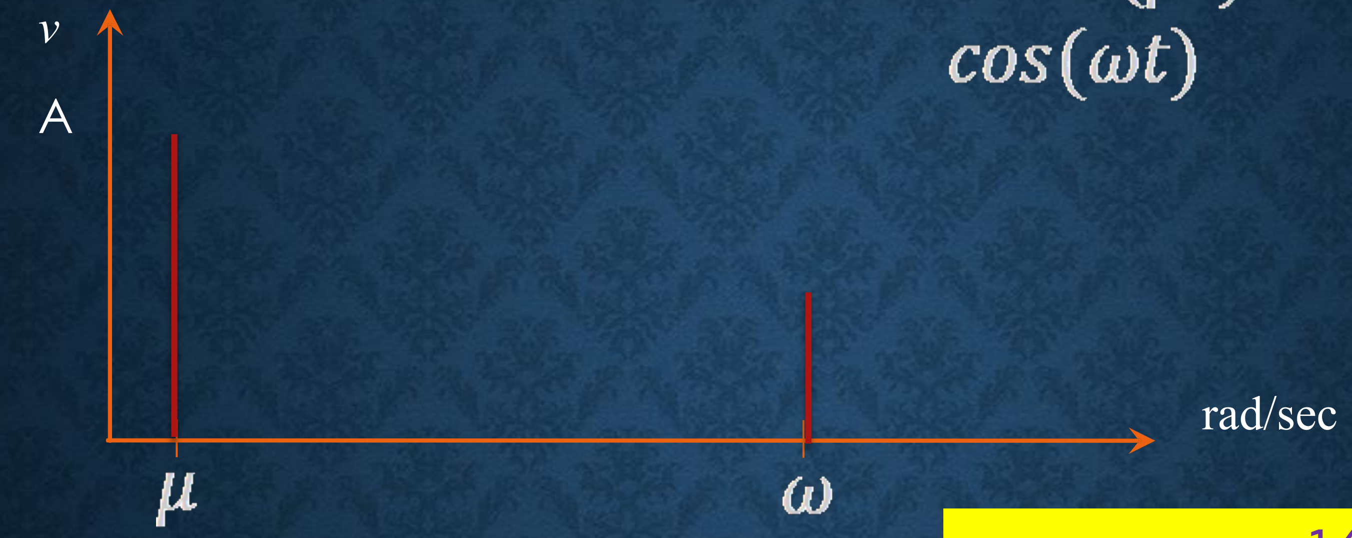
$$A\,cos(\omega t)\,cos(\mu t)$$

$$= \left(\frac{A}{2}\right) cos(\omega - \mu)t + \left(\frac{A}{2}\right) cos(\omega + \mu)t$$

$\omega \gg \mu$

$A\cos(\mu t)$

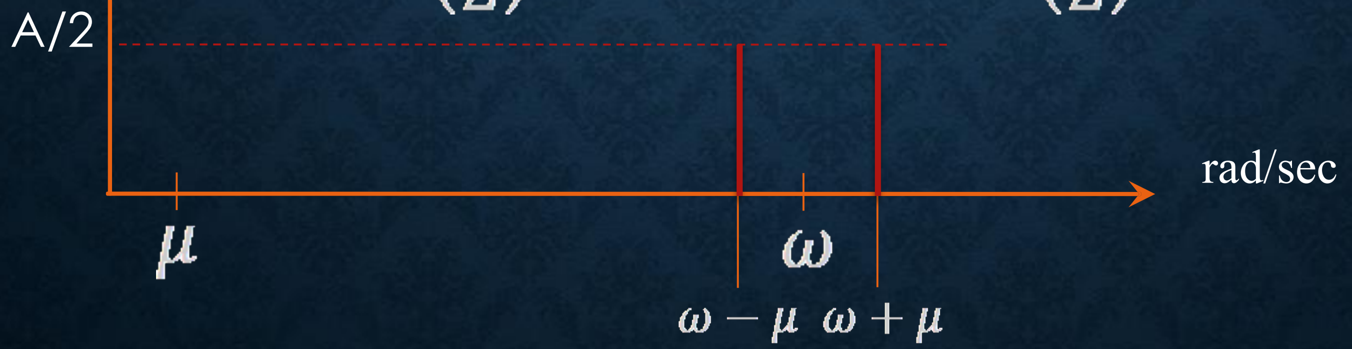
$\cos(\omega t)$



cos ω cos μ = ½(cos (ω - μ) + cos (ω + μ))

$A\cos(\omega t)\cos(\mu t)$

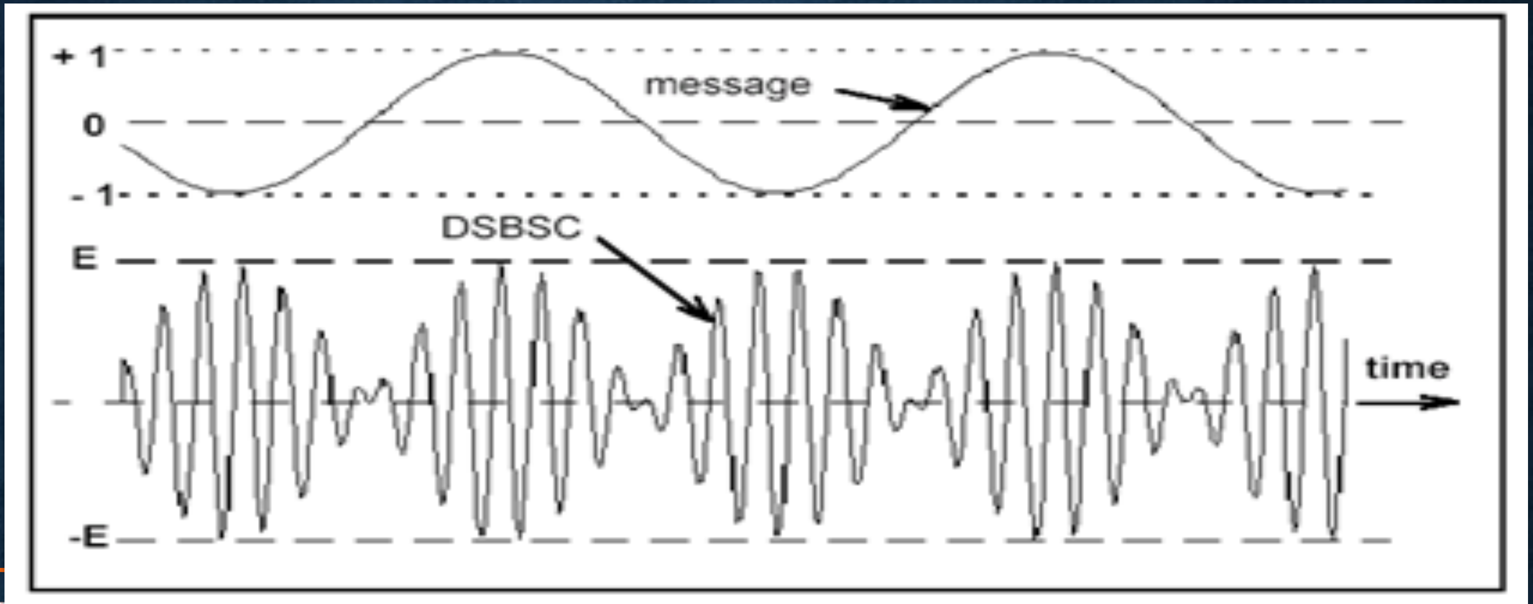
$$= \left(\frac{A}{2}\right)\cos(\omega-\mu)t + \left(\frac{A}{2}\right)\cos(\omega+\mu)t$$



$\omega \gg \mu$

v

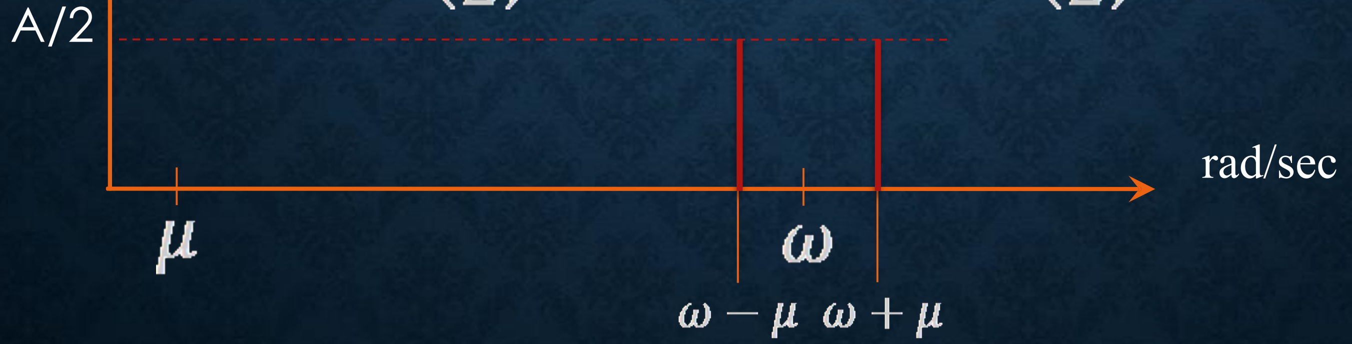
A



μ ω

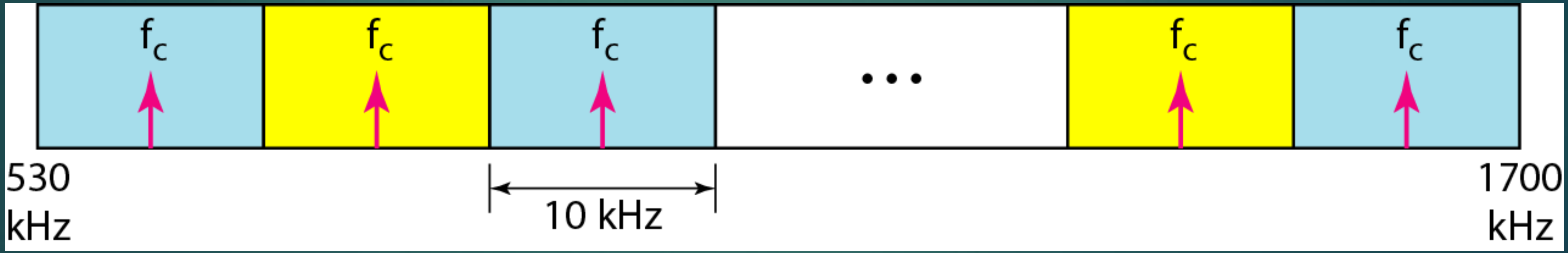
v $A\cos(\omega t)\cos(\mu t)$

$$= \left(\frac{A}{2}\right)\cos(\omega-\mu)t + \left(\frac{A}{2}\right)\cos(\omega+\mu)t$$



