Lecture 1: Introduction to Communication Systems

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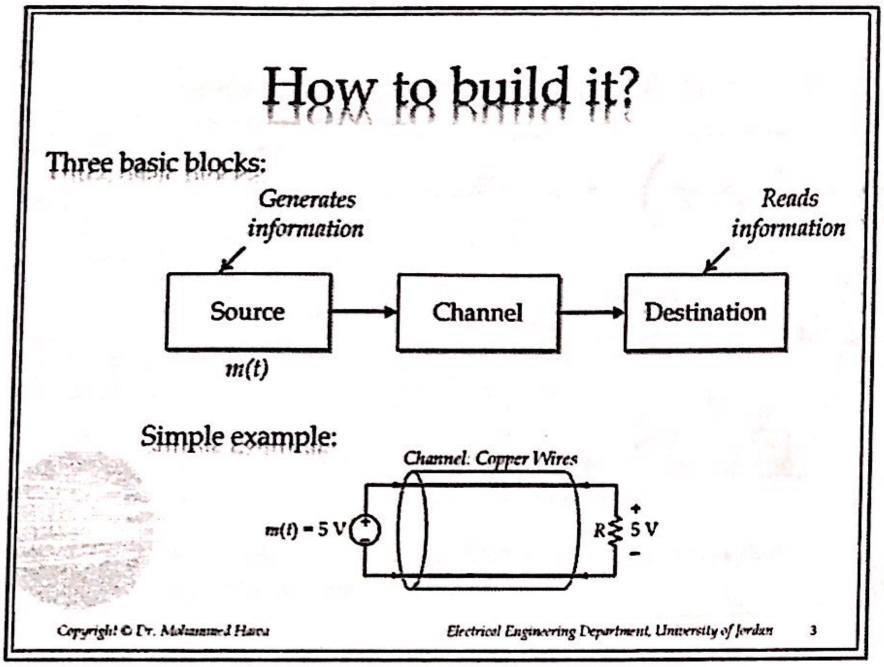
A Communication System

- Purpose of a communication system: Carry information from one point to another.
- A typical communication system consists of three main components:
  - Source
  - Channel
  - Destination

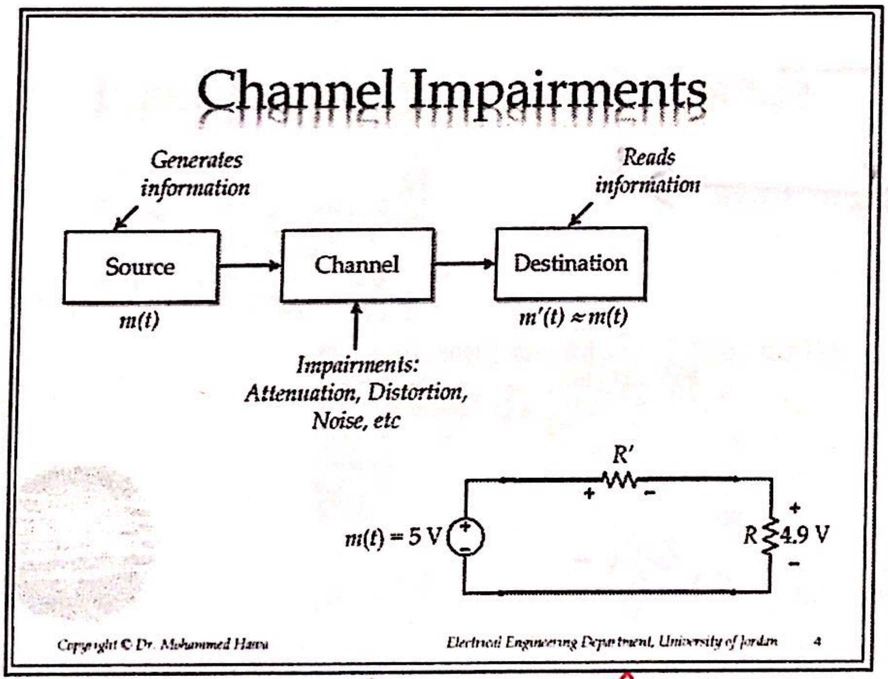


How to build it?

Three basic blocks:

Generates information → **Source** $m(t)$ → **Channel** → **Destination** ← *Reads information*

Simple example:



Channel Impairments

Generates information → **Source** $m(t)$ → **Channel** → **Destination** $m'(t) \approx m(t)$ ← *Reads information*

Impairments: Attenuation, Distortion, Noise, etc

$*m(t)_{avg} = DC = \frac{1}{T}\int_T m(t)\,.dt$

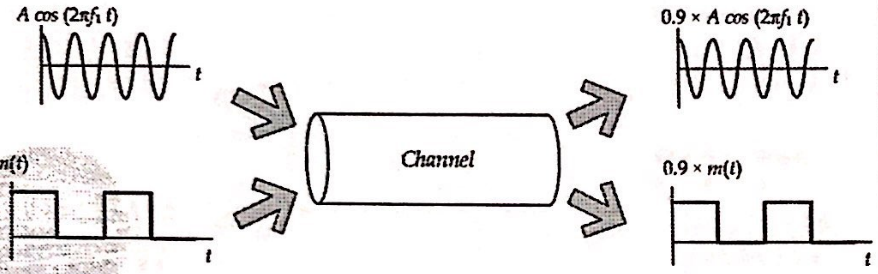
$*P_{avg} = \frac{1}{T}\int_T m^2(t)\,.dt$

$\Rightarrow P_{avg} = (RMS)^2$

$*RMS = \sqrt{\frac{1}{T}\int_T m^2(t)\,dt}$

Channel Impairments

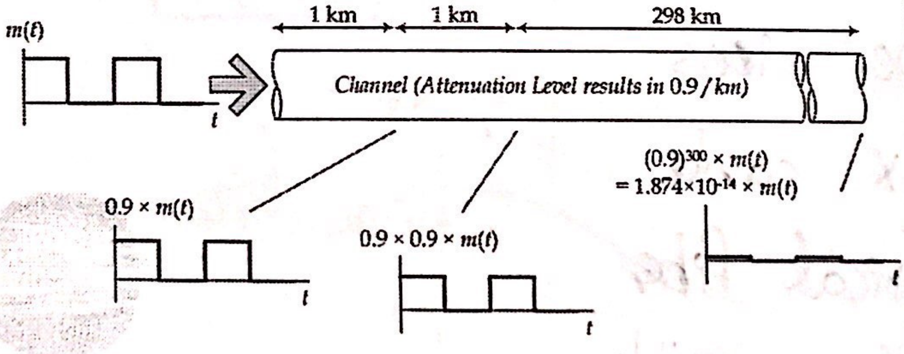
1. Attenuation: As the signal travels through the channel it loses some of its energy (*power*) as heat in the internal resistance of the channel. We say the signal is attenuated.



Attenuation

بصير عندي نقص في ال amplitude

- Attenuation can be problematic for long distance communications (say cross-country).



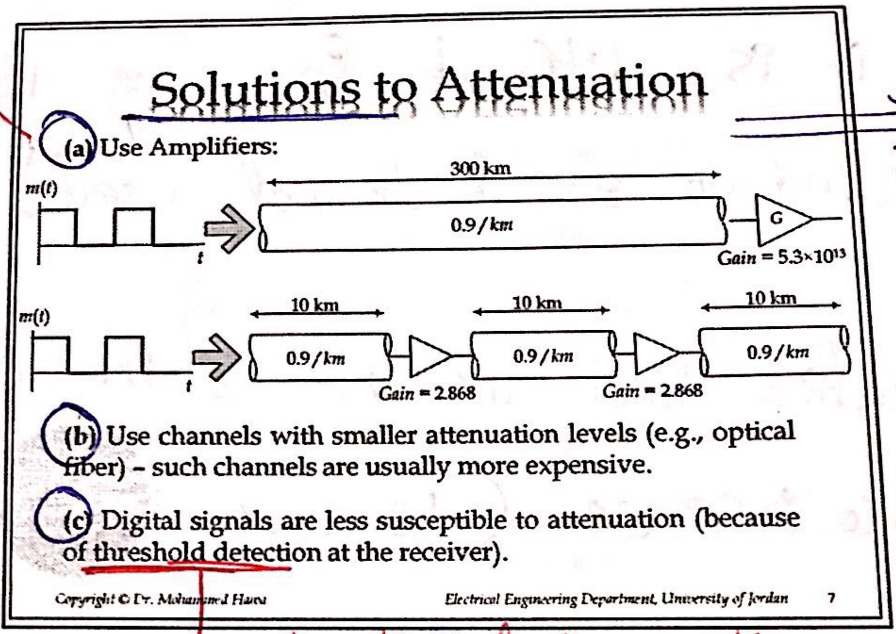
* كلما زادت ال freq.

بتزيد ال attenuation

*Note

① Copper wire: we need amplifier every 5-10 Km

② optical fibers: " " " " 50-100 Km



Solutions to Attenuation

(a) Use Amplifiers:

$V_{out} = G V_{in}$

gain

يحسن السيجنال

ويقويها

(b) Use channels with smaller attenuation levels (e.g., optical fiber) – such channels are usually more expensive.

(c) Digital signals are less susceptible to attenuation (because of threshold detection at the receiver).

by digital transmittion

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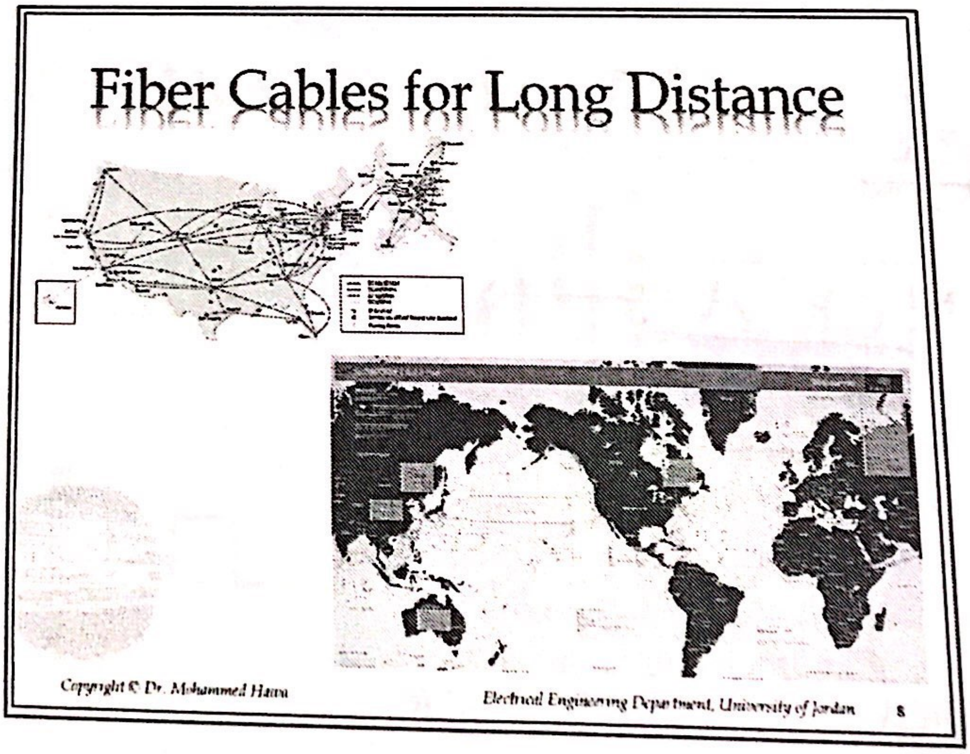

Fiber Cables for Long Distance

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*Some examples

① $m(t) = 5V$

- → $DC = 5V$
- → $P_{avg} = 5^2 = 25\ V$
- → $RMS = 5\ V$

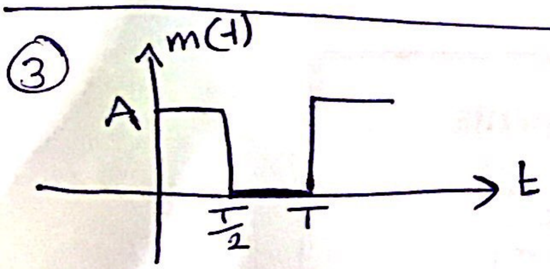
---

② $m(t) = 4\cos(\omega_0 t)$

- → $DC = \text{Zero}$ (cos over period)
- → $P_{avg} = \frac{4^2}{2} = \frac{16}{2} = 8$
- → $RMS = \frac{4}{\sqrt{2}}$

---

③



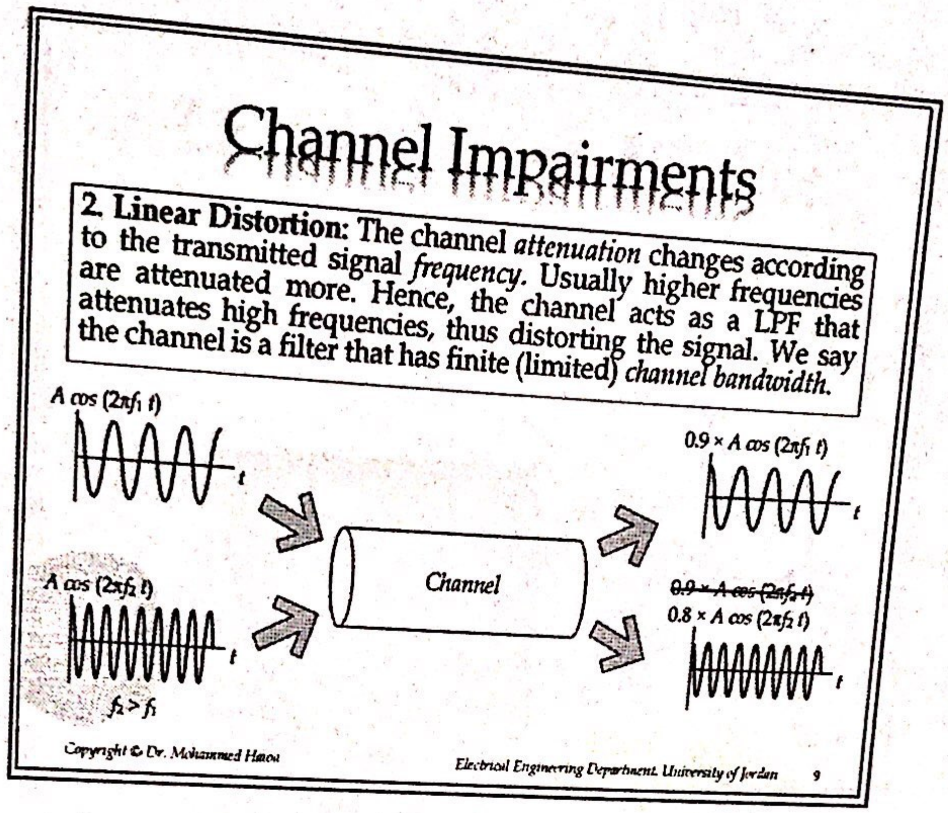
$$DC = \frac{1}{T}\int_T m(t)\,.dt$$

$$= \frac{1}{T}\int_0^{T/2} A\,.dt$$

$$= \frac{1}{\cancel{T}}\,A\frac{\cancel{T}}{2} = \frac{A}{2}$$

$$\rightarrow P_{avg} = \frac{1}{T}\int_0^{T/2} A^2\,.dt = \frac{A^2}{2}$$

*ليس بنوصل للبيوت حبال
AC بدل DC ؟
لأنه ال losing بال DC
أكبر من AC



Channel Impairments

2. Linear Distortion: The channel *attenuation* changes according to the transmitted signal *frequency*. Usually higher frequencies are attenuated more. Hence, the channel acts as a LPF that attenuates high frequencies, thus distorting the signal. We say the channel is a filter that has finite (limited) *channel bandwidth.*

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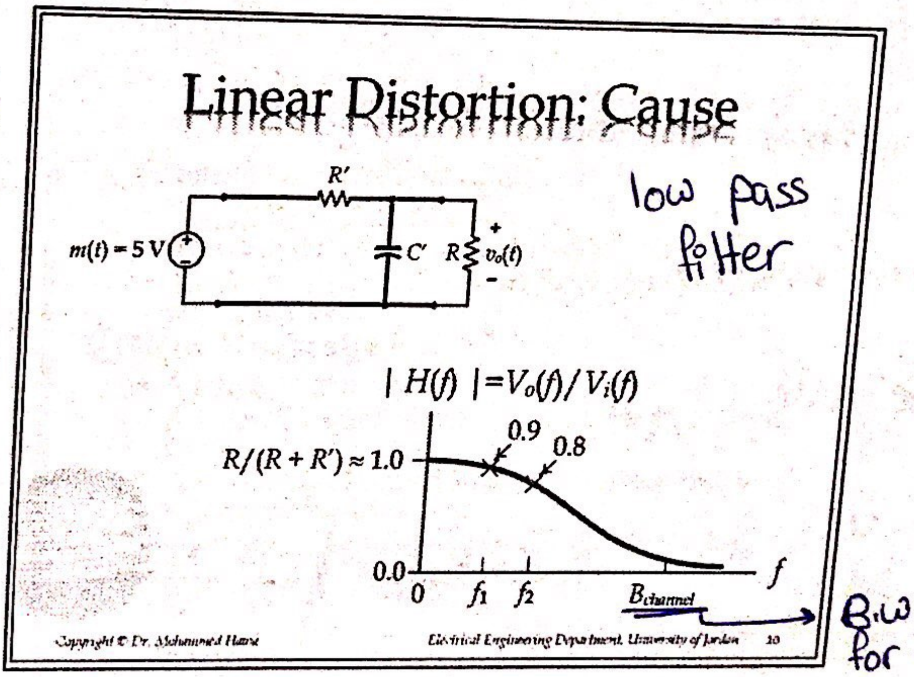

كل ما زاد ال freq
ح يزيد ال
distortion

Linear Distortion: Cause

low pass
filter

B.W
for channel

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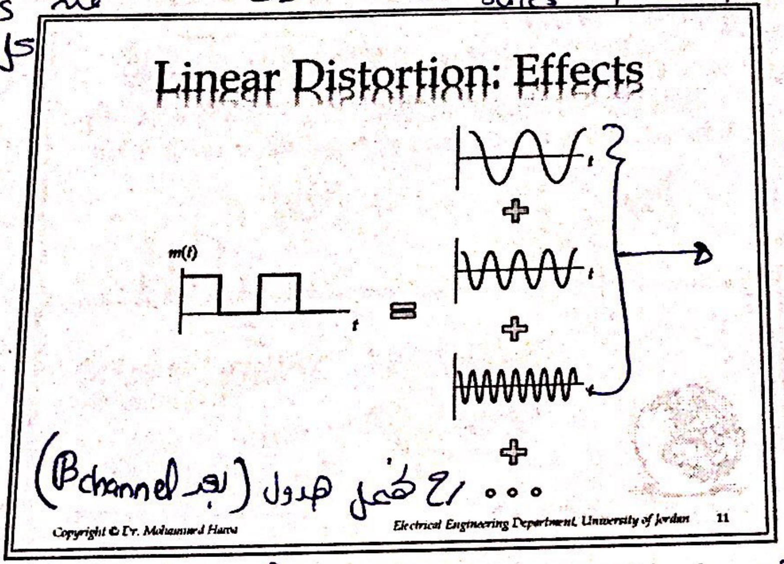
كل ما زادت ال freq ← ح يزيد distortion

باستخدام ال $forrier_{series}$ بتسير عبارة عن مجموعة من sin & cos
كل هدا اله freq. معينة



Linear Distortion: Effects

... رح تعمل هدول (لبعد Bchannel)

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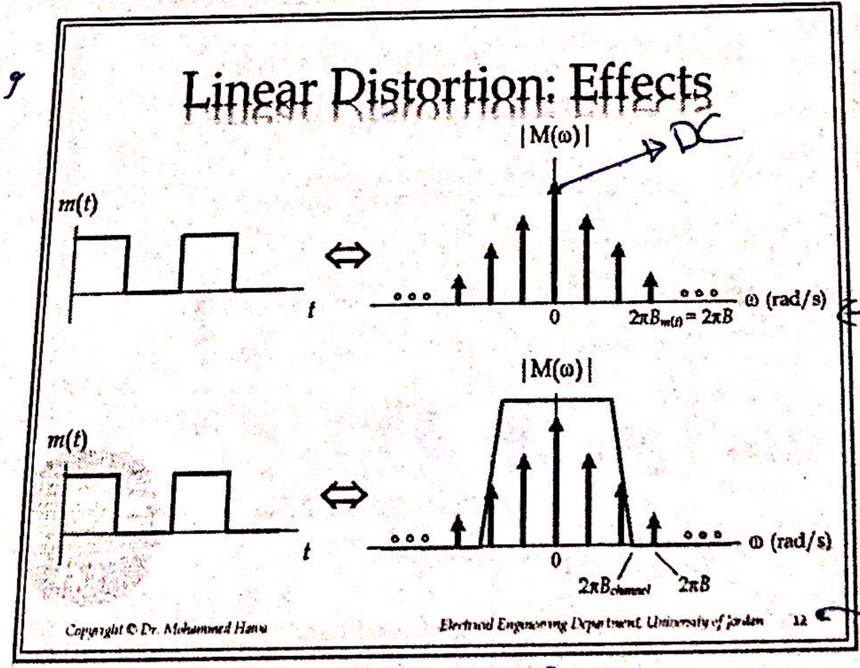
هدول ما رح
يعطوني بالزبط
نفس السيجنال
الاصلية
(رح يصير distortion)
وسببه channel
characteristic لانها بتتصرف على انها low pass filter فرح تمرق ال low freq.
وتعمل reject للhigh



Linear Distortion: Effects

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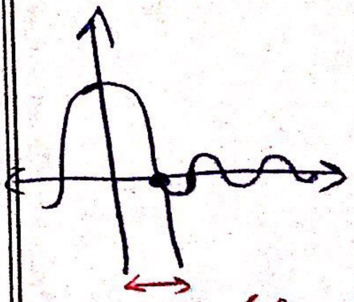


B.w (first null)

forrier transform

B.w for signal → first null

B.w for channel → Bchannel.

⊛ Facts about attenuations

1- attenuation exists for all signal type

2- " " " " Channel type

But it is different from one to other

(Depend on exact channel used)

3- attenuation level increase as the channel distance increase (beacause R' increase)

↳ internal Resistance

⊛ Example

$5 \rightarrow \boxed{\text{Ch A}} \rightarrow 4.9$

$5 \rightarrow \boxed{\text{Ch B}} \rightarrow 4.1$

channel B has more attenuation ⟹ more power loss

* note

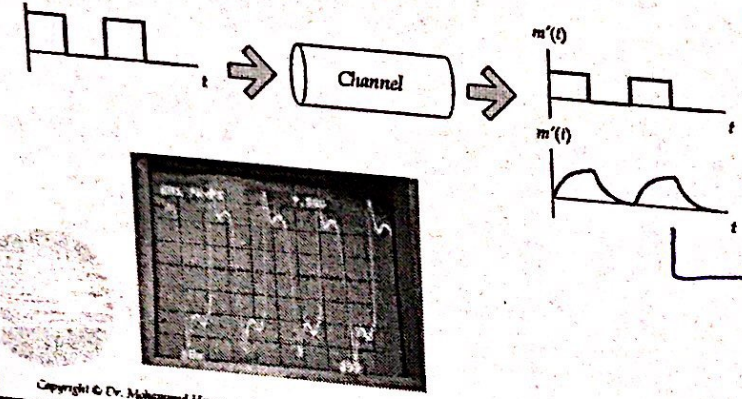
wireless
copper wires
Coax cable
optical fiber
& wave guide

more expensive ↓

↑ More attenuatio

expensive

Linearly-Distorted Signals



high freq. بتحتوي على

sharp edges فبشوي

لأنه ما بمرقهم LPF

To Summarize:

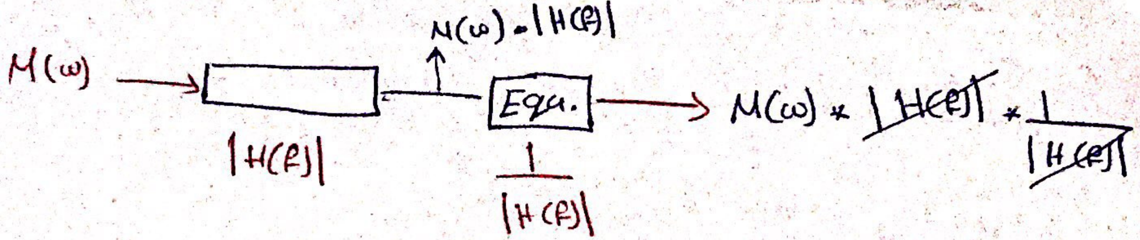
- Channel Bandwidth $B_{channel}$:
  - A property of the channel.
  - You read it from the data sheet of the channel.
  - The *frequency* after which the channel presents very high attenuation.
- Signal Bandwidth $B_{m(t)} = B$:
  - A property of the signal.
  - You figure it out from the Fourier transform of the signal.
  - The *frequency* above which $m(t)$ has insignificant (negligible) harmonics.
- *Rule of thumb*: signal bandwidth should be less than or equal to channel bandwidth.

بتعتمد على R` & C`

وبتعتمد على Length

لأنه بس يزيد الطول ح تزيد المقاومة

first null

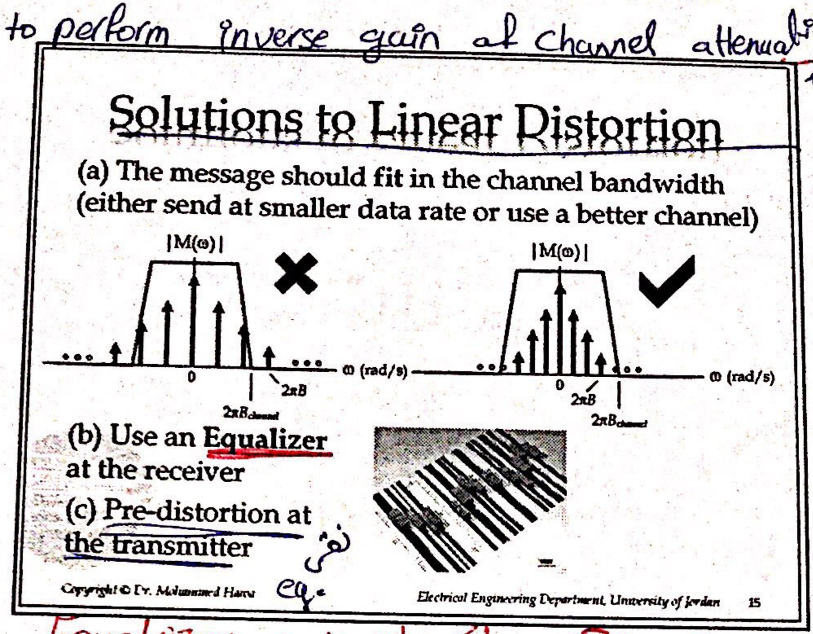


expensive ← * Equ. ⇒ a complex device used @ reciever to perform inverse gain of channel attenuation

* in digital signal
↳ Bit rate = $\frac{\# bits}{second}$
(B.W)

ex:- $R_b = 30$ bit/sec

B.W = 30 Hz



Solutions to Linear Distortion

(a) The message should fit in the channel bandwidth (either send at smaller data rate or use a better channel)

(b) Use an **Equalizer** at the receiver

(c) Pre-distortion at the transmitter نفي eq.

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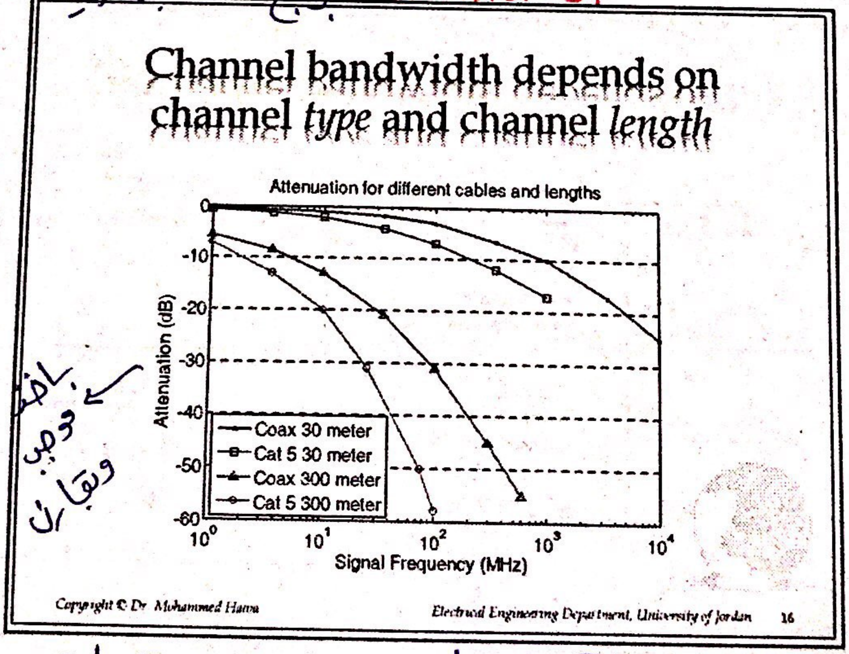
بتحتوي على

فبتسوي

لانه ما ا

Equalizer → بتقوم بشكل معاكس لتصرف ال channel فبرجع السغنال زي ما كان



Channel bandwidth depends on channel *type* and channel *length*

بأخذ موجب وبقارن

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X dB $= 10 \log_{10} X$

power 10

voltage 20

*Cat 5 → copper category 5

كل ما زاد الـ length رح يزيد ال attenuation ⇐

distance

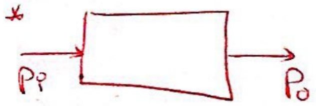
(R', C' changes)

*Note :

Channel	BW
copper wire	2 MHz for 1 Km
coax. cable	2 GHz 〃 〃 〃
optical fiber	several T Hz 〃 〃

T → 10^{12}

↓ less attenuation
wide B.W
more expensive

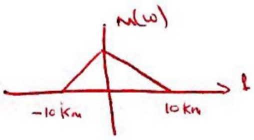


$$Gain = \frac{P_o}{P_{in}} \Rightarrow Gain_{dB} = 10\log_{10}\frac{P_o}{P_{in}} \; \text{if} \begin{cases} +ve \Rightarrow gain \\ -ve \Rightarrow attenuation. \end{cases}$$

* how to know the B.W for signal

① fourier transform

② ~~second~~ first null



B.W = 10 Km

B.W = 17

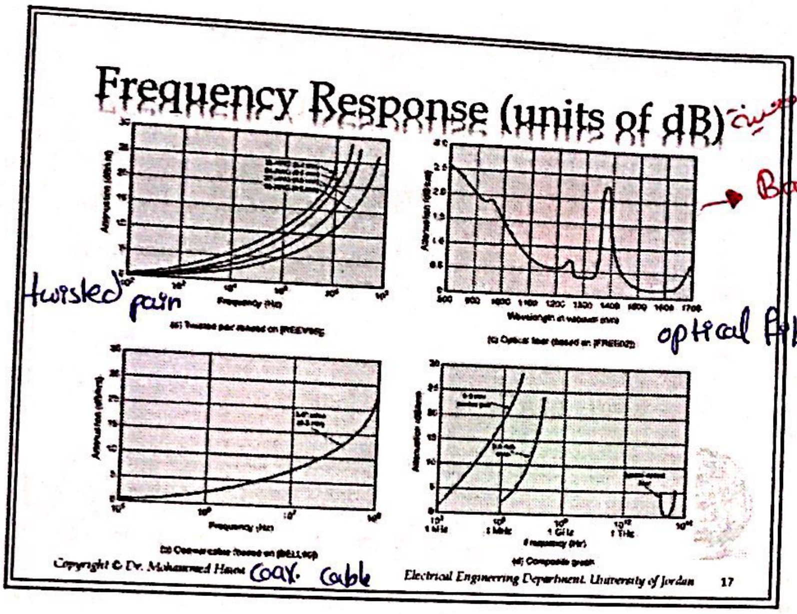
* slide 16

* اذا بدي التعامل و اقارن على gain عادي يكون سالب

* 〃 〃 〃 〃 〃 attenuation لازم يكون موجب

?

Scanned with CamScanner



Frequency Response (units of dB)

(a) Twisted pair (based on [REEV95])

(c) Optical fiber (based on [FREE02])

(b) Coaxial cable (based on [BELL90])

(d) Composite graph

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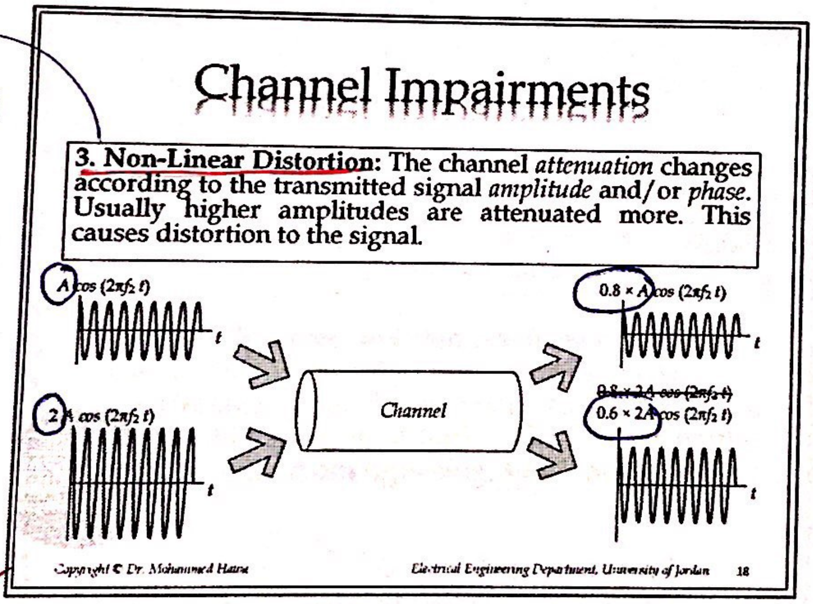
بيشتغل بفترة معينة زي → Band pass filter

twisted pair

optical fiber

coax. cable

*coax . اقل attenuation من twisted



Channel Impairments

3. Non-Linear Distortion: The channel *attenuation* changes according to the transmitted signal *amplitude* and/or *phase*. Usually higher amplitudes are attenuated more. This causes distortion to the signal.

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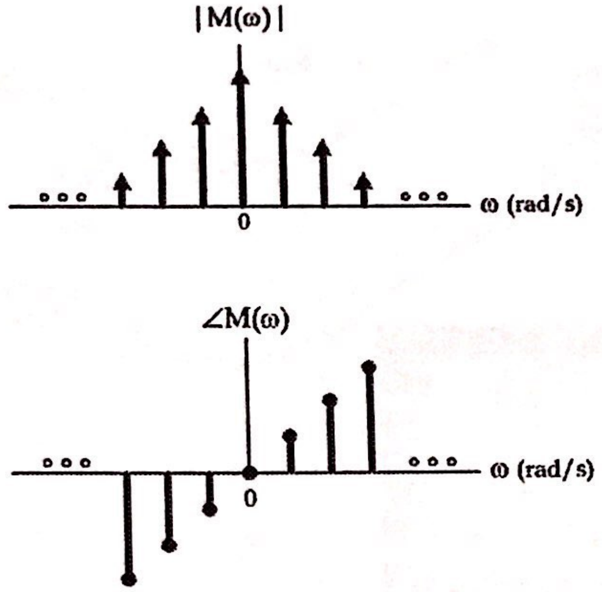
ال freq. بتتغير مع Amplitude

كل ما زاد ال amplitude ع يكون عندي more non-linear distortion [illegible]

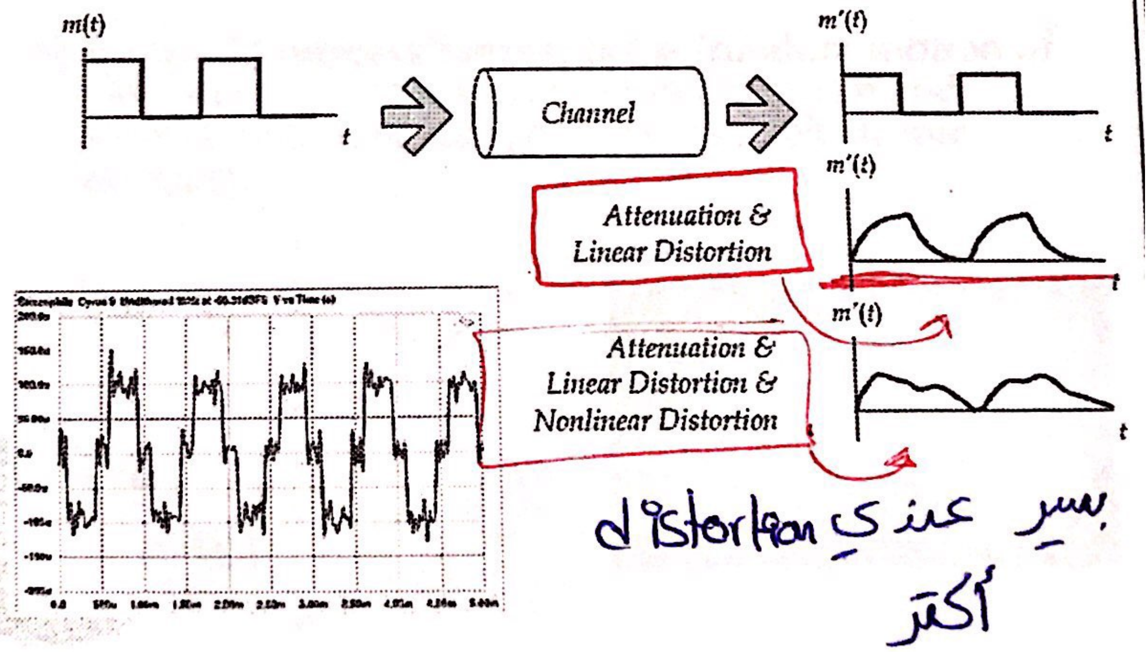
*non linear distortion depends on the physics of the channel.

Scanned with CamScanner

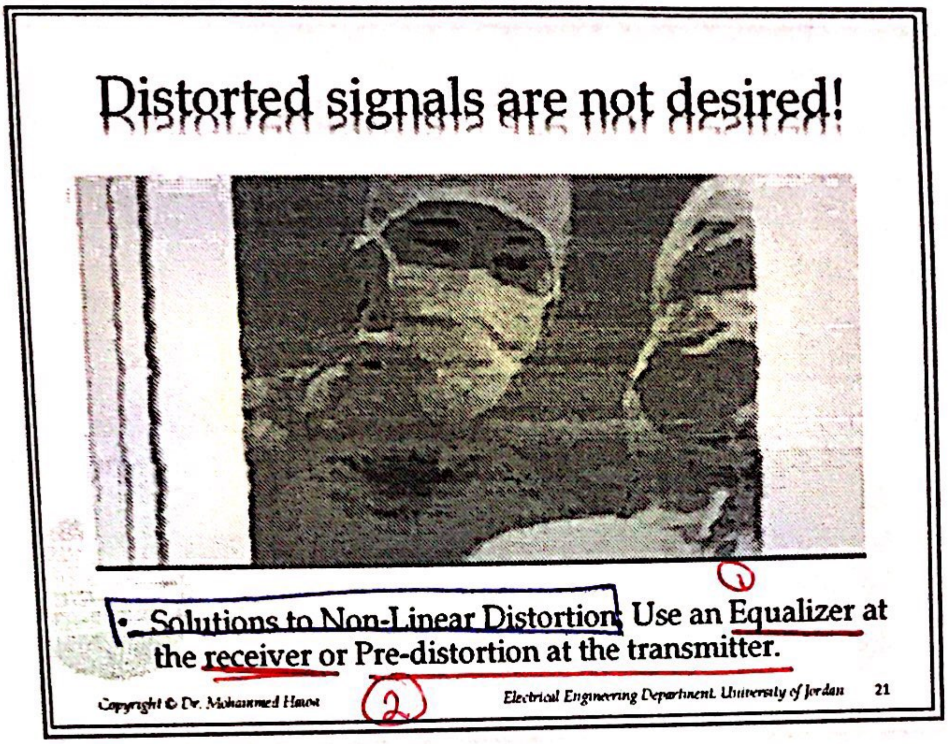
Fourier Transform *Again*!



Non-Linearly-Distorted Signals



بصير عني distortion
أكتر



Distorted signals are not desired!

- **Solutions to Non-Linear Distortion:** Use an Equalizer ① at the receiver or Pre-distortion ② at the transmitter.

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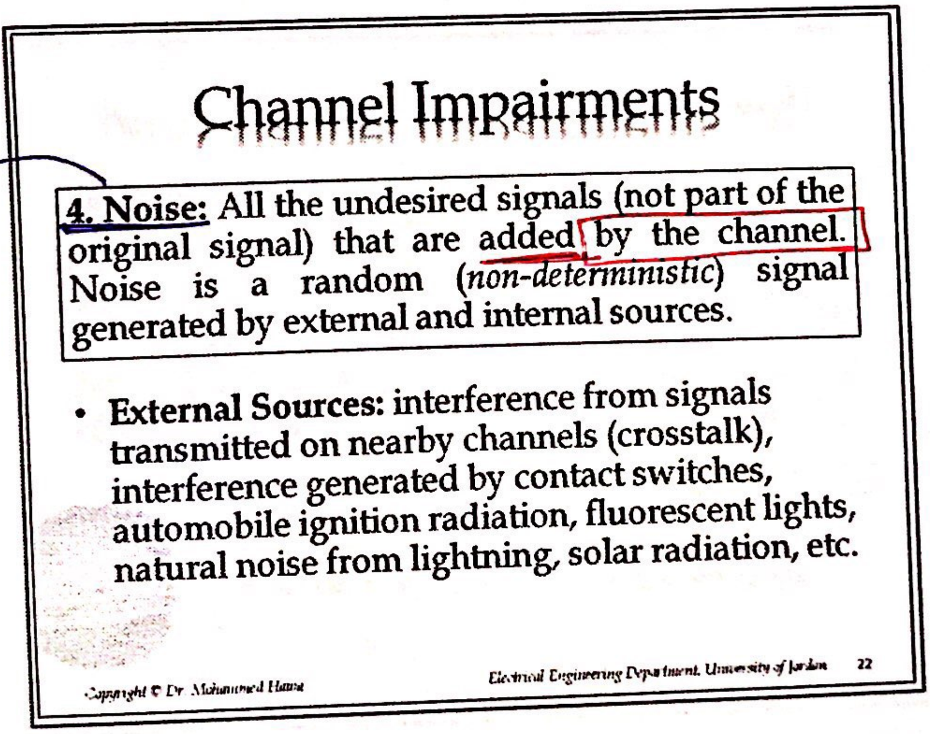

Channel Impairments

4. Noise: All the undesired signals (not part of the original signal) that are added by the channel. Noise is a random (*non-deterministic*) signal generated by external and internal sources.

- **External Sources:** interference from signals transmitted on nearby channels (crosstalk), interference generated by contact switches, automobile ignition radiation, fluorescent lights, natural noise from lightning, solar radiation, etc.