AM Bandwidth

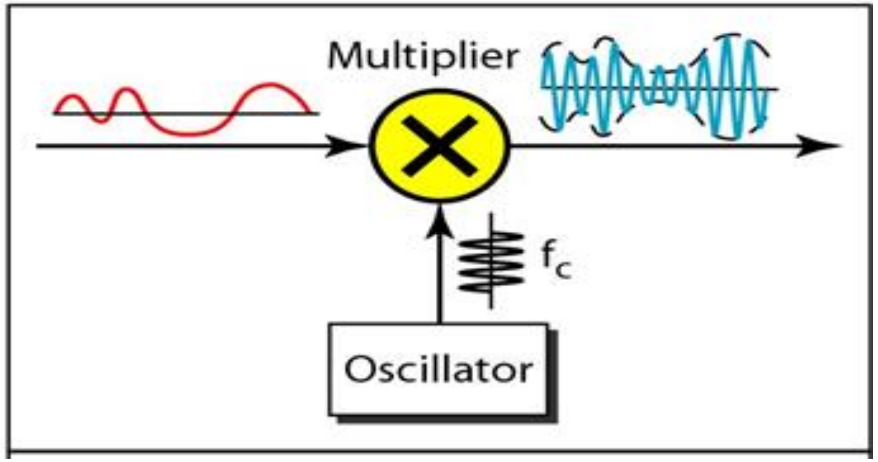
- The total bandwidth required for AM can be determined from the bandwidth of the audio signal (B):
  - $B_{AM} = 2B_{\text{analog data input}}$.

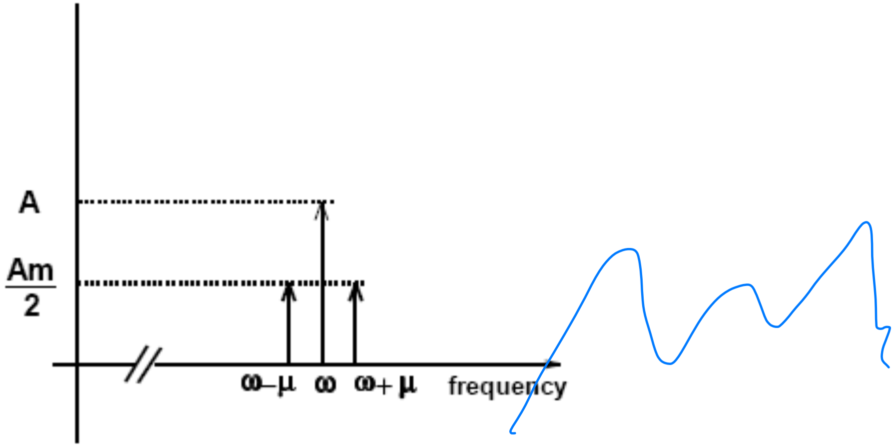


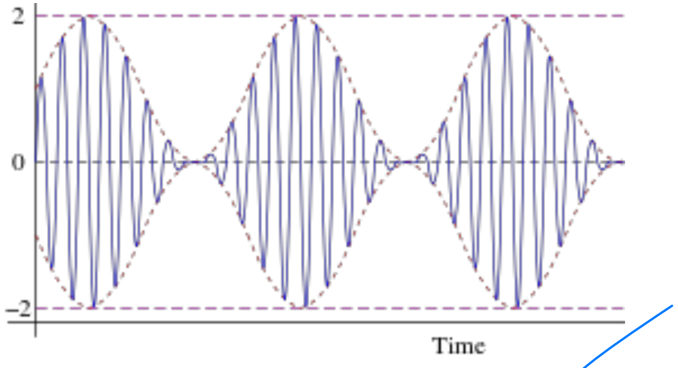
HOW CAN WE KNOW THAT THE AM SIGNAL

IS GOOD ENOUGH?

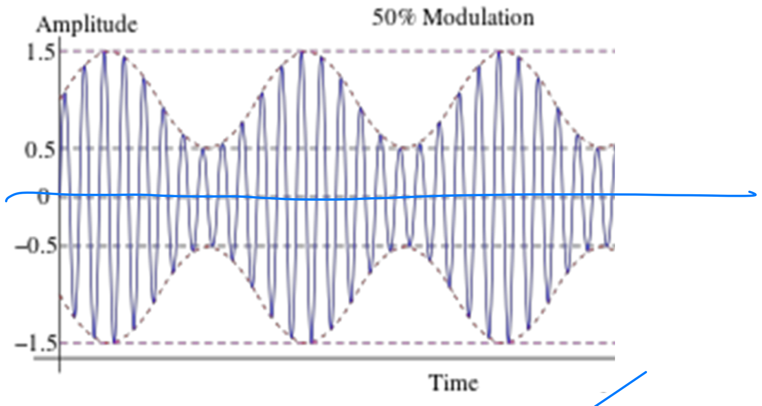
IS THE AM SIGNAL GOOD ENOUGH?



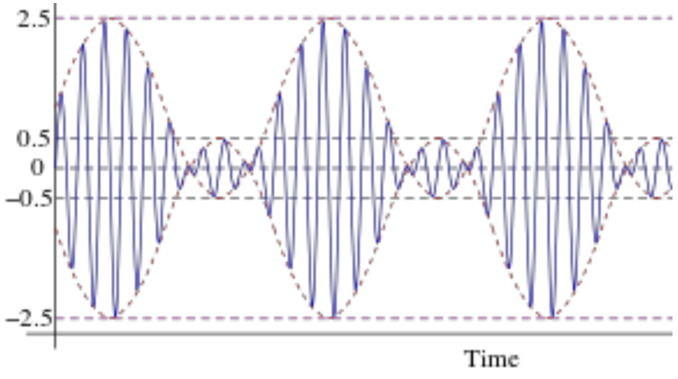




A



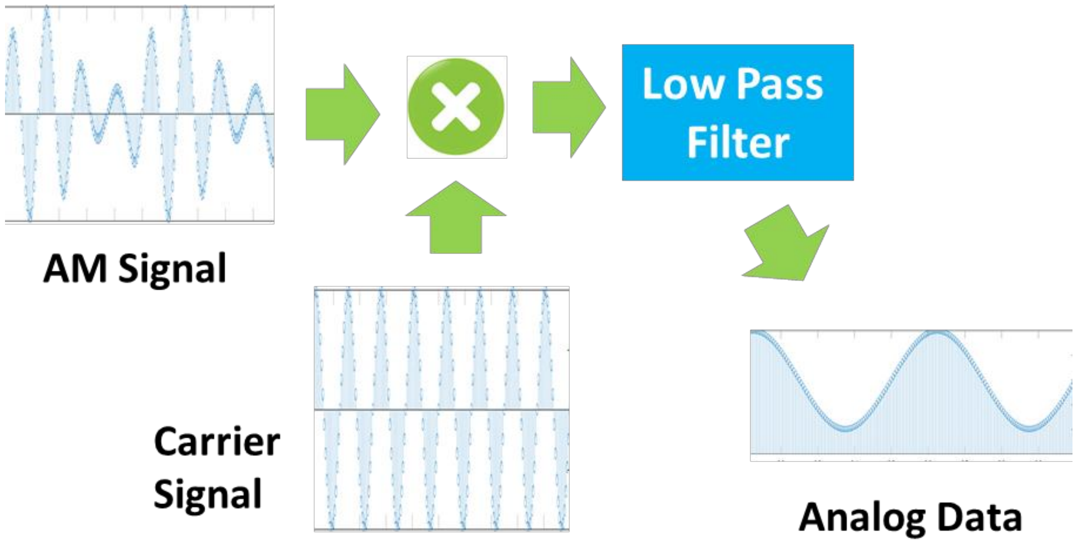
B



C

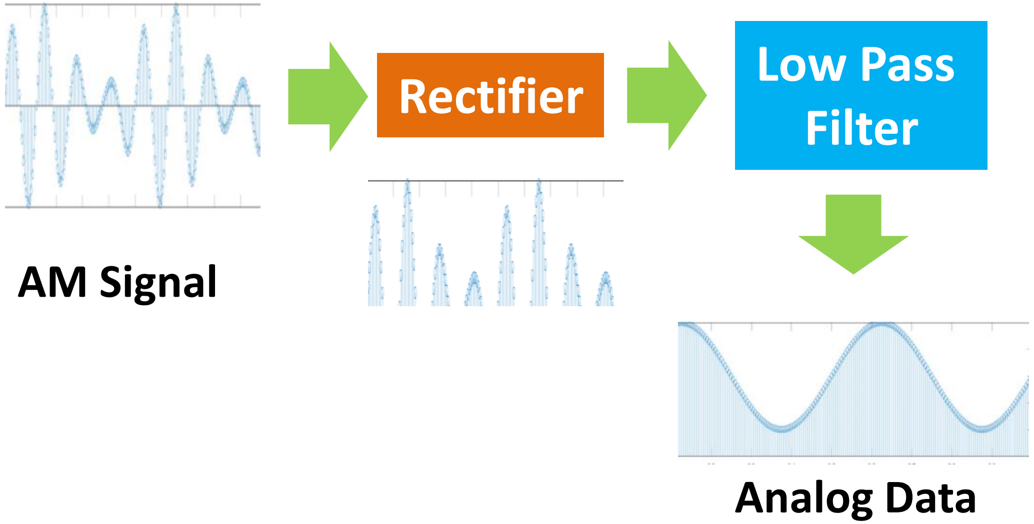
Amplitude DeMODulation Techniques

Technique 1



- Implement through
  - Multiplication
    - More complicated circuit
    - Higher computation time

Technique 2

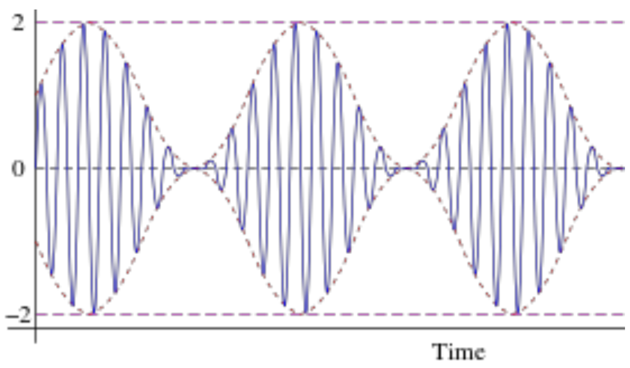


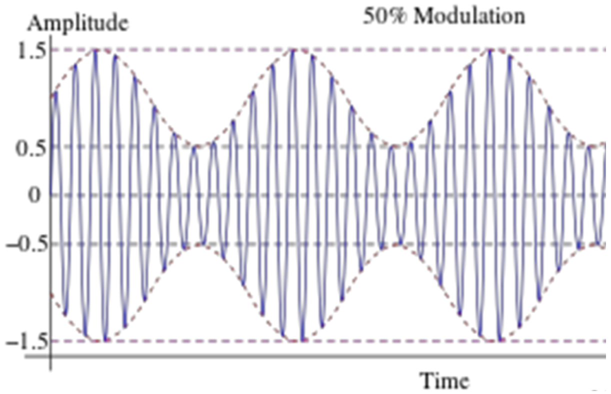
- Implement through
  - Rectifier
    - Simple circuit
    - Lower Computation time

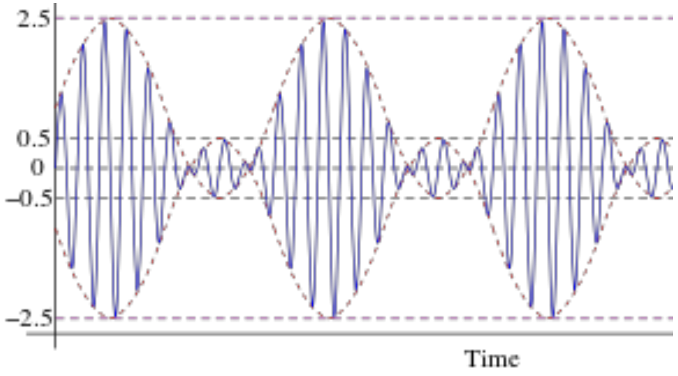
WHAT WOULD BE THE EFFECT FOR

RECTIFIER CIRCUIT?

AM Signal after rectifier







A

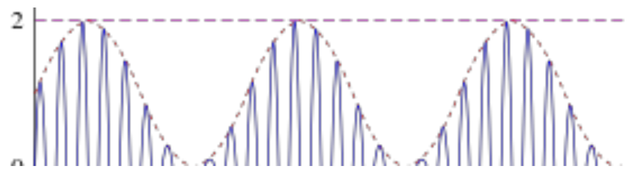
Rectifier

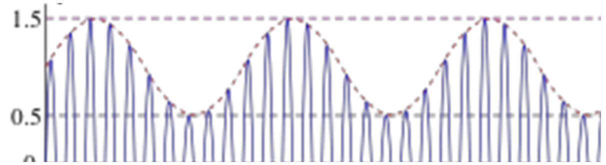
B

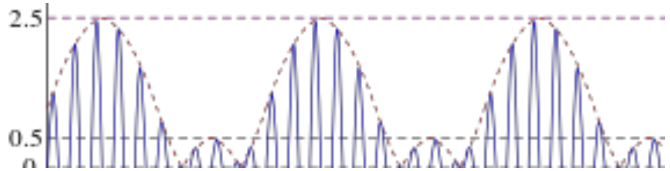
Rectifier

C

Rectifier







Which one can we get back signal close the analog data ?

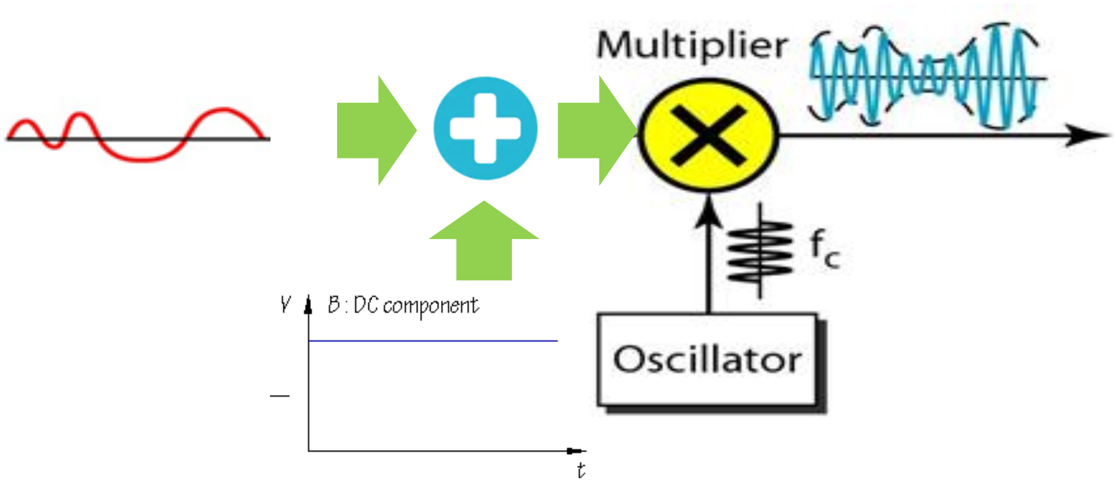
HOW CAN WE IMPLEMENT

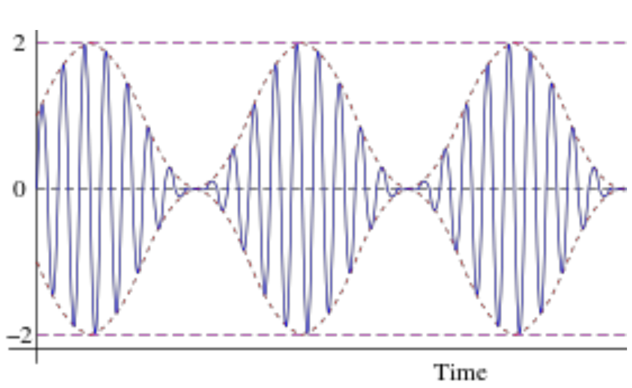
AM SIGNAL

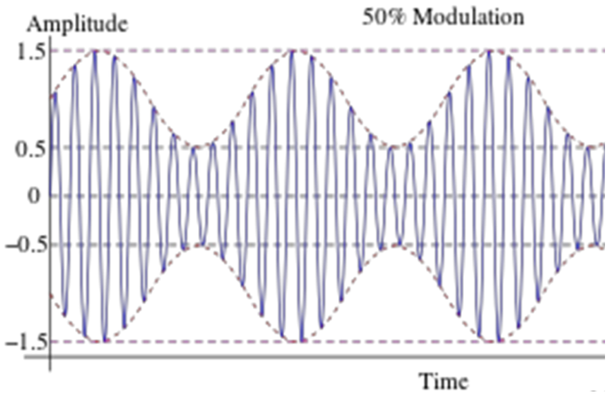
GOOD FOR

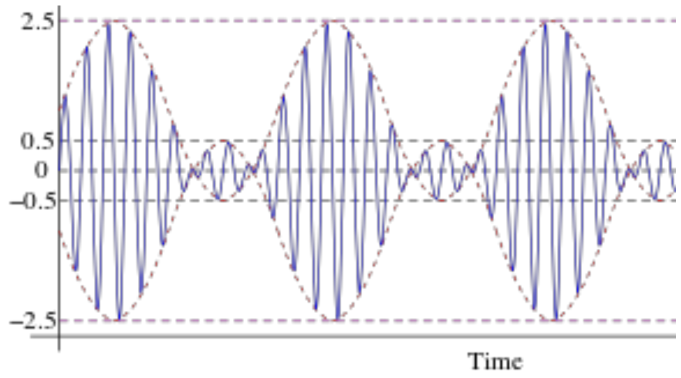
RECTIFIER CIRCUIT?