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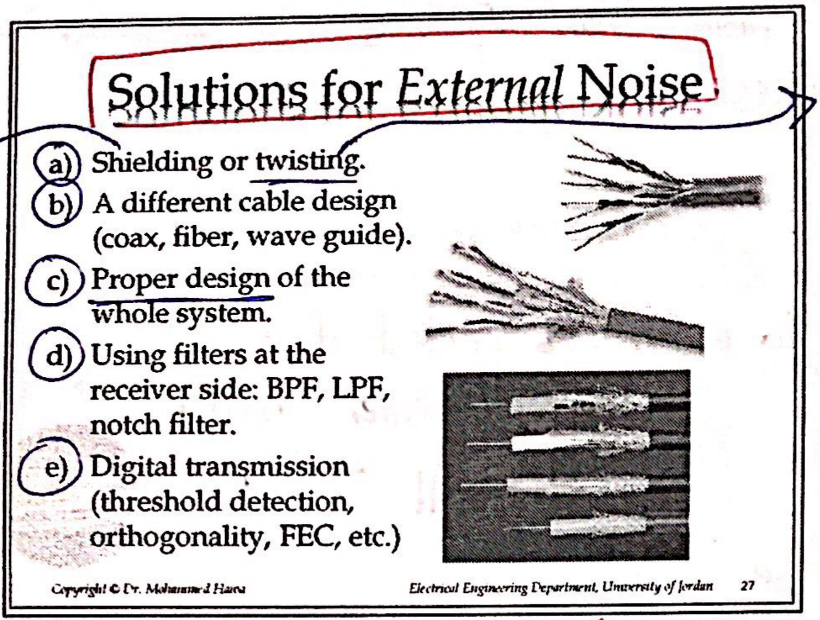
بارت مش من
السيجنال بتدخل
على السيجنال وبتغير
مواصفاتها



Solutions for *External* Noise

a) Shielding or twisting.
b) A different cable design (coax, fiber, wave guide).
c) Proper design of the whole system.
d) Using filters at the receiver side: BPF, LPF, notch filter.
e) Digital transmission (threshold detection, orthogonality, FEC, etc.)

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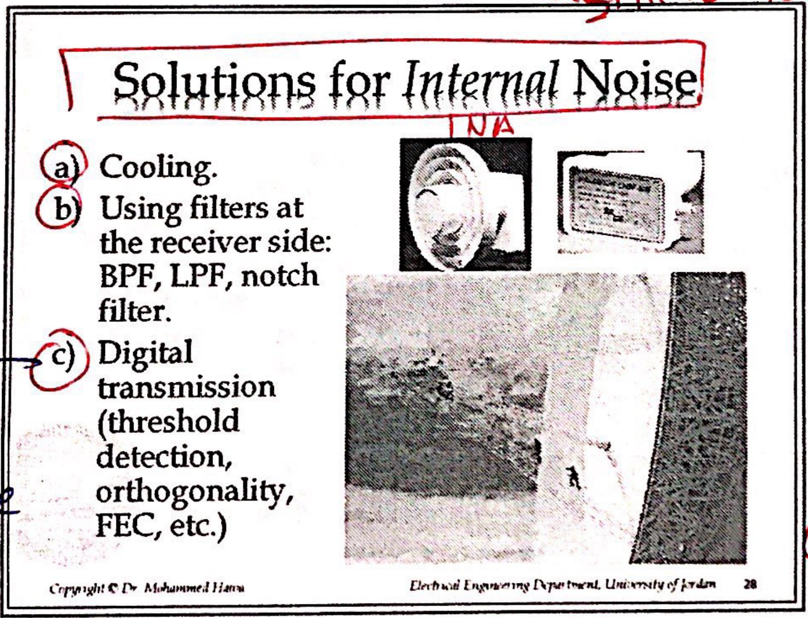
good but expensive (it removes the electromagnatic interferance)

cheaper

* in Coaxial cable → outer wire work as a shield for inner wire



Solutions for *Internal* Noise

LNA

a) Cooling.
b) Using filters at the receiver side: BPF, LPF, notch filter.
c) Digital transmission (threshold detection, orthogonality, FEC, etc.)

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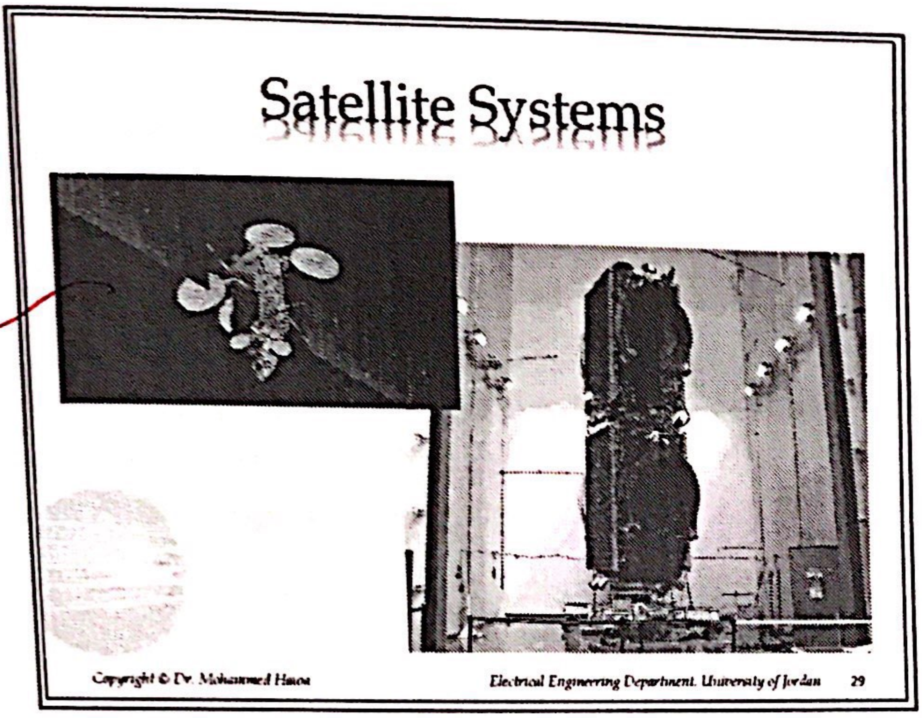
* Cooling
- ~~cheap~~
- expensive
- effective

- cheap
- effective
- good for external & internal

* LNA → low nois amplifier

Filters are
- very effective
- very cheap
- good for internal and external wires



Satellite Systems

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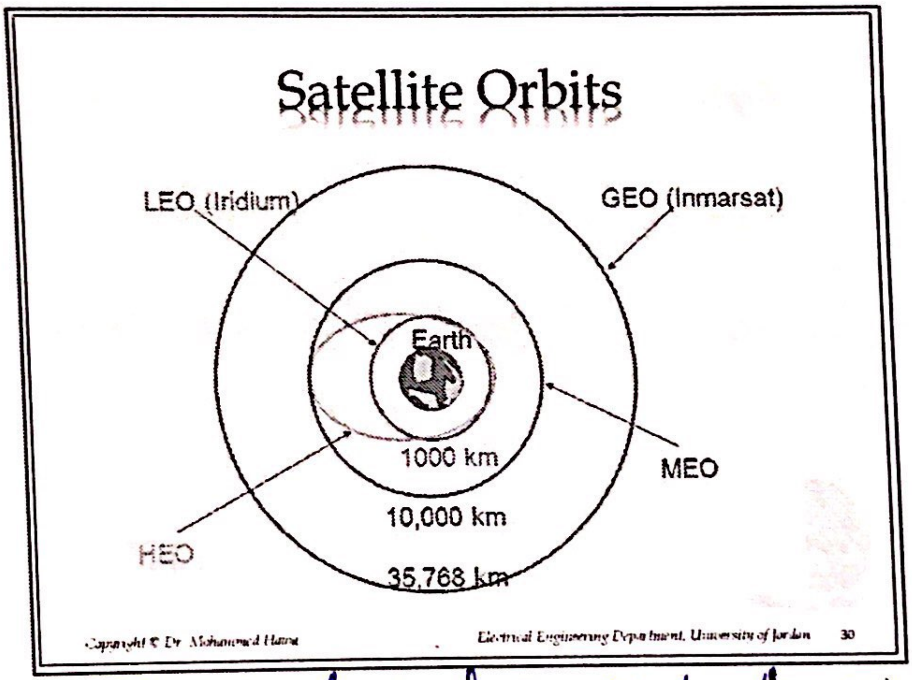
حركة دورانية حول الأرض



Satellite Orbits

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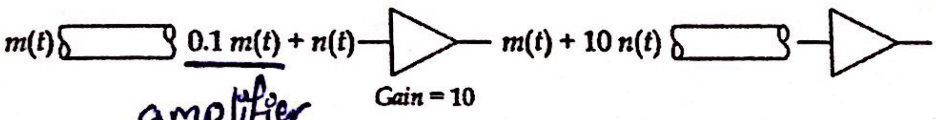
* The signal that is sent through earth is attenuated

* ليش يبعث السيجنال حول الارض مش من خلال الارض ؟

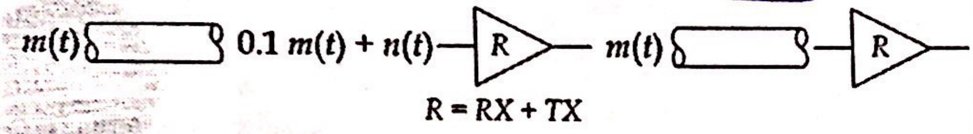
Impairments ALL Together

Attenuation + Noise:



amplifier

We need new solutions: *Regenrators* (Digital Transmission) @ noise attenuation



* Transistor nowadays are cheaper

Other Channel Impairments

5. **Fading**: Variable attenuation with time of day and receiver location (wireless systems).
6. **Doppler Shift**: Shift in the frequency of the transmitted signal. Shows up when we have a wireless channel and fast moving objects.
7. **Frequency-reuse interference**: Shows up in wireless systems when we re-use the same frequencies at multiple nearby locations to increase system capacity.
8. **Chromatic Dispersion**: Specific to optical fiber channels.

* Some notes

① LEO ⇒ low - earth orbit

above surface of earth

- 1000 Km
- we need more than 3 LEO to ~~#~~ cover earth (shortest path)

⊛ LEO advantages

1- Closest to earth → shortest distance (smaller batters) ⇒ less attenuation
Small T_x , R_x

2- less noise

3- cheaper

Ex
① ~~[illegible]~~ ridum
② global star
③ Iss (international space Station)

---

② MEO 8 medium earth ~~Rot~~ orbit

- 10,000 Km
- far from earth
- more attenuation → more expensive
- more complex → 〃 〃

EX 8- Gps

③ HEO → highly - elliptic - orbit

④ GEO → geo-stationary - elliptic - oRbit

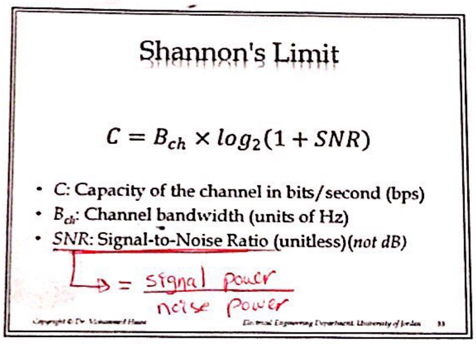
1 red/24 h (fixed/same speed of earth)

* 3600 Km

* TV

Ex Bader, Nilesat, In marsat, Thuraya

⊛ 3 GEO needed to cover earth



Shannon's Limit

$$C = B_{ch} \times log_2(1 + SNR)$$

- C: Capacity of the channel in bits/second (bps)
- B_{ch}: Channel bandwidth (units of Hz)
- SNR: Signal-to-Noise Ratio (unitless)(*not dB*)

$\rightarrow = \frac{\text{signal power}}{\text{noise power}}$

* Channel Capacity:

max. bits per second that are transmitted over a Channel reliably (acceptable, small) bit error rate

$$* \quad \log_2 x = \frac{\log_{10} x}{\log_{10} 2}$$

* if B.W ch decrease → Capacity decrease

(*) SNR = 30 dB

$= 10^{30/10} = 1000$

(*) more attenuation

→ less signal power
→ SNR less
→ C less

Lecture 2: Classification of Communication Systems

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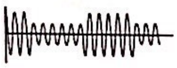
Comm Systems are classified based on the type of signal sent on the Channel

	Baseband	Carrier
Analog	*Analog Baseband Communication Systems* 	*Analog Carrier Communication Systems* 
Digital	*Digital Baseband Communication Systems* 	*Digital Carrier Communication Systems* 

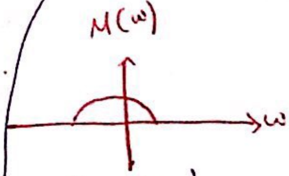
بنميز بينهم بال freq. domain

Analog → infinite value (continuous levels)

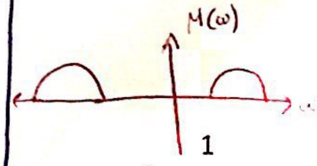
Digital → finite " (discrete levels)

بنميز بينهم بال time domain

بتبلش من Zero وبترجع ل Zero



Baseband بتكون around Zero

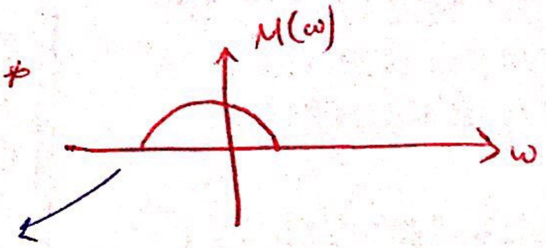


carrier

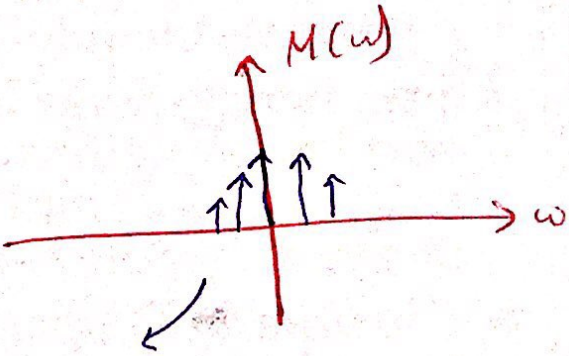
* periodic & aperiodic

↳ time & freq. domain بميز بينهم بال

*



smooth
↓
a peridic



pulses
↓
periodic

Analog to Digital Converter

① Sampling

⇒ 000 010 - -

② Quantization
(mapping)

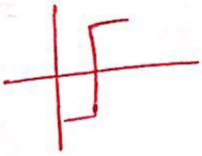
اعطِ قيم معينة وأعمل mapping
للقيم الي عندي

③ Encoding → Code by Zeros & ones

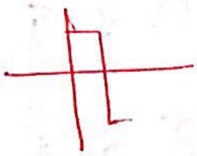
④ Shapping

مثال

Zero



one



اعطي shape معين لل pulse

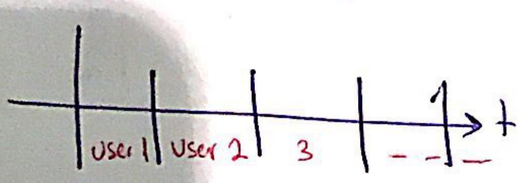
تحتاج قبلها

TDM → sampling

FDM → modulation

+حل

TDM → اقسم ال time ل slots كل user
يبعت على slot معين



Each system has its advantages!

*FDM → analog/Digital Carrie

*TDM → digital Baseband

Analog Baseband

- ⊙ *Simplest system to build*
- ⊙ *Inexpensive*

Analog Carrier

- ⊙ *Allows use of Antennas*
- ⊙ *Allows Multiplexing (FDM)* → اجمعهم كلهم وابعتهم مرة وحدة
- ⊙ *Allows exchanging SNR for Bandwidth*

Digital Baseband

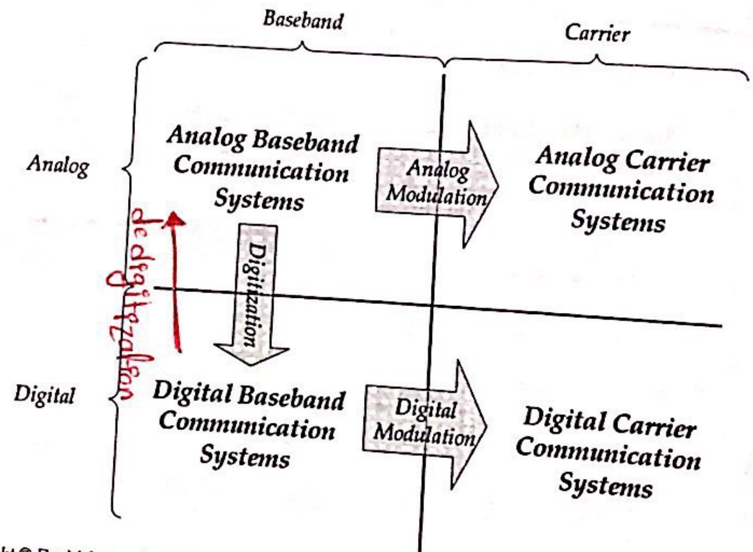
- *Immunity to Noise*
- *Allows Multiplexing at baseband level (TDM)*
- *More bandwidth efficient*
- *Allows exchanging SNR for Bandwidth*
- *For more, see Handout*

Digital Carrier

- *Allows use of Antennas*
- *Allows Multiplexing (FDM)*
- *Allows exchanging SNR for Bandwidth*
- *Also the advantages of digital baseband*

*antennas → used in wireless communications

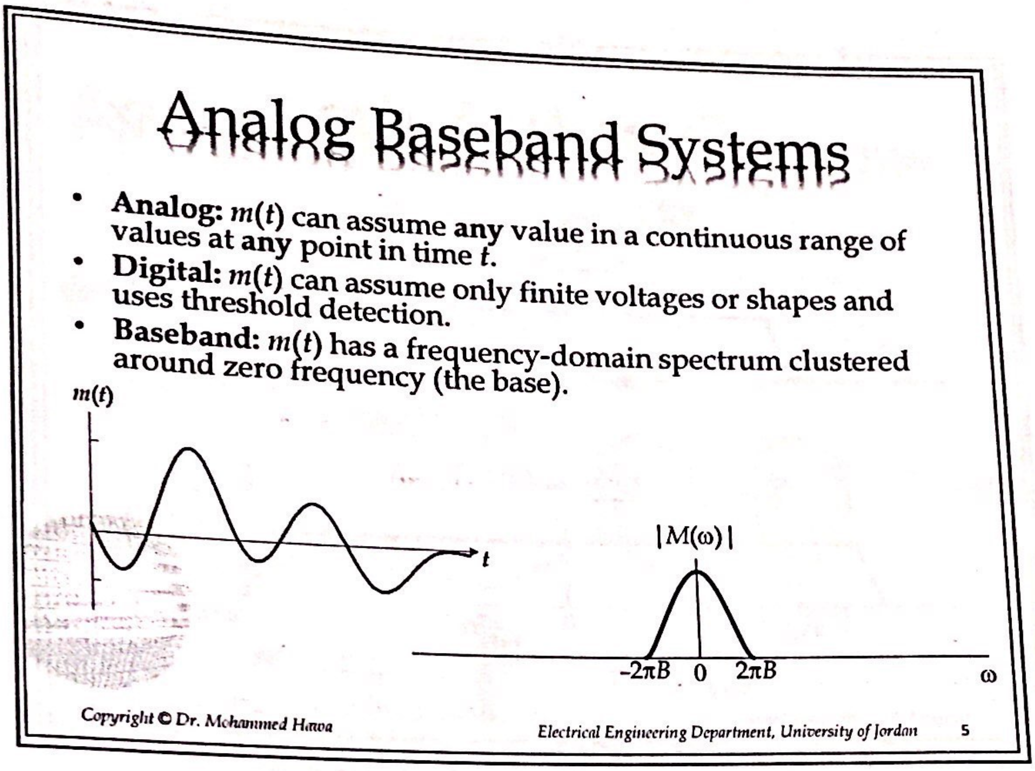
Modulation and Digitization



لما أحول من Baseband → carrier

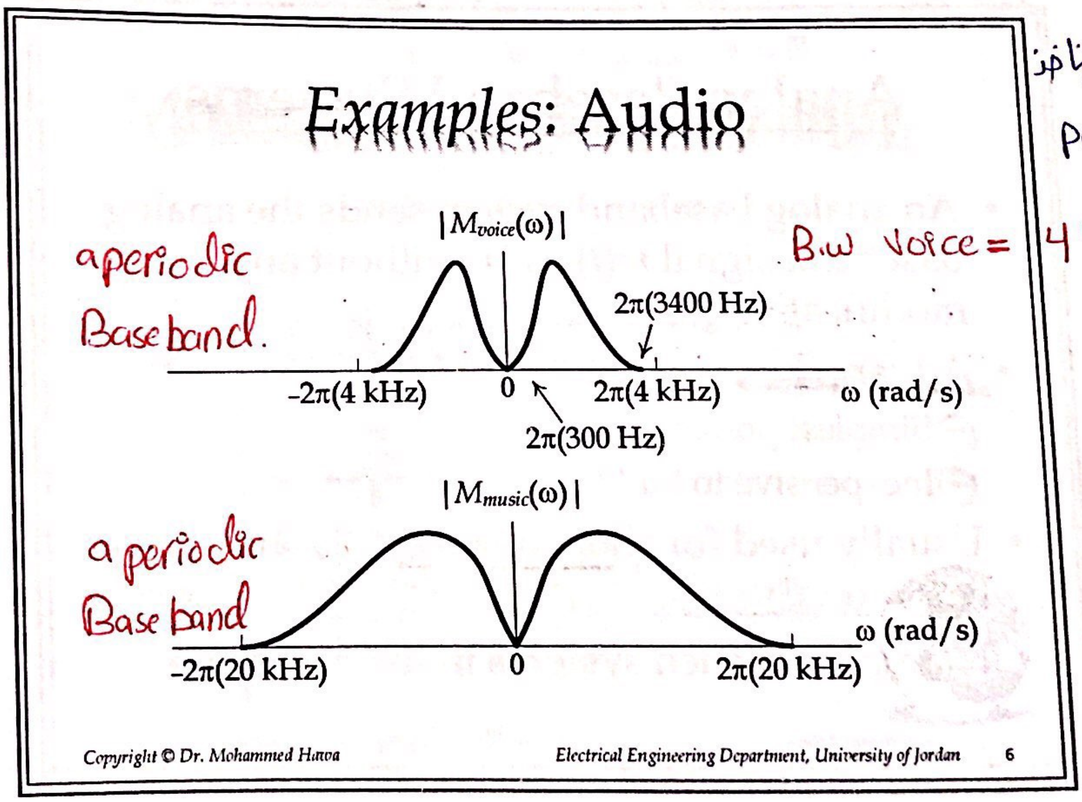
بقول ← modulation

العكس بقول demodulation



Analog Baseband Systems

- **Analog:** $m(t)$ can assume any value in a continuous range of values at any point in time t.
- **Digital:** $m(t)$ can assume only finite voltages or shapes and uses threshold detection.
- **Baseband:** $m(t)$ has a frequency-domain spectrum clustered around zero frequency (the base).



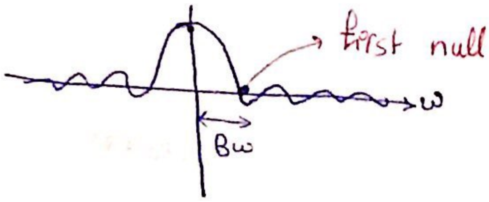
Examples: Audio

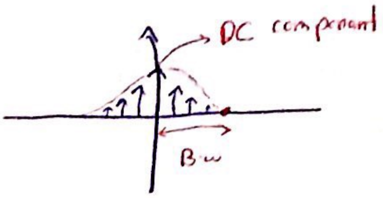
aperiodic
Baseband.

B.w Voice = 4 KHz

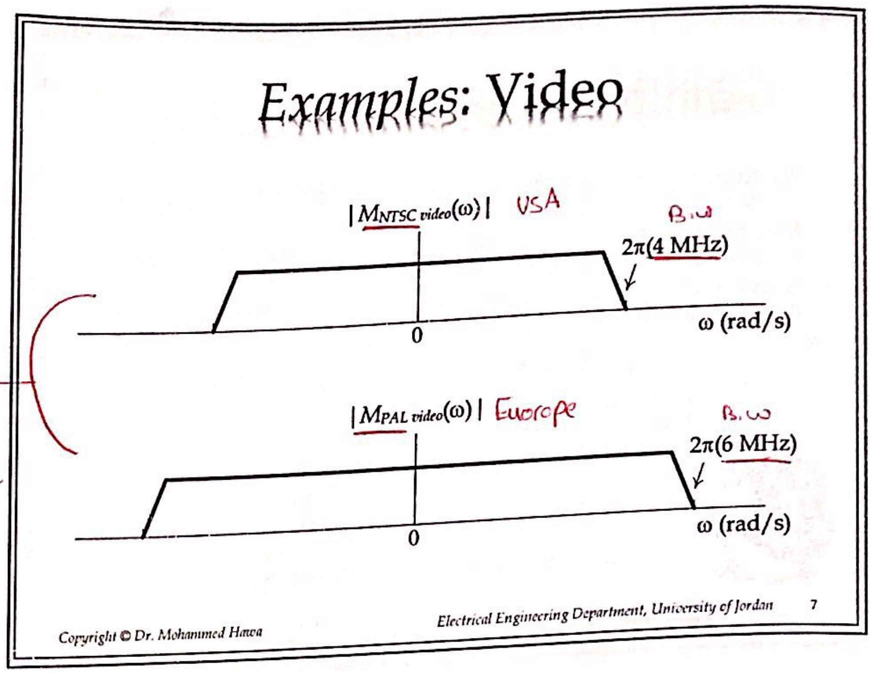
* لما نحسب B.w بناخذ ال positive side

a periodic
Base band





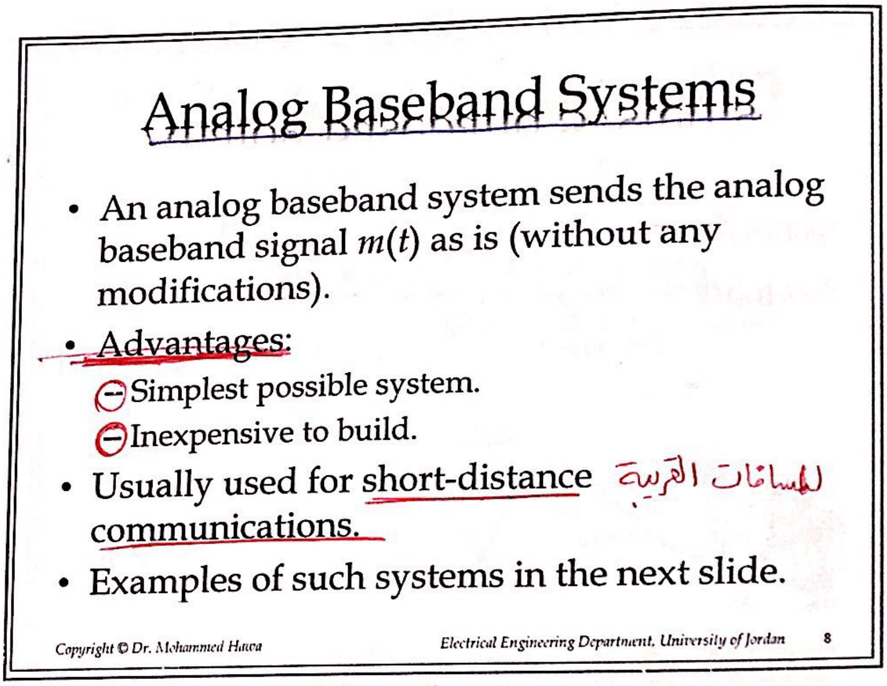
1/28,



Examples: Video

- a periodic
- BaseBand

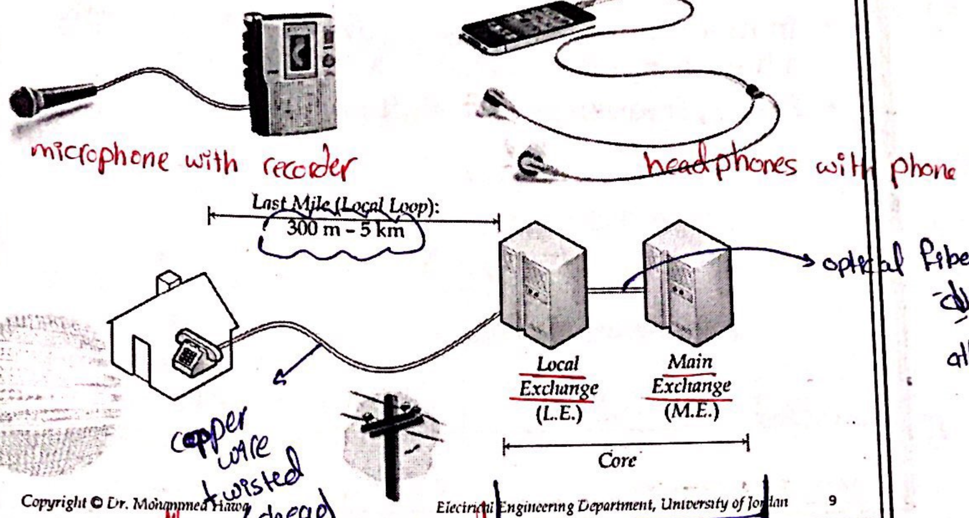
* there is no DC Value



Analog Baseband Systems

- An analog baseband system sends the analog baseband signal $m(t)$ as is (without any modifications).
- Advantages:
  - ⊖ Simplest possible system.
  - ⊖ Inexpensive to build.
- Usually used for short-distance للمسافات القريبة communications.
- Examples of such systems in the next slide.

Example Analog Baseband Systems



لانه مسافة طويلة
بصير attenuation

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9

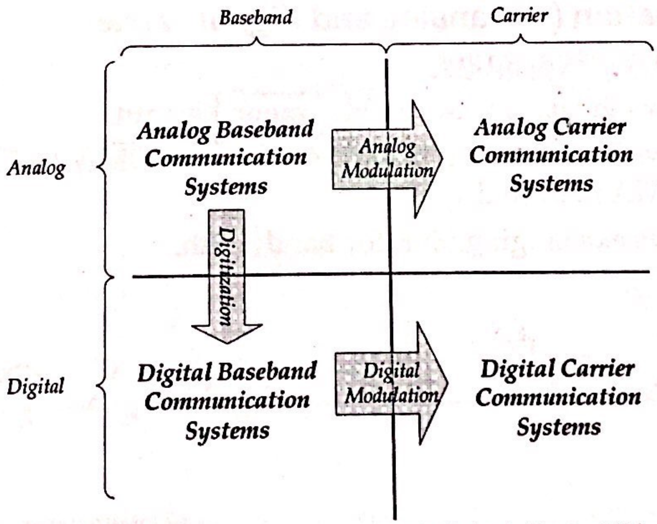
analog Baseband sys

Digital Baseband

اعمل شفت للسجنال تحول حولين الصفر

نقل من Baseband ل Carrier

Modulation and Digitization



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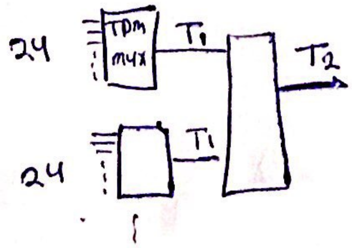
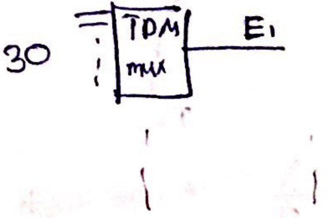
* T- System (USA)



E- system (Europe)



Ex To send Baseband voice signal (3000 Hz)

$\lambda = \frac{C}{3\times10^3} = 100\ Km \Rightarrow L_{ant} = \frac{\lambda}{2} = 50\ Km$

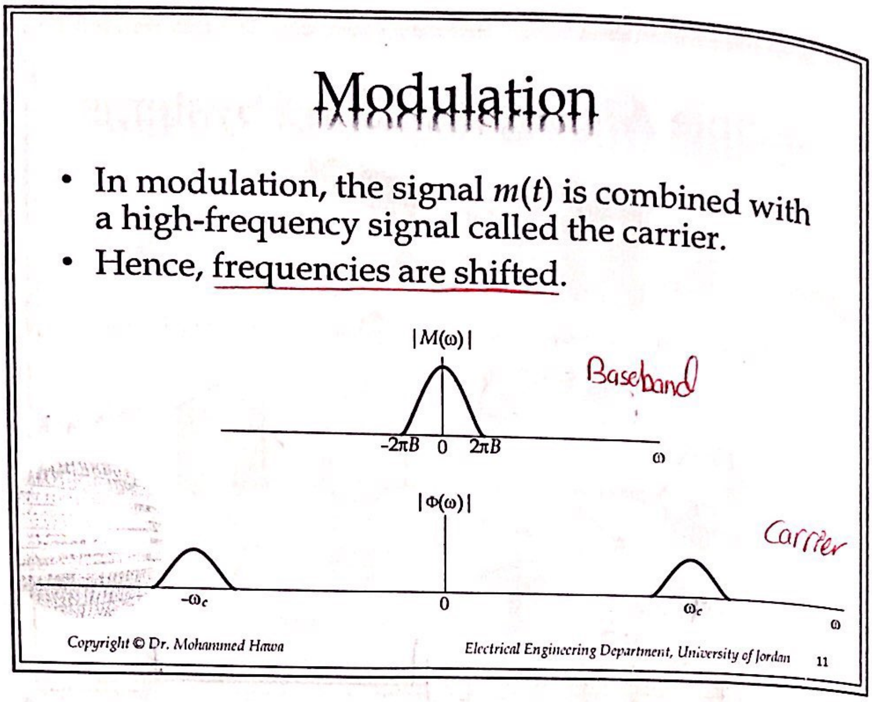
To send voice signal over wifi (f= 3GHz)

$\lambda = \frac{C}{f} = 0.1\ m \rightarrow L_{ant} = \frac{\lambda}{2} = 5\ cm$

* Note

كل ما زاد ال freq.

قل طول ال antenna



Modulation

- In modulation, the signal $m(t)$ is combined with a high-frequency signal called the carrier.
- Hence, frequencies are shifted.

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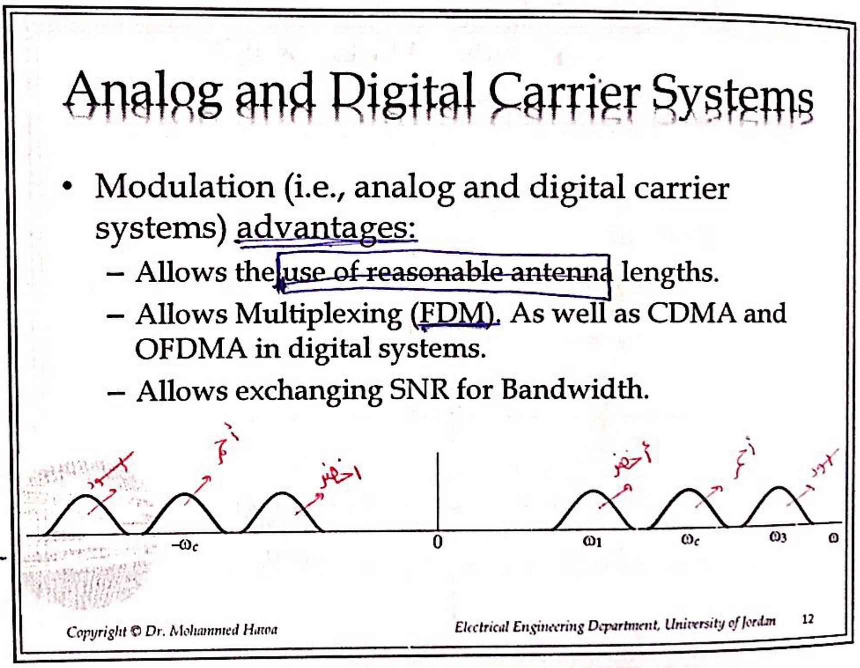

Analog and Digital Carrier Systems

- Modulation (i.e., analog and digital carrier systems) advantages:
  - Allows the use of reasonable antenna lengths.
  - Allows Multiplexing (FDM). As well as CDMA and OFDMA in digital systems.
  - Allows exchanging SNR for Bandwidth.

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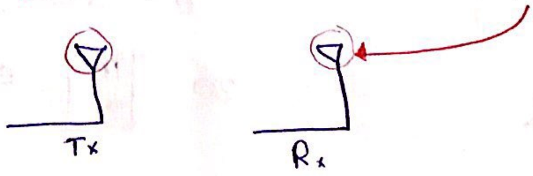
كلهم كان الهم نفس ω

وكانو عند الصفر

← بعدين عملة الهم shift

In wireless communications we use Antenna



Ex فوق

$L_{antenna} = \frac{\lambda}{2}$ → wave length of the signal

* $\lambda = \frac{C}{f} = \frac{3\times10^8\ m/sec}{\text{freq. of signal}}$

AM → amplitude modulation / FM → freq. modulation.

Example Carrier Systems

- Examples of **analog carrier** systems:
  - AM and FM radio broadcasting.
  - Analog TV broadcasting (NTSC and PAL).
- Examples of **digital carrier** systems:
  - Digital radio broadcasting (DAB). → for satelite
  - Digital TV broadcasting (DVB-S, DVB-T, ATSC)
  - WiMAX metropolitan area network.
  - Wi-Fi wireless local area network.
  - Cellular Telephony (2nd, 3rd and 4th generations).
  - Bluetooth, Zigbee and NFC
  - Old dial-up modems.
  - ADSL modems.

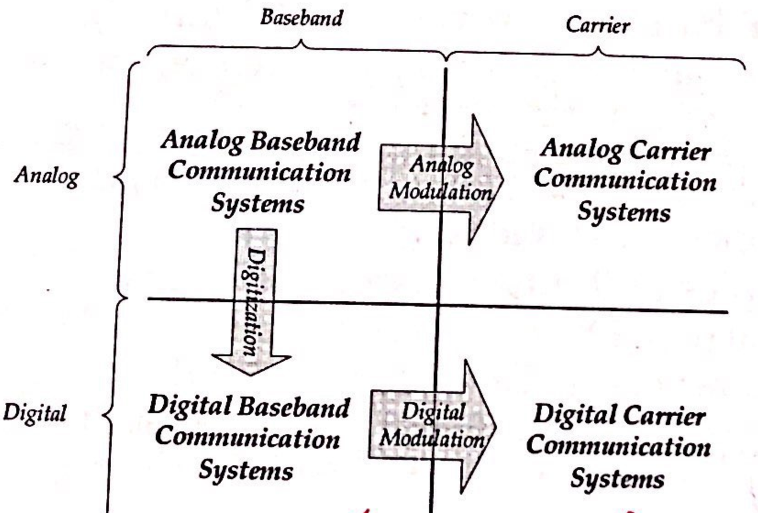
1st generation → analog

2nd G → GSM

3rd G → HSPA

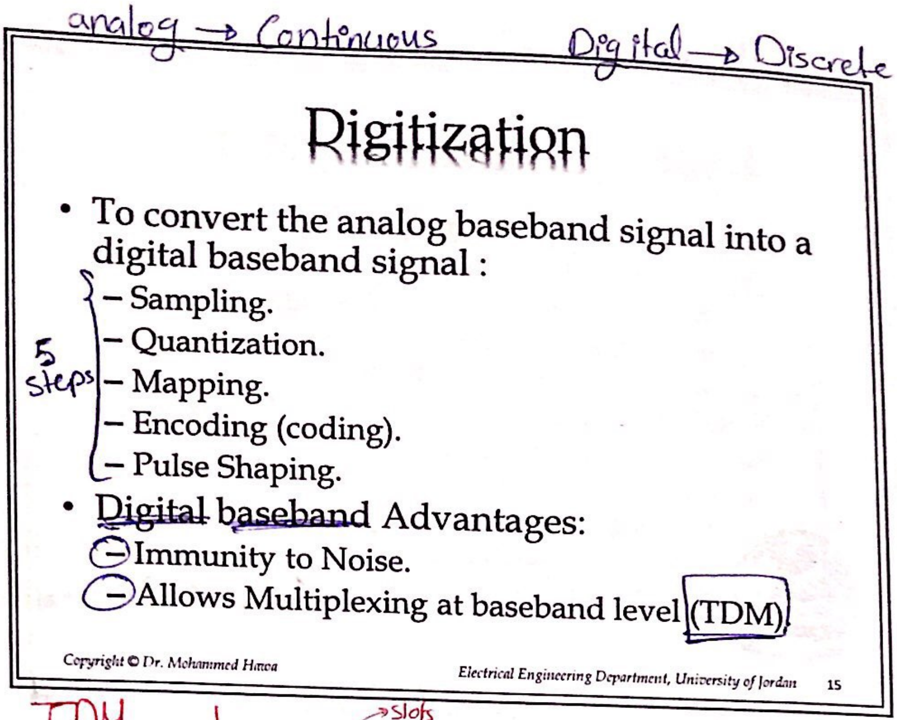
4th G → LTE

Modulation and Digitization



← Demodulation

analog → Continuous Digital → Discrete



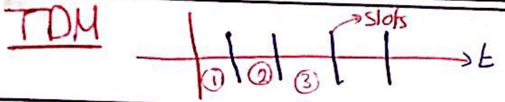
Digitization

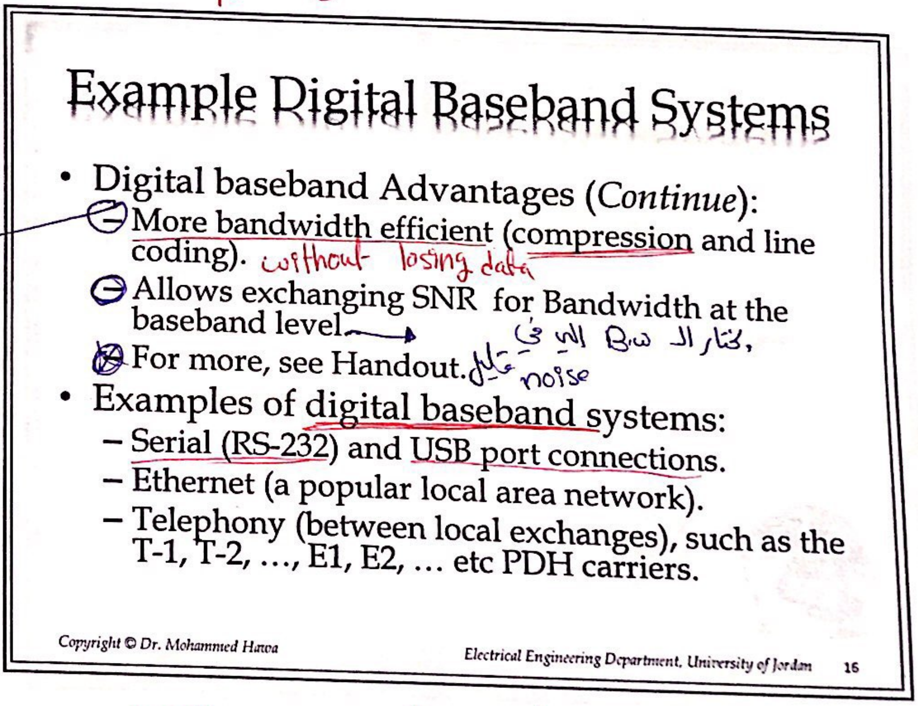
- To convert the analog baseband signal into a digital baseband signal :
  - Sampling.
  - Quantization.
  - Mapping.
  - Encoding (coding).
  - Pulse Shaping.