Amplitude Modulation with different DC offsets









A: DC = Vpp

B: DC > Vpp

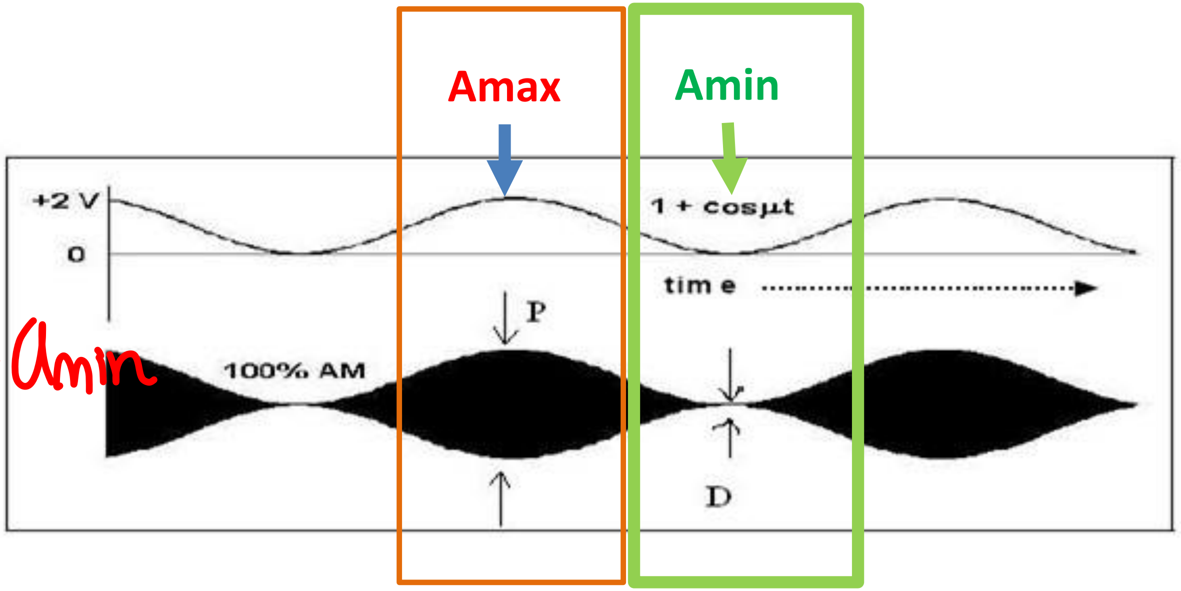
C: DC < Vpp

HOW CAN WE KNOW IF DC OFFSET

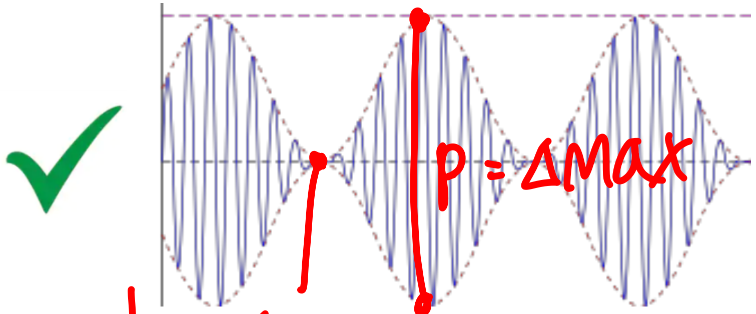
IS APPROPRIATE?

Offset Factor: Modulation Index (m)