5 steps

- ~~Digital~~ baseband Advantages:
  - ⊖ Immunity to Noise.
  - ⊖ Allows Multiplexing at baseband level (TDM).

TDM





Example Digital Baseband Systems

- Digital baseband Advantages (*Continue*):
  - ⊖ More bandwidth efficient (compression and line coding). without losing data
  - ⊖ Allows exchanging SNR for Bandwidth at the baseband level → بختار ال BW الي في noise قليل
  - ⊗ For more, see Handout.
- Examples of digital baseband systems:
  - Serial (RS-232) and USB port connections.
  - Ethernet (a popular local area network).
  - Telephony (between local exchanges), such as the T-1, T-2, …, E1, E2, … etc PDH carriers.

بحث

more information

USB → universal serial Bus

RS → Btwn. mouse & Computer

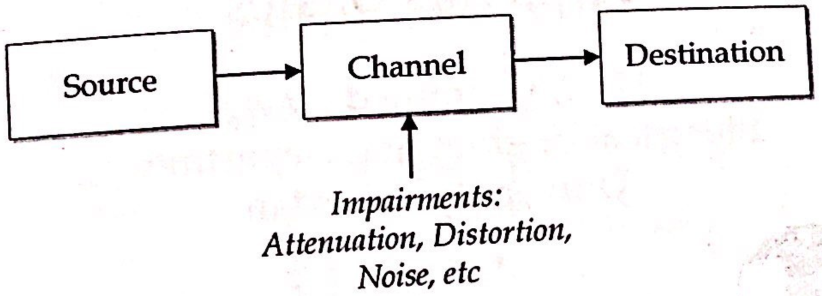
Keyboard & s

بتوصل مسافة قصيرة ليش

ما استخدم analog Baseband ؟

لأنه كل الكمبيوتر أجهزة digital

Block Diagram of a Communication System

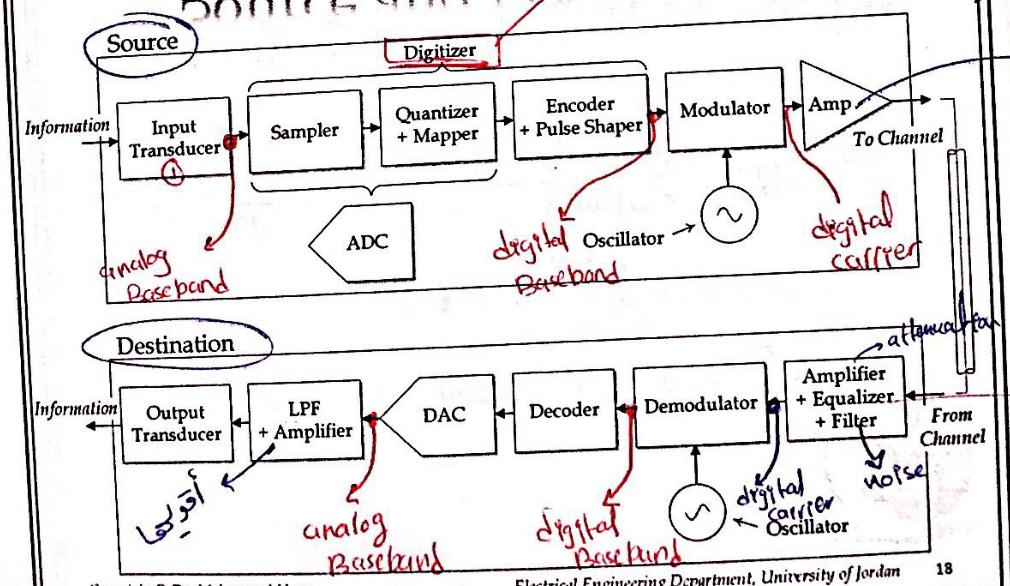


Impairments:
Attenuation, Distortion,
Noise, etc

اختياري

تفصيل :

Source and Destination



تقوي
السيجنال
solve attenuation

linear distortion
& non linear ↳

Transducer → device that change physical quantity
to electrical signal والعكس

physical quantity ⟷ electrical signal

⊛ α_n ≑ Complex expon. forrier series coefficient

↳ $\alpha_n = \frac{1}{T} \int_T x(t) e^{-jnw_0 t} \cdot dt$

9/2

⊛ ω_0 → fundemental freq. of $x(t) = \frac{2\pi}{T}$

- $n = 0$
  ↳ α_0 = DC value of $x(t)$
- $n = 1$
  ↳ α_1 = fundemental exponant
- $n = 2, 3 \ldots$
  ↳ harmonics

⊛ $\omega_0 \neq$ B.W of $x(t)$

Lecture 3: Review of Signal Analysis Basics

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EE421: Communications I

Exponential vs. Compact

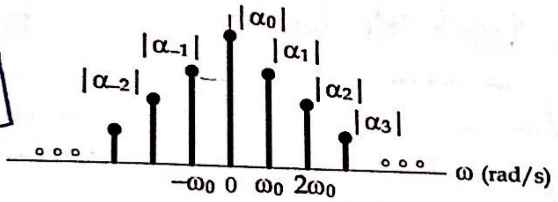
$$x(t) = \sum_{n=-\infty}^{\infty} \alpha_n \cdot e^{jn\omega_0 t}, \quad \omega_0 = \frac{2\pi}{T}$$

$$x(t) = \frac{c_0}{2} + \sum_{n=1}^{\infty} c_n \cos(n\omega_0 t - \theta_n), \quad \omega_0 = \frac{2\pi}{T}$$

Exponential Fourier Series

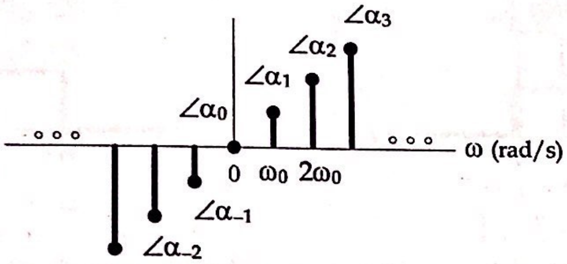
$* \omega = n\omega_0$

Magnitude Spectrum

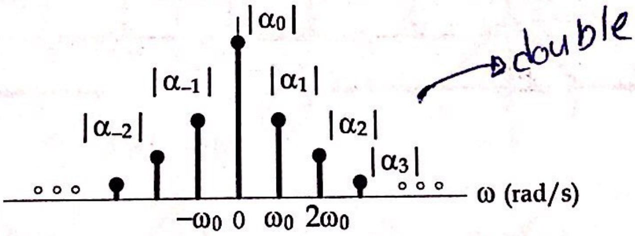


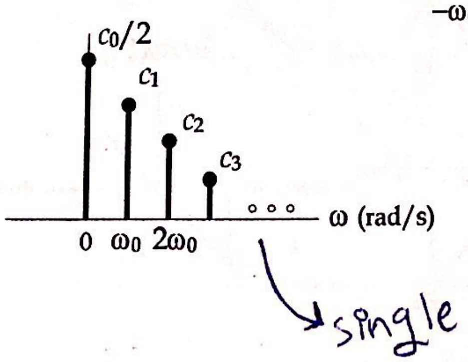
Phase Spectrum

الزوايا

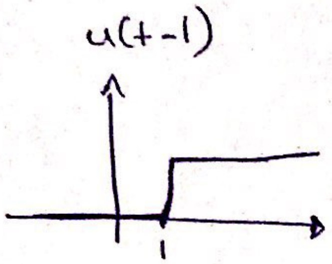


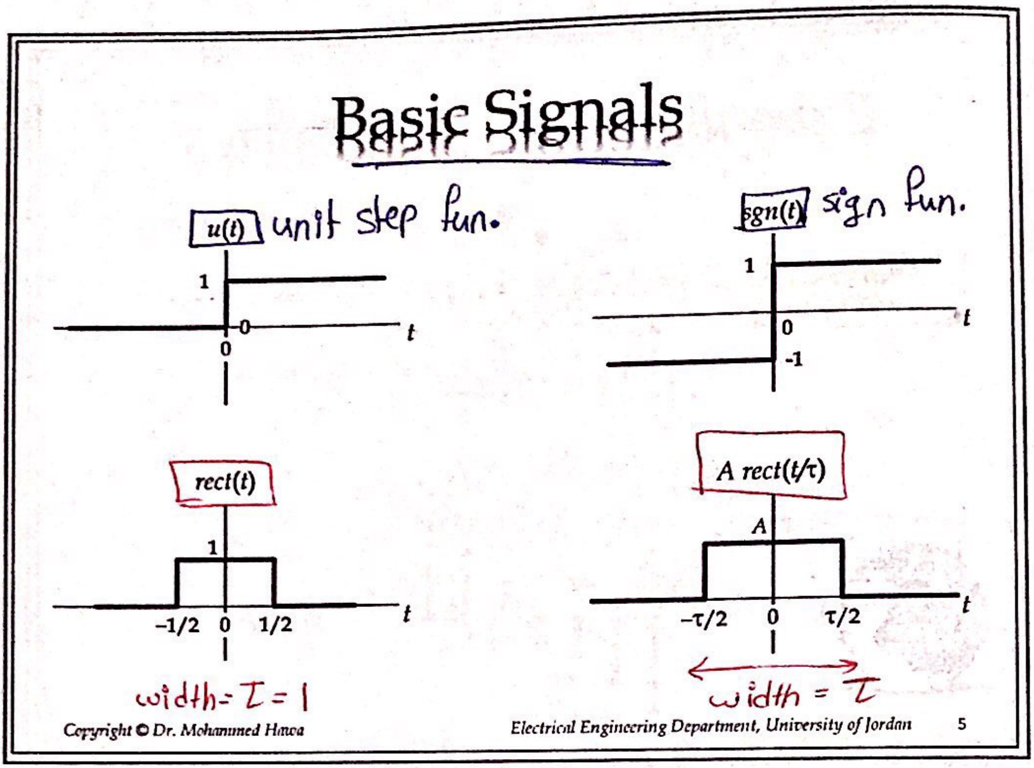
Single-Sided vs. Double-Sided





$C_n = 2\alpha_n$





Basic Signals

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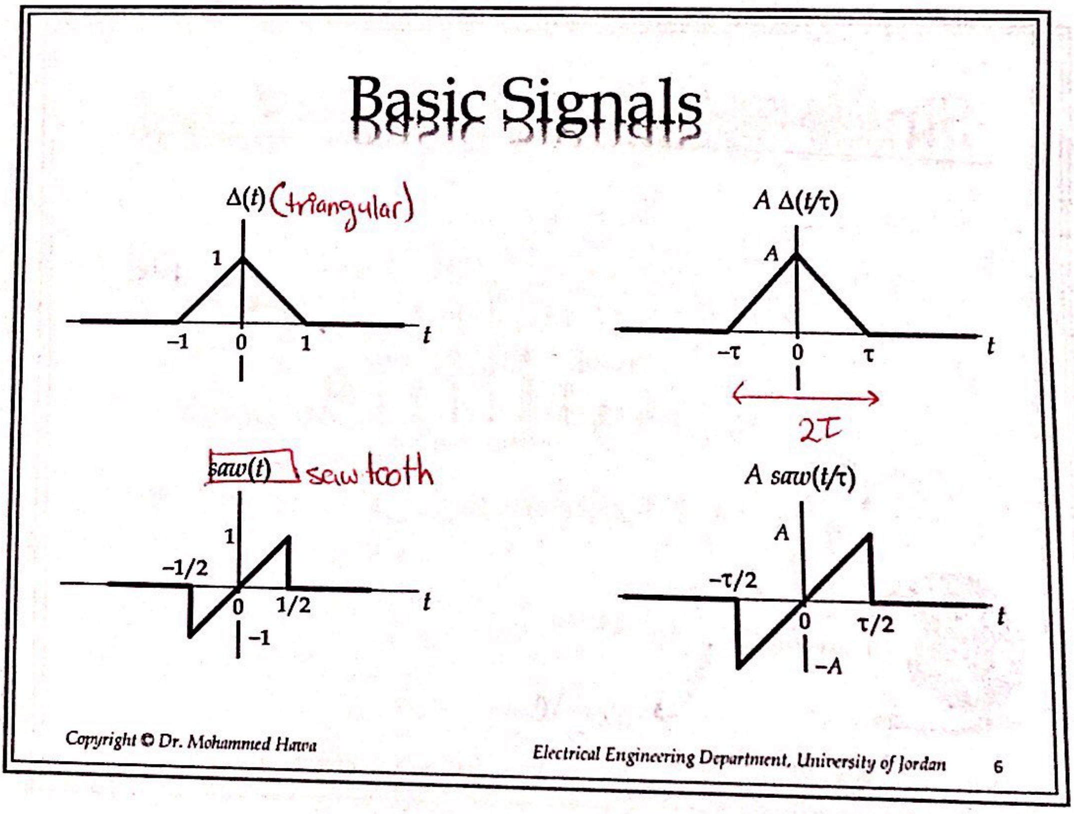

Basic Signals

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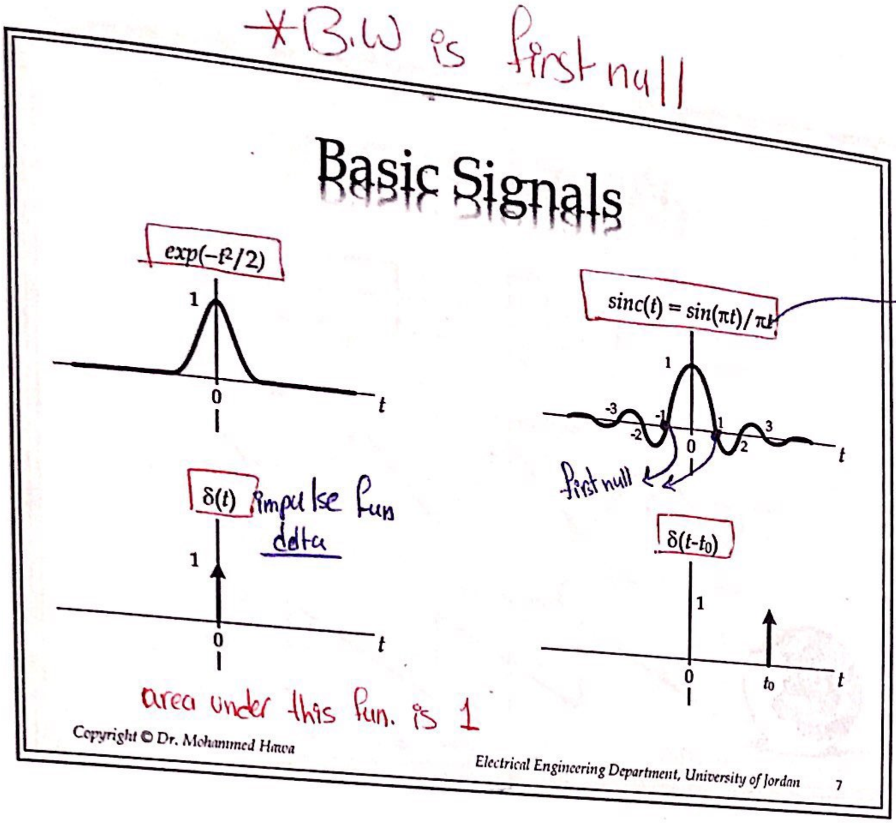
*B.W is first null



Basic Signals

$exp(-t^2/2)$

$sinc(t) = sin(\pi t)/\pi t$ → sinc(0) = 1

sinc(int) = 0

↳ integer 1, 2, 3 . . .

first null

δ(t) impulse fun
delta

δ(t-t₀)

area under this fun. is 1

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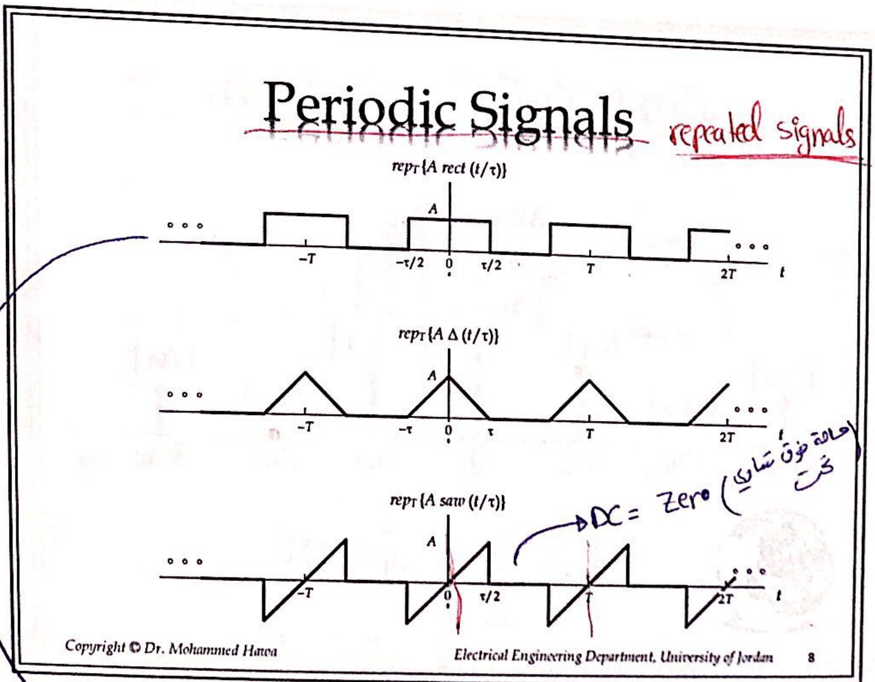

Periodic Signals

repeated signals every T

$rep_T\{A\ rect\ (t/\tau)\}$

$rep_T\{A\ \Delta\ (t/\tau)\}$

$rep_T\{A\ saw\ (t/\tau)\}$

→ DC = Zero (مساحة فوق تساوي تحت)

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* $B.\omega = \frac{1}{\tau}$ Hz

÷2

DC $\overline{x(t)} = \frac{1}{T}\int_T x(t).dt$

$= \frac{1}{T}\int_{-\tau/2}^{\tau/2} A\ dt$

$\alpha_0 = \frac{1}{T}\left[A\left(\frac{\tau}{2}+\frac{\tau}{2}\right)\right] \boxed{= \frac{A\tau}{T}}$

pulse width

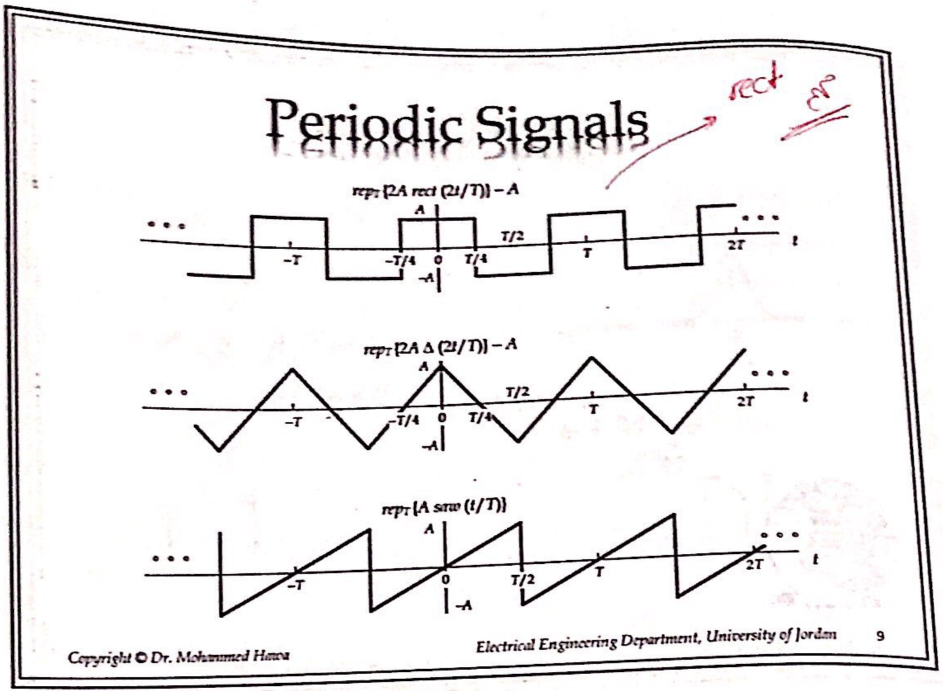
period

$\alpha_n = \frac{A\tau}{T}\,\mathrm{sinc}\left(\frac{A\omega_0\tau}{2\pi}\right)$ ω

$\frac{\omega\tau}{2\pi} = 1$

↳ $\omega = \frac{2\pi}{\tau}$ rad/sec ⇒ B.w of x(t)

9/2



Periodic Signals

rect

$rep_T\{2A\ rect\ (2t/T)\} - A$

$rep_T\{2A\ \Delta\ (2t/T)\} - A$

$rep_T\{A\ saw\ (t/T)\}$

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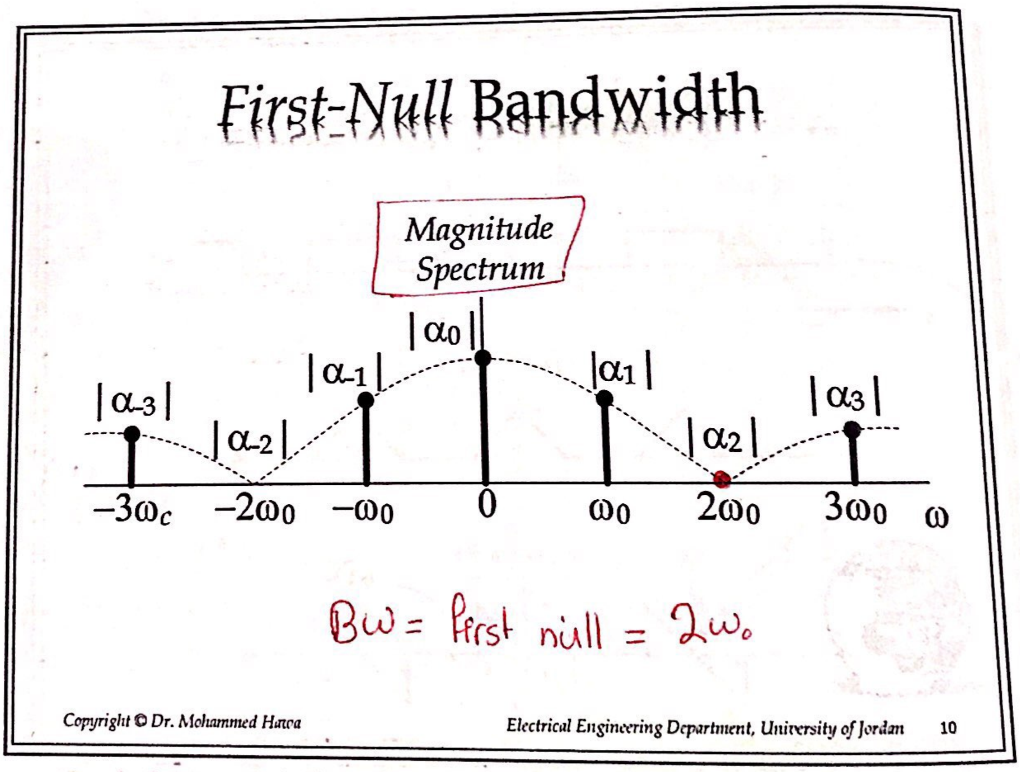

First-Null Bandwidth

Magnitude Spectrum

BW = first null = $2\omega_0$

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* forier series → for periodic signals

Fourier Transform

→ for periodic & Aperiodic signals

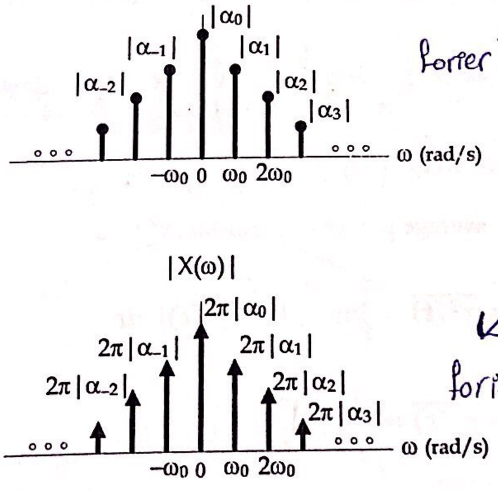
$$\boxed{X(\omega)} = \mathscr{F}\{x(t)\} = \boxed{\int_{-\infty}^{\infty} x(t)e^{-j\omega t}\,dt}$$

t → ω

$$\boxed{x(t)} = \mathscr{F}^{-1}\{X(\omega)\} = \boxed{\frac{1}{2\pi}\int_{-\infty}^{\infty} X(\omega)e^{j\omega t}\,d\omega}$$

ω → t

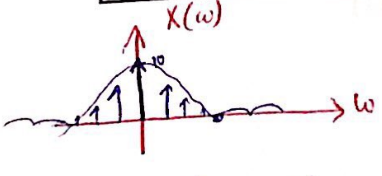
Fourier Series vs. Tranform



forier series magnitudes

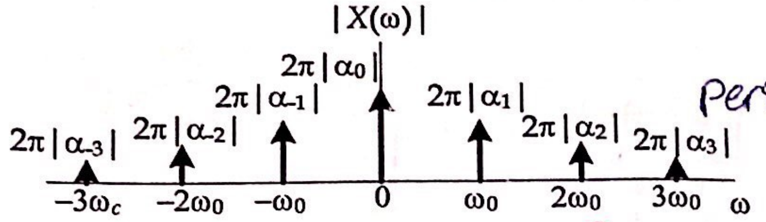
$\boxed{*2\pi}$

forier transform impulses



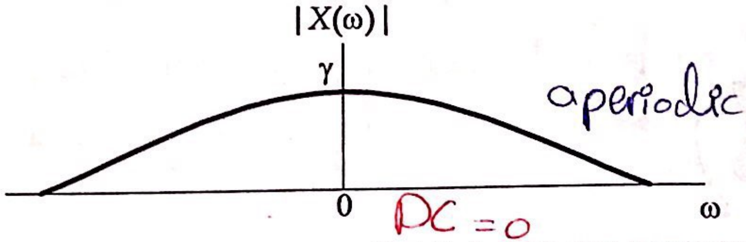
$DC = \frac{10}{2\pi} = \alpha_0 \longrightarrow$ DC باخذ من fourier series!!

Periodic vs. Aperiodic



periodic

$DC = \alpha_0$



aperiodic

$DC = 0$

*DC value for sin & cos = $\boxed{\text{Zero}}$

DC vs. Average Power

The DC value or average value of the signal $x(t)$ is:

$$\boxed{DC} = \overline{x(t)} = \lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} x(t)dt$$ time domain

$$\boxed{DC} = \overline{x(t)} = \boxed{\alpha_0}$$ freq.

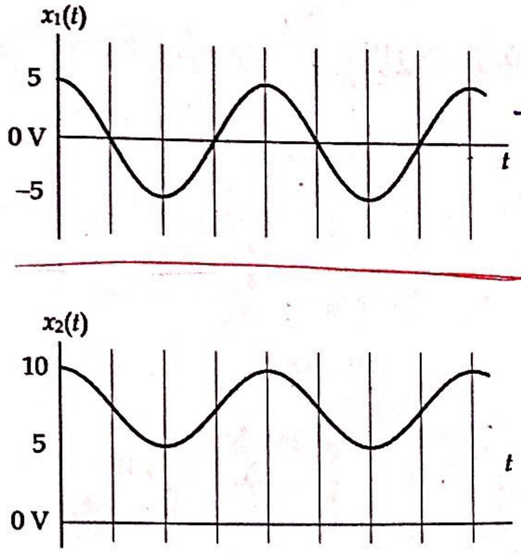
The average power in the signal $x(t)$ is:

$$P_x = \overline{x^2(t)} = \lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} |x(t)|^2 dt$$

$$P_x = \overline{x^2(t)} = \frac{1}{2\pi}\int_{-\infty}^{\infty} \boxed{S_x(\omega)} d\omega$$

power spectral density (PSD)

DC vs. Average Power



→ $P_{avg} = \frac{5^2}{2} = 12.5$

* for sin/cos wave signals $x(t) = V_m\cos(\omega_0 t)$

↳ $P_{avg} = \boxed{\frac{V_m^2}{2}}$

$rms = \frac{V_m}{\sqrt{2}}$

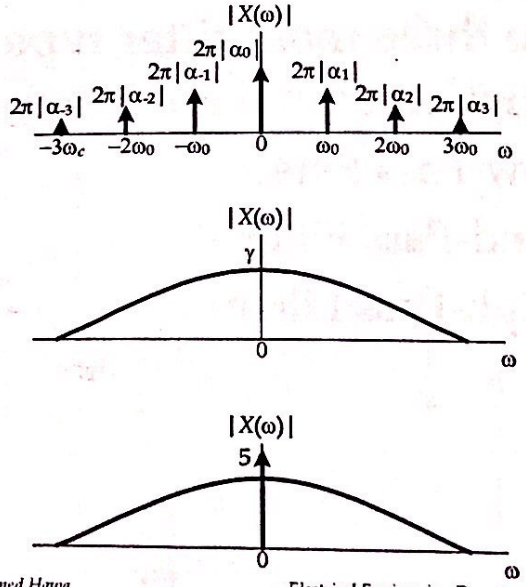
⊛ $P_{avg} = (rms)^2$

$x_2(t) = 2.5\cos(\omega_0 t) + \boxed{7.5}$ DC

⊙ $\overline{x_2(t)} = 7.5$

⊛ $P_{avg} = \frac{(2.5)^2}{2} + (7.5)^2 = 59.375$ w

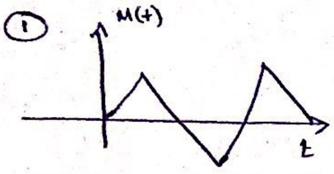
DC from Frequency Domain



Examples (part 2)

Slide 2

①



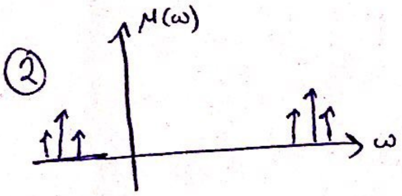
analog

peridic

Can't determine (carrier, Baseband)

↳ we need to make forier transform

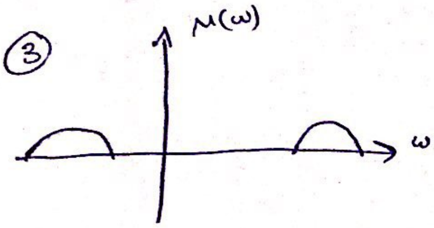
②



carrier

peridic

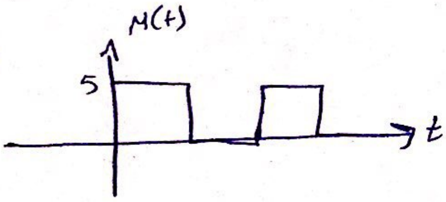
③



Carrier

aperiodic

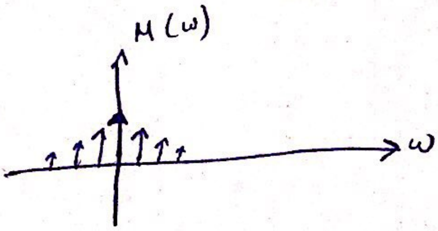
4



digital

peridic

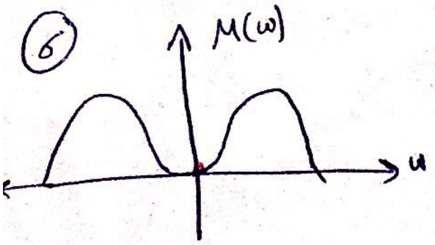
5



Baseband

Periodic

⑥



Baseband

aperiodic

*Check the handout :

① جدول الصغير حفظ

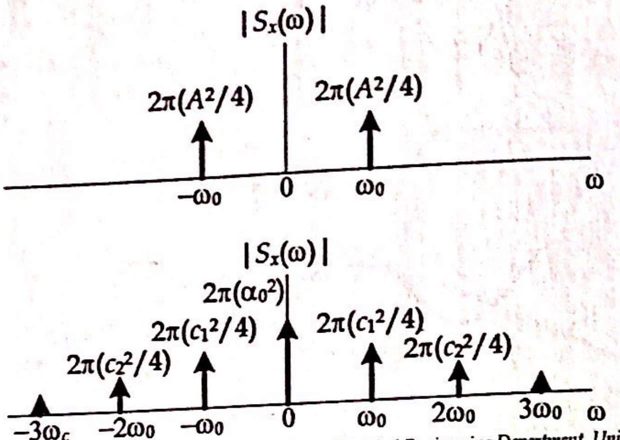
② الجدول الطويل بس نحفظ α_n

لأنه C_n ---

ما بنحتاجهم

Power Spectral Density

$$\text{PSD} = S_x(\omega) = \lim_{T\to\infty} \frac{1}{T}|X_T(\omega)|^2 = \mathcal{F}\{R_{xx}(\tau)\}$$



DC = α_0

Bw = first null

$\alpha_n = \frac{A\tau}{T} \text{sinc}\left(\frac{\overset{\omega}{n\omega_0}\tau}{2\pi}\right)$ ↳ = 1

$B\omega = \omega = \frac{2\pi}{\tau}$ rad/sec

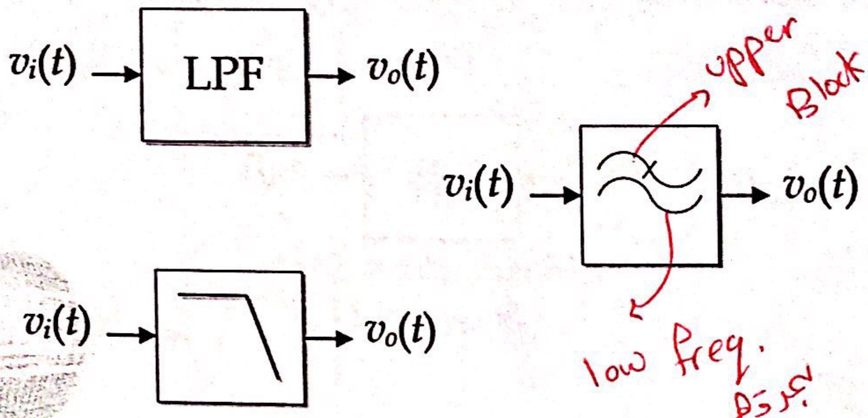
$\omega = \frac{1}{\tau}$ Hz

Quick Review of Filters

- There are three main filter types that you studied in signal analysis:
  - LPF: Low-Pass Filter → low frequency بمرق
  - BPF: Band-Pass Filter
  - HPF: High-Pass Filter

Low-Pass Filter (LPF)

- **Symbol:**

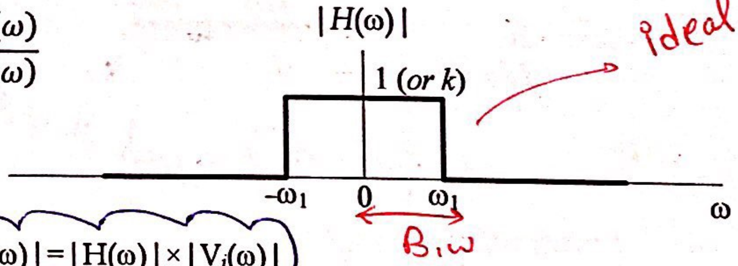


upper freq
Block لل العالي

low freq.
بمررهم

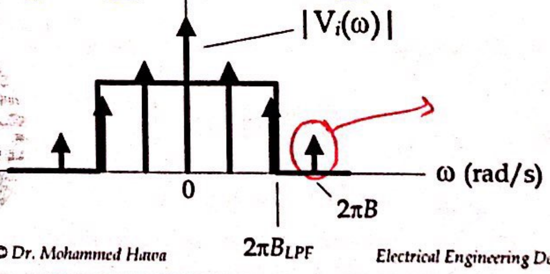
Frequency-response function

$$H(\omega) = \frac{V_o(\omega)}{V_i(\omega)}$$



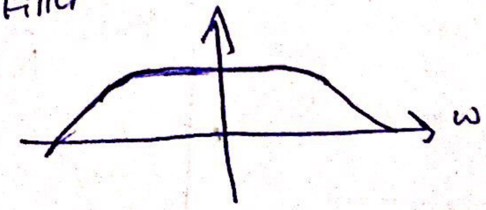
ideal Low pass filter

$$|V_o(\omega)| = |H(\omega)| \times |V_i(\omega)|$$



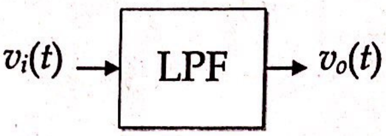
يصير الها
cancelation

practical filter



Characteristics

- ⊙ Always centered at 0 rad/s.
- Bandwidth = Cut-off frequency = $\boxed{\omega_1}$ rad/s
- Gain = k.

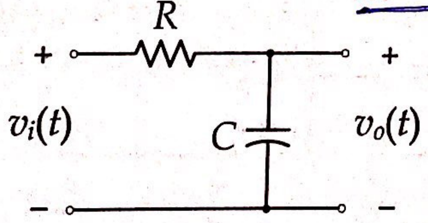


w/ Bandwidth = 5 kHz
& Gain = 2

Example Circuit

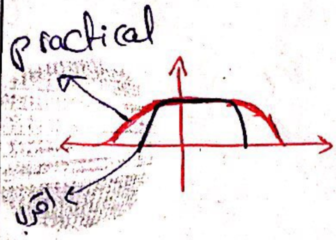
first order low pass filter

أقرب لل ideal



$$B_{LPF} = \frac{1}{2\pi RC}\ \text{Hz}$$

$$Gain = 1$$



لل ideal

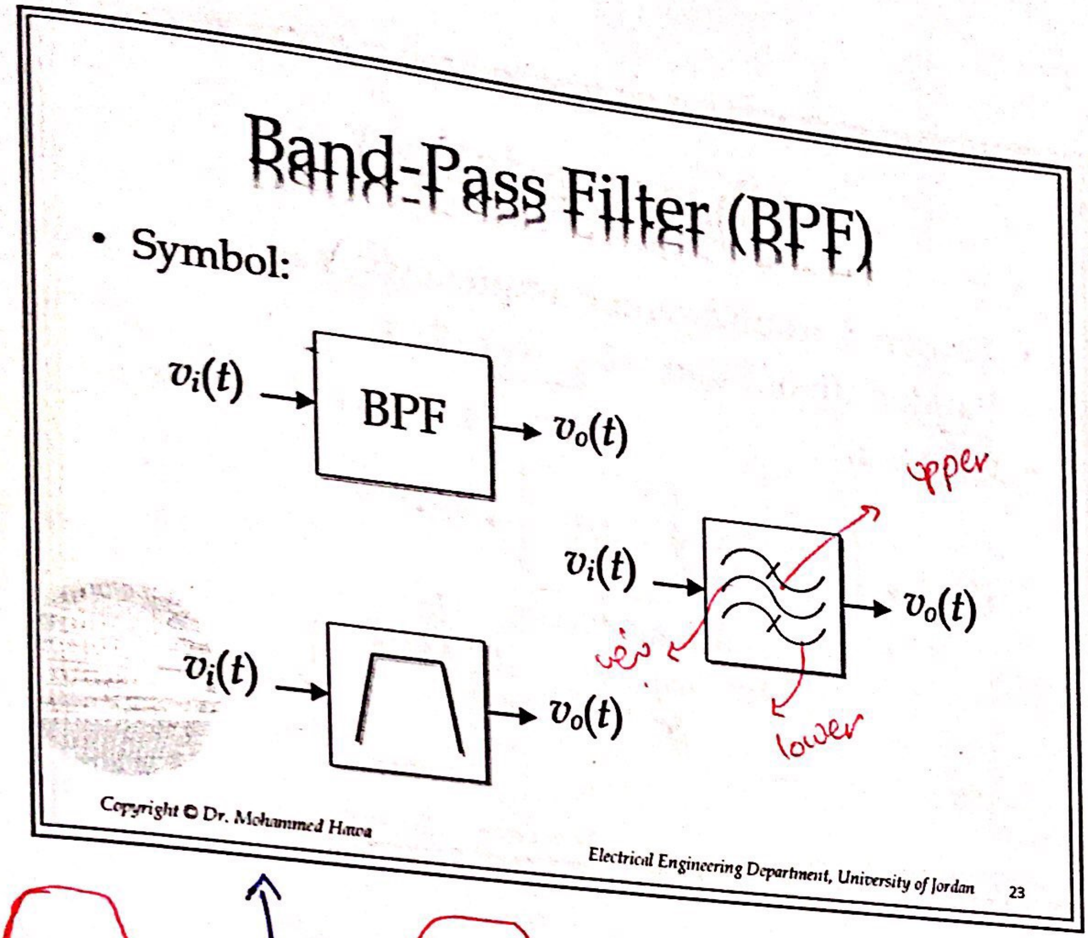
$$H(s) = \frac{V_o(s)}{V_i(s)}$$

$$= \frac{\dfrac{\cancel{V_i(s)} \times \frac{1}{sC} \times sC}{\left(R + \frac{1}{sC}\right) sC}}{\cancel{V_i}} \rightarrow$$

$$H(s) = \frac{1}{1 + R\boxed{s}C}$$

$$s^{(1)}$$

First order



Band-Pass Filter (BPF)

- Symbol:

$v_i(t)$ → BPF → $v_o(t)$

$v_i(t)$ → → $v_o(t)$

$v_i(t)$ → → $v_o(t)$

upper

نص

lower

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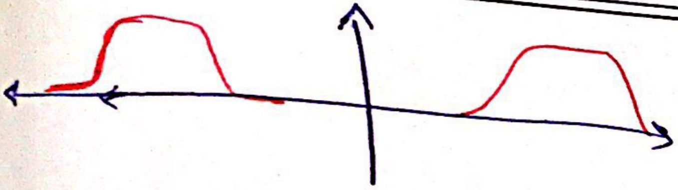

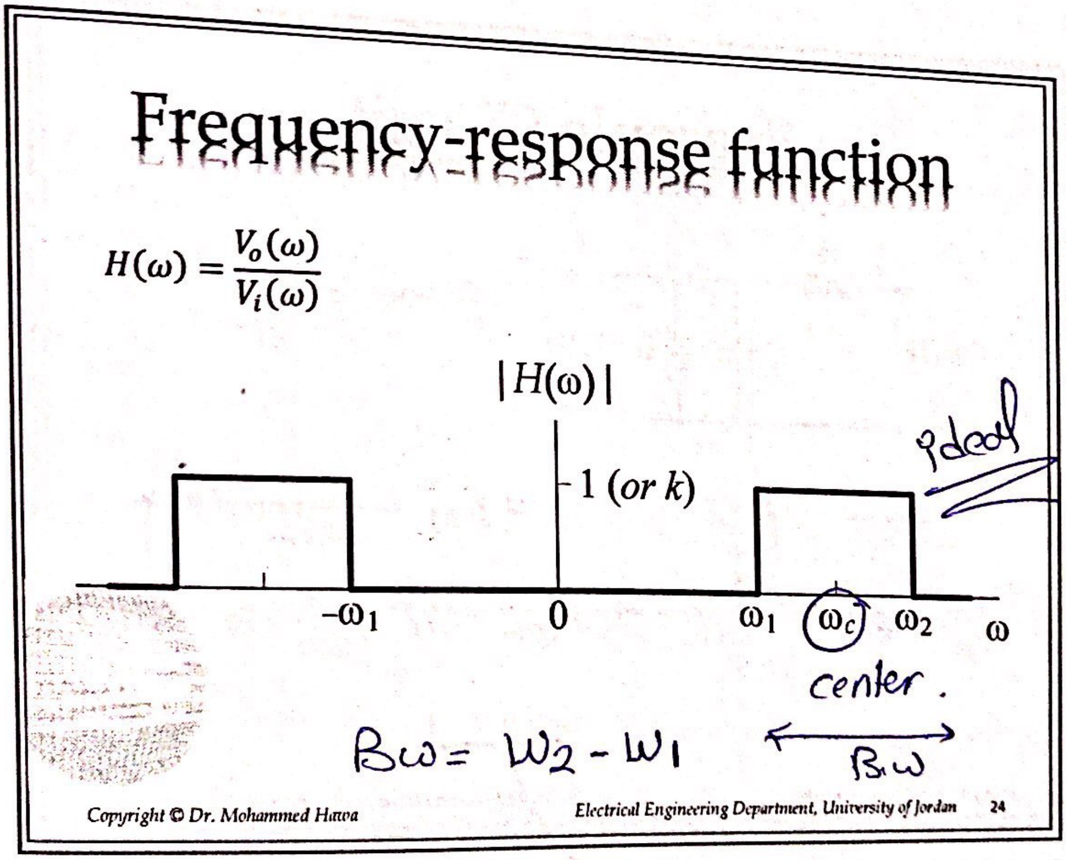

Frequency-response function

$$H(\omega) = \frac{V_o(\omega)}{V_i(\omega)}$$

$|H(\omega)|$

1 (or k)

$-\omega_1$ 0 ω_1 ω_c ω_2 ω

ideal

center.

$B\omega = W_2 - W_1$

$\longleftrightarrow$ $B\omega$

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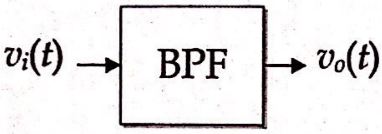
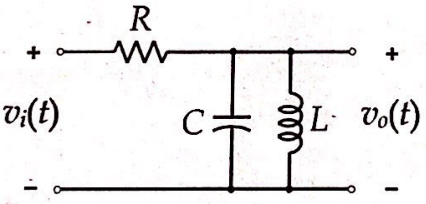
Characteristics

- Centered around center frequency ω_c rad/s.
- Bandwidth of Filter = $\omega_2 - \omega_1$ rad/s
- Gain = k.



w/ Bandwidth = 80 kHz
Center Frequency = 100 MHz
& Gain = 1

Example Circuit



second order

اذا طلعنا H(s)
ع تطلع قوة S
من الدرجة الثانية

$$f_c = f_{res} = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}$$

$$B_{BPF} = \Delta f = \frac{R}{2\pi L} \text{ Hz}$$

$$Gain = 1$$

حفظ

ليس واحد
لأن كل ال element
passive

* modulation: process that causes a shift of frequencies ~~ ~~ of a signals (m(t)) from Baseband to Carrier. and it is achieved by changing amplitude or freq. or shift of a high frequency periodic signal signal called carrier (c(t)) in proportion to the Base band msg signal (m(t))

Lecture 4: Amplitude Modulation (Double Sideband Suppressed Carrier, DSB-SC)

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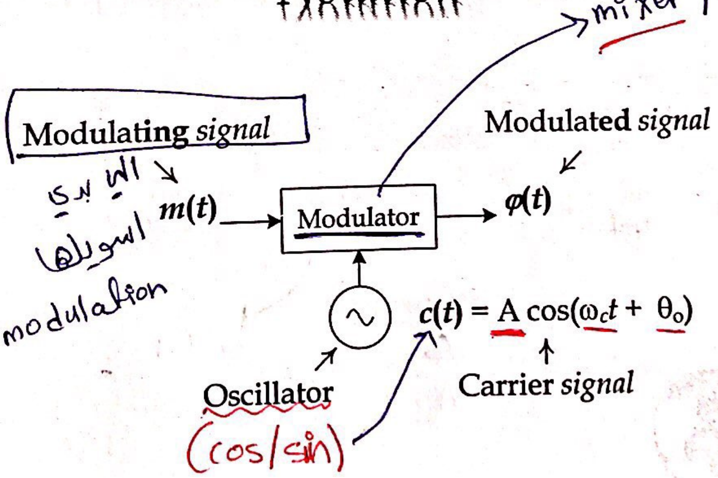
modulation → shift in freq. componant of a signal.

Carrier ←ل— Baseband أحول من

Notation



* if c(t) is a cosine → it is called continuous wave modulation)
(CW modulation)

* التغير بسير :-

① amplitude modulation
② freq. 〃
③ phase 〃

Three Modulation Types

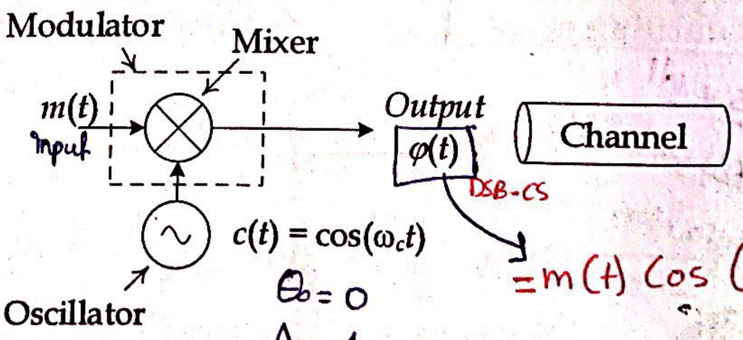
- $A \propto m(t)$; $\omega_c = constant$; $\theta_o = constant$
  - Amplitude Modulation (AM)
  - Amplitude Shift Keying (ASK)
- $A = constant$; $\omega_c \propto m(t)$; $\theta_o = constant$
  - Frequency Modulation (FM)
  - Frequency Shift Keying (FSK)
- $A = constant$; $\omega_c = constant$; $\theta_o \propto m(t)$
  - Phase Modulation (PM)
  - Phase Shift Keying (PSK)

* Note

AM → amplitude modulation (DSB-LC)
↓
large carrier

double side Band - subs carrier

DSB-SC Modulator: Mixer



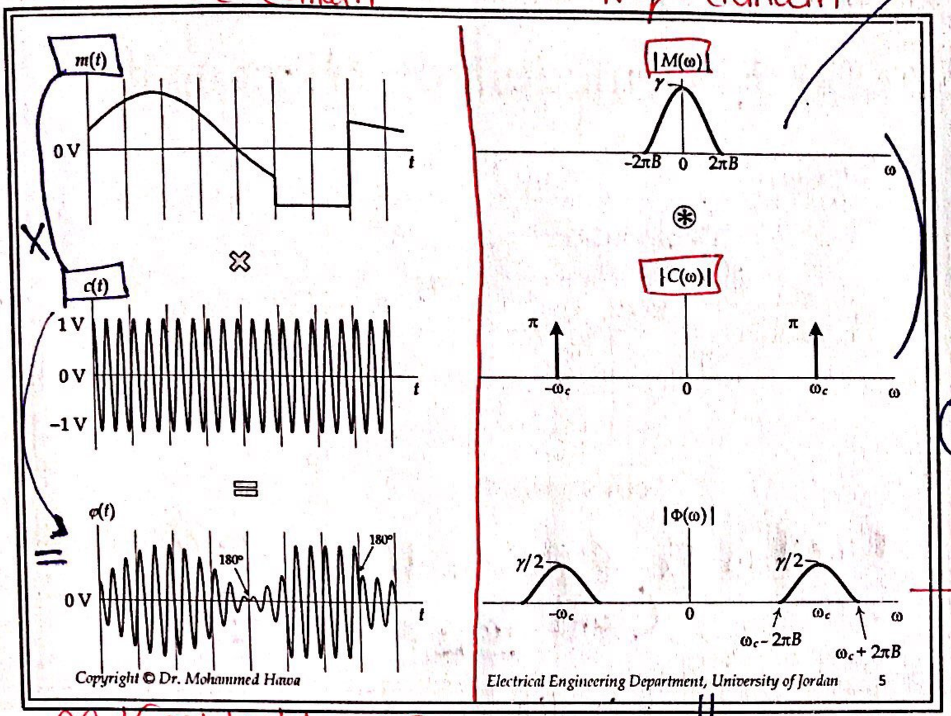
$= m(t) \cos(\omega_c t)$

$\theta_o = 0$

$A = 1$

$B.\omega = 2\pi B$ rad/sec
$= B$ Hz

Time domain freq. domain



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برمز
ferrier trasform

☆ Convluation

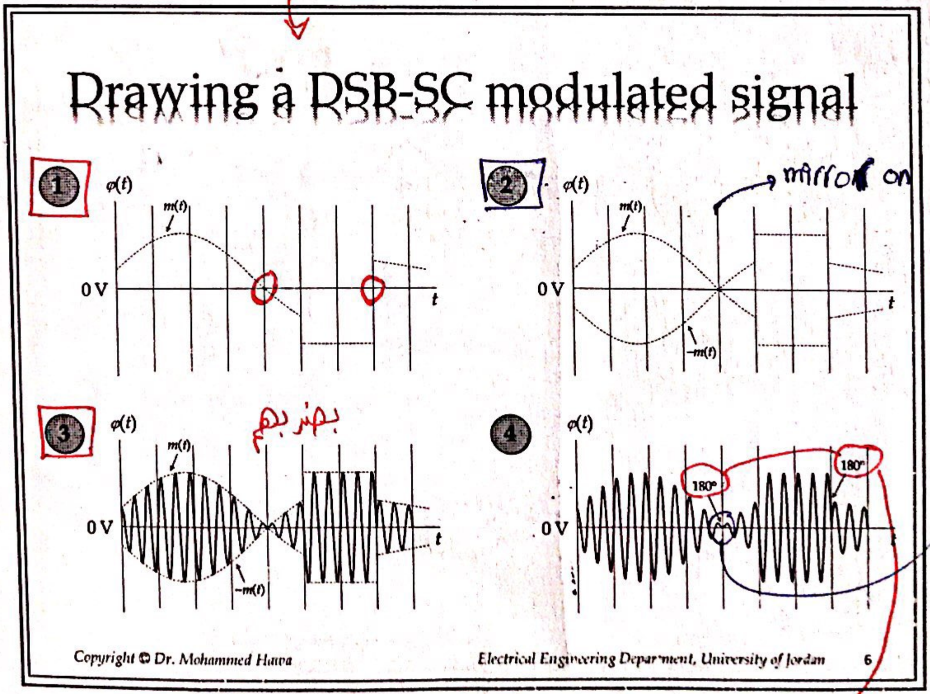
(الضرب بال ferrier
عبارة عن كونفليوشن)

$\phi(\omega) = \frac{1}{2\pi} M(\omega) * C(\omega)$

كيف حولنا هاد الشكل ؟؟

check paper!

٤ - خطوات
Time domain لـ



Drawing a DSB-SC modulated signal

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أشكال الـ phase shift

عدة أشكال إله حسب
وين صار الـ shift

لما انتقل من positive لـ negative
أو العكس بالرسمة الأولية (1)
بيصير عندي شفت 180

Ex if $m(t) = \alpha \cos(\omega_m t) \Longrightarrow P_{avg} = \frac{\alpha^2}{2}$

$c(t) = \cos(\omega_c t)$

2/15/

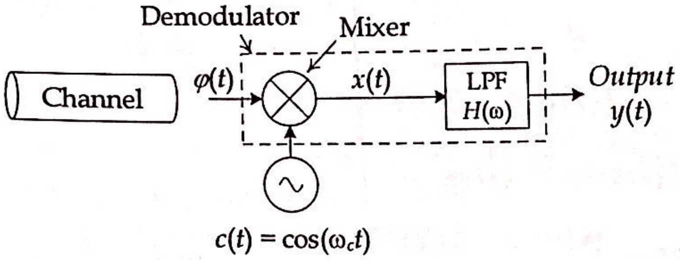
$\phi(t) = \alpha \cos(\omega_m t) \cos(\omega_c t)$

$= \alpha \left[\frac{1}{2} \cos(\omega_m t + \omega_c t) + \frac{1}{2} \cos(\omega_m t - \omega_c t)\right] \Rightarrow P_{avg} = \frac{(\alpha/2)^2}{2} + \frac{(\alpha/2)^2}{2}$

$= \frac{\alpha^2}{4}$

$= \frac{1}{2} P_{m(t)}$

DSB-SC Demodulator: Mixer again!



* $c(t)$ in T_x & R_x Should be synchronized (same freq. & same phase)

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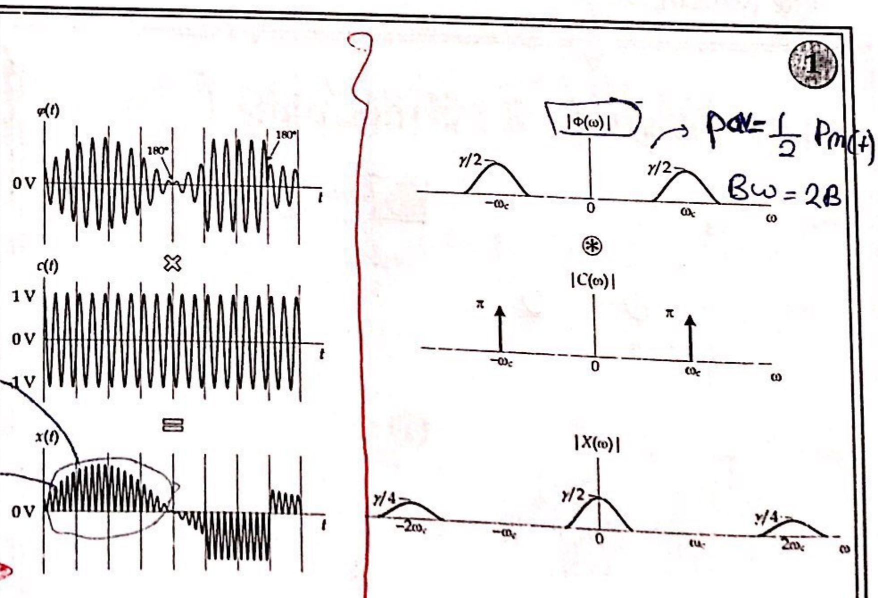
* amplitude ⟶ عادي تتغير



$P_{av} = \frac{1}{2} P_{m(t)}$

$B\omega = 2B$

sharp edges from $\frac{m(t)}{2} \cos(2\omega_c t)$

positive في منهم
po [illegible]
neg. ع neg. أ

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* Time domain: $x(t) = \phi(t) * \cos(\omega_c t) = m(t) \cos(\omega_c t) \cos(\omega_c t)$

$= \frac{m(t)}{2} [1 + \cos(2\omega_c t)] = \frac{m(t)}{2} + \frac{m(t)}{2} \cos(2\omega_c t)$

$y(t) = \frac{m(t)}{2}$

reject by LPF لأنه high freq.

* Frequency domain slide 5 / lect 4

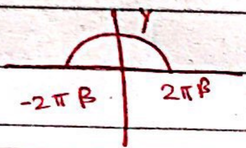
$\phi(\omega) = f\{m(t) \cdot c(t)\}$

$= \frac{1}{2\pi} M(\omega) \star C(\omega)$

$= \frac{1}{2\cancel{\pi}} M(\omega) \star [\cancel{\pi}\,\delta(\omega-\omega_c) + \cancel{\pi}\,\delta(\omega+\omega_c)]$

$\hookrightarrow \phi(\omega) = \frac{1}{2} M(\omega-\omega_c) + \frac{1}{2} M(\omega+\omega_c)$

㊉ $M(\omega)$



① DC=0 → there is no pulse (aperiodic)

② $BW = 2\pi\beta$ rad/sec , β Hz → in فقط positive side

③ $P_{av} = \overline{m(t)^2}$

㊉ $c(t)$

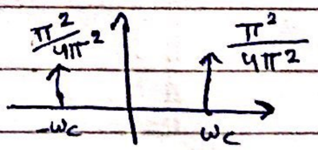
① DC=0 (cos over period)

② $BW = \omega_c$ rad/sec = fundemantal freq.

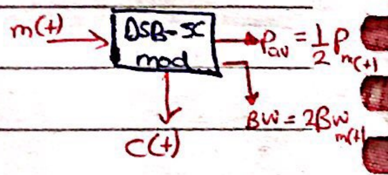
③ $P_{av} = \frac{V_{max}^2}{2} = \frac{1}{2}$ watt

$\hookrightarrow C(\omega)$

Pavg → PSD = $S_c(\omega)$



$\hookrightarrow = \frac{1}{4} + \frac{1}{4} = \frac{1}{2}$



㊉ $\phi(t) \Rightarrow$ ① DC=0

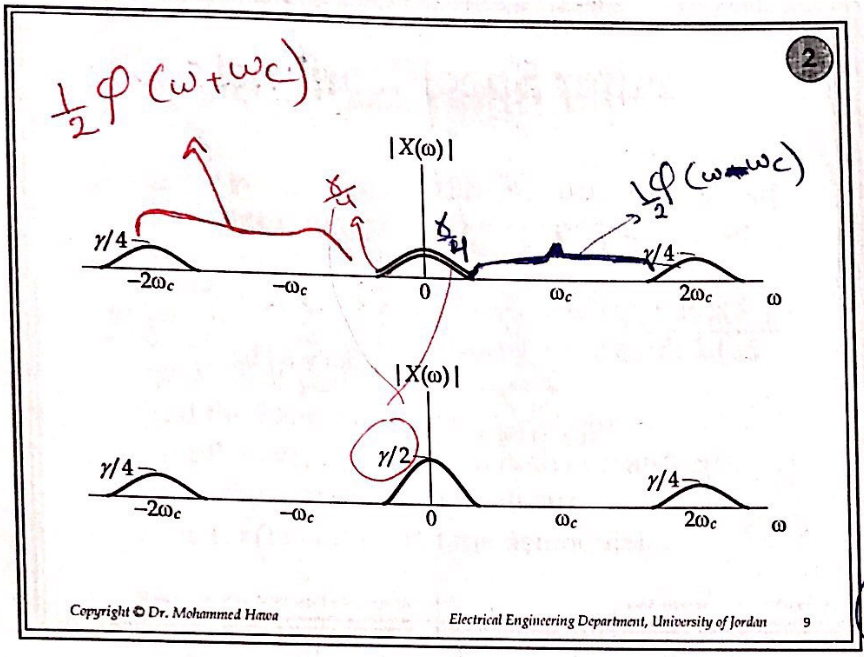
② BW= 2B Hz or $4\pi B$ rad/sec (disadvantage)

Rule فقط ← ③ $P_{avg} = \frac{1}{2} P_{av(m(t))}$

* freq. domain: $X(\omega) = \frac{1}{2\pi}\Phi(\omega) * \left[\pi \, \delta(\omega c+\omega c) + \pi \, \delta(\omega-\omega c)\right]$

$= \frac{1}{2}\Phi(\omega+\omega_c) + \frac{1}{2}\Phi(\omega_s-\omega_c)$

2/15/2017



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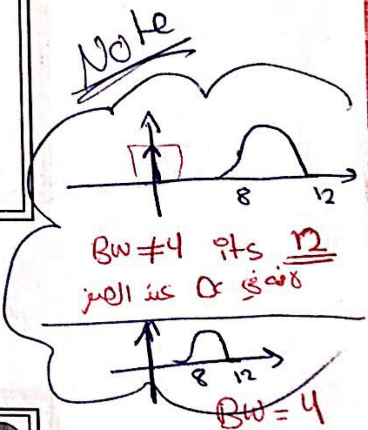
Note

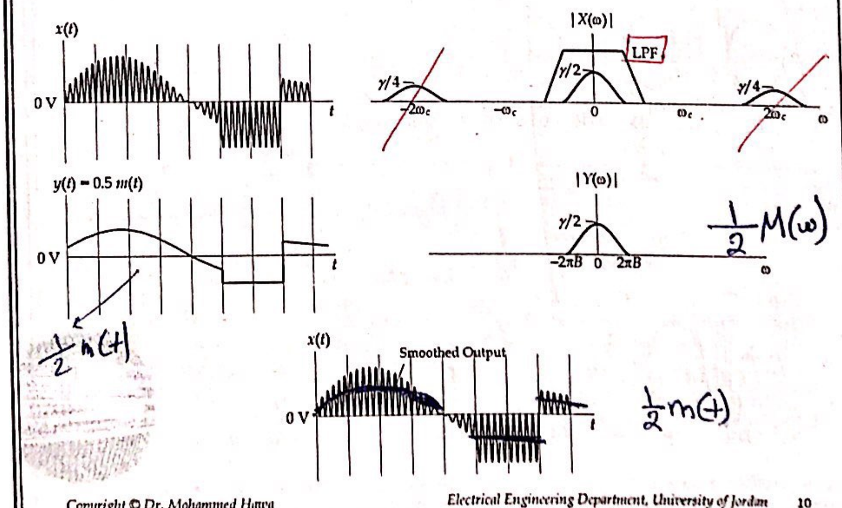


BW ≠ 4 its 12

بدي 0 عند الصفر

BW = 4

The LPF is *the missing piece!*



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ما بمرقهم ال LPF

قبل الفلتر $X(t)$: $BW = 2\pi B + 2\omega_c$

من نظرتي لل freq domain

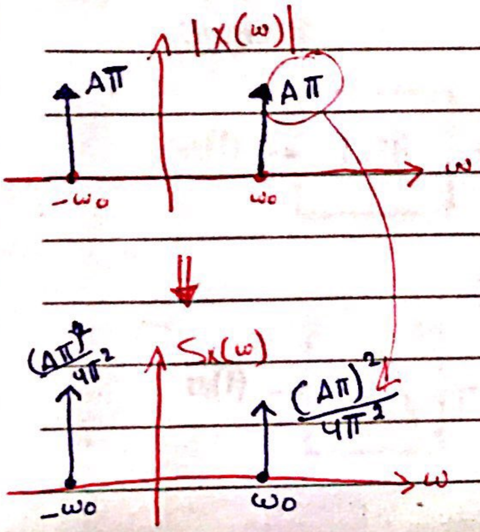
$Y(t)$: $2\pi B = B$ Hz

$P_{avg} = \frac{1}{2}P_{\phi(t)} = \frac{1}{4}P_{m(t)}$

*lec. 3 - slide 17

power spectral Density:

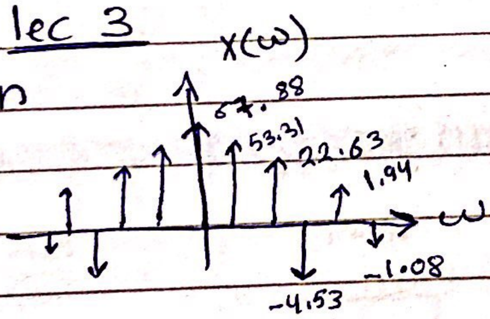
Ex $x(t) = A\cos(\omega_0 t)$



$$P_{avg} = \frac{A^2}{4} + \frac{A^2}{4} = \frac{A^2}{2}$$

Ex: lec 3

Given

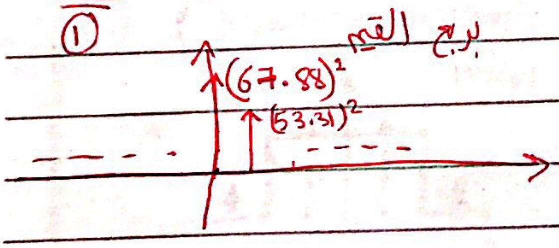


draw S(x) then find Pav?

Sol

①

ربع القيم

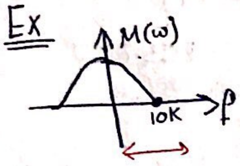


سؤال كتاب

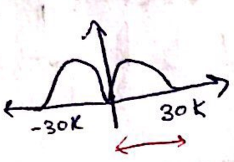
② $P_{avg} = \Sigma = \frac{(67.88)^2}{(2\pi)^2} + \frac{(53.31)^2}{(2\pi)^2}$ - - - -

* B.w for Baseband signal = max. freq.

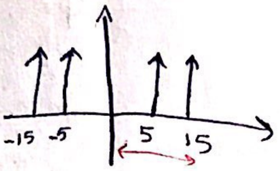
Ex



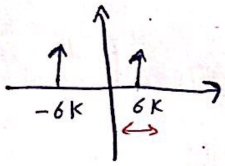
B.ω= 10KHz



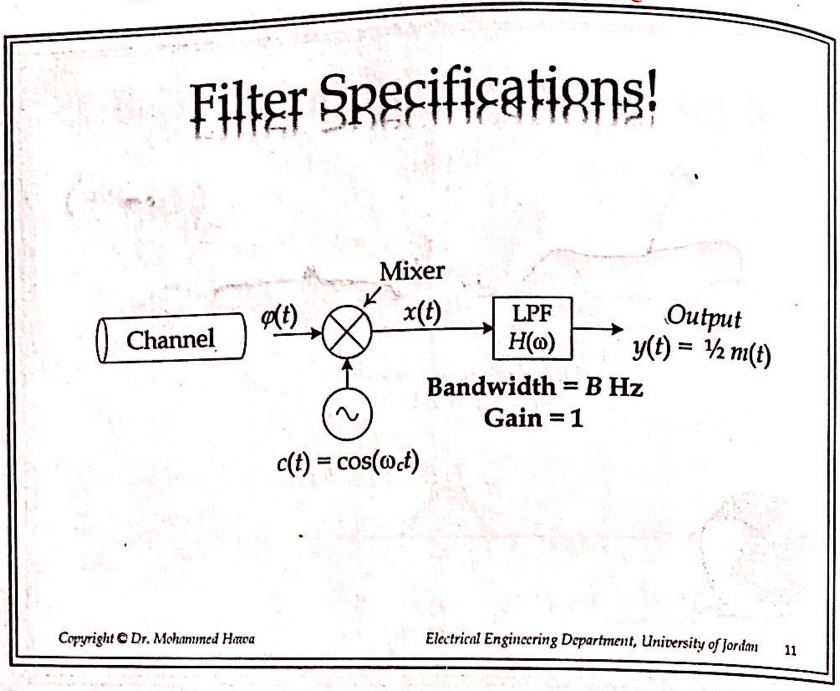
B.ω= 30K Hz



B.ω= 15 K Hz



B.ω= 6KHz



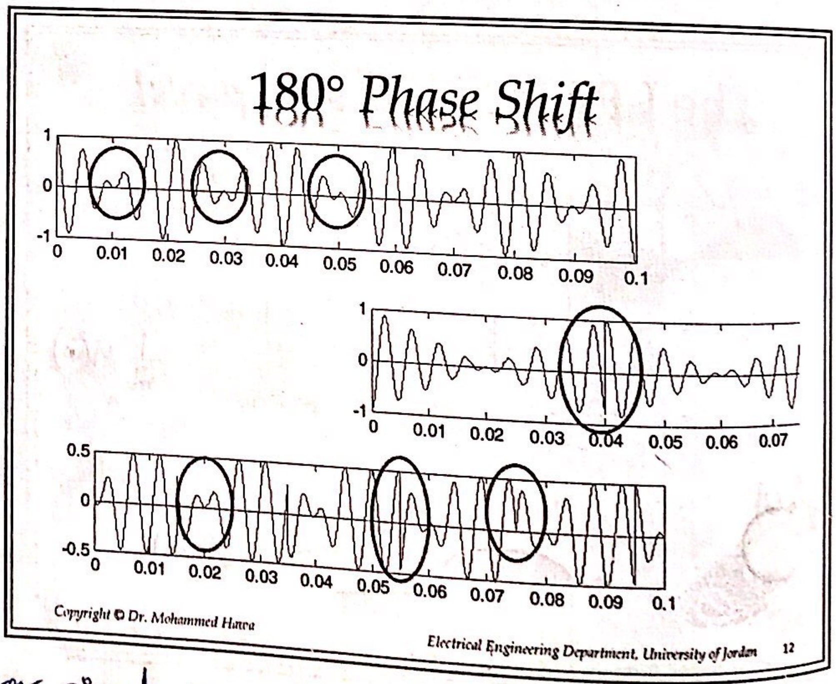
Filter Specifications!

Mixer

Channel → $\varphi(t)$ → ⊗ → $x(t)$ → LPF $H(\omega)$ → Output $y(t) = \frac{1}{2} m(t)$

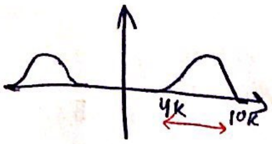
Bandwidth = B Hz
Gain = 1

$c(t) = \cos(\omega_c t)$

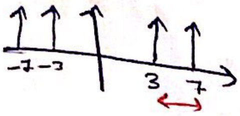


180° *Phase Shift*

* B.w for Carrier signal = $\omega_{max} - \omega_{min}$



B.ω = 6KHz



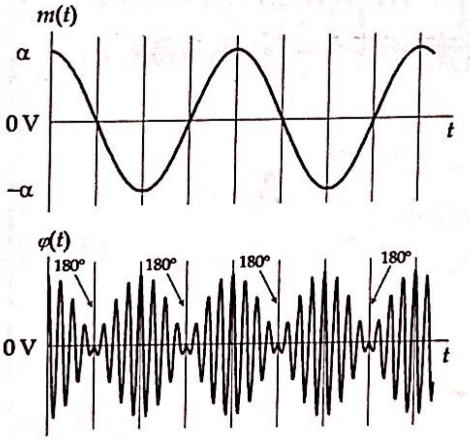
B.ω = 4KHz

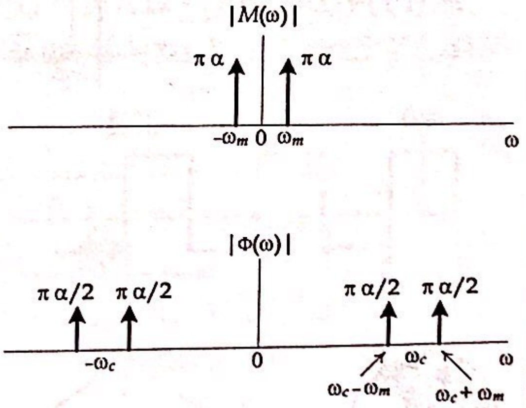
Example

- Assume we perform DSB-SC modulation for the baseband signal $m(t) = \alpha \cos(\omega_m t)$ [the case of tone modulation], where $\omega_c >> \omega_m$:
  - – Sketch the **time-domain** modulated signal $\varphi(t)$.
  - – Sketch the **Fourier transform** of the modulated signal $\Phi(\omega)$ [frequency domain].
  - – Find the **bandwidth** of $m(t)$ and $\varphi(t)$.
  - – Find the **average power** in both $m(t)$ and $\varphi(t)$.
  - – Show the demodulator hardware.
  - – Sketch $x(t)$ and $y(t)$ in the demodulator.

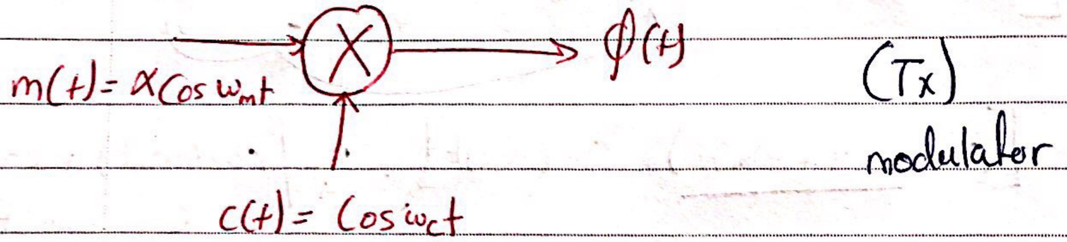
حل على الورقة ☆

Solution





*Lecture 4 ,, Example slide 13

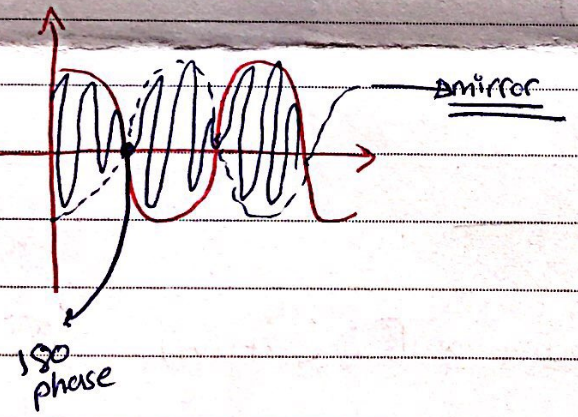


① time domain

$$\phi(t) = m(t).c(t) = \alpha \cos \omega_m t \ \cos \omega_c t$$

$$= \alpha \left[\frac{1}{2} \cos((\omega_m + \omega_c)t) + \frac{1}{2} \cos((\omega_m - \omega_c)t) \right]$$

$$= \frac{\alpha}{2} \cos(\omega_m + \omega_c)t + \frac{\alpha}{2} \cos(\omega_m - \omega_c)t$$



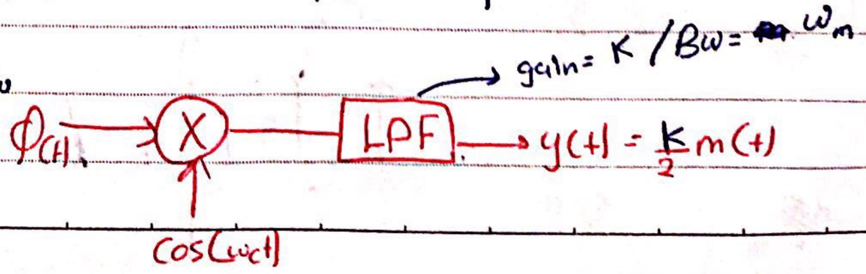
③ $B_{m(t)} = \omega_m$ rad/sec

$B_{\phi(t)} = 2 B_{m(t)} = 2\omega_m$ rad/sec

freq. من
اسهل اجيبه

④ $P_{av_{m(t)}} = \frac{\alpha^2}{2}$, $P_{av_{\phi(t)}} = \frac{\alpha^2}{4}$

⑤ شرحه لقدام

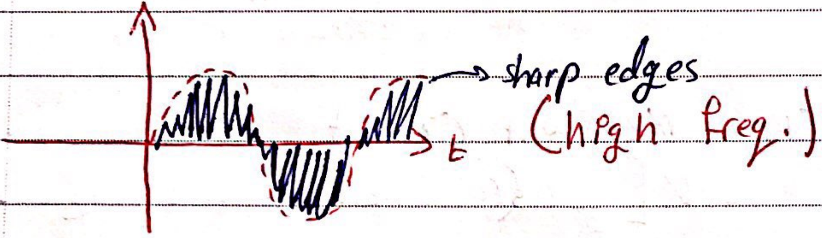


⑥ $x(t) = \phi(t)\cos(\omega_c t)$

$= \left[\frac{\alpha}{2}\cos((\omega_c+\omega_m)t) + \frac{\alpha}{2}\cos((\omega_m-\omega_c)t)\right]\cos\omega_c t$

$= \frac{\alpha}{4}\left[\cancel{\cos((2\omega_c+\omega_m)t)} + \cos(\omega_m)t\right] + \frac{\alpha}{4}\left[\cos(\omega_m t) + \cancel{\cos(\omega_m - 2\omega_c t)}\right]$

rejected by LPF ∵ high freq.



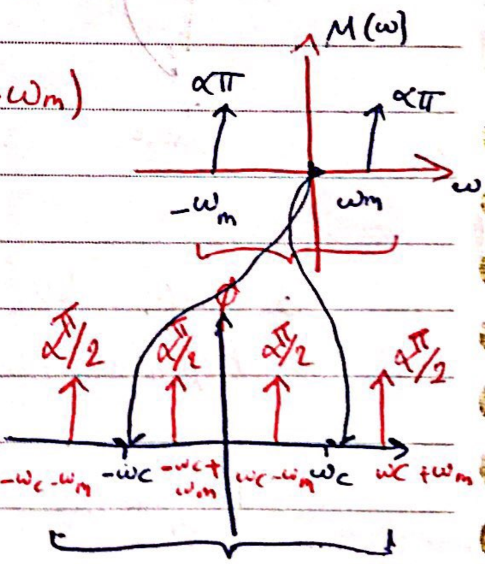
$y(t) = \frac{\alpha}{2}\cos(\omega_m t)$

$y(t) = \frac{1}{2}\, m(t)$

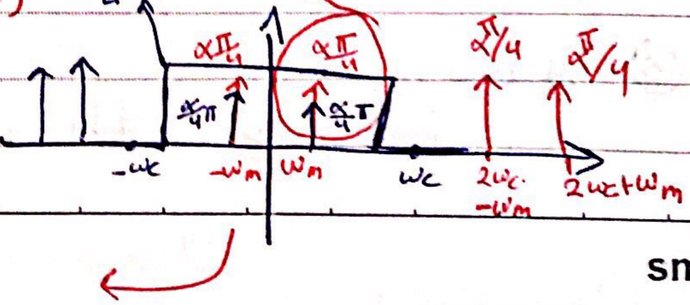
(*) freq. domain:

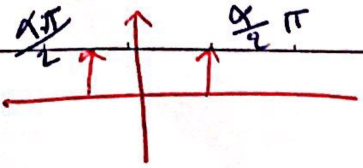
$M(\omega) = \alpha\pi\,\delta(\omega-\omega_m) + \alpha\pi\,\delta(\omega+\omega_m)$

$\phi(\omega) = \frac{1}{2\pi}|M(\omega)| * |C(\omega)|$



$X(\omega) = \frac{1}{2\pi}\phi(\omega) * C(\omega)$



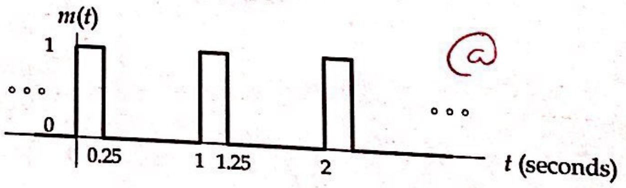


Homework

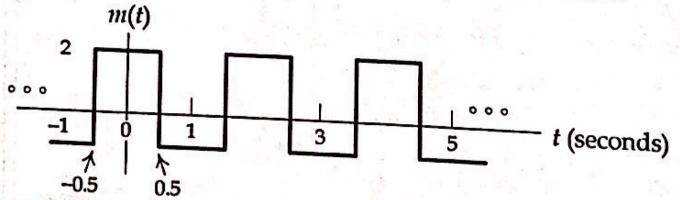
- For the following signals $m(t)$, sketch:
  - – The modulated signal $\varphi(t)$ at the modulator
  - – The Fourier transform $\Phi(\omega)$
  - – The signals $x(t)$ and $y(t)$ at the demodulator
  - – The Fourier transform $X(\omega)$ and $Y(\omega)$
- Find the average power and bandwidth for the signals $\varphi(t)$ and $y(t)$.
- Are there any phase shifts in $\varphi(t)$? If so, where?
- Determine the DC value in $m(t)$, $\varphi(t)$ and $y(t)$.

* اكل على الورقة

Homework

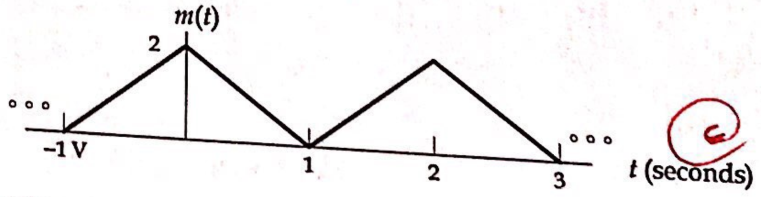


ⓐ



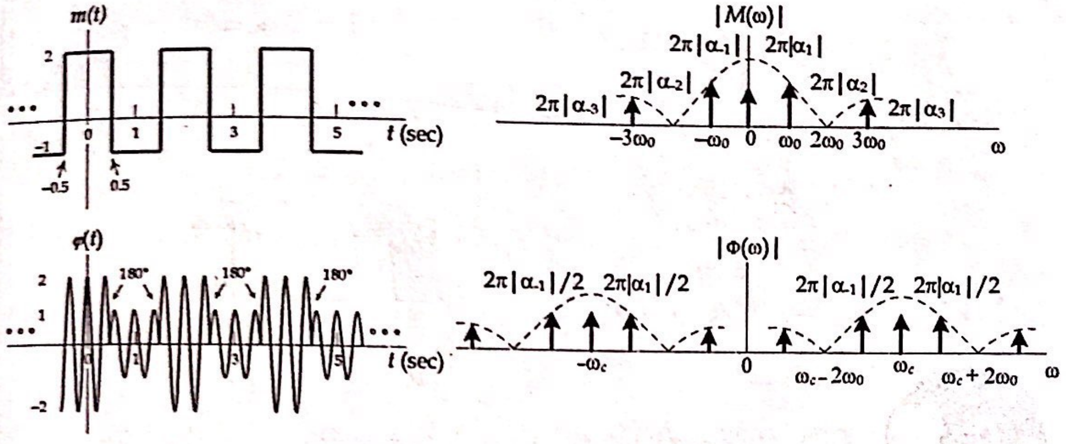
ⓑ A = 3

[illegible]



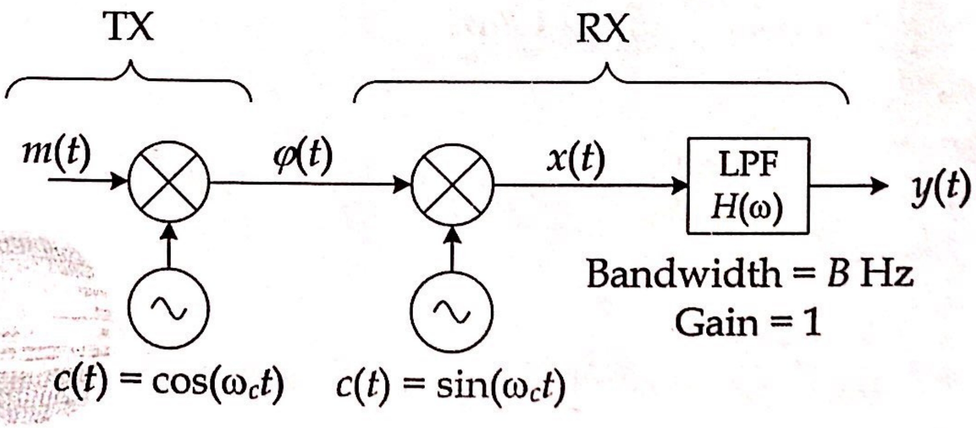
ⓒ

Solution: Part(b)



Homework

- For the following circuit, sketch $x(t)$ and $y(t)$, along with the Fourier transform $X(\omega)$ and $Y(\omega)$.