P = Amax-Amin



$$m = \frac{P - D}{P + D}$$

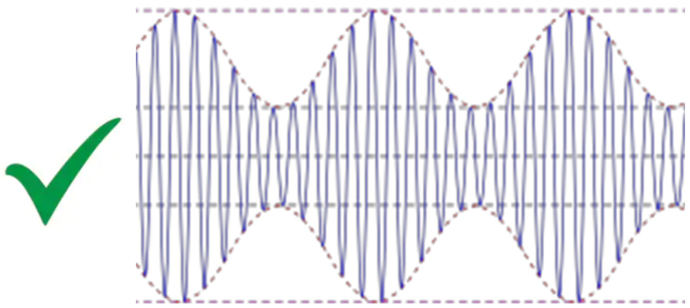


p = Amax

d = Amin

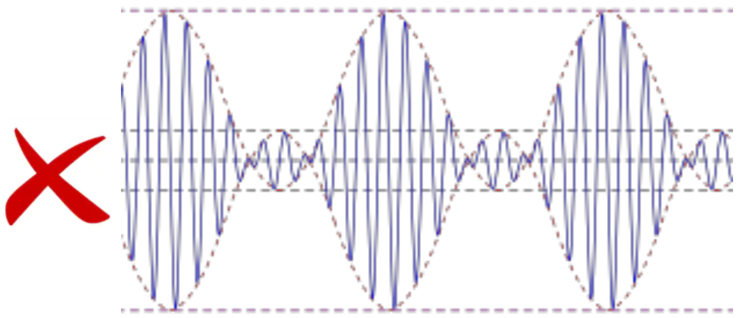
DC offset = 1V / P = 4V / D = +0V

m = 4/4 = 1 : 100%



DC offset = 1.5V / P = 5V / D = +1V

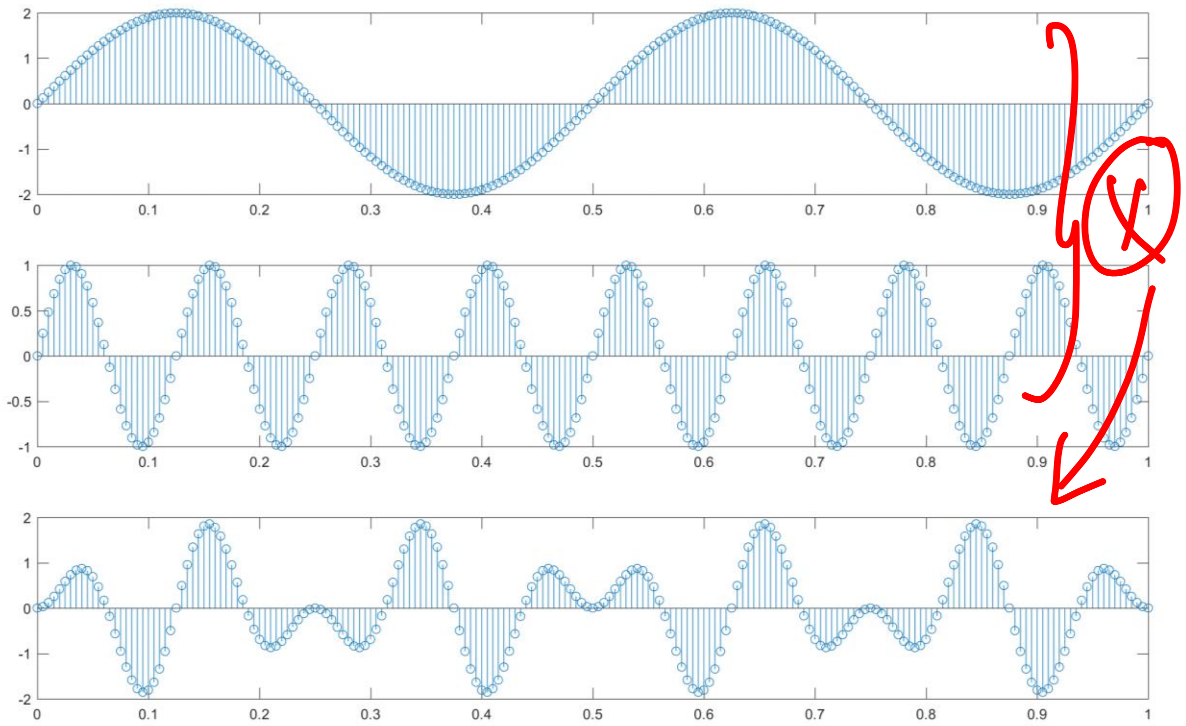
M = 2/3 = 0.667 = 66.7 %: < 100%

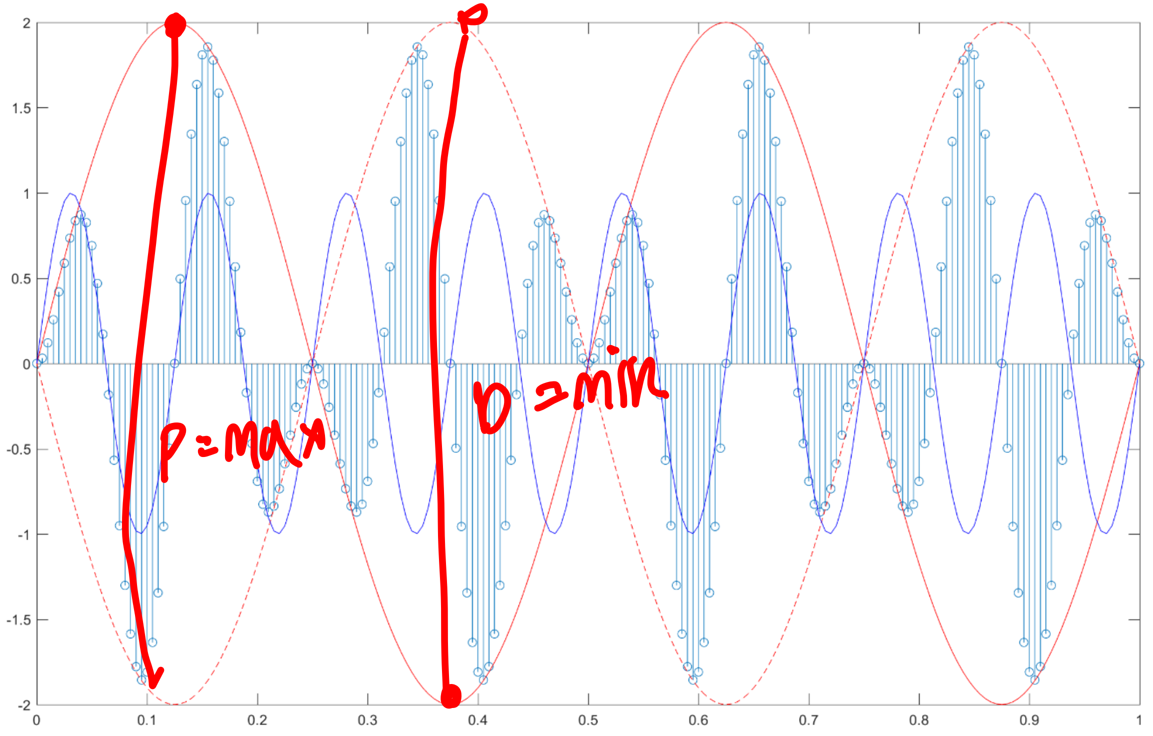


DC offset = 0.5V / P = 3V / D = -1V

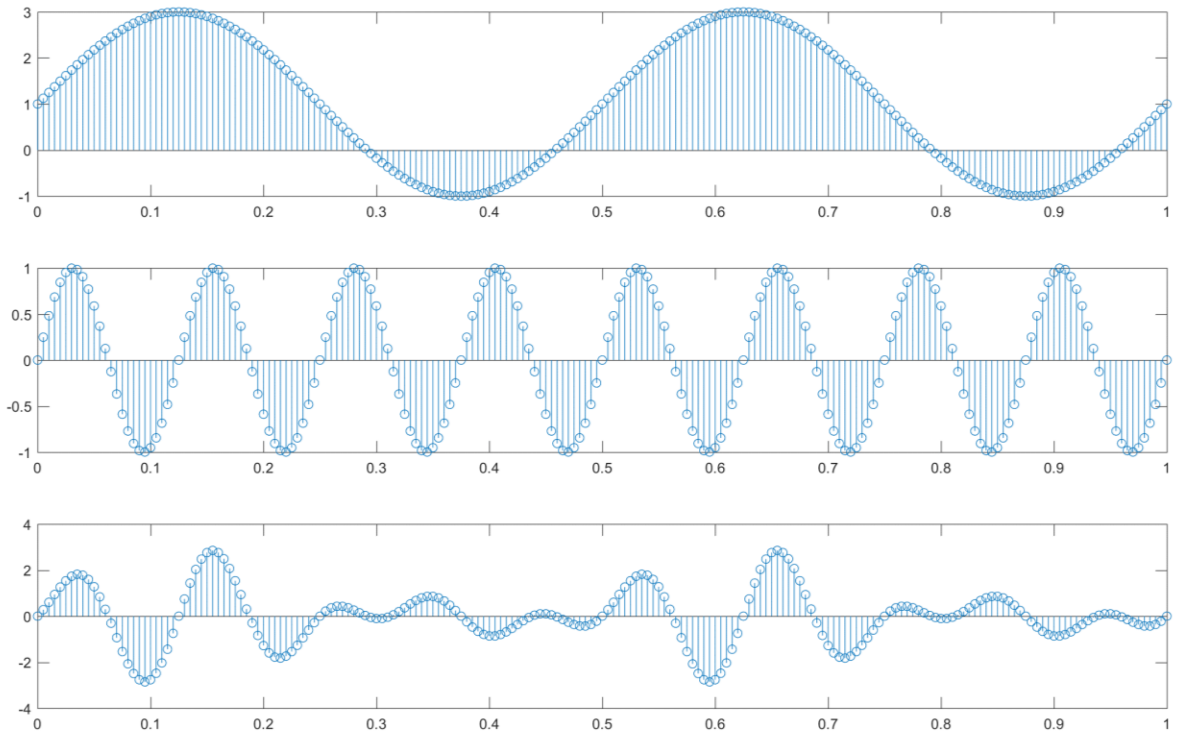
M = 4/2 = 2 = 200 %: > 100%

m=0, c=0, P=4, D=4

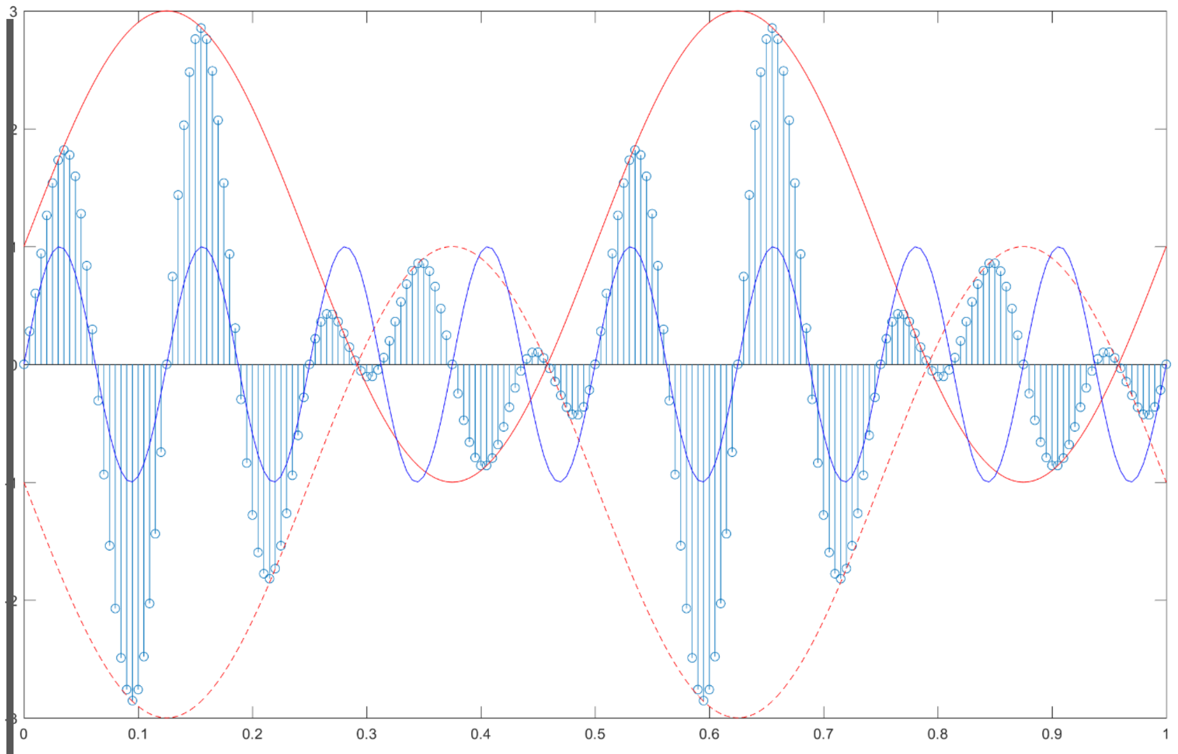




m>1, c=1, P=6,D=-2

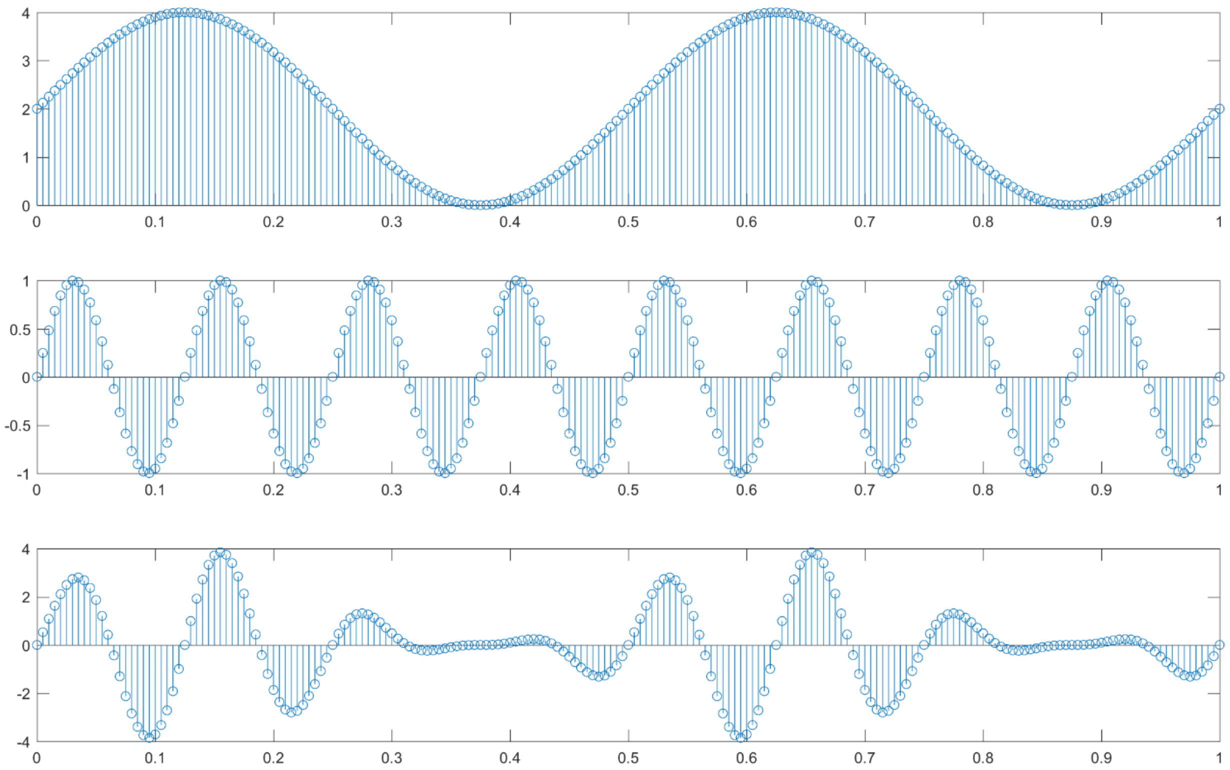


3
2
1
0
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.5
-0.5
4
-2
-4

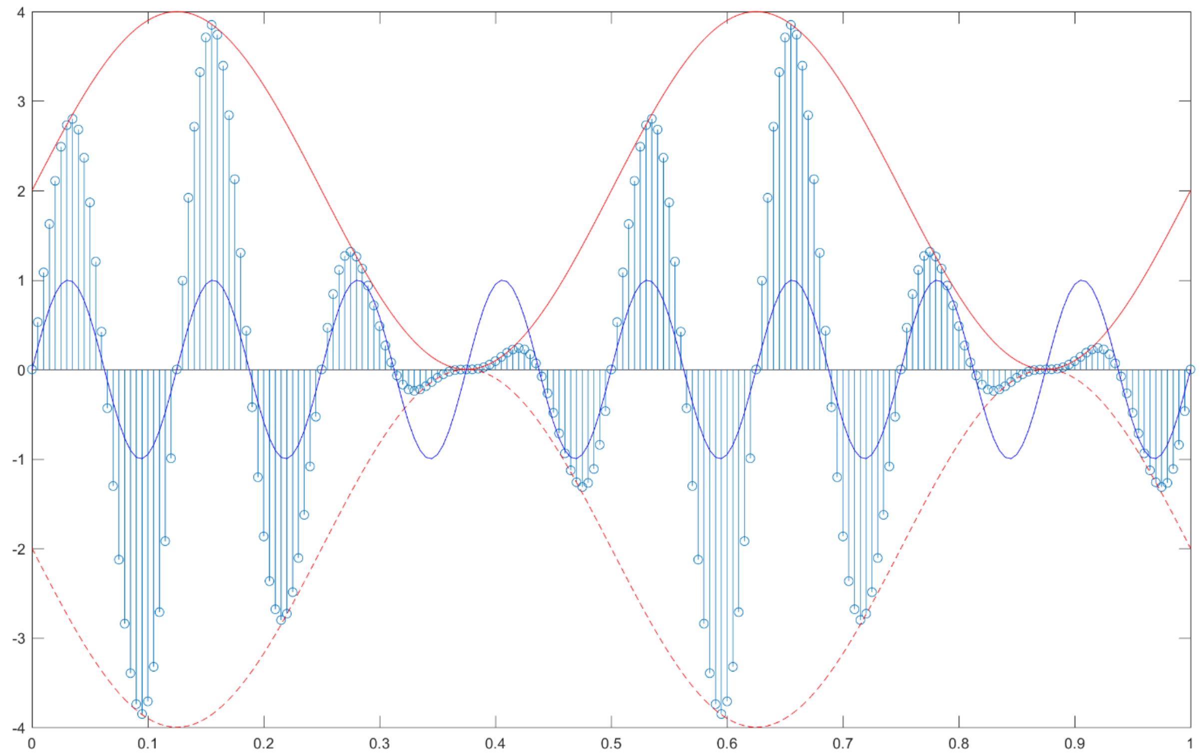


3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

m=1, c=2, P=8,D=0

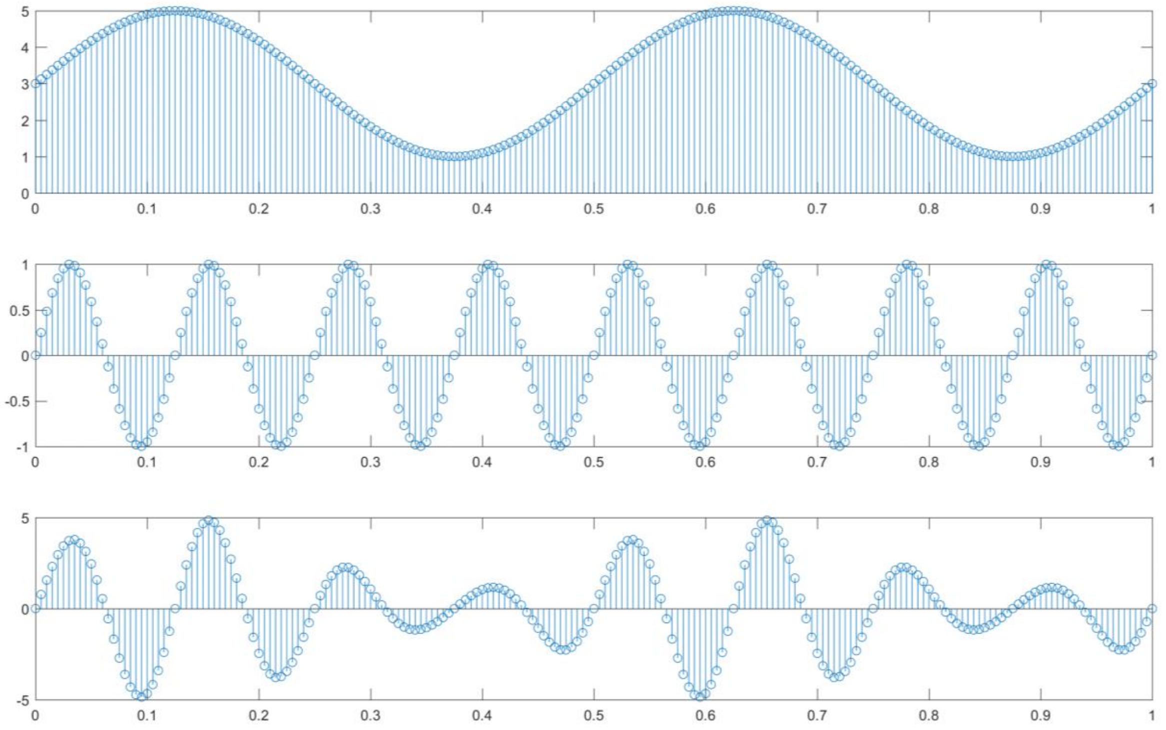


4
3
2
1
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
1
0.5
0
-0.5
-1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
4
2
0
-2
-4
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

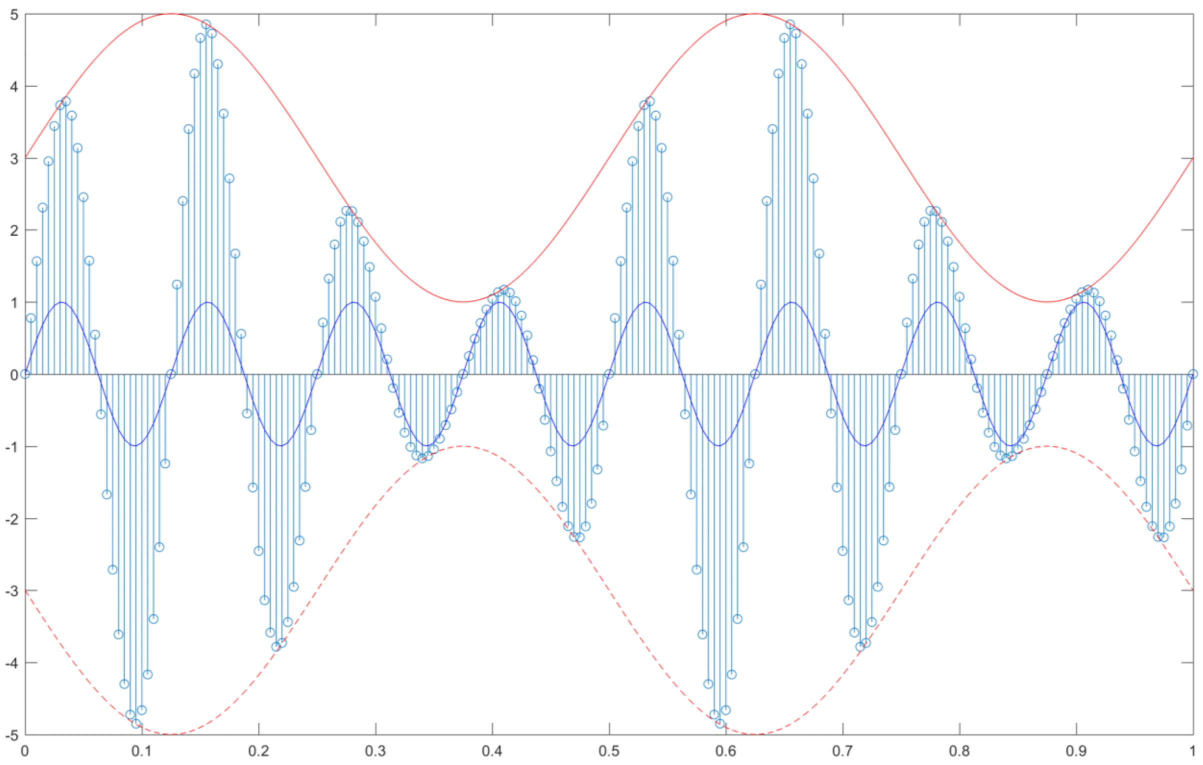


4
3
2
1
0
-1
-2
-3
-4
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

m<1, c=3, P=10,D=2



5
4
3
2
1
0
0.5
-0.5
-1
-5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9



5
4
3
2
1
0
-1
-2
-3
-4
-5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

ACTIVITY # 11.1

- วาดกราฟ $\mathbf{A(t) = 2\cos(2\pi f_m t)} \rightarrow f_m$= 2 Hz
- วาดกราฟ $\mathbf{\cos(2\pi f_c t)} \rightarrow f_c$= 8 Hz
- วาดกราฟ $(\mathbf{A(t) + DC})$ x $\cos(2\pi f_c t)$
  - กำหนดค่า DC offset ที่ทำให้ modulation index (m)