TX

RX

$m(t)$

$\varphi(t)$

$x(t)$

LPF
$H(\omega)$

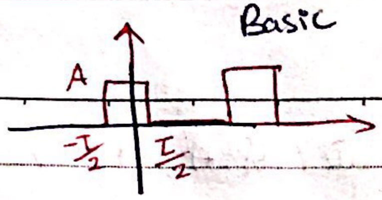
$y(t)$

Bandwidth = B Hz
Gain = 1

$c(t) = \cos(\omega_c t)$

$c(t) = \sin(\omega_c t)$

No.



Homework slide 15

ⓐ $m(t) = rep_T\{A\ rect(t/\tau)\}$

بشكل عام

period ← $T = 1$, $\tau = 0.25$, $A = 1$ (magnitude)

width pulse

*الي عملنا عليه shift

$m(t) = rep_T\{rect\left(\frac{t - 0.125}{\tau}\right)$

ⓑ $m(t) = rep_T\{\underset{\text{magnitude}}{3}\ rect\left(\frac{t}{1}\right)\} - \underset{\text{shift}}{1}$

$T = 2$

A طلع

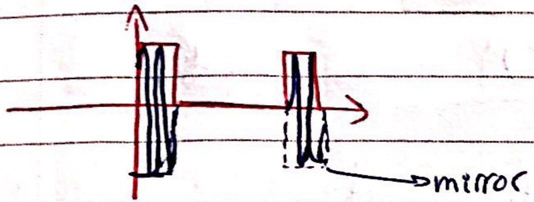
$P_{avg} = \overline{m(t)^2} = \frac{1}{T}\int_T m^2(t).dt$

$= \frac{1}{1}\int_0^{0.25} 1^2 .dt = 0.25$ W

$DC = \overline{m(t)} = \frac{1}{\cancel{T}_{1}}\int_{T \to 0-0.25} \overset{1}{\cancel{m(t)}}.dt = 0.25$ V

No.

① $\phi(t) = m(t)\cos(\omega_c t)$



* no phase shift

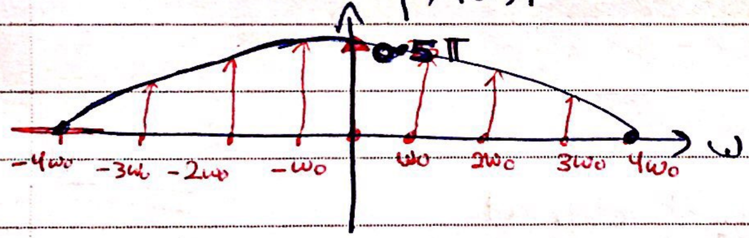
$P_{\phi(t)} = \frac{1}{2} P_{m(t)} = 0.125\ W$

② $\phi(\omega) = \frac{1}{2}|M(\omega-\omega_c)| + \frac{1}{2}|M(\omega+\omega_c)|$ 1

table fourier transform $\Leftarrow$ $M(\omega) = \underbrace{\sum_{n=-\infty}^{\infty} 2\pi \frac{\overset{1}{\cancel{A}}\overset{0.25}{\cancel{\tau}}}{\cancel{T}_1} \operatorname{sinc}\left(\frac{n\omega_0\tau}{2\pi}\right)\delta(\omega-n\omega_0)}_{\text{magnitude}} e^{j\omega_0 \cancel{0.125}}$

مقدار الشفت

$|M(\omega)|$



$\omega_0 = \frac{2\pi}{T}$

$\omega_0 = 2\pi$ rad/sec

$\delta(\omega - n\omega_0) \longrightarrow$ impulses @ $n\omega_0$

@ $n=0 \Rightarrow 0.25\pi = 2\pi\alpha_0$

$DC = \alpha_0 \doteq 0.25$

@ first null

$\operatorname{sinc}\left(\frac{n\overset{2\pi}{\cancel{\omega_0}}\overset{0.25}{\cancel{\tau}}}{2\pi}\right)$

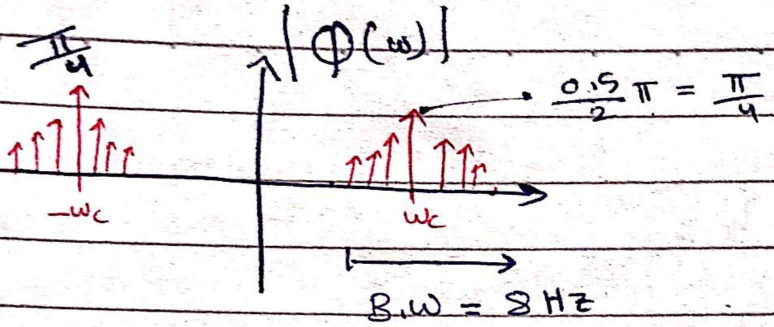
كم n مشان يكونا واحد

$\boxed{n=4}$

$B.\omega = 4\omega_0 = 8\pi$ rad/sec

$= 4$ Hz

Scanned with CamScanner



H.W
slide 15

$$P_{avg}\,\phi(\omega) = \overline{\left(m(t)\cdot\cos(\omega_c t)\right)^2}$$

$$= m(t)^2 \cdot \cos(\omega_c t)^2$$

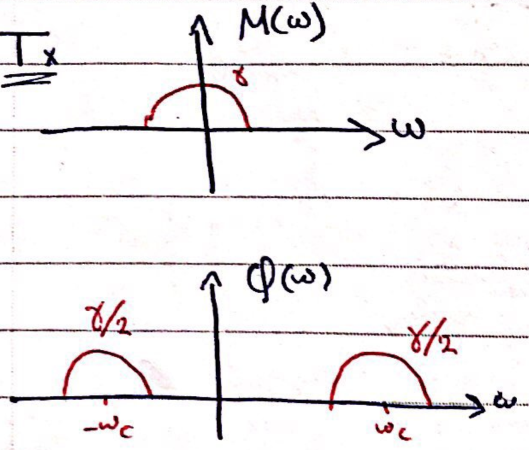
$$= \overline{\frac{1}{2}\, m^2(t)} + \overline{\frac{1}{2}\,\cancel{\cos(2\omega_c t)}}$$

zero

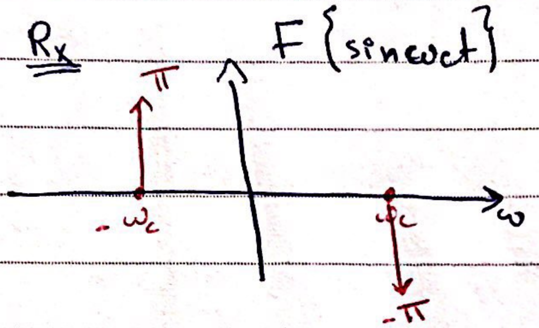
$$= \frac{1}{2}\, P_{av}\,(m(t) = 0.125\,W$$

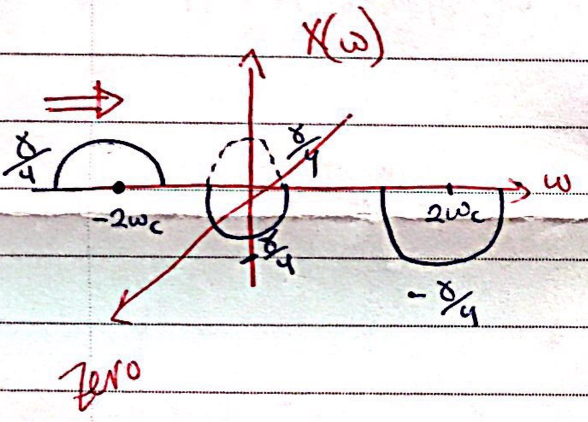
* Homework slide 18 Lec 4

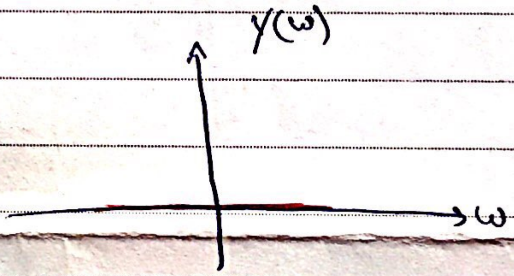
Tx



Rx







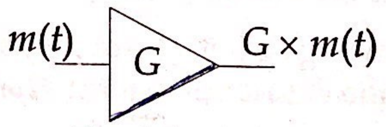
لانه LPF رح يلغي
اللي على الاطراف !!

multiplier

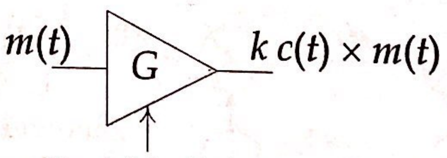
How to build a Mixer?

- Variable Gain Amplifier
  - The basic design.
- Gilbert Cell (e.g., MC 1496)
  - Popular (used in Integrated Circuits).
  - Uses variable gain differential amplifiers.
- Switching Modulator
  - Uses diodes.
  - Cheaper design (was popular before ICs).

Variable Gain Amplifier

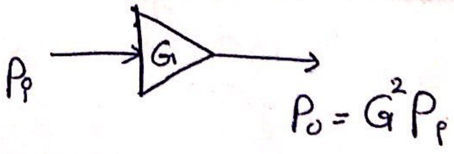


Fixed Gain

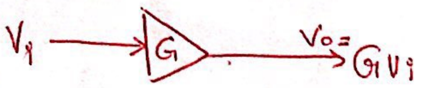


Variable Gain

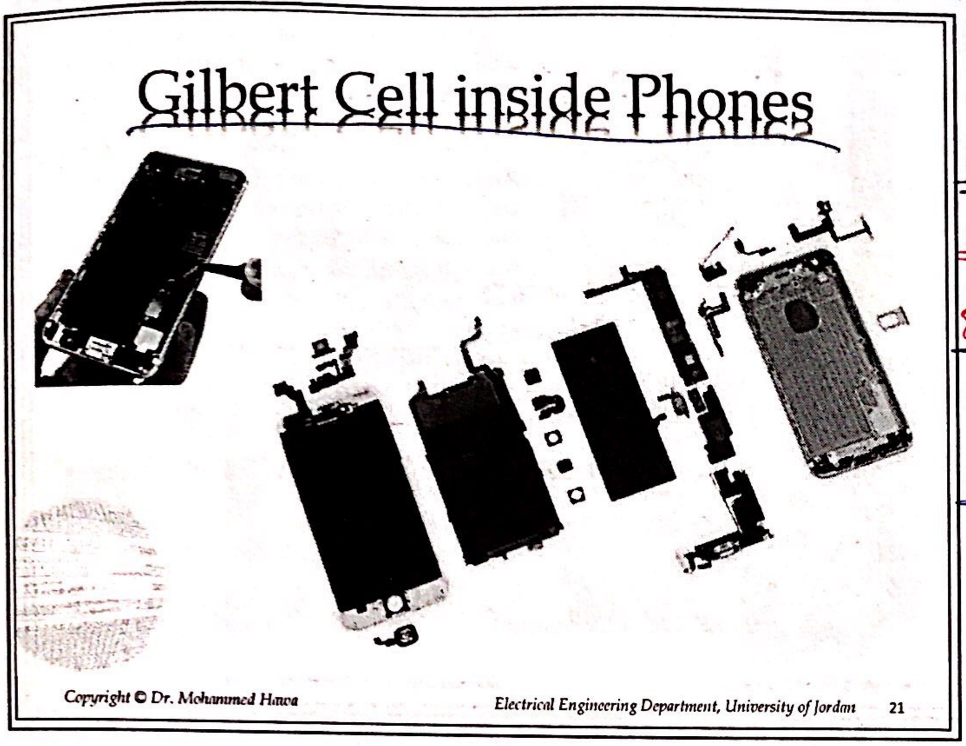
$G = \boxed{k\,c(t)} \rightarrow$ in general



$P_o = G^2 P_i$



$V_o = G V_i$



Gilbert Cell inside Phones

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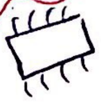
حفظاً

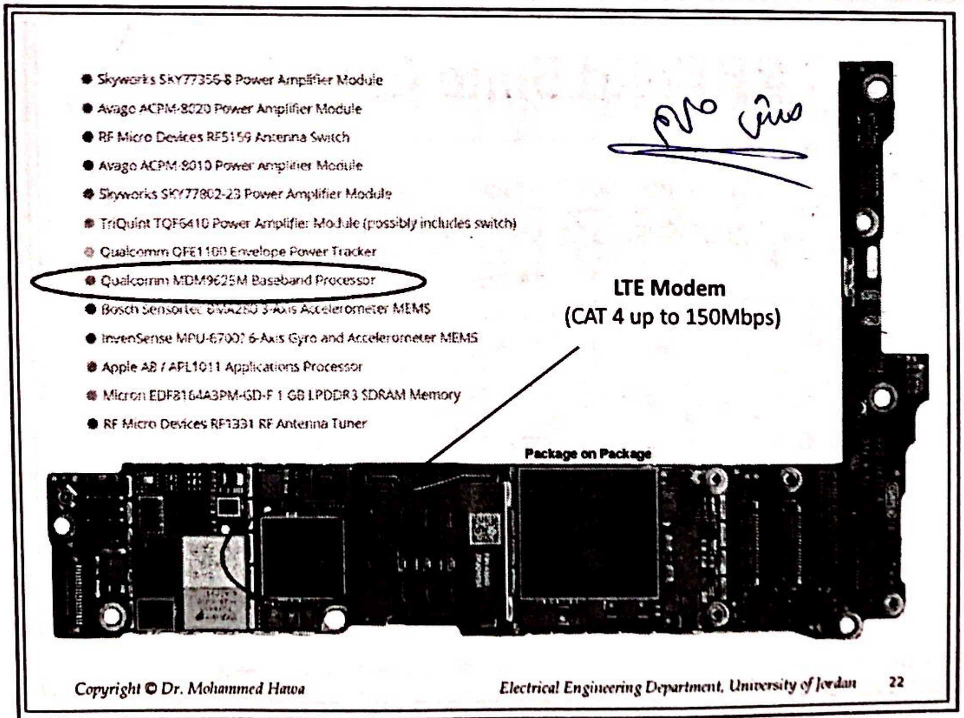
Notes



Ic

⇒ e.g: MC1496

⇒ it is built using 8 transistors configured as 3 different amplifier



- Skyworks SKY77356-8 Power Amplifier Module
- Avago ACPM-8020 Power Amplifier Module
- RF Micro Devices RF5159 Antenna Switch
- Avago ACPM-8010 Power Amplifier Module
- Skyworks SKY77802-23 Power Amplifier Module
- TriQuint TQF6410 Power Amplifier Module (possibly includes switch)
- Qualcomm QFE1100 Envelope Power Tracker
- Qualcomm MDM9625M Baseband Processor
- Bosch Sensortec BMA280 3-Axis Accelerometer MEMS
- InvenSense MPU-6700 6-Axis Gyro and Accelerometer MEMS
- Apple A8 / APL1011 Applications Processor
- Micron EDF8164A3PM-GD-F 1 GB LPDDR3 SDRAM Memory
- RF Micro Devices RF1331 RF Antenna Tuner

مش مهم

LTE Modem
(CAT 4 up to 150Mbps)

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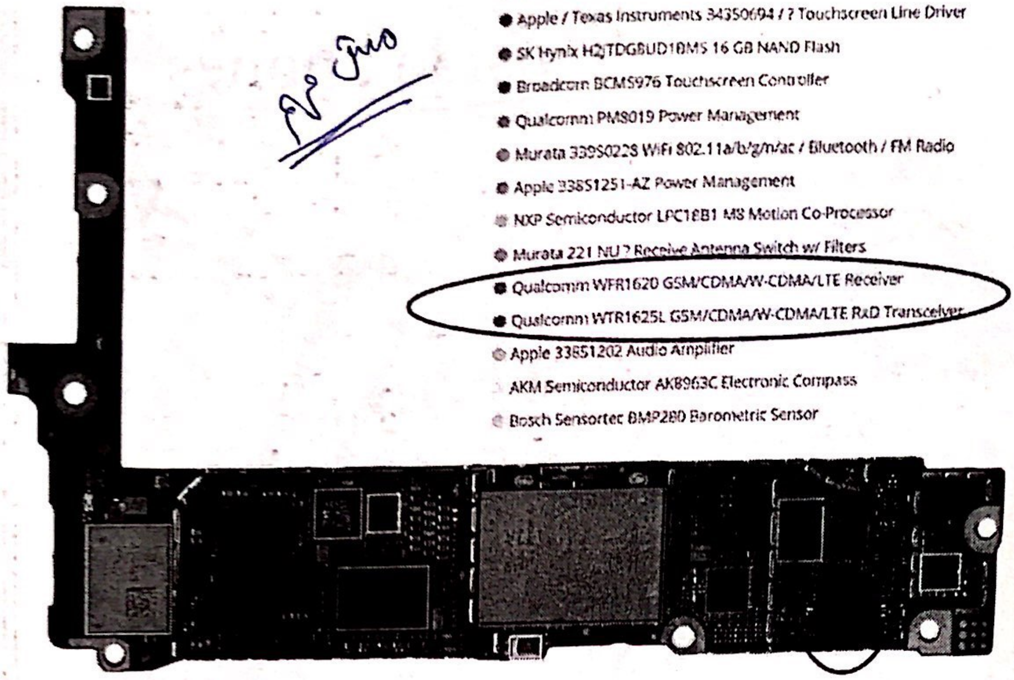
* LTE Modem: modulator / demodulater

long term evolution

(4 G Cellular)

مش مهم

- ● NXP Semiconductor PN548 NFC Controller w/ Secure Element Chip
- ● Apple / Texas Instruments 343S0694 / ? Touchscreen Line Driver
- ● SK Hynix H2JTDG8UD1BMS 16 GB NAND Flash
- ● Broadcom BCM5976 Touchscreen Controller
- ● Qualcomm PM8019 Power Management
- ● Murata 339S0228 WiFi 802.11a/b/g/n/ac / Bluetooth / FM Radio
- ● Apple 338S1251-AZ Power Management
- ● NXP Semiconductor LPC18B1 M8 Motion Co-Processor
- ● Murata 221 NU ? Receive Antenna Switch w/ Filters
- ● Qualcomm WFR1620 GSM/CDMA/W-CDMA/LTE Receiver
- ● Qualcomm WTR1625L GSM/CDMA/W-CDMA/LTE RxD Transceiver
- ● Apple 338S1202 Audio Amplifier
- ● AKM Semiconductor AK8963C Electronic Compass
- ● Bosch Sensortec BMP280 Barometric Sensor



RF Solid State Circuits

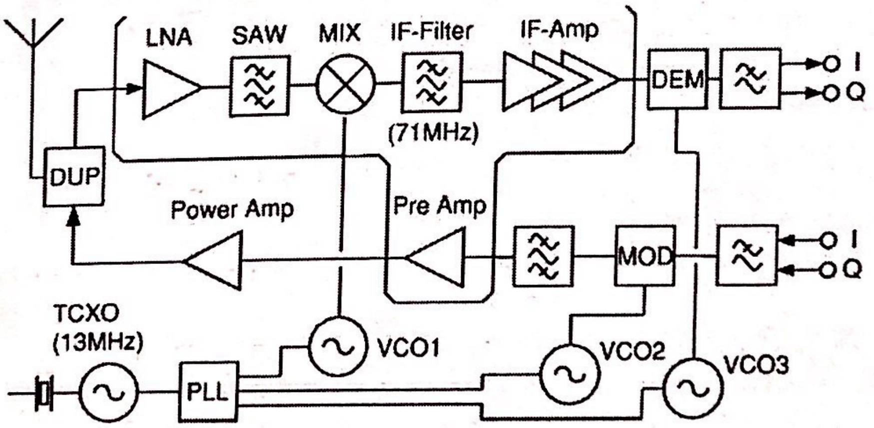


Fig. 1. Transceiver block diagram: single-IF superhet receiver, direct up-conversion transmitter.

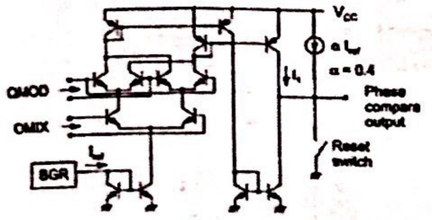


Fig. 8. Phase comparator.

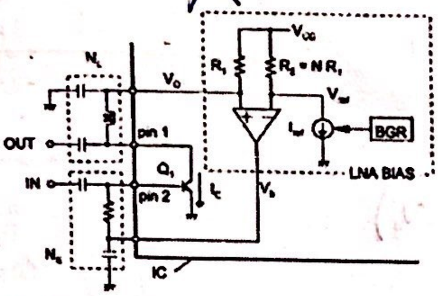


Fig. 9. LNA and active bias.

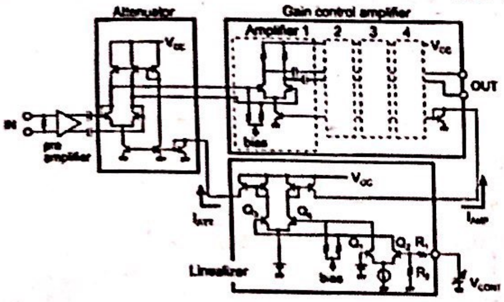
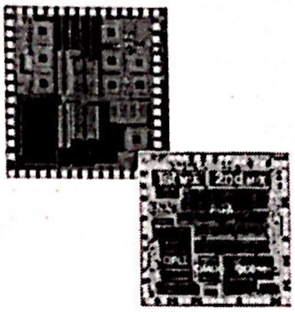
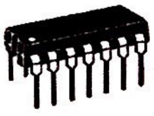


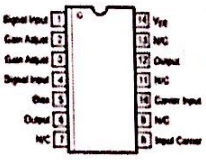
Fig. 10. PGA.

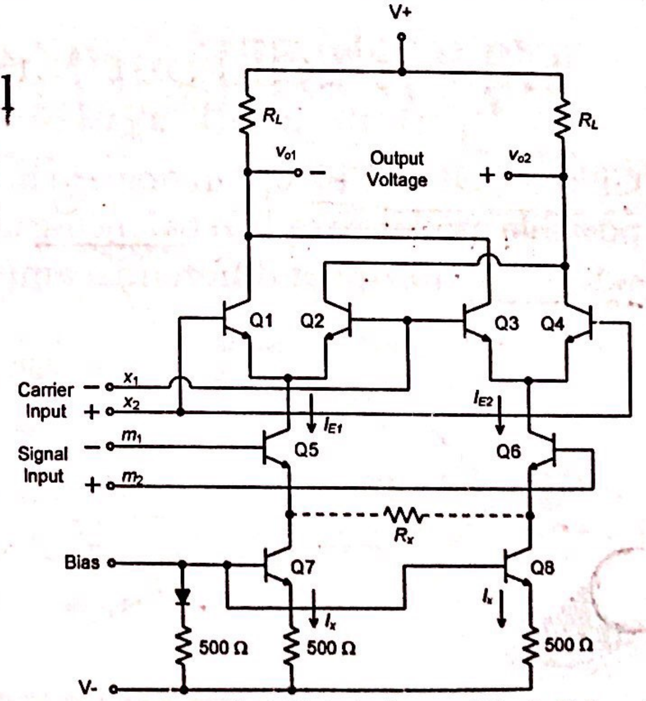


* الرسمة مش حفظ بس لازم نعرف انه بتكون من 8 transistor.

Gilbert Cell (MC1496) Schematic







مش مهم

Note

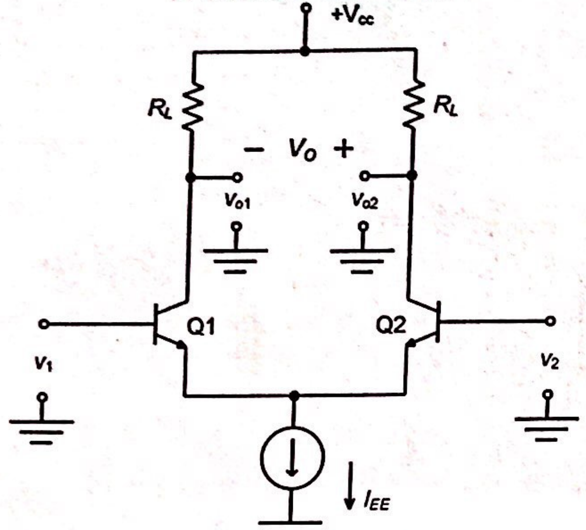
* الرسمة مش حفظ

$$* \; V_o = V_{o2} - V_{o1}$$

$$= -\frac{I_{EE} R_L}{2 V_T}(v_2 - v_1)$$

Differential Amplifier

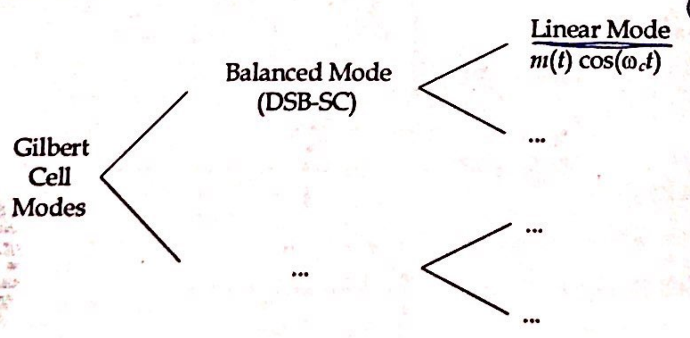
(Differential Pair)



* فقط مطلوب حفظ انه ال 4 modes ..

Gilbert Cell Four Modes

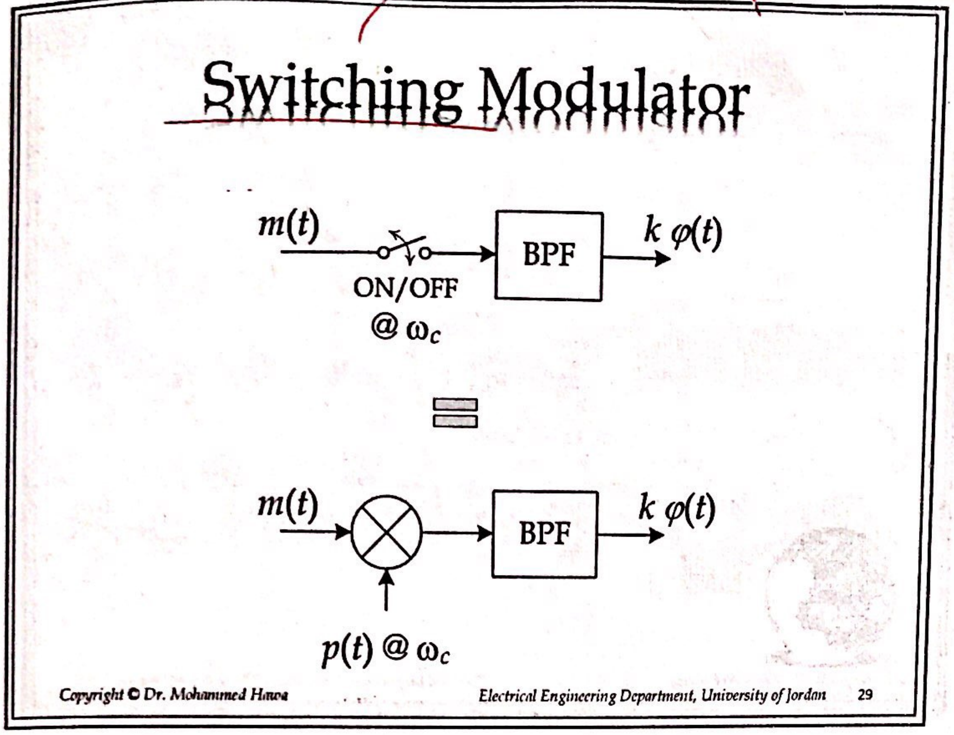
- Gilbert Cell (MC1496) can operate ① in one of four possible modes based on balancing and/or ② saturating the upper differential amplifiers.



* To work as DSB-SC it has to be in Balanced & linear mode

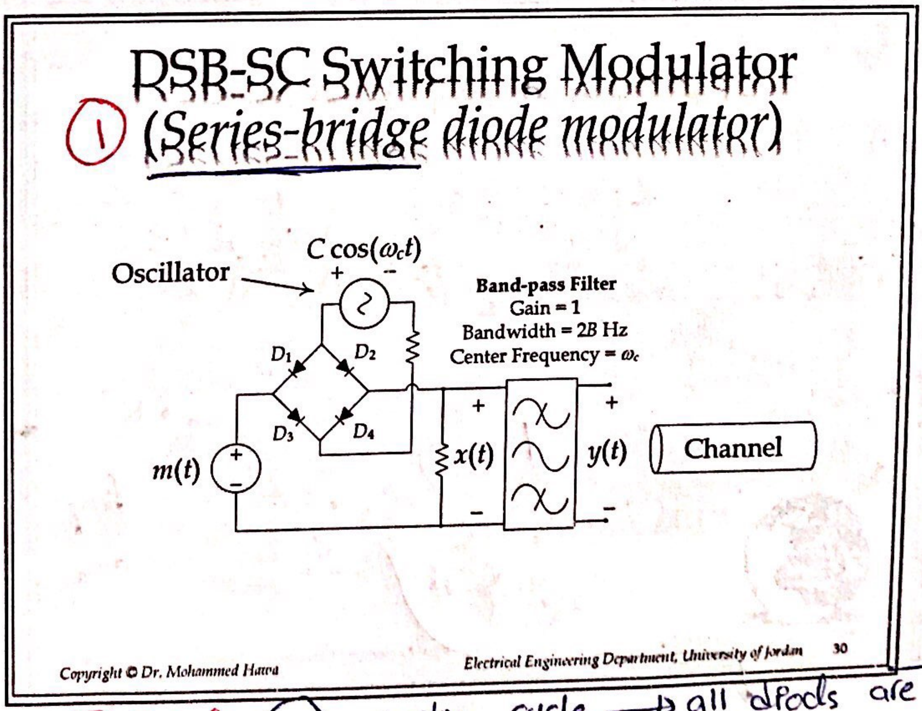
مهم

→ multiplication with pulses



Switching Modulator

* بكون موج. ع شكل ٣ أنواع



DSB-SC Switching Modulator

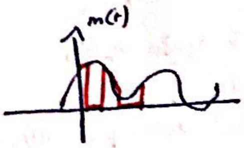
① (Series-bridge diode modulator)

$f = \frac{1}{t_c}$

$x(t) = \underbrace{m(t), 0, m(t)}$ - - - - - -

مرة بتاخذ قيمة m(t)

مرة صفر



* In cos ⌒(+) positive cycle → all diodes are ON
→ $x(t) = m(t)$

$C > 1.4$ V ← 0.7 + 0.7

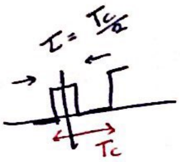
2 diode

⌒(−) −ve cycle → all diodes are OFF
→ $x(t) = 0$

2/1

* rect func.

$BW = \frac{1}{\tau} Hz = \frac{2\pi}{\tau}$ rad/sec



rect fun:

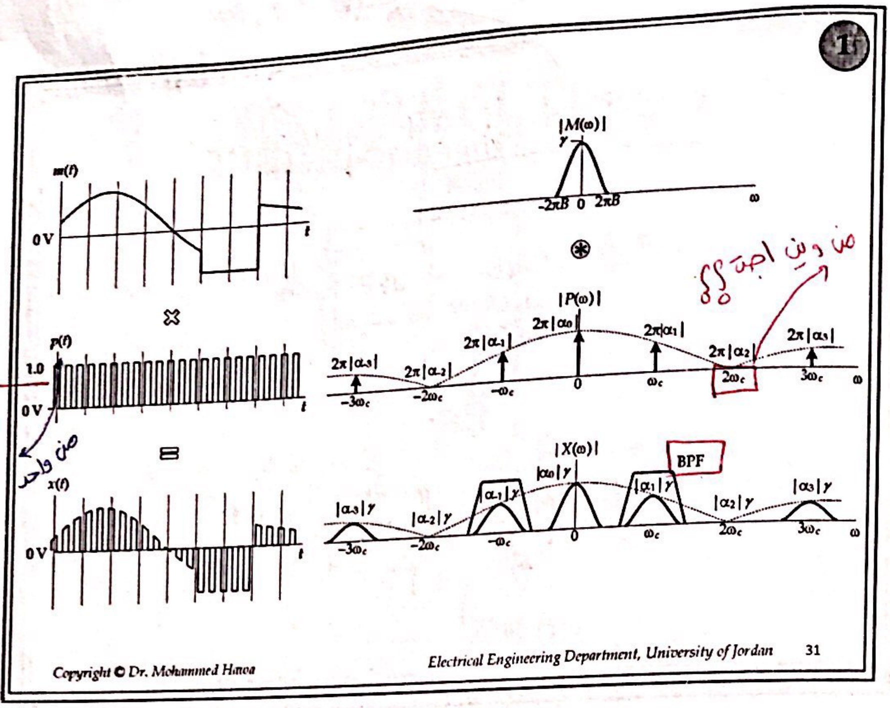
$BW = \frac{1}{\tau} = \frac{2}{T_c}$

$= 2f_c$ Hz

$= \underset{\sim}{2\pi}(2\underline{f_c})$ rad/s

$BW = 2\omega_c$

↳ first null



من وين اجت؟؟

من واحد

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*BW for LPF = $4\pi B$

↳ $M(\omega)$ نجيبو من

* if gain for BPF $= 1$

↳ $y(t) = 2|\alpha_1|\, m(t) \cos(\omega_c t)$

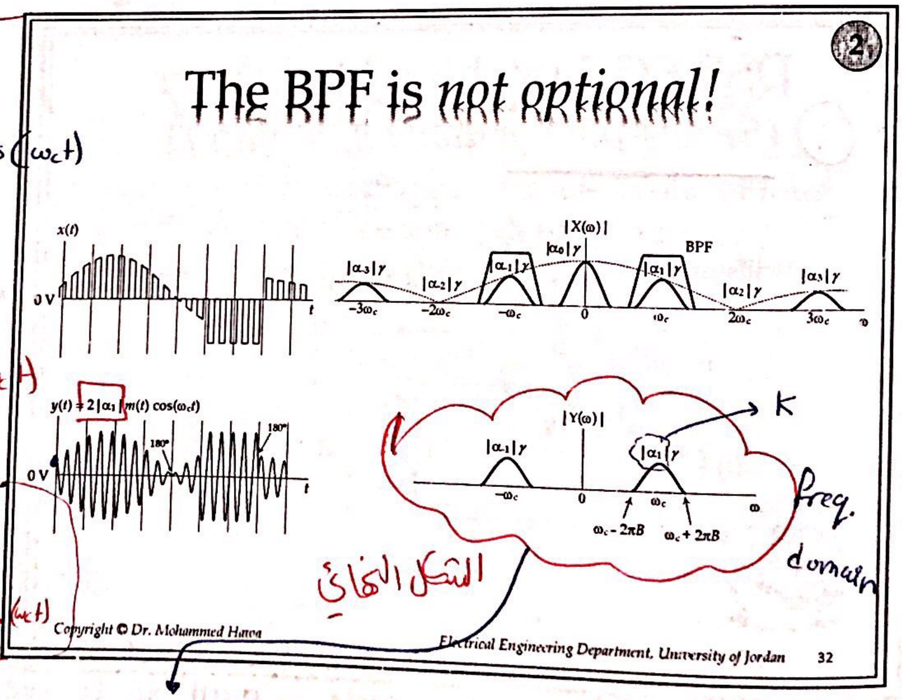
* if gain for BPF $= \boxed{z}$

↳ $y(t) = m(t) \cos(\omega_c t)$

$z = \frac{1}{2\alpha_1}$

* if gain $= \alpha_1$

↳ $y(t) = 2|\alpha_1|^2 m(t) \cos(\omega_c t)$



The BPF is not optional!

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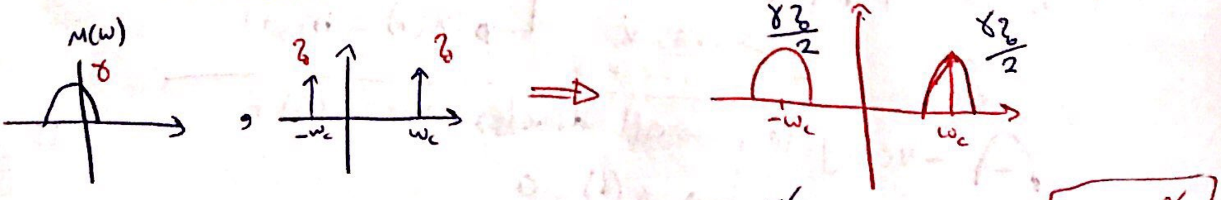
* time domain



$\frac{\cancel{\gamma} z}{2} = \alpha_1 \cancel{\gamma}$ $\boxed{z = 2\alpha_1}$

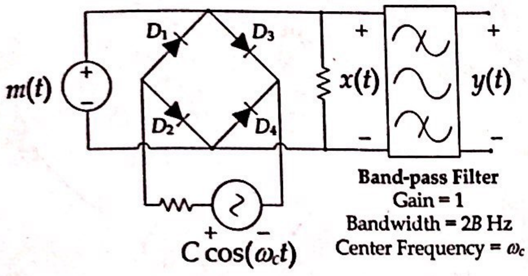
* (+) +ve cycle → all diodes are on → S.C ⇒ X(t) = 0

* (−) −ve cycle → 〃 〃 〃 OFF → x(t) = m(t) 2/15/2017

$$x(t) = \underbrace{\overset{Tc/2}{0}, \overset{Tc/2}{m(t)}}_{Tc}, 0, m(t) - - - -.$$

* زي اللي قبل
بس rect fun
محول الـ shift
مقدارو τ

DSB-SC Switching Modulator
(Shunt-bridge diode modulator)



Band-pass Filter
Gain = 1
Bandwidth = 2B Hz
Center Frequency = ω_c

C > 1.4

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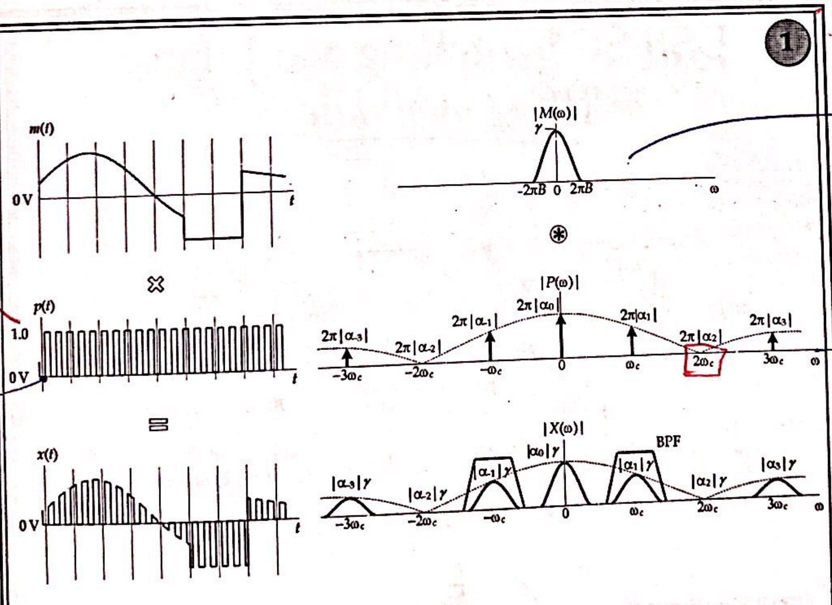

بتبلش من zero

Hz
$B.\omega = B$ ~~rad/sec~~
$= 2\pi B$ rad/sec

$B\omega = \frac{1}{\tau}$ (first null)
$= \frac{1}{Tc/2} = \frac{2}{T_c}$
$= 2f_c$ Hz
$= 2\pi(2f_c)$ rad/sec

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* الـ rect بالـ time domain ← يقابلها بالـ freq. domain على شكل pulses بـ sinc

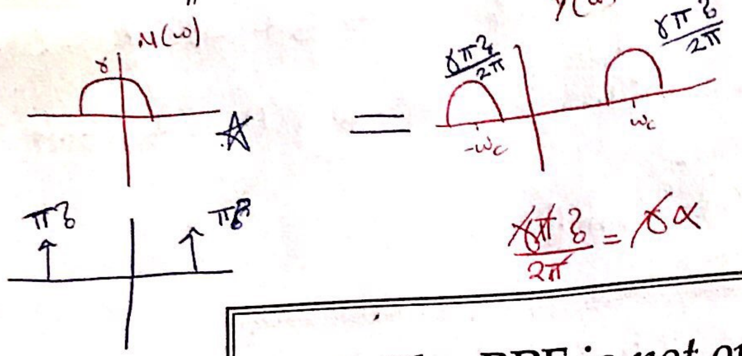
$B.\omega = \boxed{2\omega_c}$

$\boxed{\omega_0 = \omega_c}$

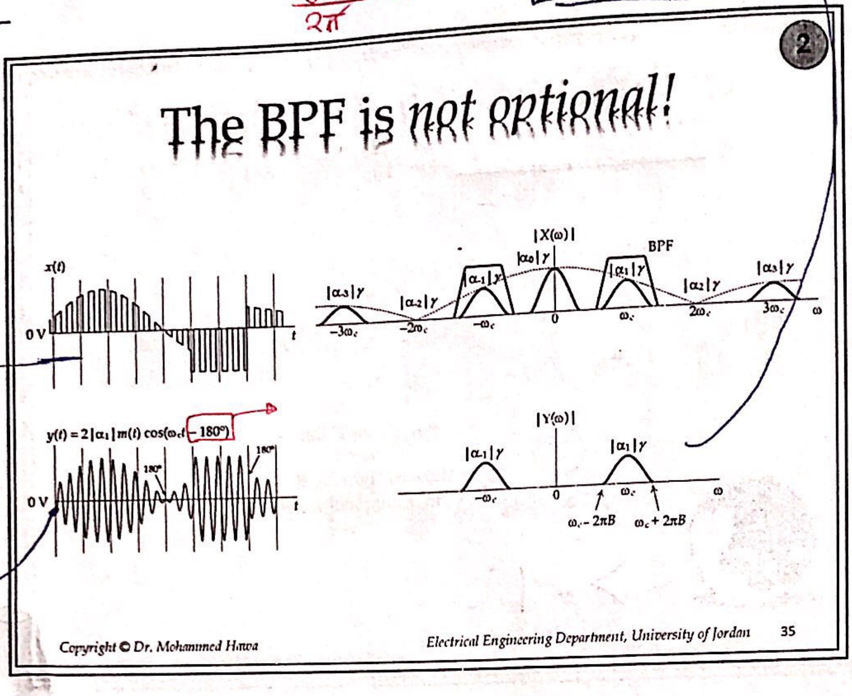
fundemental freq.

character? gnized for a st-

2/15/



$\frac{\cancel{\gamma}\pi z}{2\cancel{\pi}} = \cancel{\gamma}\alpha$ $\boxed{2\alpha = z}$



The BPF is *not optional!*

$y(t) = 2|\alpha_1|\, m(t) \cos(\omega_c t \boxed{-180^\circ})$

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shifted

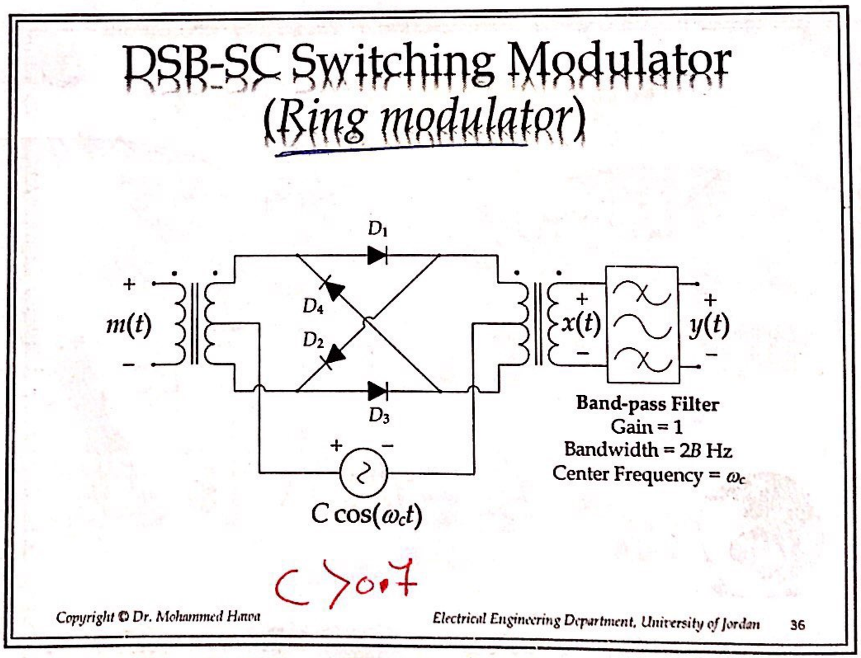
$* \cos(\omega_c t - 180)$

$= -\cos(\omega_c t)$

لو ، اول

mirror لـ

X axis



DSB-SC Switching Modulator
(Ring modulator)

Band-pass Filter
Gain = 1
Bandwidth = 2B Hz
Center Frequency = ω_c

$C > 0.7$

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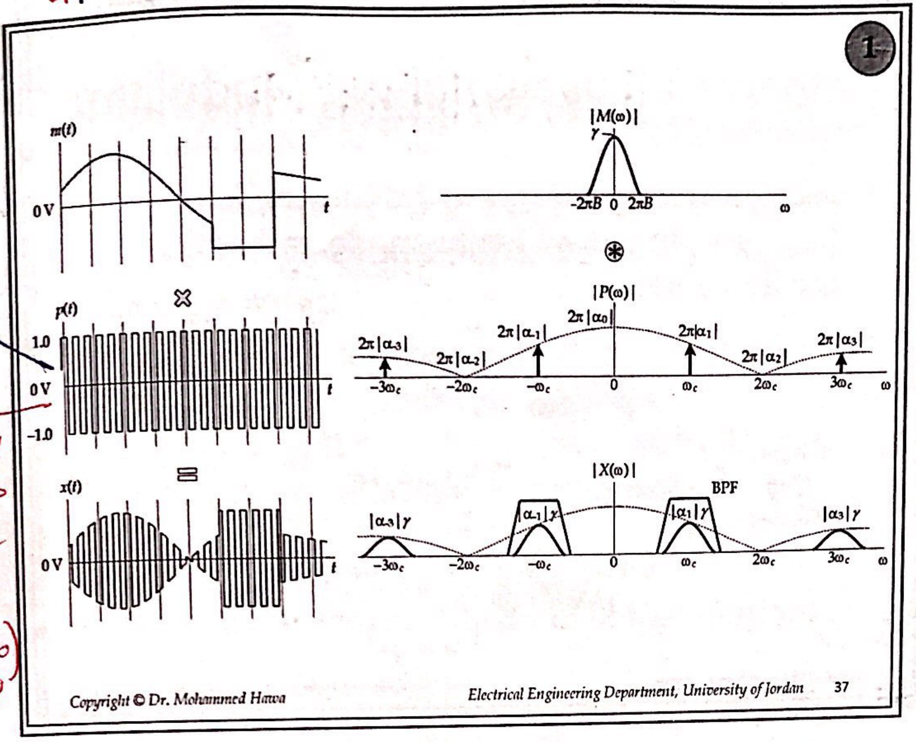
(+) +ve cycle ⇒ D_1 & D_3 ON ⇒ $x(t) = m(t)$

(−) −ve cycle ⇒ D_2 & D_4 ON ⇒ $x(t) = -m(t)$

$* \quad x(t) = \overbrace{m(t), -m(t)}^{T_c}, m(t), -m(t) \;- - - -$

$\underleftrightarrow{T_c/2} \quad \underleftrightarrow{T_c/2}$

Tc/2



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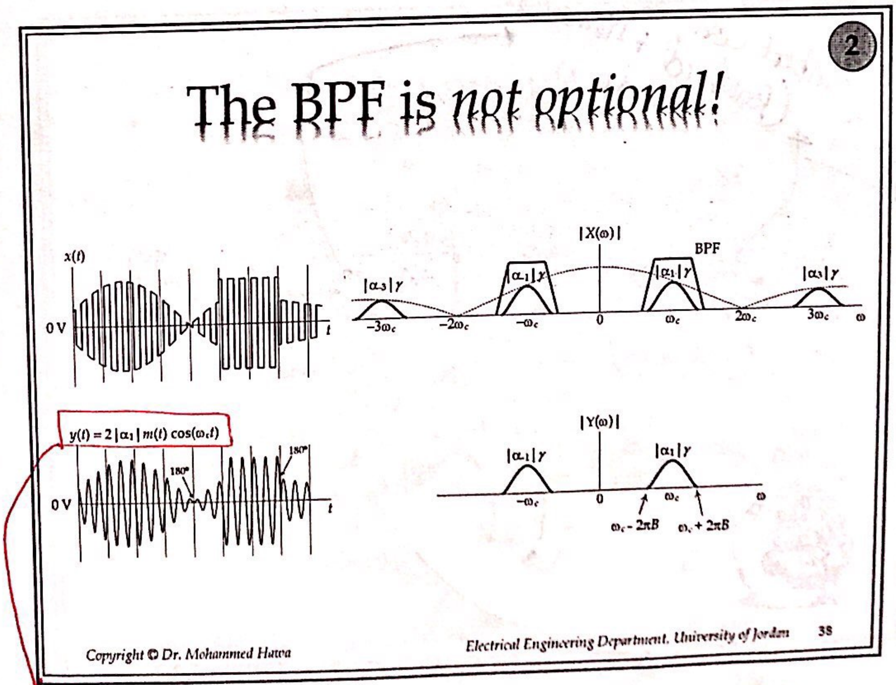
there is No DC Value

(مساحة الي فوق = الي تحت)



The BPF is *not optional!*

$y(t) = 2|\alpha_1|\, m(t) \cos(\omega_c t)$

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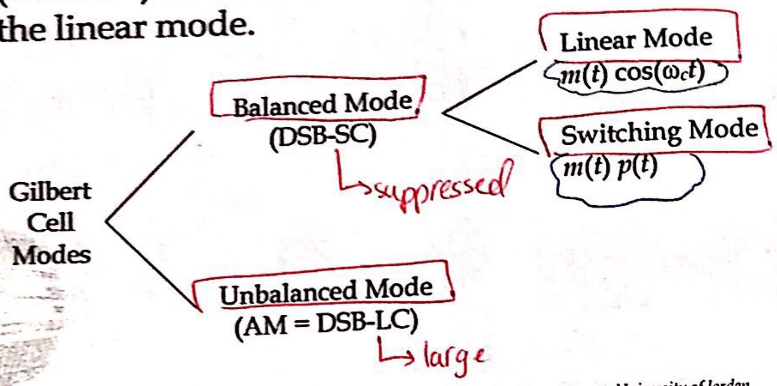
if gain = 1

if gain = k $\longrightarrow$ $y(t) = K\, 2|\alpha_1|\, m(t) \cos(\omega_c t)$

Gilbert Cell as Switching Modulator

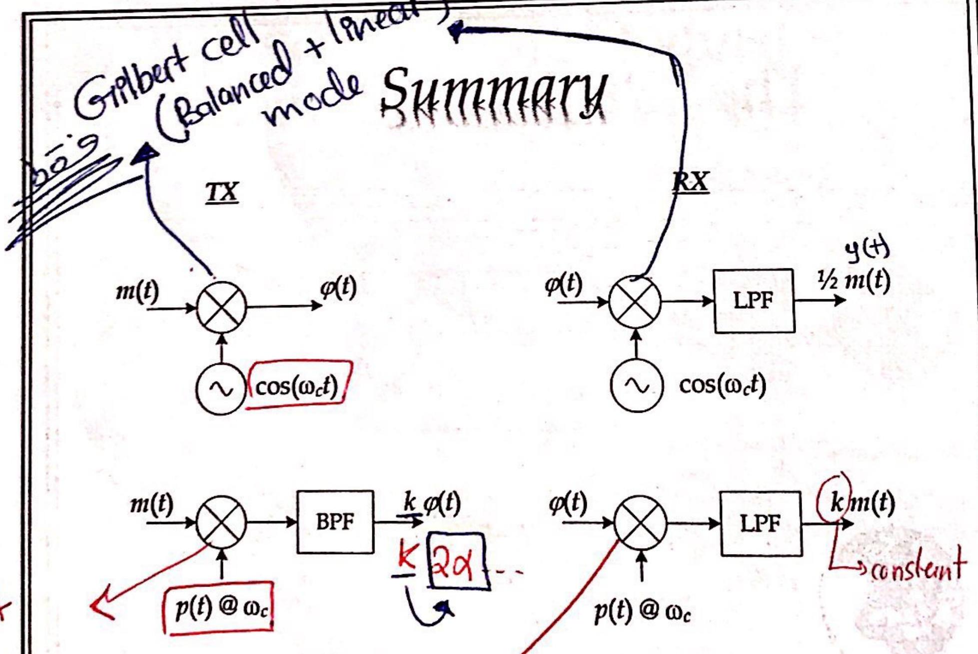
- It is recommended to use the Gilbert Cell (MC1496) in the switching mode, rather than the linear mode.

حفظ ال modes



ما بقدر اسوي mixing
احط نوع عـ Tx ونوع عـ Rx

Summary



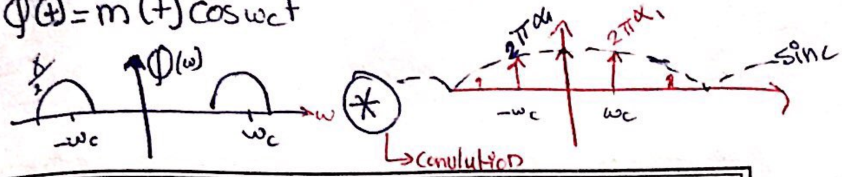
* Gilbert cell (Balanced + switching mode)

OR

* switching modulater (shunt, ring, series)

R_x

$\phi(t) = m(t) \cos \omega_c t$



Homework

- If we use a switching demodulator (say a series-bridge diode demodulator), answer the following: LPF

1 – What are the specifications of the filter? LPF

2 – What is the value of *k* in the output $y(t) = k\, m(t)$ if the input is $\varphi(t) = m(t) \cos(\omega_c t)$

3 – What is the value of *k* in the output $y(t) = k\, m(t)$ if the input is $\varphi(t) = 2\,|\alpha_1|\, m(t) \cos(\omega_c t)$, $\gamma/2$

4 – Sketch the Fourier transform of the solution.

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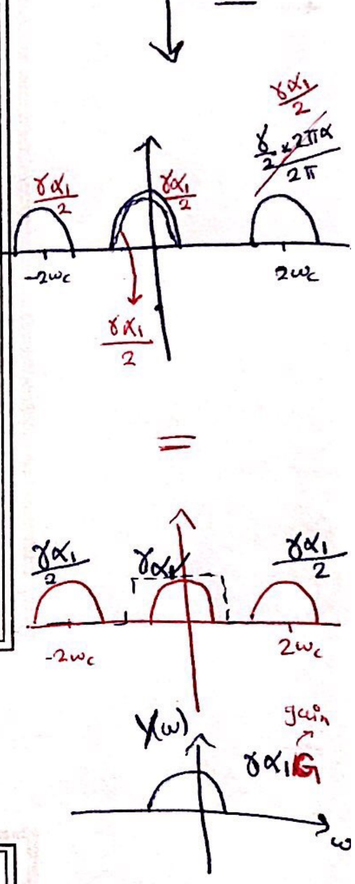
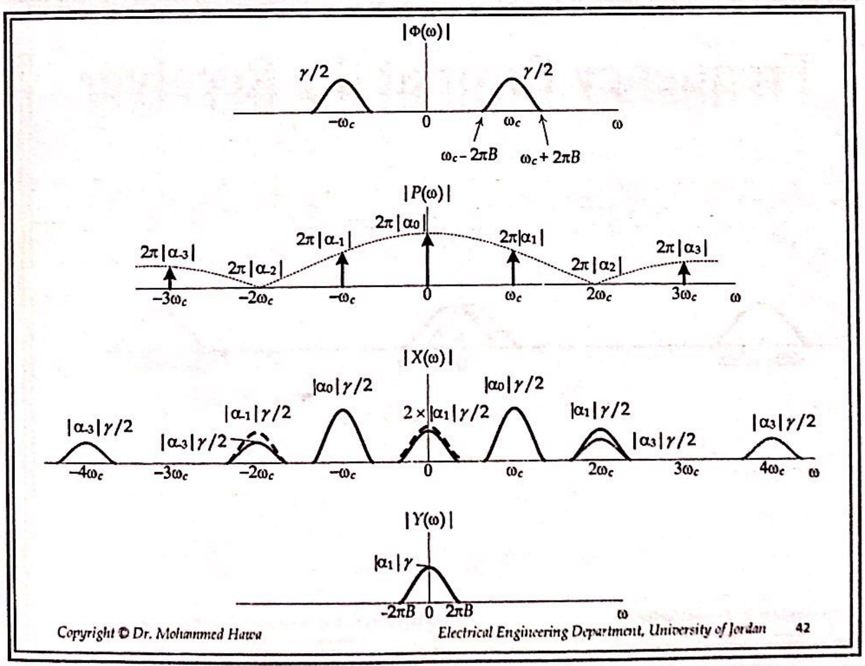


*LPF: gain = G (gain filter)

BW = B Hz = 2πB

centre freq = zero



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$\boxed{2}$ $y(t) = K m(t)$

$|y(\omega)| = K|M(\omega)|$

$\cancel{\gamma}|\alpha_1| G = K \cdot \cancel{\gamma}$ → magnitude $M(\omega)$

constant ← $\boxed{K = \alpha_1 G}$ → gain filter

$\boxed{3}$ $\phi(\omega) = \frac{\gamma * \cancel{2\pi}\, \alpha_1}{\cancel{2\pi}}$

$= \gamma\alpha_1$

↳ $y(\omega) = G\, 2\, \gamma\, |\alpha_1|^2$

[illegible] *

$y(\omega) = K\, M(\omega)$

$G\, 2\, \gamma\, |\alpha_1|^2 = K\gamma$

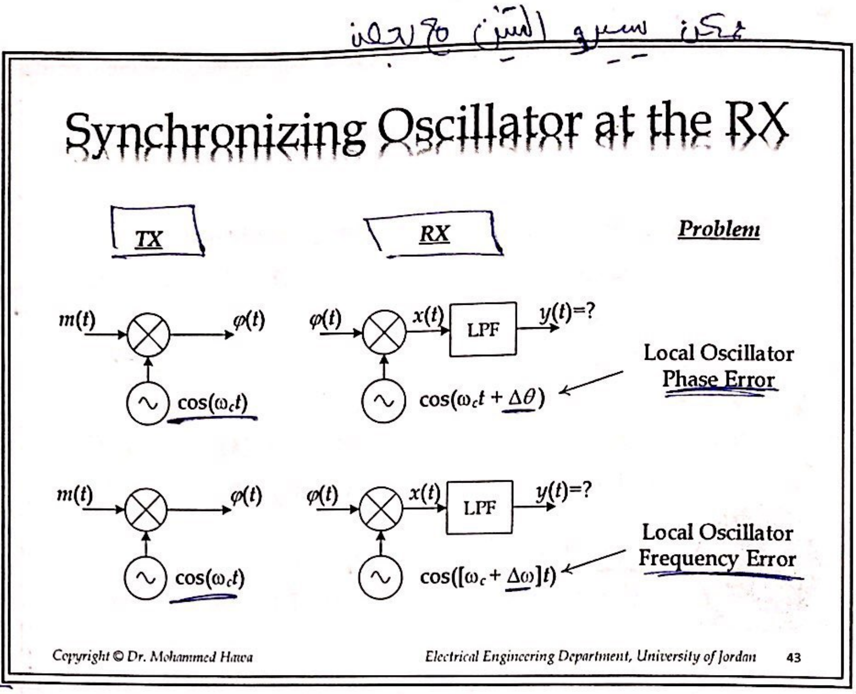
$\boxed{K = 2G|\alpha_1|}$

* CDMA → أكبر synchroni مشكلة الـ

* GSM → أقل " ال ى

2/15/

ممكن سيرو التين 80 بحلهن



Synchronizing Oscillator at the RX

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سبب الـ phase error ↓ Attenuation

*سبب الـ Freq. error ↓ Distortion

*** Freq. error**

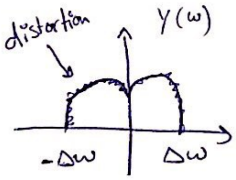
Tx: $\phi(t) = m(t)\cos(\omega_c t)$

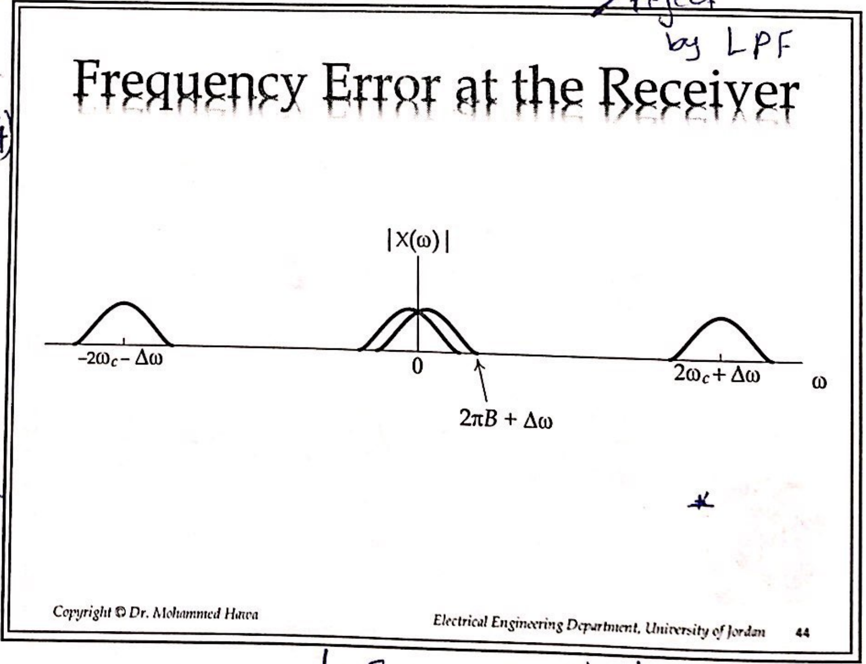
Rx: $X(t) = \phi(t)\cos((\omega_c+\Delta\omega)t) = m(t)\cos\omega_c t \cos((\omega_c+\Delta\omega)t)$

$= \frac{1}{2} m(t)\left[\cos(2\omega_c+\Delta\omega)t + \cos(\Delta\omega t)\right]$

reject by LPF

$\to y(t) = \underbrace{\frac{1}{2}\cos(\Delta\omega t)}_{\text{not constant}} m(t)$





Frequency Error at the Receiver

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*** phase error:**

Tx: $\phi(t) = m(t)\cos\omega_c t$

Rx: $X(t) = m(t)\cos(\omega_c t + \Delta\theta)$

$= \frac{1}{2} m(t)\left[\cos(2\omega_c t + \Delta\theta) + \cos(\Delta\theta)\right]$

reject by LPF

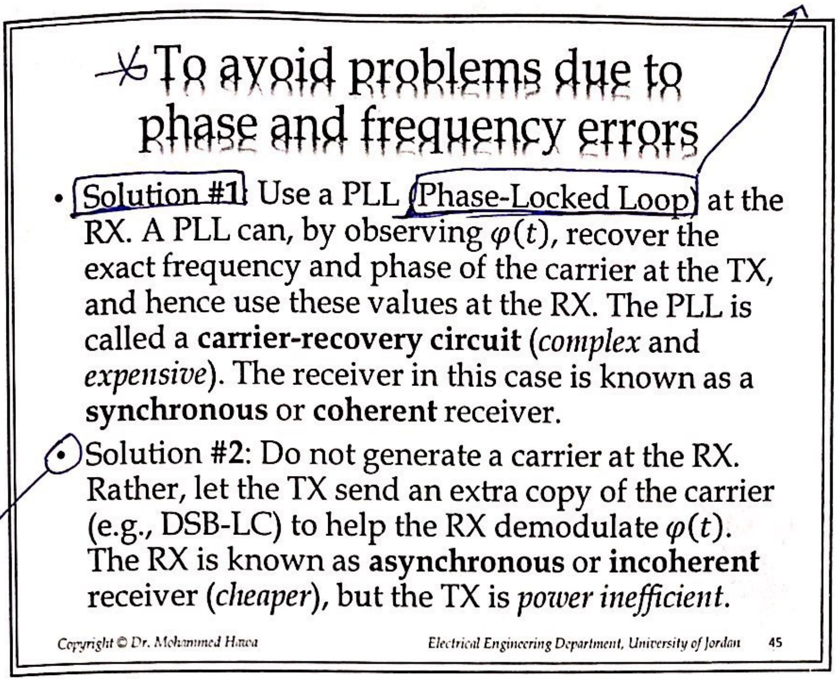
$y(t) = \underbrace{\frac{1}{2}}_{\text{constant}} \cos(\Delta\theta)\, m(t) \longrightarrow$ attenuation

$\Delta\theta = 0 \longrightarrow y(t) = \frac{1}{2} m(t)$

$\Delta\theta = 60 \longrightarrow y(t) = \frac{1}{4} m(t)$

$\Delta\theta = 90 \longrightarrow y(t) = 0 \Longrightarrow$ مشكلة كبيرة

ببعت السجنال بدون كارير



*To avoid problems due to phase and frequency errors

- Solution #1: Use a PLL (Phase-Locked Loop) at the RX. A PLL can, by observing $\varphi(t)$, recover the exact frequency and phase of the carrier at the TX, and hence use these values at the RX. The PLL is called a **carrier-recovery circuit** (*complex* and *expensive*). The receiver in this case is known as a **synchronous** or **coherent** receiver.
- Solution #**2**: Do not generate a carrier at the RX. Rather, let the TX send an extra copy of the carrier (e.g., DSB-LC) to help the RX demodulate $\varphi(t)$. The RX is known as **asynchronous** or **incoherent** receiver (*cheaper*), but the TX is *power inefficient*.

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حل قديم

Solution 2

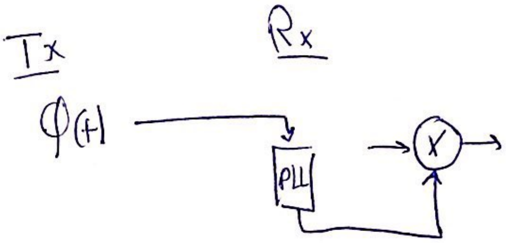
باخذ نفس الكارير هون مشان أنتج السجنال

*disadv. → we need more power to resend the carrier

عليه Ex: DSB-LC (AM)

Rx → incoherent /asynchronous

Solution 1



Rx → coherent/synchronous.

more expensive

2/

Lecture 5a: Sampling and Quantization

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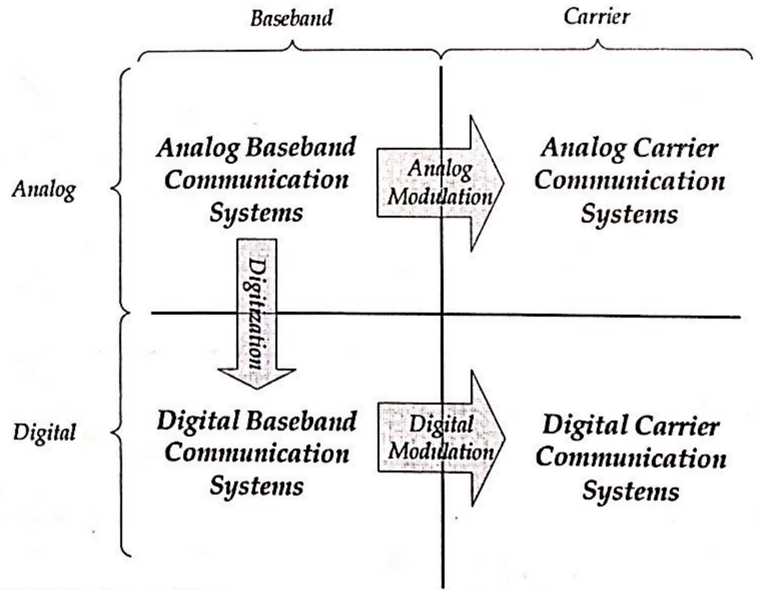
Digitization



Baseband

Carrier

Analog

Analog Baseband Communication Systems

Analog Modulation

Analog Carrier Communication Systems

Digitization

Digital

Digital Baseband Communication Systems

Digital Modulation

Digital Carrier Communication Systems

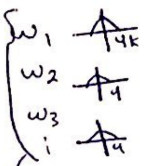
*TDM

only digital
- U1 101—
- U2 10100 ‥
- U3 010 —

|U1|U2|U3|‥|U1|U2 ‥

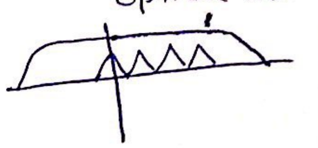
switch يمر عليهم
ع شكل أجزاء

*FDM



digital or analog.

optical fiber



2/15/2017

Digital Systems Advantages

- Immunity to noise (threshold detection; regenerative repeaters).
- Multiplexing at the baseband level (e.g., TDM) and carrier level (e.g., FDM, CDMA and OFDMA).
- Spread spectrum techniques and orthogonality.
- Channel coding (i.e., error correcting codes).
- Source coding techniques (i.e., compression). *Also* Encryption.
- Exchanging SNR for bandwidth.
- Using microprocessors and DSP.
- Digital signal storage is relatively easy and inexpensive.

كم ما يسير عندي noise يميز بين ال zero & one

بتزيد ال capacity للchannel

data

in Analog we can only make multiplex in the carrier

5 stages الها

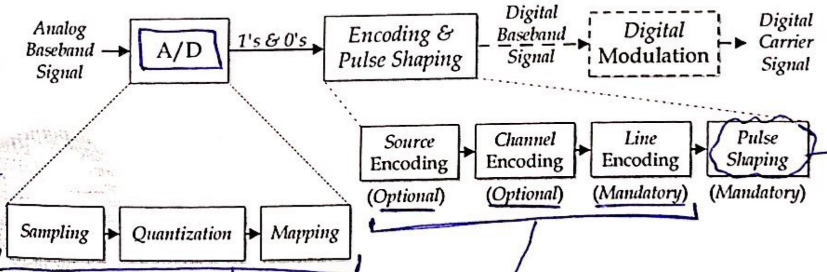
Digitization

- **Sampling** (discrete analog signal).
- **Quantization** (quantized discrete signal)
- **Mapping** (stream of 1's and 0's).
- **Encoding** and **Pulse Shaping** (digital baseband signal).

أخذ samples ع حسب قواعد معينة

اعمل Level وأقرب كل sample لأقرب Level

كل Level يعطيها رقم



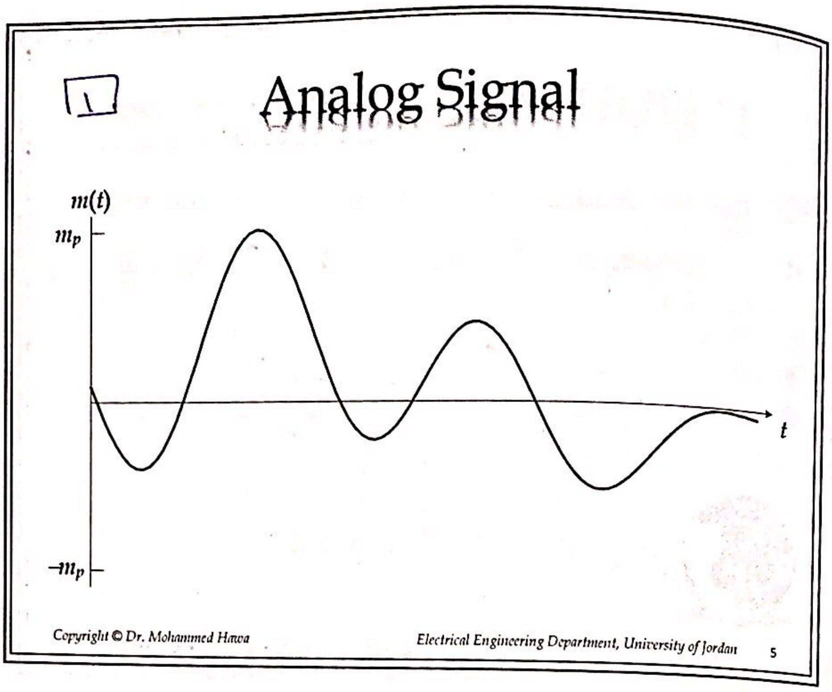
أول ٣ خطوات بيصيروا من خلال ADC

ال Encoding ٣ أنواع ٢ منهم optional وفي واحد اجباري (Line)

اعطي شكل يمثل ال zero & ones نحيث ما تضيع السيجنال 2 and remove/reduce ISI

* خطوات تحويل analog → Digital

*



1

Analog Signal

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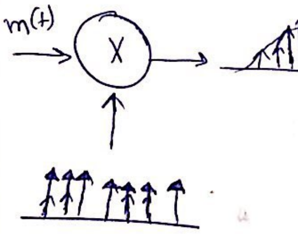
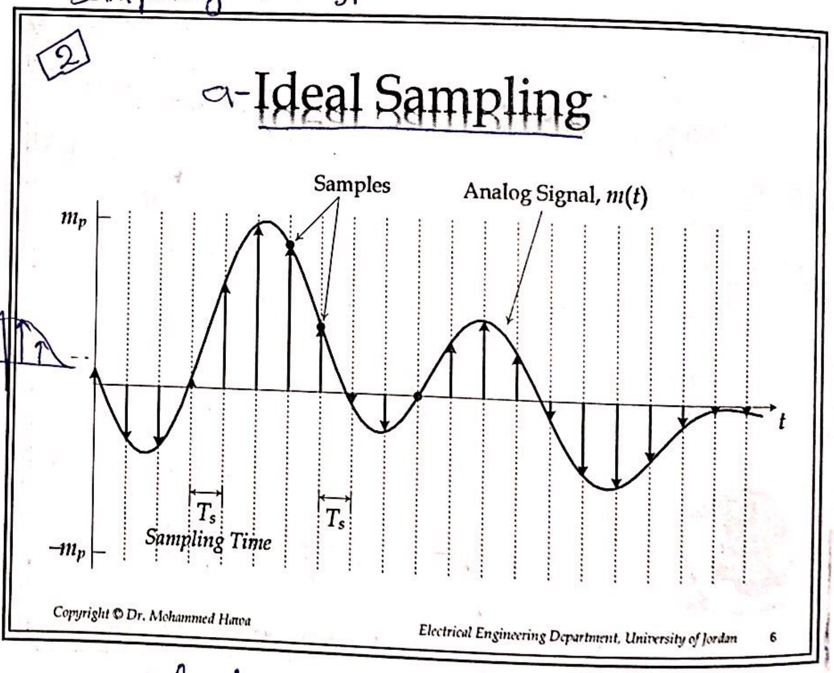
5

Sampling has types:-





2

a-Ideal Sampling

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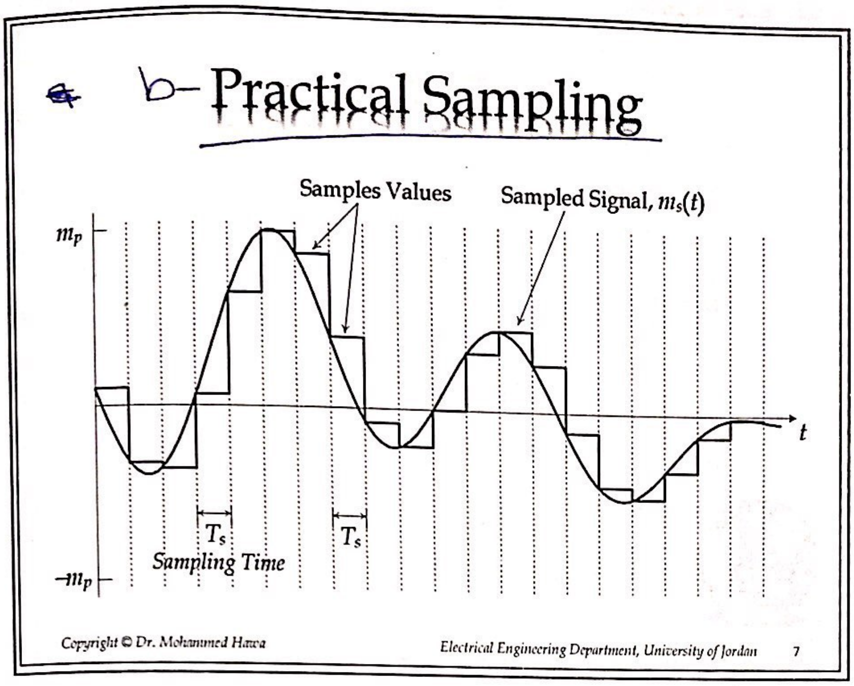
6

ideal → ادخل pulses

لهم نفس amplitude



b- Practical Sampling

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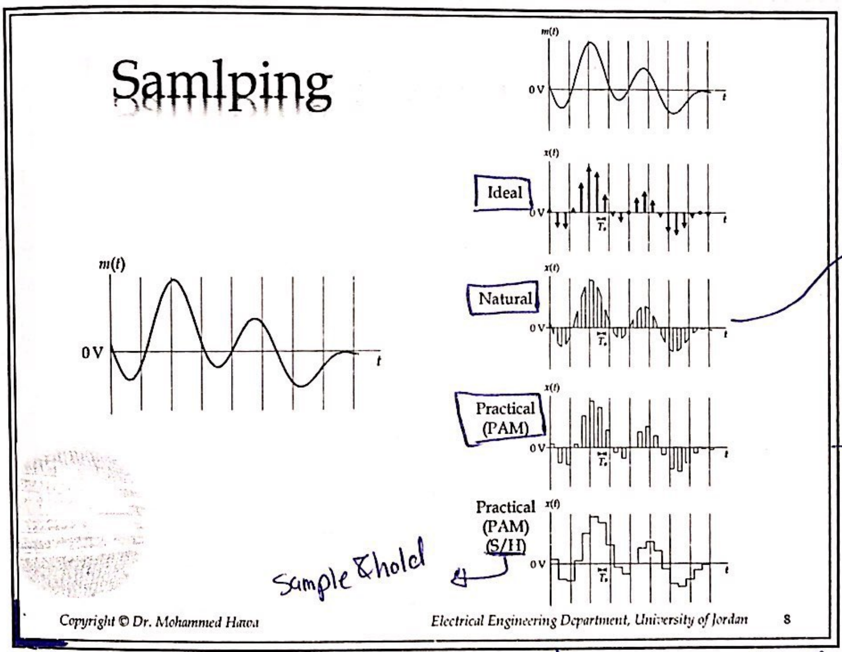

Samlping

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Natural

بقطع السجنال لأجزاء

بحيث بكون

عندي switch

مرة يكون 1 او 0

$\Rightarrow m(t), 0, m(t), 0 \cdots$

PAM → pulse amplitude modulation

بعمل مرة pulse مرة Zero

* sample & hold

ما بكون عندي Zero

4 بعمل sample بعدين بعمل

هولد (hold) لفترة Ts

بعمل sample جديد

كيف اعمل
اختار Ts ؟

* Nyquist theorme to not have Aliasing.

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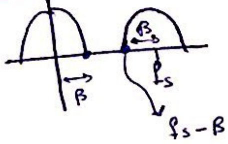
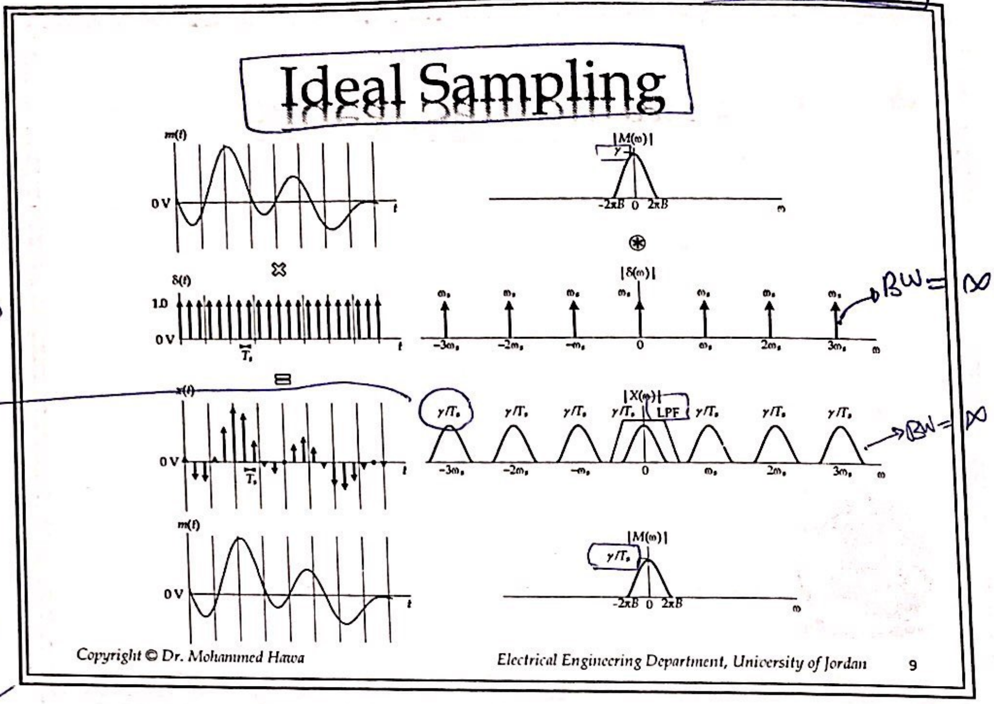
$f_s \geq 2B$

sampling freq.

Bw of m(t)



$f_s - B \geq B \Rightarrow \boxed{f_s \geq 2B}$



Ideal Sampling

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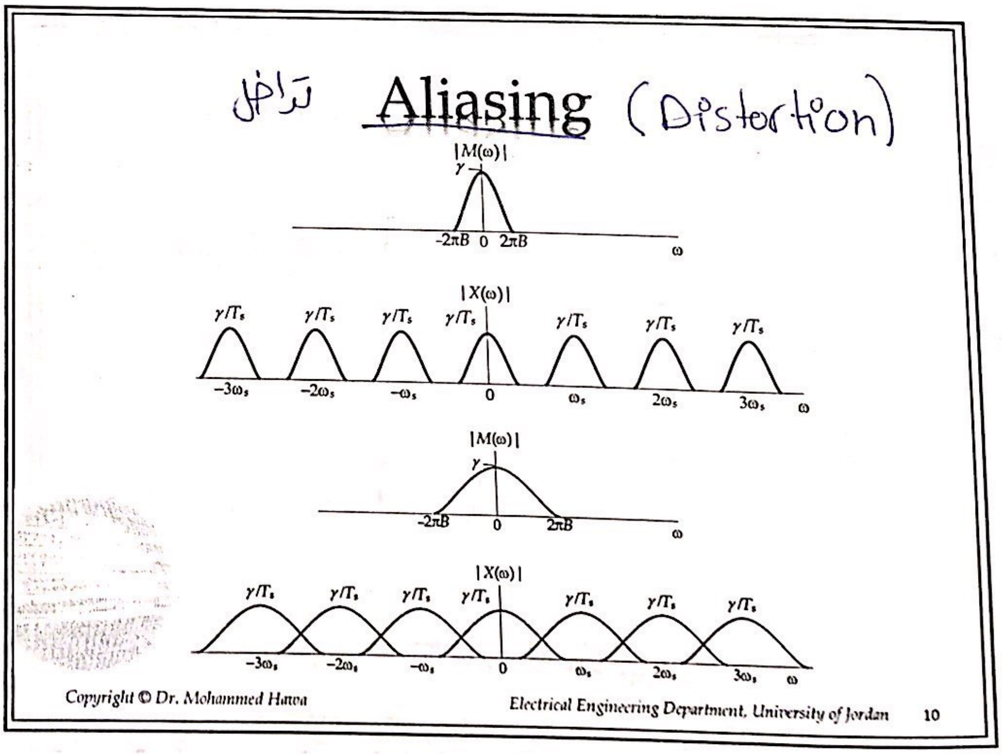
M(ω)

δ(ω)

$$\gamma T_s = \frac{\gamma \omega_s}{2\pi}$$

$$= \frac{\gamma(\cancel{2\pi}/T_s)}{\cancel{2\pi}}$$



تداخل Aliasing (Distortion)

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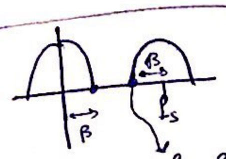
* Nyquist theorms to not have Aliasing.