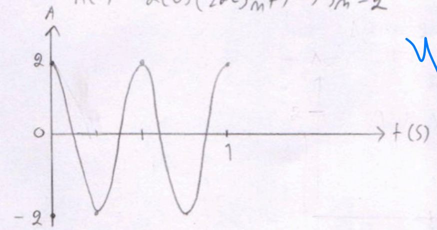
    m = 1 -> = 100%

    m < 1 -> < 100%

    m > 1 -> > 100%

นาย เศรษฐ์สวัสดิ์ ศักดิ์กรณ์ศิริสมุทร 61011433

$A(t) = 2\cos(2\pi f_m t) \rightarrow f_m = 2$



ไม่ค่อยละเอียด เรียบร้อย

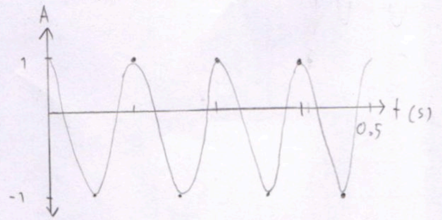
เฉพาะ dc < 2 m > 1

dc = 2 m = 1

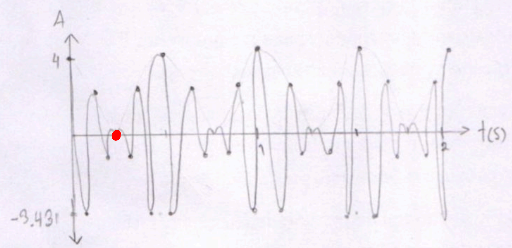
dc > 2 m < 1

$\frac{8-0}{8+0} = 1$ ✓

$\cos(2\pi f_c t) \rightarrow f_c = 8$



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



$\rightarrow \quad m = \frac{8-2}{8+2} = \frac{6}{10} = 0.6$ ✗

$m = \frac{p-d}{p+d}$	$p = 4-(-4) = 8$, $d = 2$	$\frac{6}{10} = 0.6$	# $m < 1$ ถ้า $d > 0$ แล้ว $d >$ amplitude ของ data $\Rightarrow m < 1$
	$p = 8$, $d = 0$	$\frac{8}{8} = 1$	# $m = 1$ ถ้า $d = 0$ $m = 1$
	$p = 8$, $d = -2$	$\frac{10}{6} = 1.3$	# $m > 1$ ถ้า $d < 0$ $m > 1$

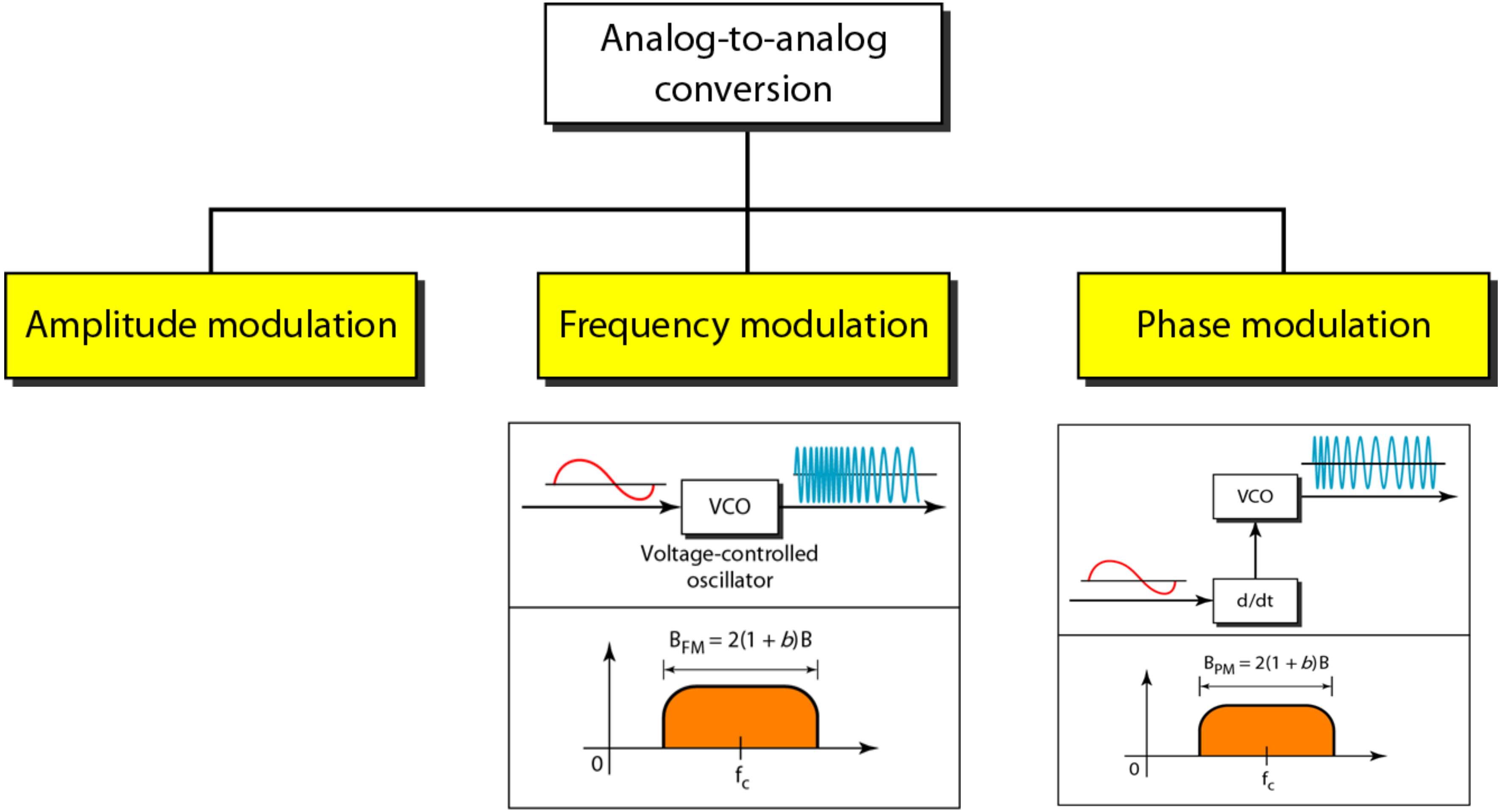
ตรงนี้ผิดเยอะ

ผิดหมด

FREQUENCY & PHASE MODULATION (FM & PM)