لكن δ اهمل
δ Ts [illegible]

$$f_s \geq 2B$$

sampling freq. ← f_s

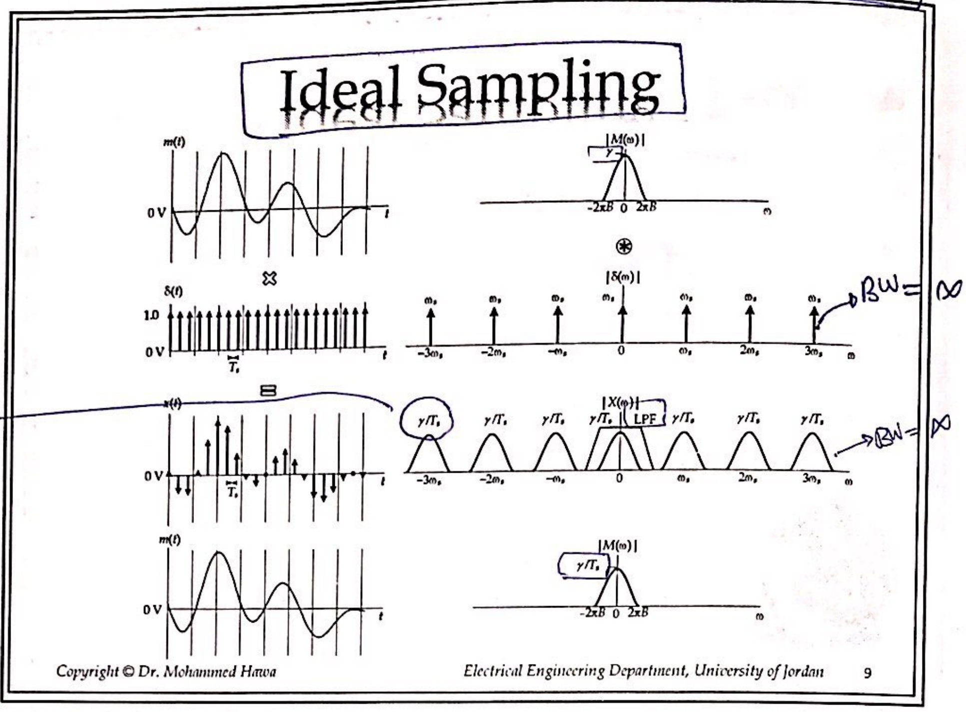
$2B$ → B.w of m(t)



$$f_{s-B} \geq B \Rightarrow \boxed{f_s \geq 2B}$$

2/1

Ideal Sampling



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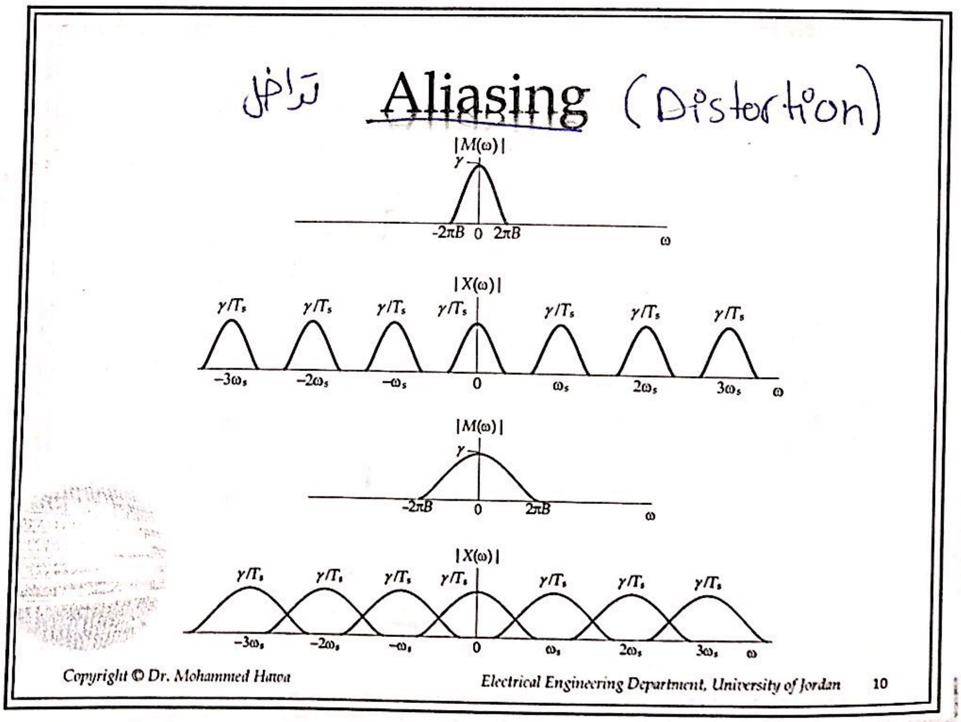
M(ω)   δ(ω)

$$\gamma T_s = \frac{\gamma \omega_s}{2\pi}$$

$$= \frac{\gamma(\cancel{2\pi}/T_s)}{\cancel{2\pi}}$$

تداخل Aliasing (Distortion)



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* we can use Both solutions

Ts قللت

solution for Aliasing: ① increase fs ⇒ more samples/sec

⇓

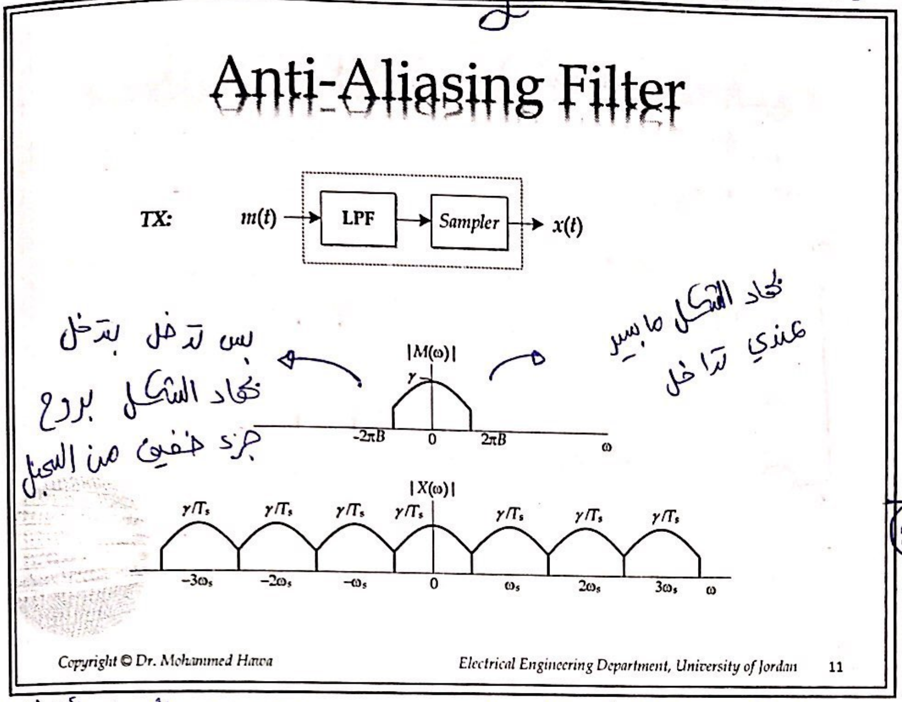
more $\underbrace{\text{bits/sec}}_{\text{bit-rate}}$

and bitrate ∝ B.w of channel

⇓

more cost !!

② reduce B using anti_aliasing filter



Anti-Aliasing Filter

TX: m(t) → LPF → Sampler → x(t)

بس تدخل بتدخل نكاد الشكل بروح جزء خفيف من السجنل

نكاد الشكل ما بسير عندي تداخل

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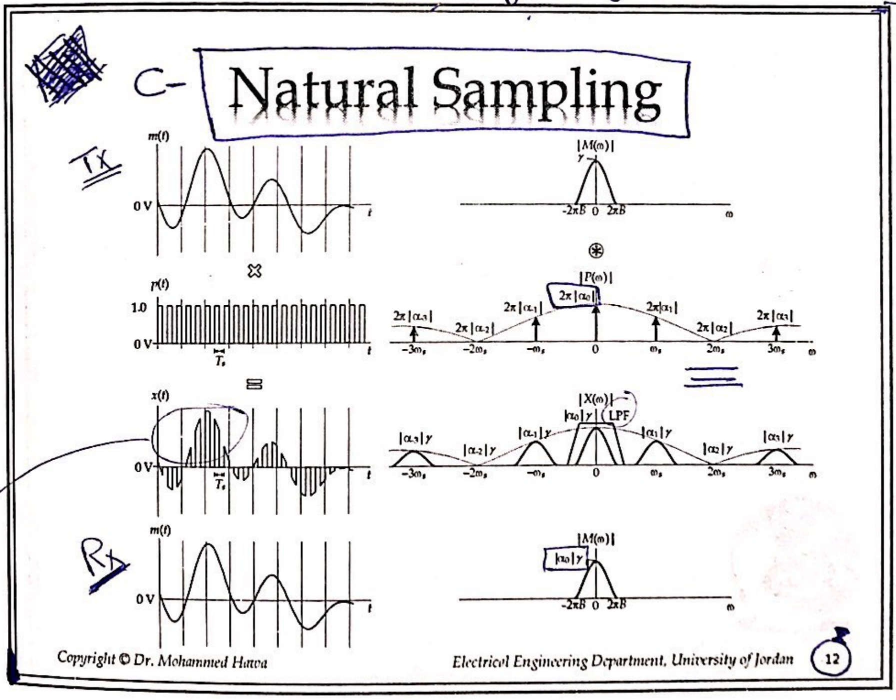
* هون بيتنازل عنه انه يروح جزء خفيف من السجنل أفضل من تداخل سجنل تانية عليها !!



C- Natural Sampling

Tx

Rx

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$$n\omega_0 = \frac{2\pi}{T_0} = \frac{2\pi}{T_s} = \omega_c$$

$$Bw = \frac{1}{\tau} Hz = \frac{2\pi}{\tau}$$

$$= \frac{2\pi}{T_s/2} \text{ rad/sec}$$

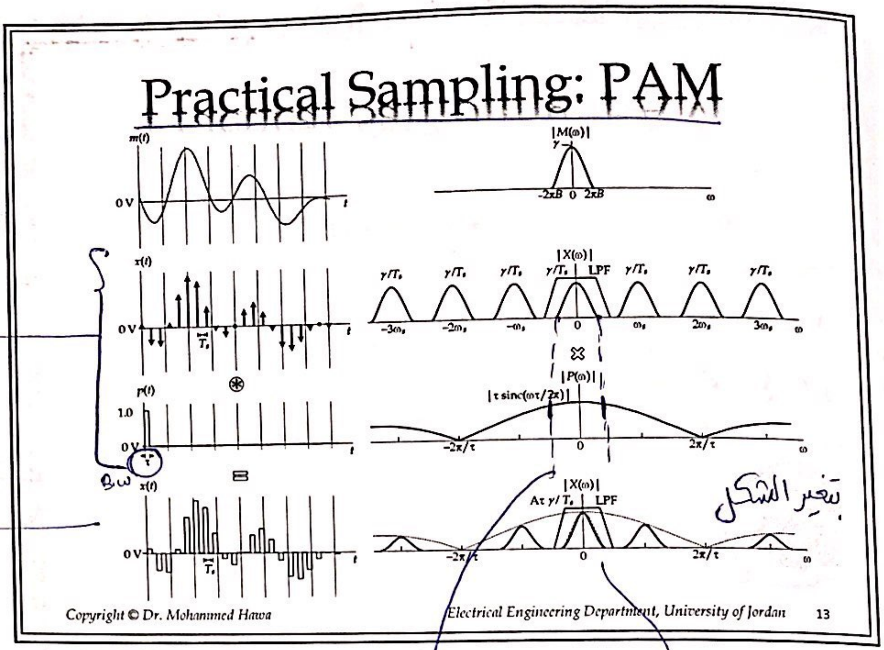
$$= 2\left(\frac{2\pi}{T_s}\right)$$

$$\boxed{= 2\omega_s}$$

first null

صعوبة انه ال x(t) كل فترة في عندي amplitude

2/15/20



Practical Sampling: PAM

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13

B.w

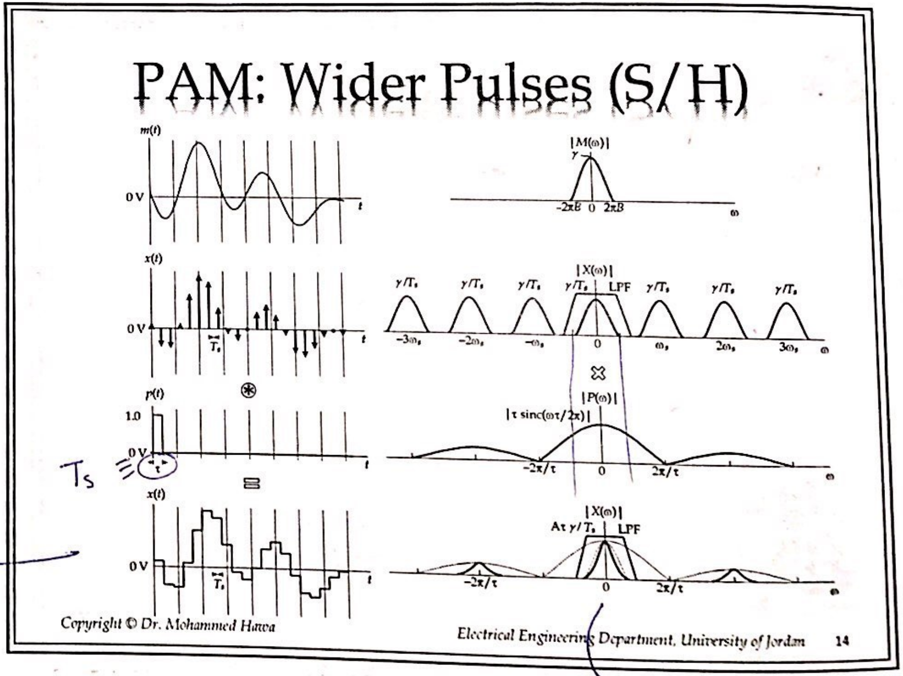
لازم اعلي هدول البين
عشان اكون الي تحت

صعب أحصل
هاي دايركت من
function معين
فبعمل شغلتين فوق

بتغير الشكل

هدول البارتين بدخلو

بس distortion
خفيف



PAM: Wider Pulses (S/H)

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14

T_s ≡

هاي سهلة
أصنعها
لانه ال
B.w
لل p(t) أكبر (أعرض)
لكن رح تكون
distortion
أكبر
لانه sinc فيها ميلان أكثر

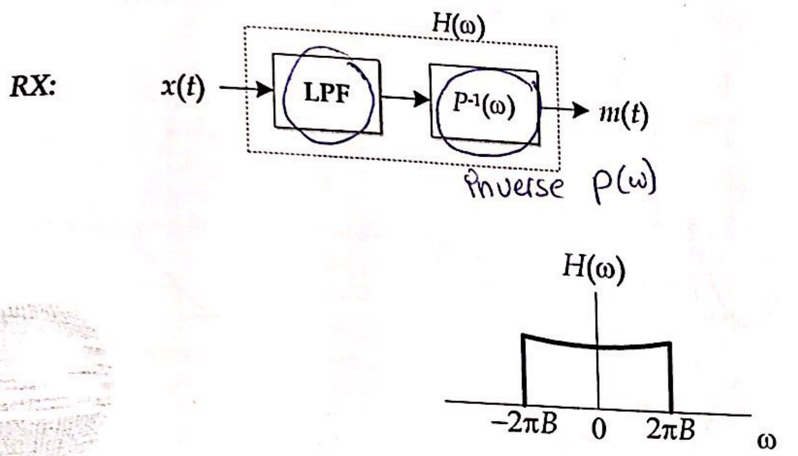
ال distortion هون
بزيد لما T تزيد
ولما B.w يقل

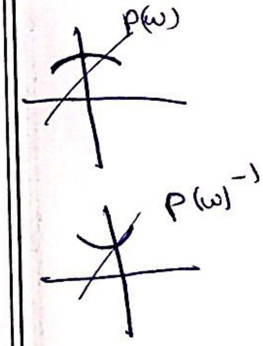
*Solution for distortion in PAM (S/H):

① use small τ ⇒ (expesive hardware)

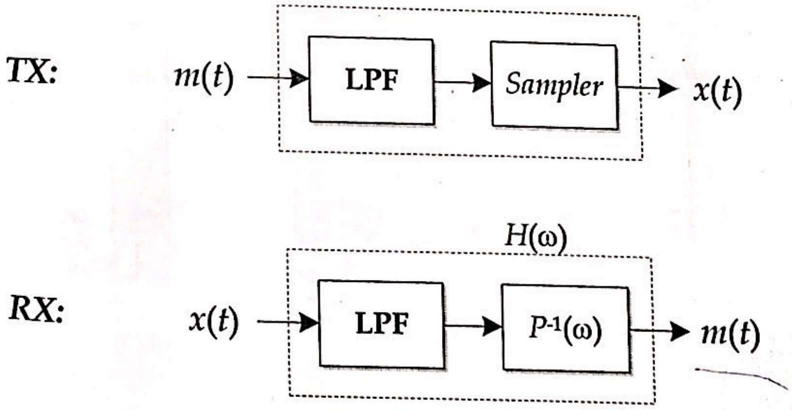
② use equalizer @ Rx

Distortion solved by Equalizer





Summary



2/15

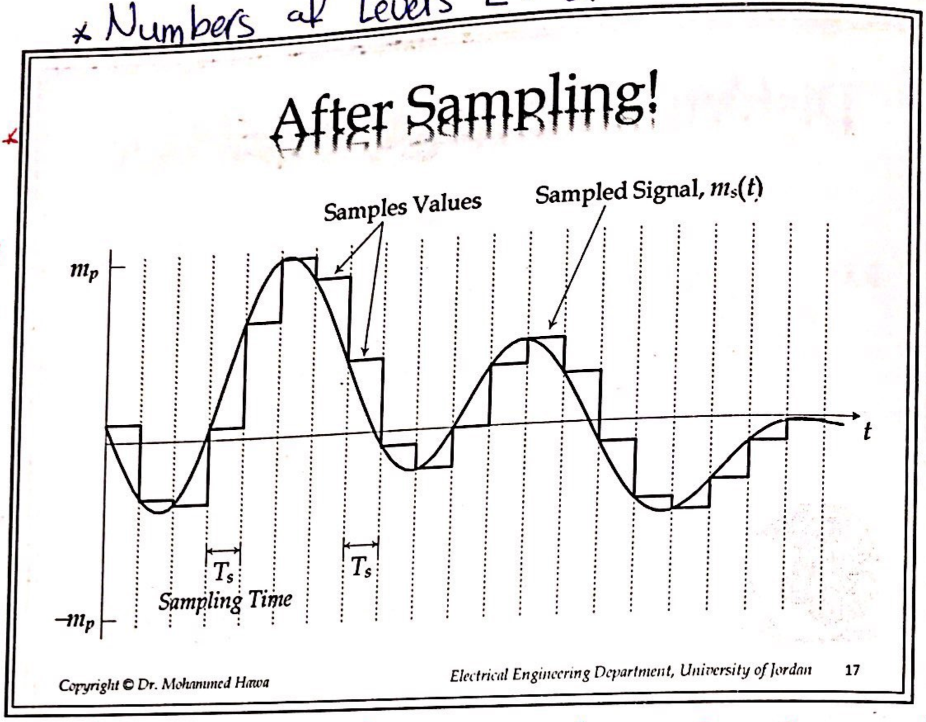
# of bits

* Numbers of Levels $L = 2^{n}$

* كل ما زاد عدد ال Levels

بكون ال error أقل

والـquality أحسن



After Sampling!

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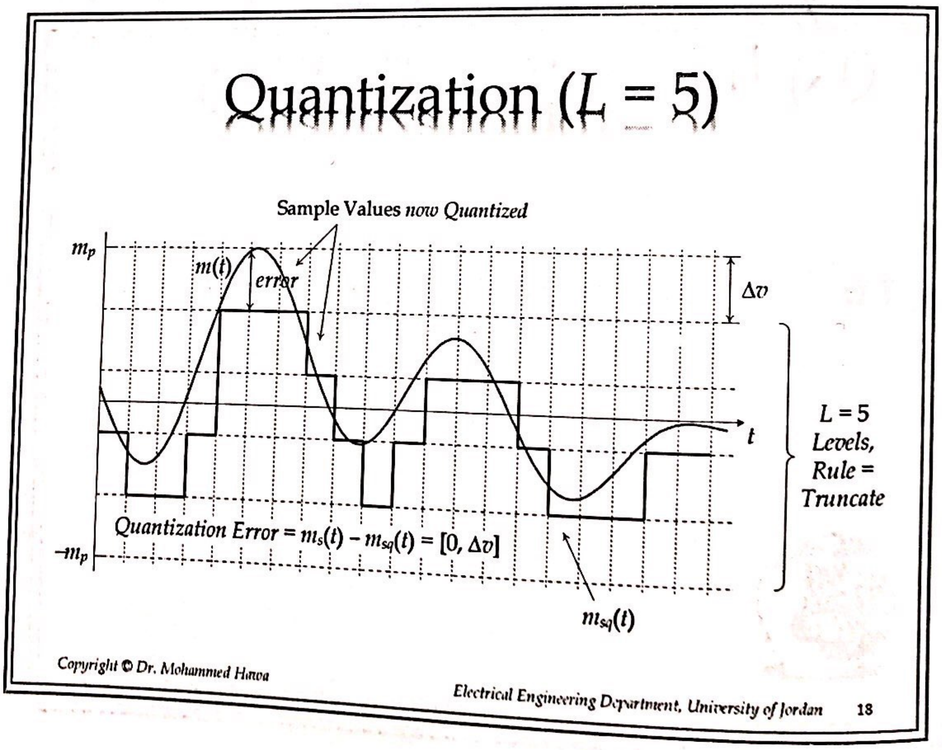
L↑ → Quality ↑ → n ↑ → B.W ↑ → cost ↑



Quantization ($L = 5$)

$L = 5$ Levels, Rule = Truncate

Quantization Error = $m_s(t) - m_{sq}(t) = [0, \Delta v]$

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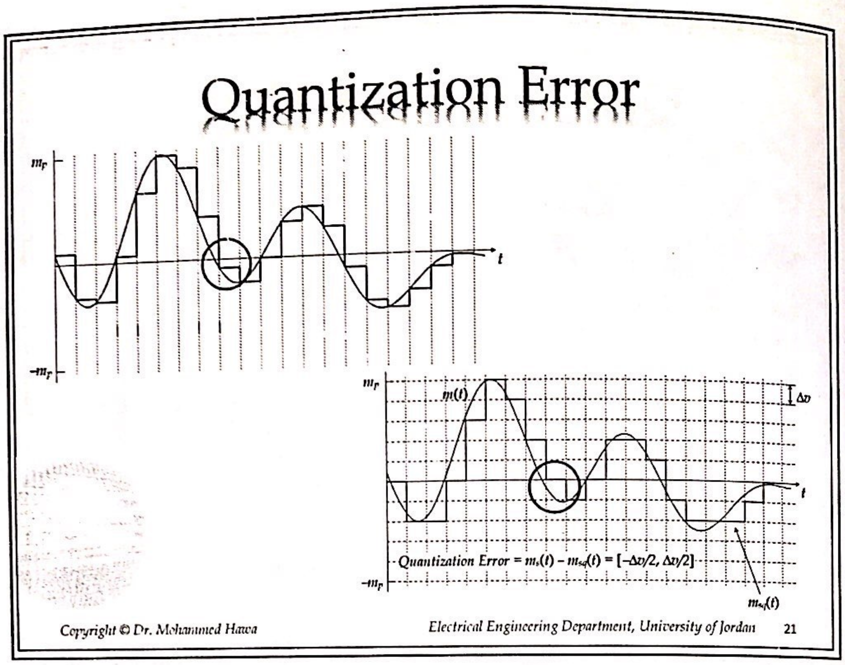
Ex Calculate crest factor of $m(t) = \alpha \cos(\omega_m t)$

2/15/2

sol $m_p = \alpha \quad \Rightarrow \quad K_m^2 = \frac{\alpha^2}{\frac{\alpha^2}{2}} = 2$

$m_{rms} = \frac{\alpha}{\sqrt{2}}$



Quantization Error

Quantization Error = $m_s(t) - m_{sq}(t) = [-\Delta v/2, \Delta v/2]$

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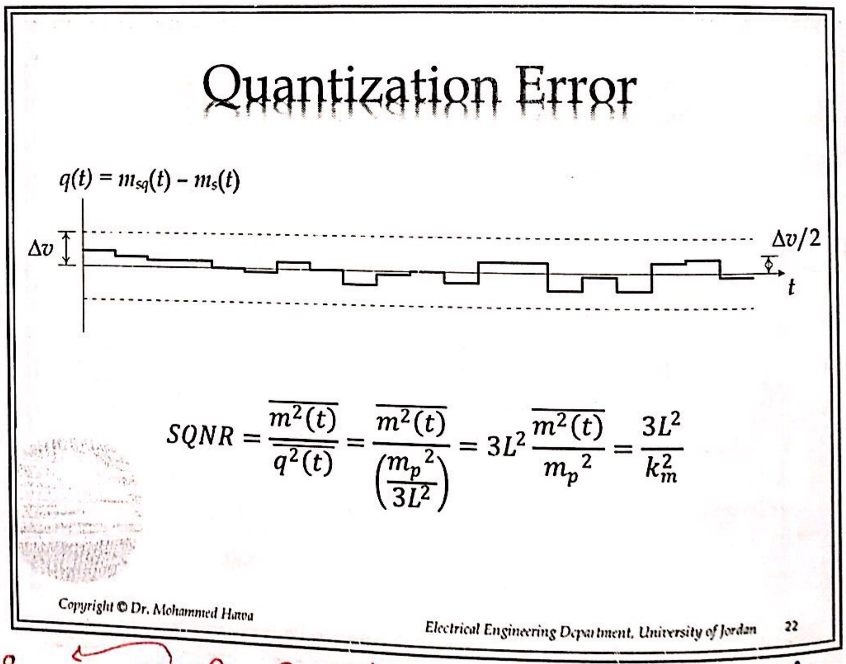

Quantization Error

$q(t) = m_{sq}(t) - m_s(t)$

$$SQNR = \frac{\overline{m^2(t)}}{\overline{q^2(t)}} = \frac{\overline{m^2(t)}}{\left(\frac{m_p{}^2}{3L^2}\right)} = 3L^2\frac{\overline{m^2(t)}}{m_p{}^2} = \frac{3L^2}{k_m^2}$$

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signal to noise ratio

$SQNR = \frac{P_{signal}}{P_{error}} = \frac{3L^2}{K_m^2}$

$L \rightarrow$ # of quantization Levels

crest factor or peak to rms ratio

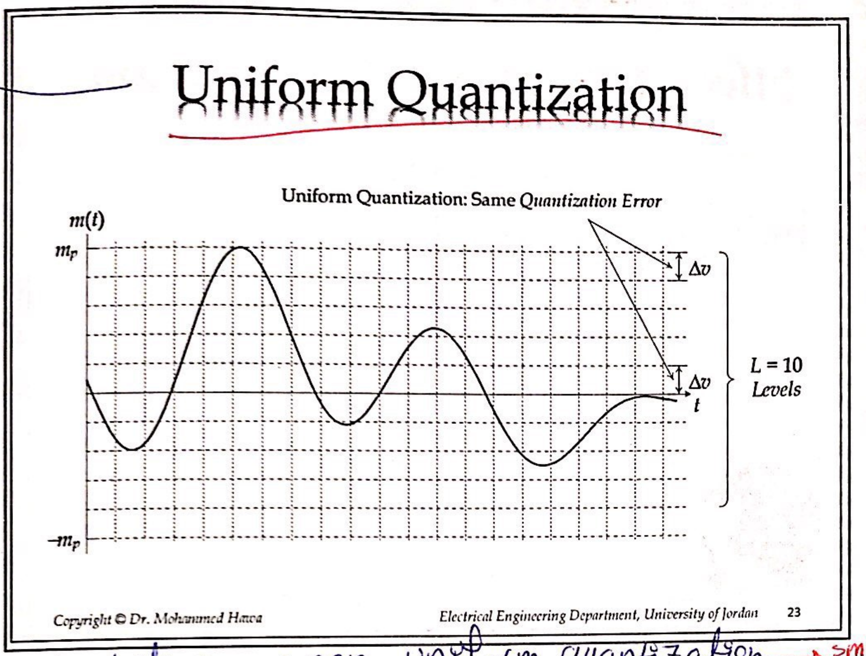
peak of m(t)

$K_m^2 = \frac{m_p^2}{m_{rms}^2} = \frac{m_p^2}{\overline{m^2(t)}}$

* quantization step large → adv. :- small n → small Bw
disadv :- large error for small signals

* quantization step small → adv. :- small error for small signal
disadv :- large n → wide Bw

2/15/2017



Uniform Quantization

Uniform Quantization: Same *Quantization Error*

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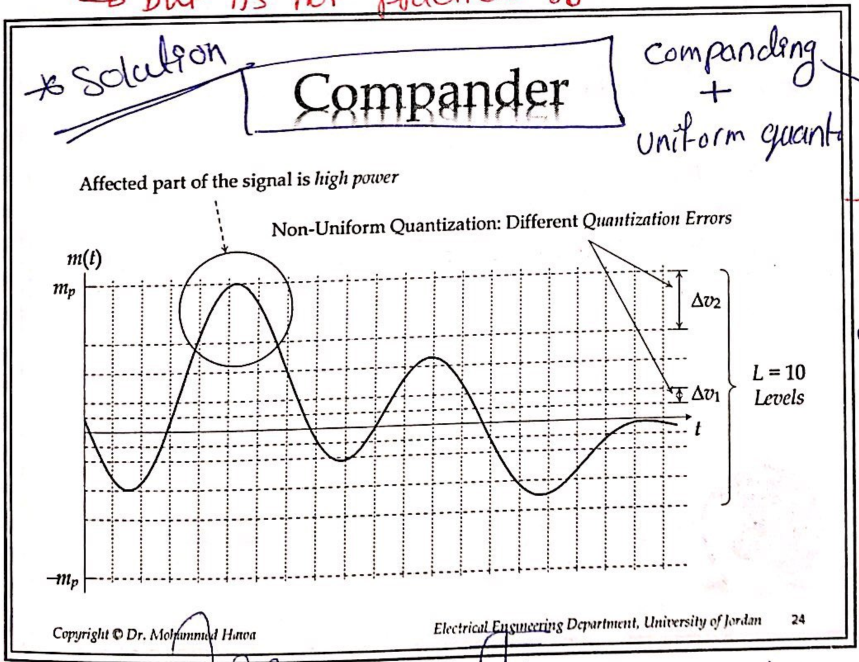
* solution → non uniform quantization → small signal → small step
large signal → large step

↳ but its not practical bb



* solution

Compander

companding + uniform quant → to improve SQNR

Affected part of the signal is *high power*

Non-Uniform Quantization: Different *Quantization Errors*

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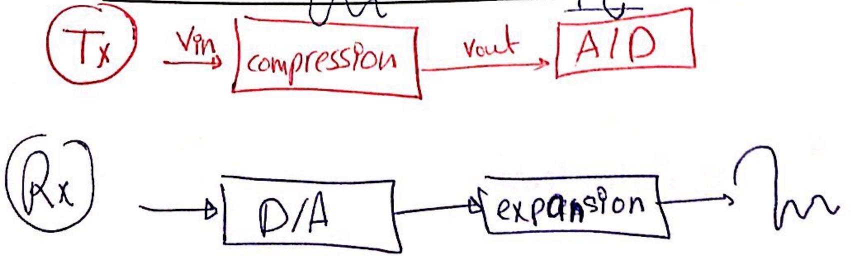
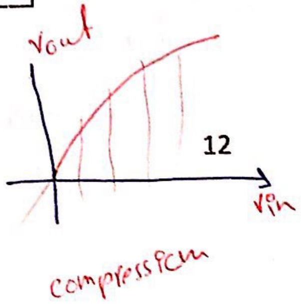
* companding

- compress @ Tx
- Expand @ Rx





compression

A_ low Companding → compression
↳ expansion (rest of the world)

M_ low " → compression
↳ expansion (USA & Japan)

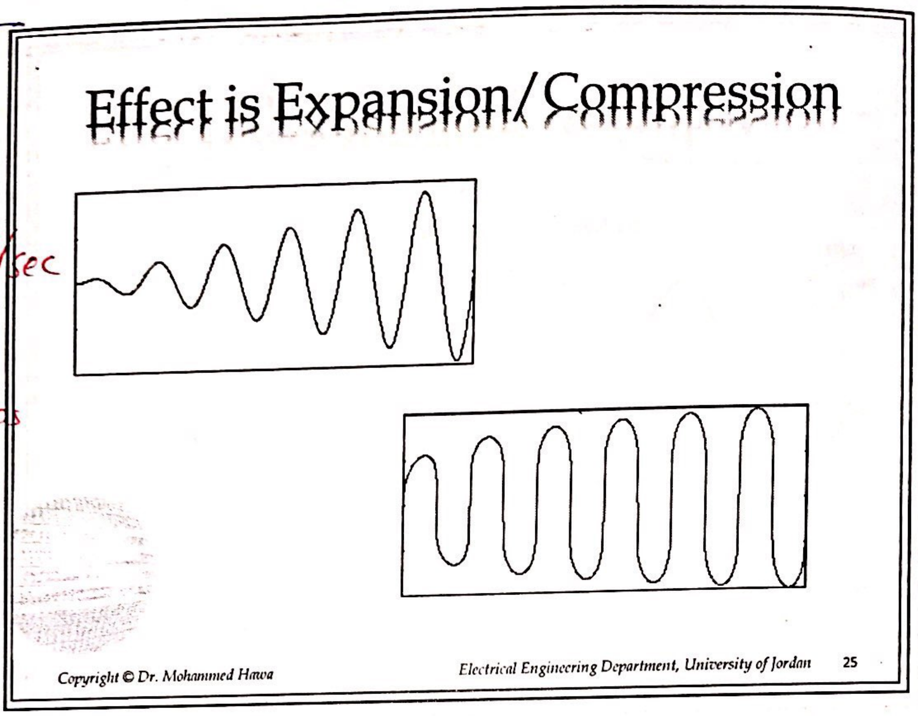
2/15/2

Ex in telephone systems

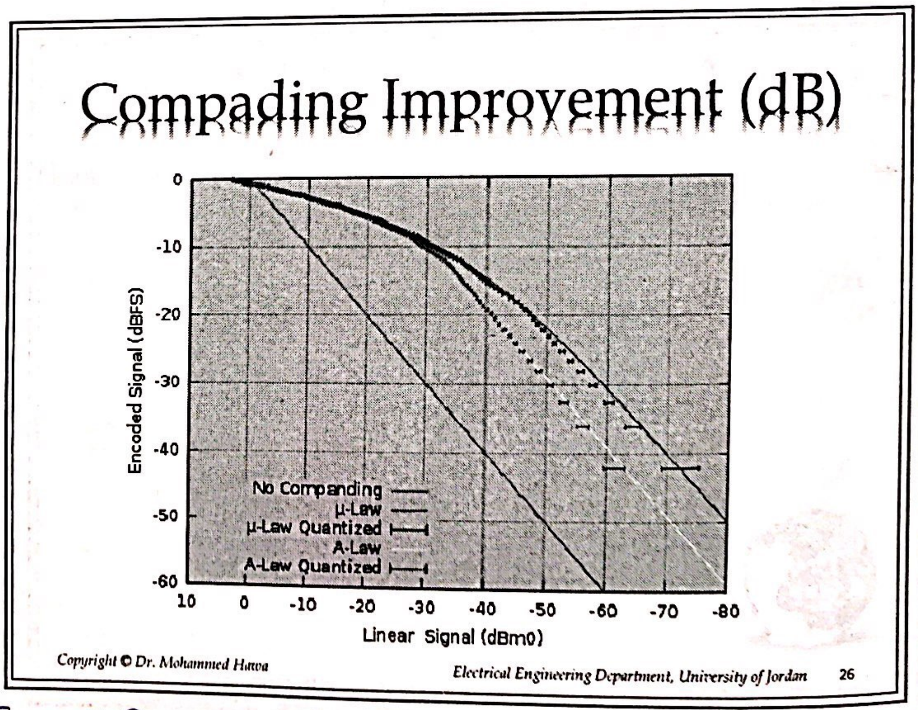
n=8 bits

fs = 8 K sample/sec

↳ bit rate = 64 K bps



Effect is Expansion/Compression



Compading Improvement (dB)

Ex In CDs

n = 16 bits

levels = 2^{16} = 65 536 levels

Ts → sampling period

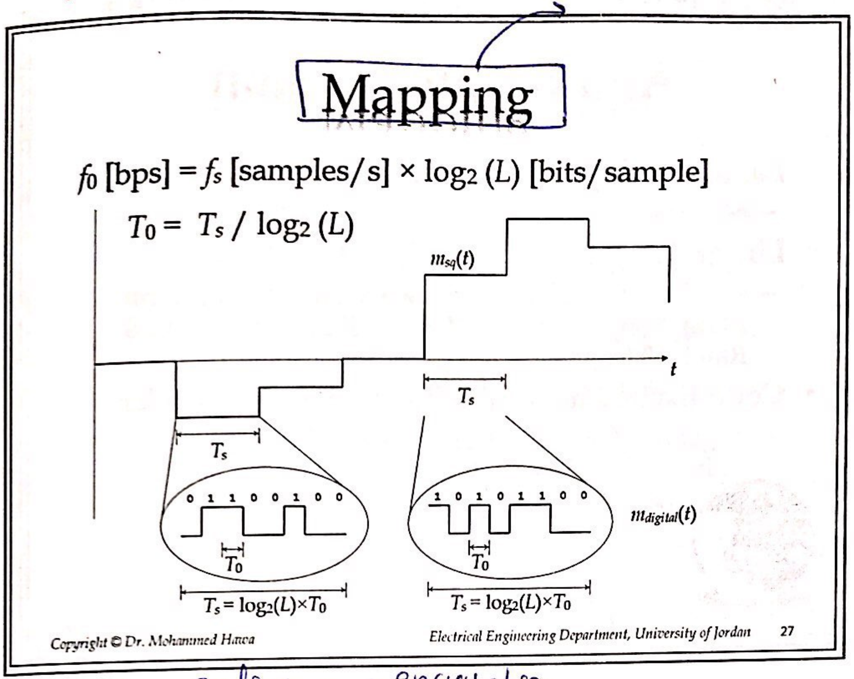
To → bit duration

$T_s = n T_o$

$T_s = \log_2(L) T_o$

$f_s = \frac{f_o}{\log_2(L)}$

code اعطي level كل

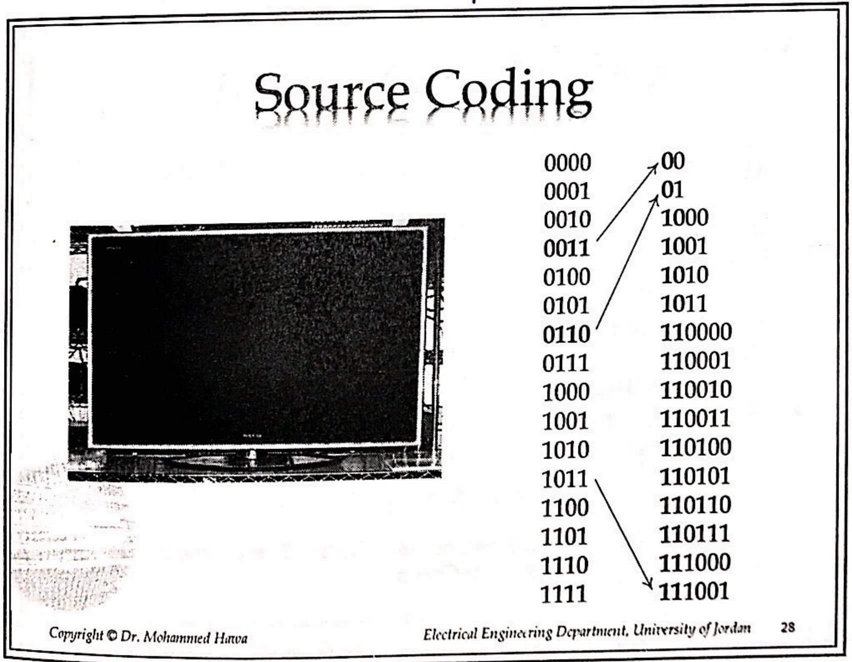


Mapping

f_0 [bps] = f_s [samples/s] × $\log_2(L)$ [bits/sample]

$T_0 = T_s / \log_2(L)$

source coding used for → encryption → compression



Source Coding

0000	00
0001	01
0010	1000
0011	1001
0100	1010
0101	1011
0110	110000
0111	110001
1000	110010
1001	110011
1010	110100
1011	110101
1100	110110
1101	110111
1110	111000
1111	111001

Ex (source coding)

- Huff man ecoding
- Run-length ecoding (RLE)

2/15/201

اي digital داتا تقدر اسويلها Compression

Audio Compression

- Landline telephony (PCM, no compression)
  - 64 kbps
- Linear Prediction Coding (LPC) vocoder
  - e.g., RPE-LTP (regular pulse excitation, long-term prediction) LPC codec (GSM cellular phones, Full Rate): **13 kbps**.
- Code-Excited linear Prediction (CELP) vocoder
  - Algebraic CELP(ACELP) (GSM cellular phones, Enhanced Full Rate): **12.2 kbps**
  - FS-1016 (United States Department of Defense): **4.8 kbps**

مش حفظ

Video Compression

- **MPEG-2:** DVD, Digital TV Broadcasting.
- **H.261:** Videophone.
- **H.263:** Low bit rate Video Conferencing.
- **H.264:** Almost everything.

MPEG	**ITU-T**
MPEG-1	H.261
↓	↓
MPEG-2	H.263
↓	↓

H.264/MPEG-4 Part 10 *or* AVC (*Advanced Video Coding*)

↓ ↓

H.265/MPEG-H Part 2 *or* HEVC (*High Efficiency Video Coding*)

- ITU-T: International Telecommunication Union - Telecommunication
- MPEG: Moving Picture Experts Group

Channel Coding

111001010111010001010100

→ 1110010101110100010101001011

→ 1110010101$\cancel{0}$10100010101001011

→ 111001010111010001010100

$$C = B_{ch} \times \log_2(1 + SNR)$$

capacity

channel B.W

*Channel coding → for error detection and/or correction

Ex parity bit (even /odd)

↳ even

Ex

1010 0

احط رقم بحيث يكون عدد الواحدات زوجي

Ex forward error correction

Ex hamming code

Turbo code

2/1

Lecture 5b: Line Codes

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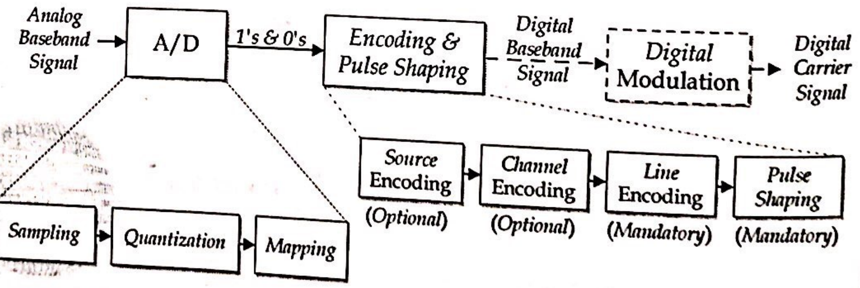
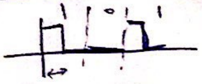
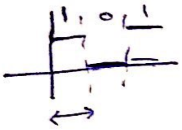
Digitization

- **Sampling** (discrete analog signal).
- **Quantization** (quantized discrete signal)
- **Mapping** (stream of 1's and 0's).
- **Encoding** and **Pulse Shaping** (digital baseband signal).





$Bw_1 = \frac{1}{\tau}$



$Bw_2 = \frac{1}{\tau}$

$Bw_1 < Bw_2$ ✓✓

how to choose the best voltage pattern from ones & zeros

Line Coding

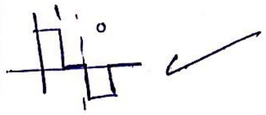
Advantages of a good *Line Code*:
- *Clock recovery* at the receiver (enough transitions in the received bit sequence).
- No *DC component* nor *low-frequency* power content (important for long-distance communication channels).
- Smaller transmission bandwidth.
- Maximum power in the signal to improve Signal-to-Noise Ratio (SNR).