GENERATION THROUGH VOLTAGE CONTROL OSCILLATOR

Figure 5.15 *Types of analog-to-analog modulation*

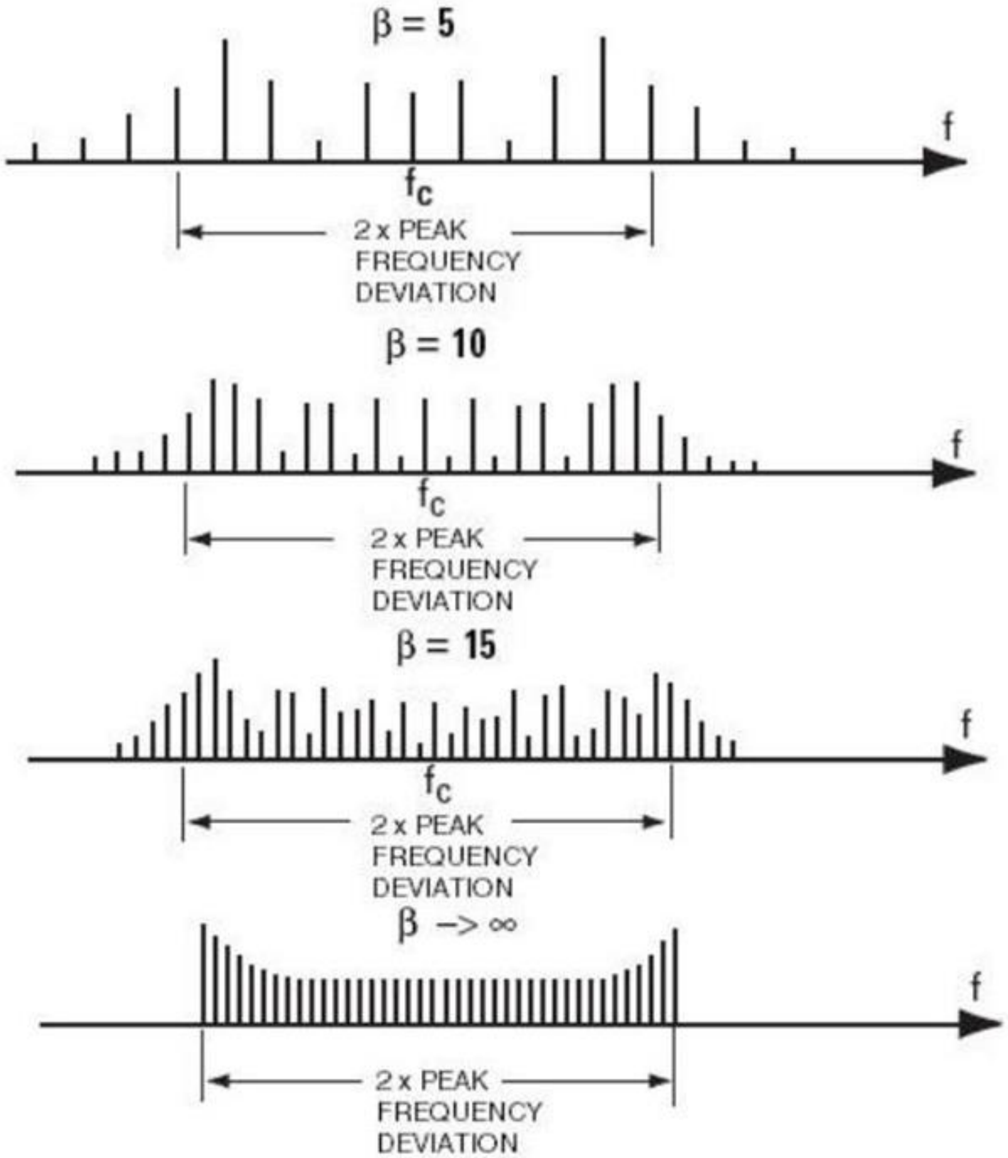


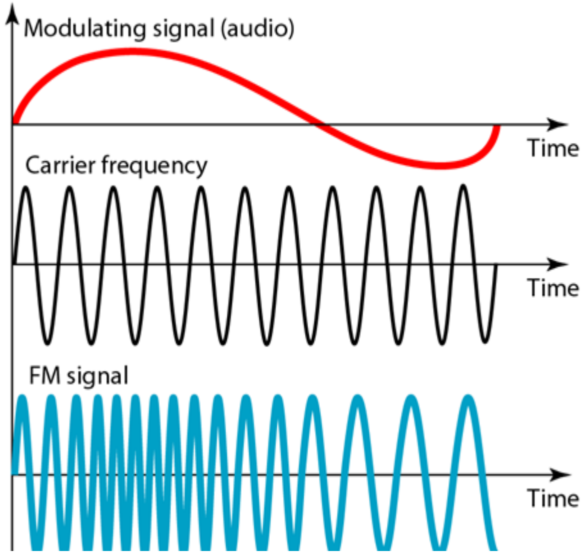
Frequency & Phase MODULALTION

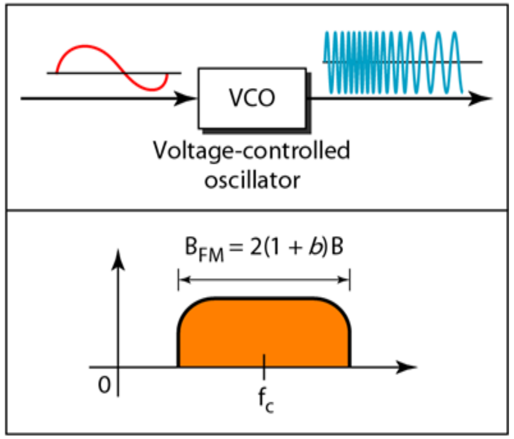
Bandwidth

FREQUENCY SPREADING FACTOR

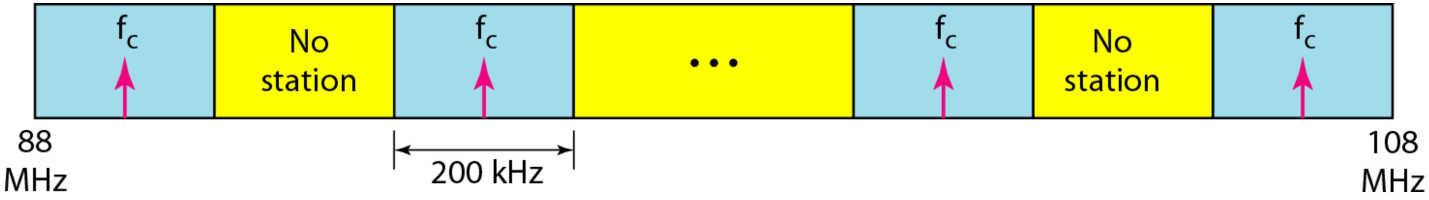
β







The total bandwidth required for FM can be determined from the bandwidth of the audio signal: $BW_{FM} = 2(1 + \beta)BWsignal$.



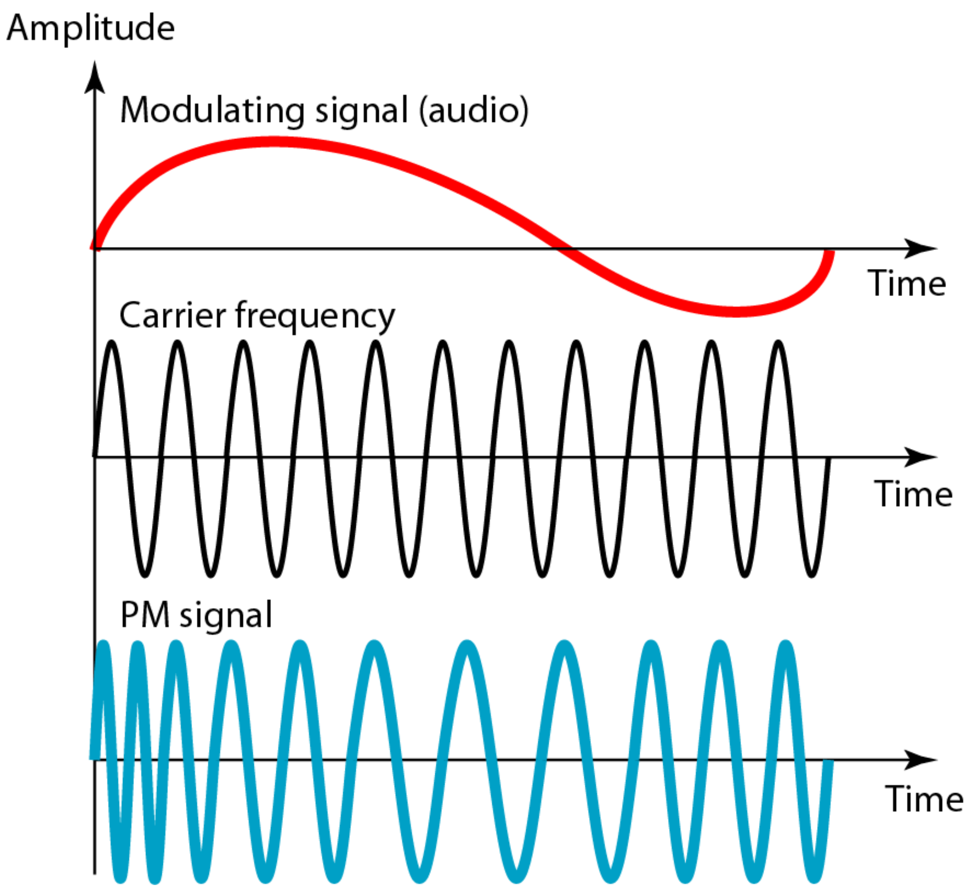
FM Radio: BWsignal = 15kHz **(รองรับเสียงร้องและเครื่องดนตรี)**

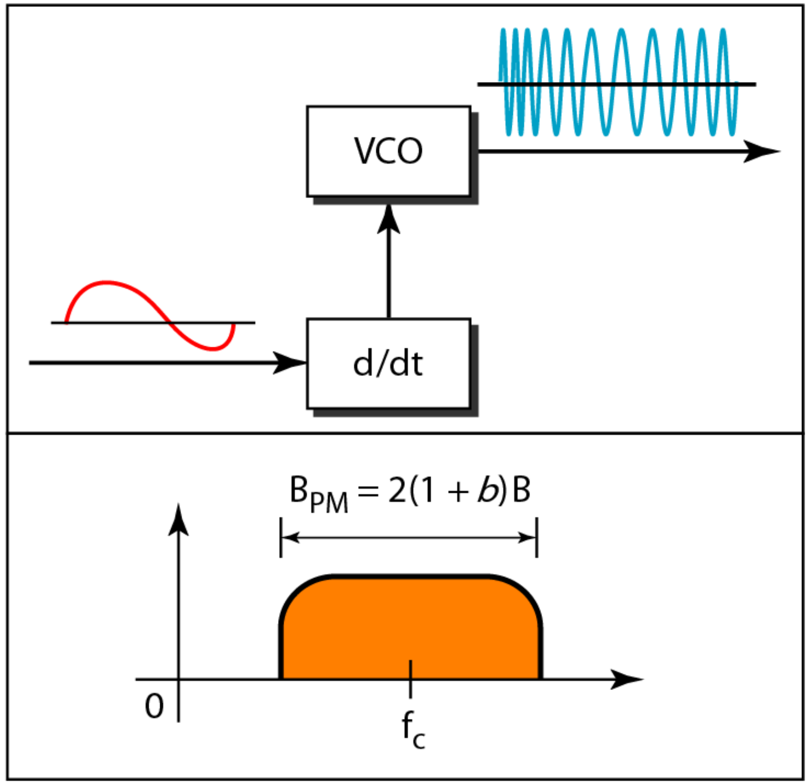
Beta = 5

$BW_{FM} = 2(1 + \beta)BWsignal = 2(1+5)15kHz = 180kHz \rightarrow 200kHz$

Figure 5.20 *Phase modulation*

Use slop of Analog data input
To select fc





The total bandwidth required for PM can be determined from the bandwidth and maximum amplitude of the modulating signal:
$B_{PM} = 2(1 + \beta)B$.