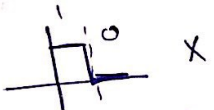
اللي ال Power اعلى بكون افضل

يكون قيمة DC قليلة أفضل

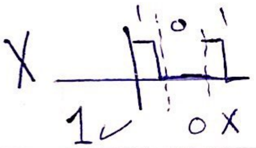
*self-cloking Line code :-

انه بقدر اميز كل 1 او 0 من اجا



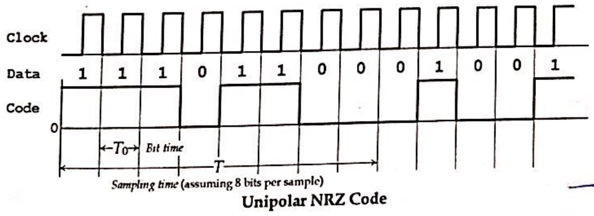


اذا اجا مجموعة 1 ما بميز كل وحدة من اجت

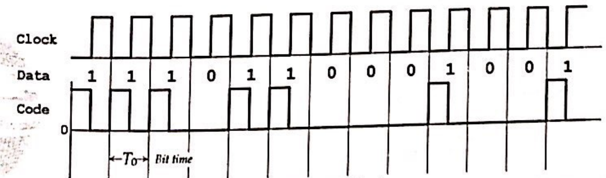


Unipolar NRZ and Unipolar RZ

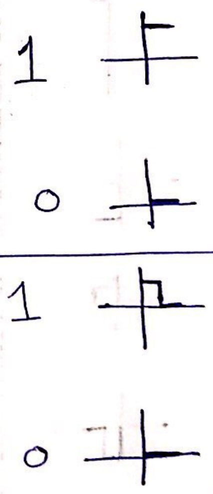
Uses a positive rectangular pulse p(t) to represent binary 1, and the absence of a pulse (i.e., zero voltage) to represent a binary 0.



Unipolar NRZ Code



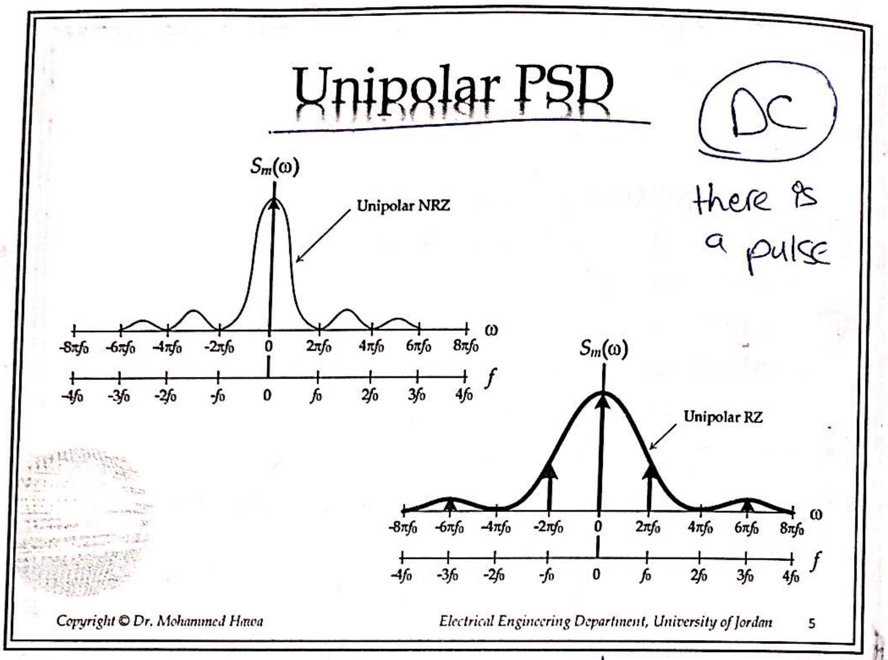
Unipolar RZ Code



* Unipolar NRZ & R.Z :
1. $Dc \neq 0$
2. no clock information (at long sequence)

adv → 3. NRZ is compatable with TTL logic (transistor_transistor)

4. B.W of RZ = 2 B.w of NRZ



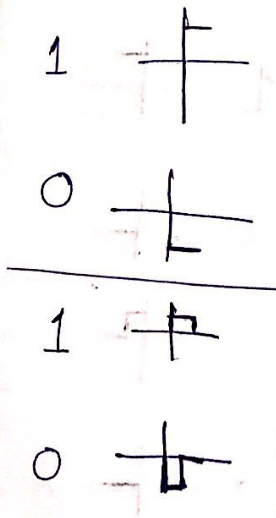
Unipolar PSD

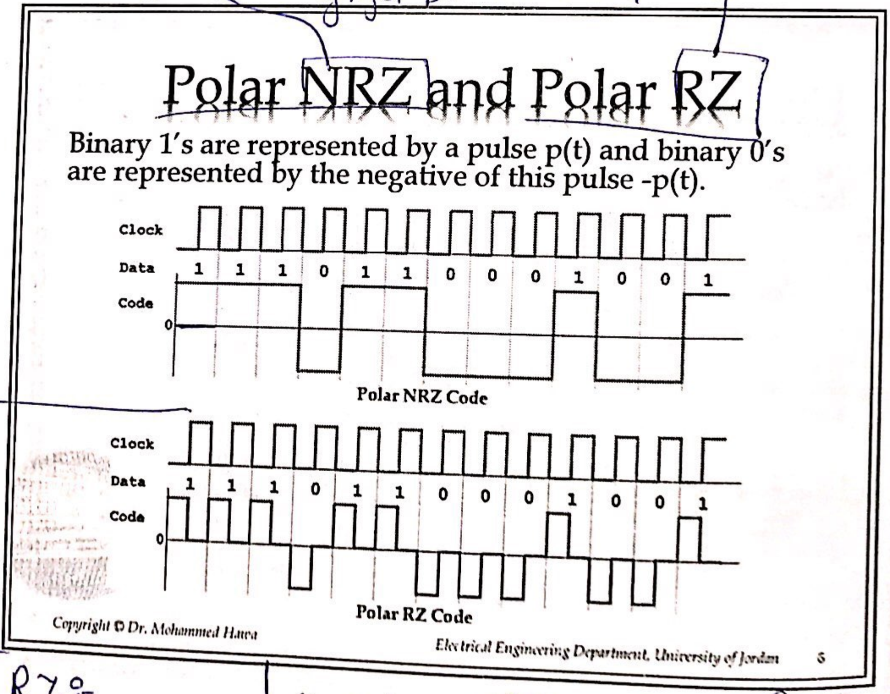
DC

there is a pulse

used in mother boards & in fiber based

giga bit ethernet.



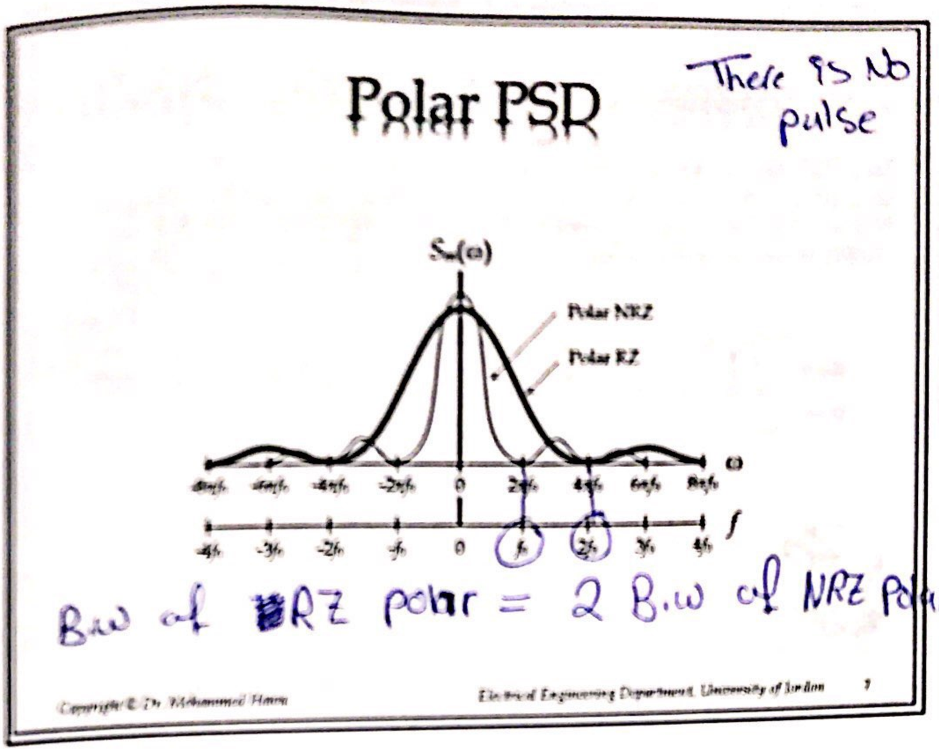


Polar NRZ and Polar RZ

Binary 1's are represented by a pulse p(t) and binary 0's are represented by the negative of this pulse -p(t).

*polar NRZ & RZ:

1. DC ≈ 0
2. SNR > SNR(unipolar).
3. power of NRZ > P of RZ
4. polar NRZ no clock info
5. polar RZ there is clock info
   ↳(self clocking line coding)



Polar PSD

There is No pulse

B.w of RZ polar = 2 B.w of NRZ Polar

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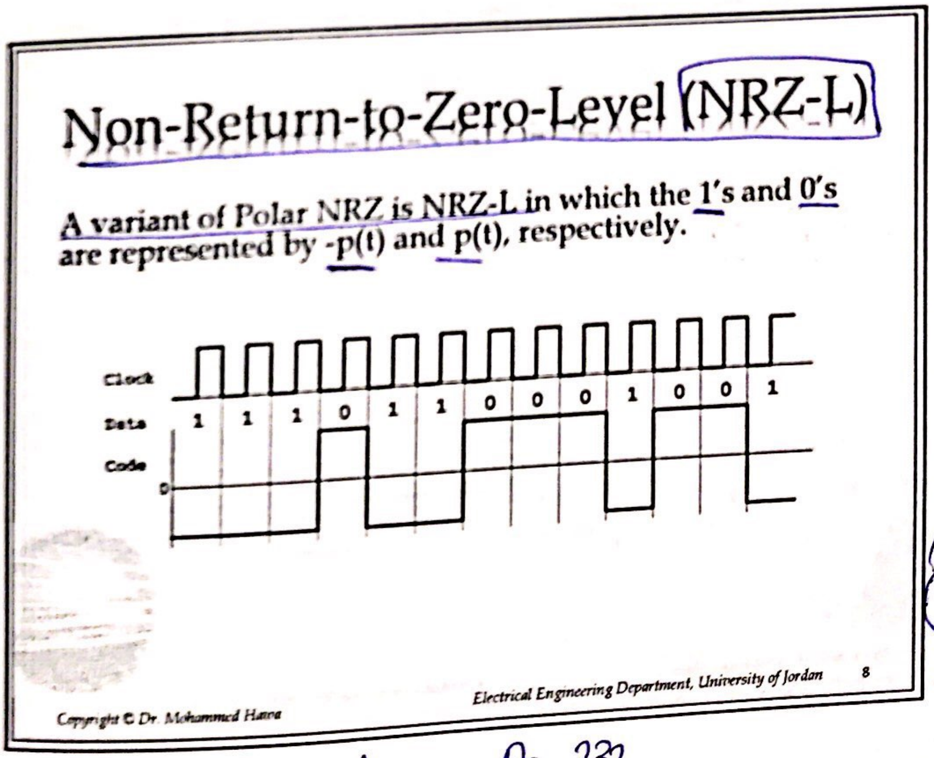

Non-Return-to-Zero-Level (NRZ-L)

A variant of Polar NRZ is NRZ-L in which the 1's and 0's are represented by -p(t) and p(t), respectively.

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مثلاً لو اجا

واحد ومثلته

ب -p(t)

فلما يجي Zero

بعكس لـ p(t)

$1 \rightarrow -p(t)$

$0 \rightarrow p(t)$

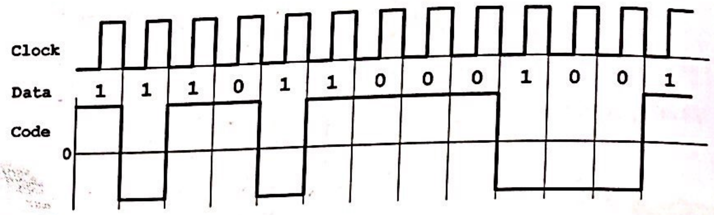
NRZ polar عكس

Usings & 1. used in Rs-232

serial port communication

Non-Return-to-Zero, Inverted (NRZI)

In NRZI there are two possible pulses, p(t) and -p(t). A transition from one pulse to the other happens if the bit being transmitted is a logic 1, and no transition happens if the bit being transmitted is a logic 0.

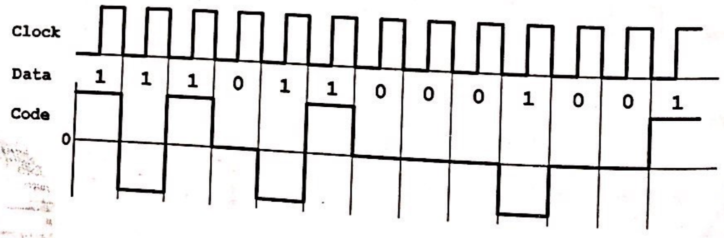


① used in CD
② usend in USB ports
③ used in fiber-based fast ethernet at 100 Mbps (100 base-Fx)

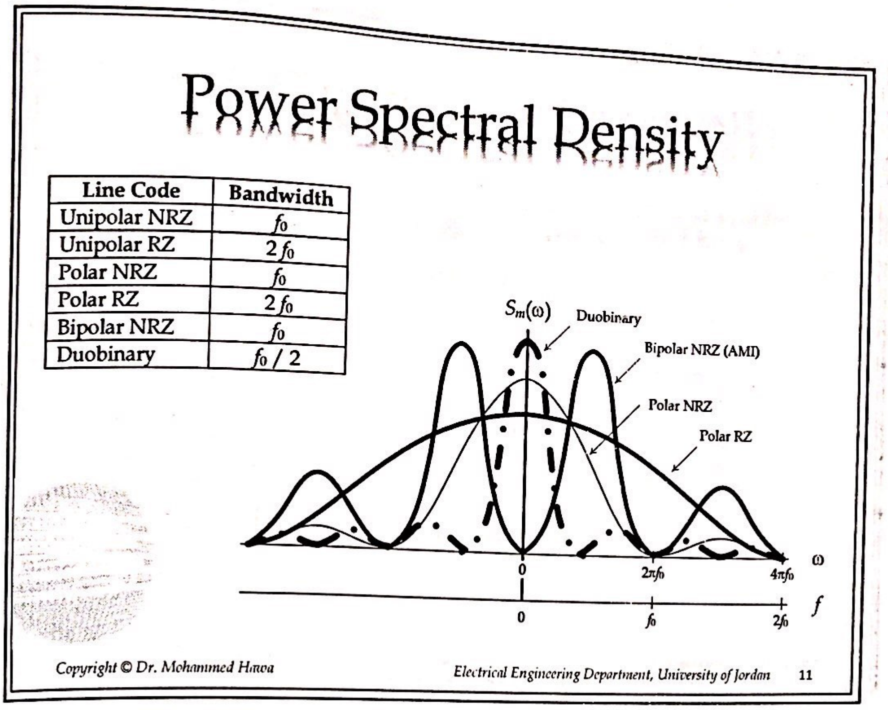
Alternate mark inversion

Bipolar (AMI)

A logic 0 is represented with a grounded or absent pulse, and a logic 1 by either a positive pulse p(t) or negative pulse -p(t). The direction of the pulse is opposite of the pulse sent for the previous logic 1 (mark).



① DC = 0
② no low freq. componant
③ used in 1'st generation digital telephony PCM network
④ not self clocking



Power Spectral Density

Line Code	Bandwidth
Unipolar NRZ	f_0
Unipolar RZ	$2 f_0$
Polar NRZ	f_0
Polar RZ	$2 f_0$
Bipolar NRZ	f_0
Duobinary	$f_0 / 2$

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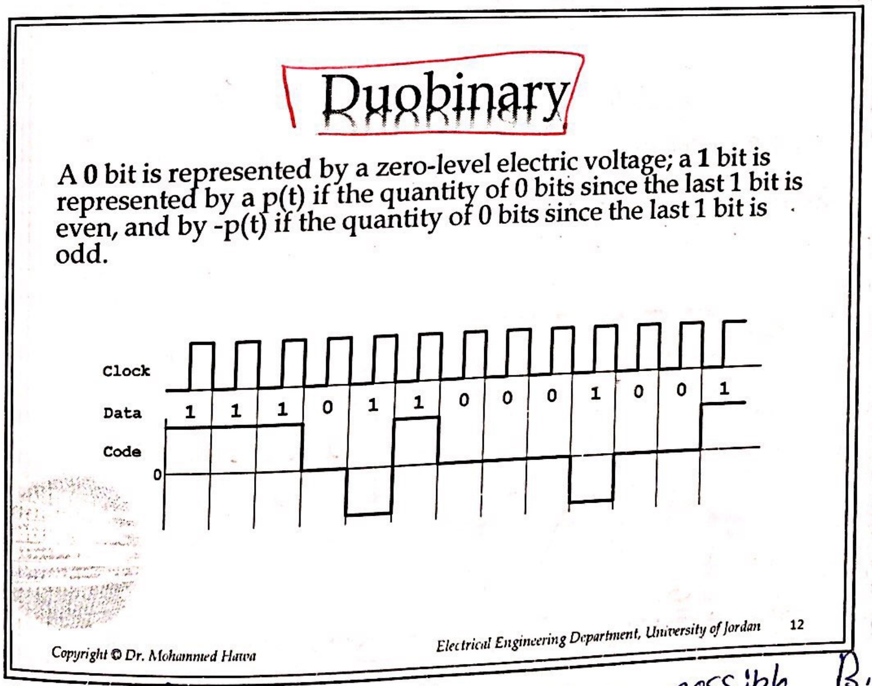

Duobinary

A **0** bit is represented by a zero-level electric voltage; a **1** bit is represented by a p(t) if the quantity of 0 bits since the last 1 bit is even, and by -p(t) if the quantity of 0 bits since the last 1 bit is odd.

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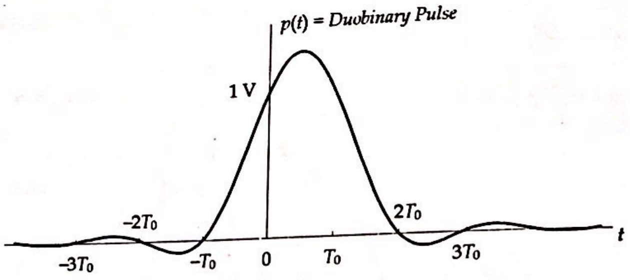
① $Bw = \frac{f_0}{2}$ which is the minimum possible B.w for any digital baseband signal (Nyquist B.w)

② it has low freq. components

③ it is used in 20Gbits/sec & 40Gbits/sec optical fiber comm.

④ it permits the detection of some transmission error without channel decoding

Be ware: Duobinary Pulse



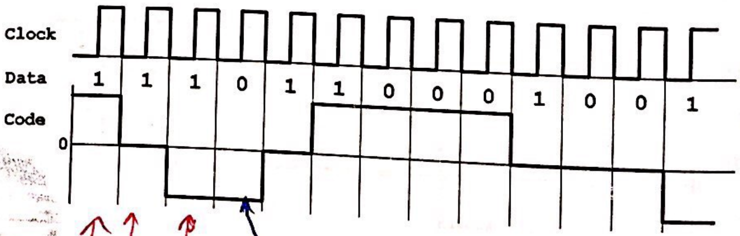
ضل يتقلب بين p(t),0,-p(t) لما يكون عندي 1

واذا اجى صفر
أضل زي ما انا

MLT-3

multi level transmission
level 3

MLT-3 cycles through the states -p(t), 0, p(t), 0, -p(t), 0, p(t), 0, ... etc. It moves to the next state to transmit a **1** bit, and stays in the same state to transmit a **0** bit.



كل ما يجي 1 غير

بس يجي صفر ثبت

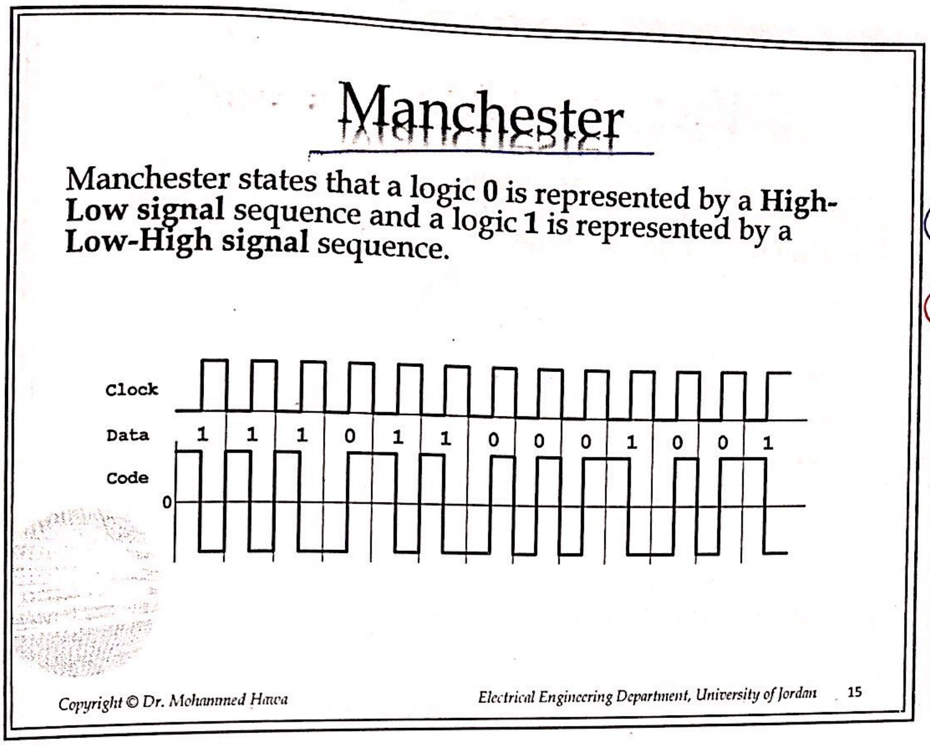
① used in 100 Base-Tx fast ethernet

② used EM interference

③ Small B.W

1 → Low-high

0 → high low



Manchester

Manchester states that a logic **0** is represented by a **High-Low signal** sequence and a logic **1** is represented by a **Low-High signal** sequence.

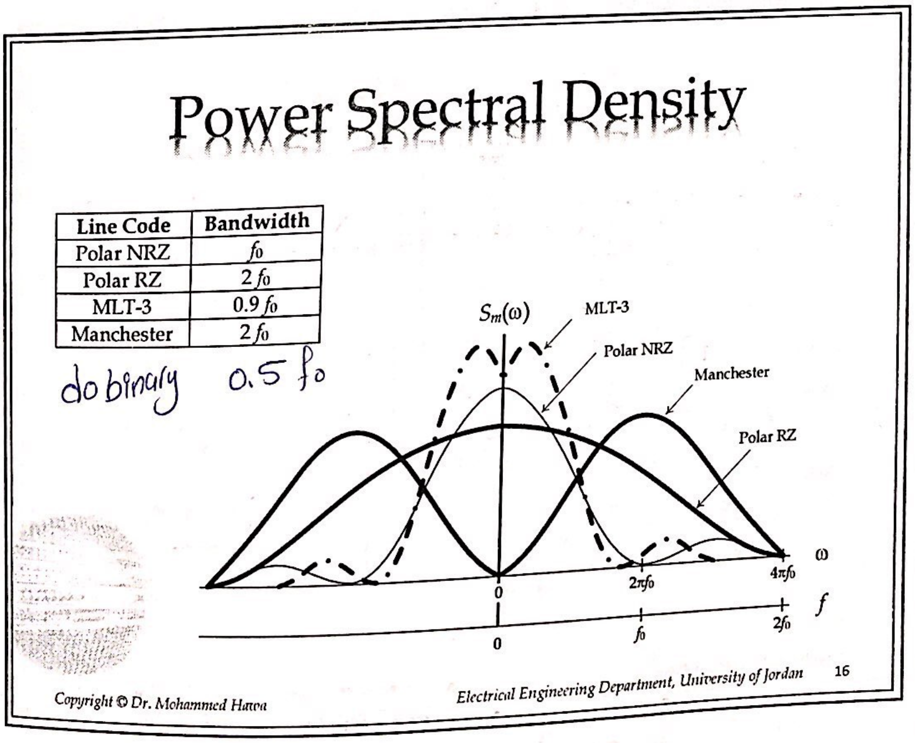
features :

① No Dc

② self-clocking

③ $Bw = 2f_0$ → bit rate

→ disadv.



Power Spectral Density

Line Code	Bandwidth
Polar NRZ	f_0
Polar RZ	$2\ f_0$
MLT-3	$0.9\ f_0$
Manchester	$2\ f_0$

dobinary $0.5\ f_0$

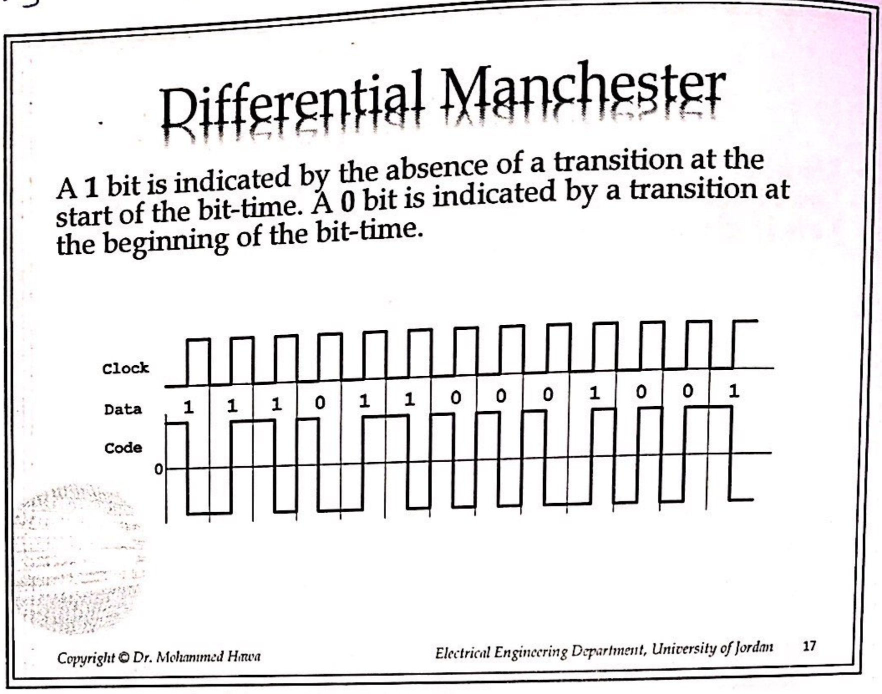
* binary line codes

$\underbrace{p(t), -p(t)}_{1}, \underbrace{0}_{0}$

so we used only two symbols:

$p(t), 0$

$\#$ bits/symbol = 1



Differential Manchester

A 1 bit is indicated by the absence of a transition at the start of the bit-time. A 0 bit is indicated by a transition at the beginning of the bit-time.

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* M-ary line code

→ M symbol

→ $\#$ bits /symbol = n

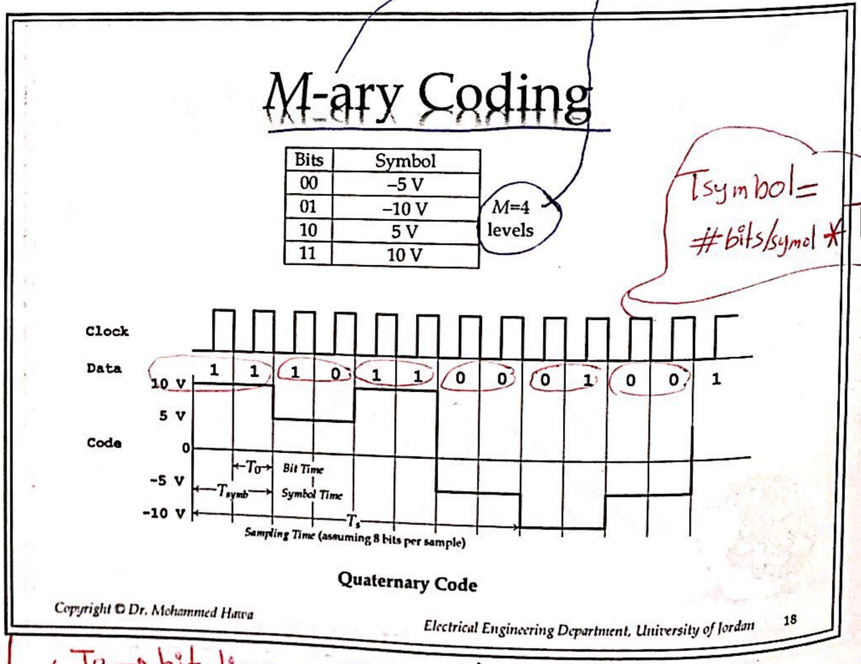
when $M = 2^n$

Ex 4 ary line coding $2^{2=n}$

bits	symbol
00	-5 V
01	-10 V
10	5 V
11	10 V

كل 2bit بيطلع Symbol

$\nearrow n$



M-ary Coding

Bits	Symbol
00	–5 V
01	–10 V
10	5 V
11	10 V

M=4 levels

$T_{symbol} = \#bits/symol * T_0$

Quaternary Code

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* T_0 → bit time = $\frac{T_s}{8}$

* T_{symbol} → symbol time = $\frac{T_s}{4}$

* T_{sample} → مجموع bit الـsample

* $T_s = \frac{1}{f_s}$

$f_s \geq 2f_m$

$f_s = 2f_m$

* bit rate → # of bits /sec

* Baud rate → # of symbol/sec

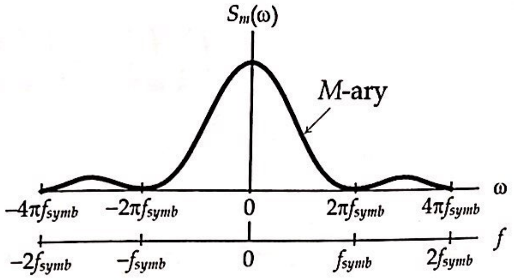
2/15/2017

* Baud rate = $\frac{1}{\log_2 M}$ bit rate

n ← (# of bits/symbol)

→ in general & $\log_2 X = \frac{\log_{10} X}{\log_{10} 2}$

M-ary PSD and Bandwidth



symbol rate [*in units of* baud] = (1/log₂ (*M*)) × data bit rate [*in units of* bit/s]

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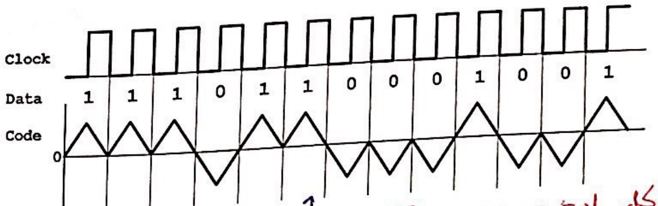
* in binary coding :-
Baud rate = Bit rate

* B.W of a signal is related to it's B.W

problem

intersymbol interferance (ISI)

Pulse Shaping



* اكل استخدم عند Tx لأنه ال sharp أخف

فما بظهر عندي high freq. -

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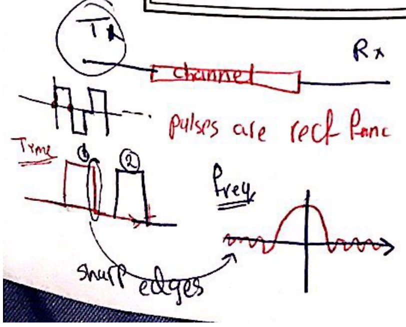
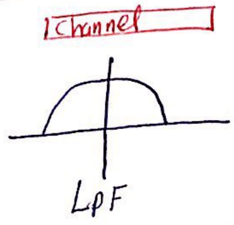
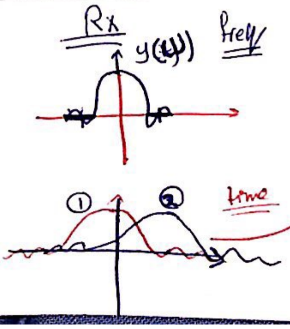
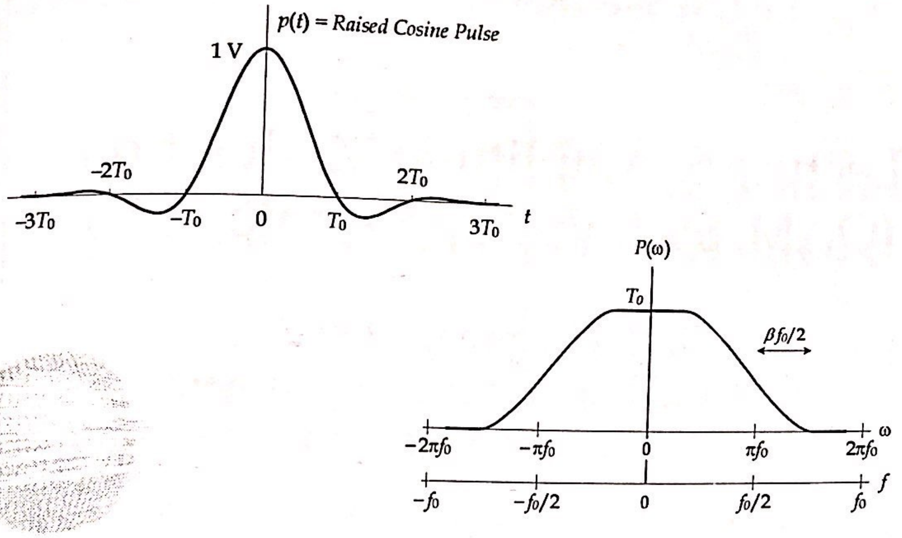




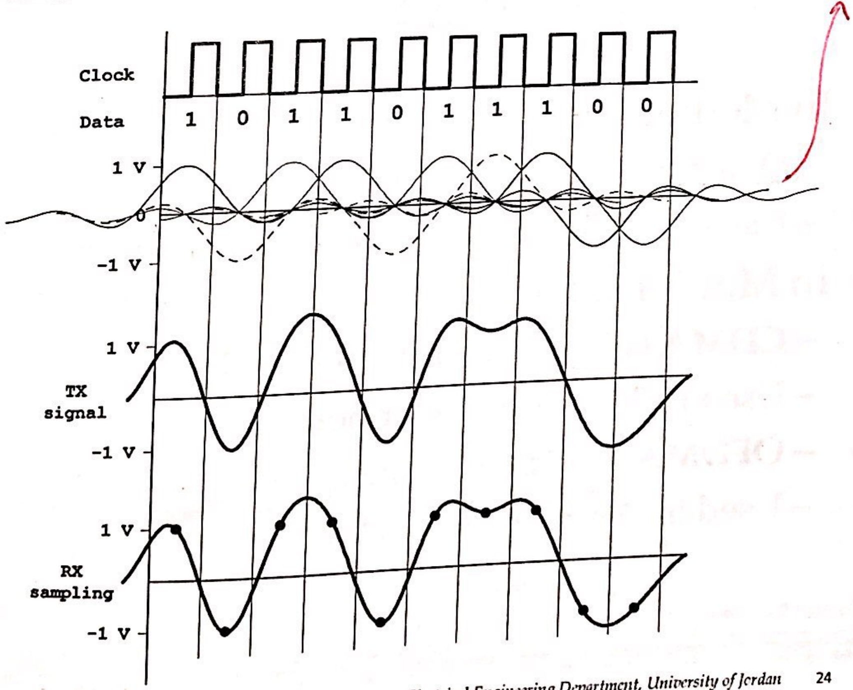


Pulse Shaping: Polar *Raised-Cosine*



---

* من اللابتوب لانها ملونة



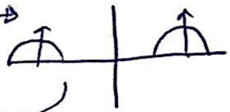
* amplitude modulation:

S. carrier →

→ adv. low power for carrier

→ disadv. complex Rx synchronous (coheranse) (using PLL)

L. carrier →



→ adv. simple Rx asynchonous (non-coherance)

→ disadv. high power

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بدها power اكثر مشان تبعت ال carrier

★ Amplitude modulation

1- DSB-SC
2-DSB-LC
3- SSB - LSB
4- SSB - VSB
5- SSB-LSB
6- SSB - USB
7- VSB - LSB
8- VSB - USB
9- VSB - LSB
10- VSB - USB
11- QAM

Lecture 6: Amplitude Modulation (QAM, SSB, VSB and Analog TV)

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Electrical Engineering Department
University of Jordan

EE421: Communications I

Orthogonality

- In Modulation:
  - **QAM modulation** (sin/cos)
  - Used in DVB, Wi-Fi, WiMAX, 3G, 4G LTE
- In Multiplexing:
  - **CDMA** (Walsh codes, GOLD codes)
  - Used in 3G cellular telephony
  - **OFDMA** (multiple cosines)
  - Used in Wi-Fi, WiMAX, 4G LTE

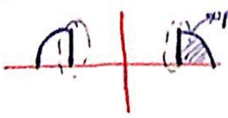
digital video Broadcasting

codes orthogonal

freq all cos لـ

single side band

⊛ SSB



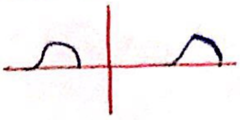
→ adv. small B.w

→ disadv. sharp filter (shap edge بسبب ال)

DSB

⊛ VSB

vistegal



→ adv. no need for shap filter

→ SSB < Bw < DSB

Note orthogonal → $\overline{x_1(t) \cdot x_2(t)} = 0$

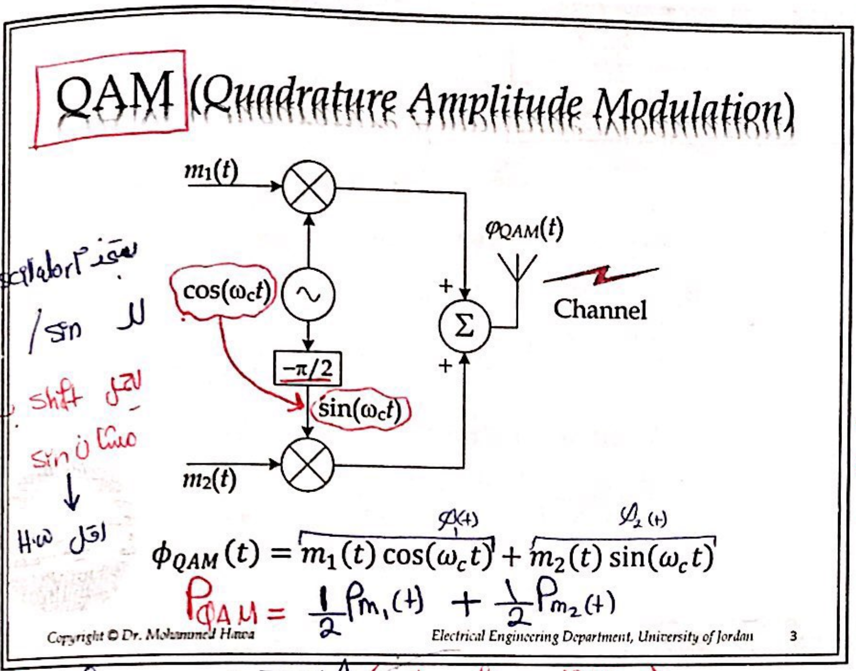
Ex: $x_1(t) = \sin(\omega_c t)$
$x_2(t) = \cos(\omega_c t)$

3/14/2017

* فكرة QAM

ارسل 2-signals بنفس الوقت وعلى نفس الـ channel بحيث اضاعف الـ capacity

لازم يكونوا orthogonal → to increase the capacity of channel
عدد Users



QAM (Quadrature Amplitude Modulation)

$$\phi_{QAM}(t) = \overbrace{m_1(t)\cos(\omega_c t)}^{\phi_1(t)} + \overbrace{m_2(t)\sin(\omega_c t)}^{\phi_2(t)}$$

$$P_{QAM} = \frac{1}{2}P_{m_1(t)} + \frac{1}{2}P_{m_2(t)}$$

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1-oscillator يعني الـ cos / sin

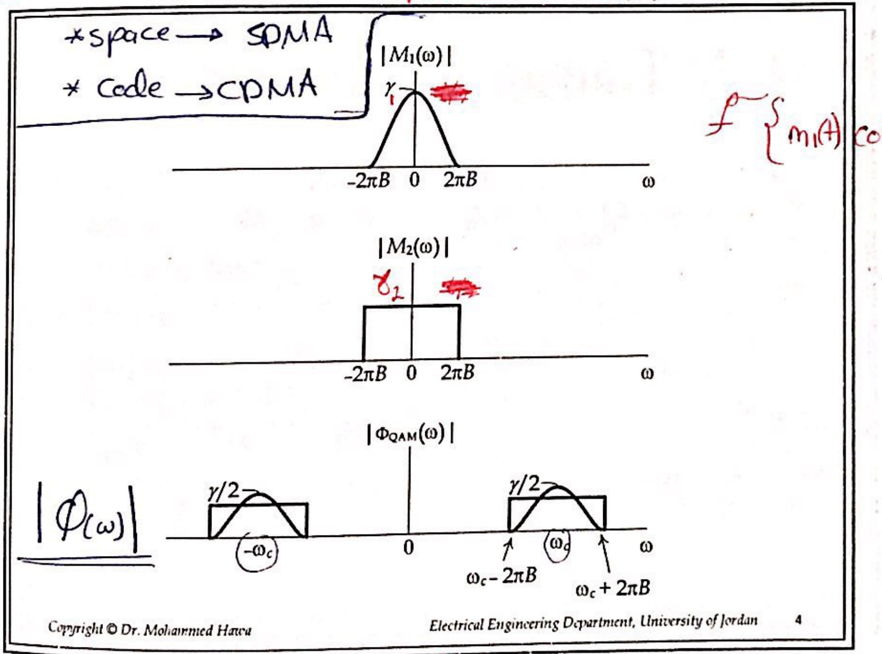
بعمل shift 90 ← منه sin

↓

اقل H.w و cost

كيف بنجمع بين signals?

* freq. → OFDMA (ortho. freq. division)
* time → TDMA (time division mul.)
* space → SDMA
* code → CDMA



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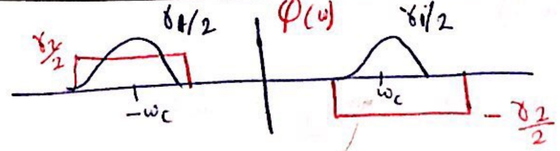
$\mathcal{F}\{m_1(t)\cos(\omega_c t) + m_2(t)\sin(\omega_c t)\}$

⇒ $\Phi(\omega)$



sin
بيكون مرة تحت ومرة فوق

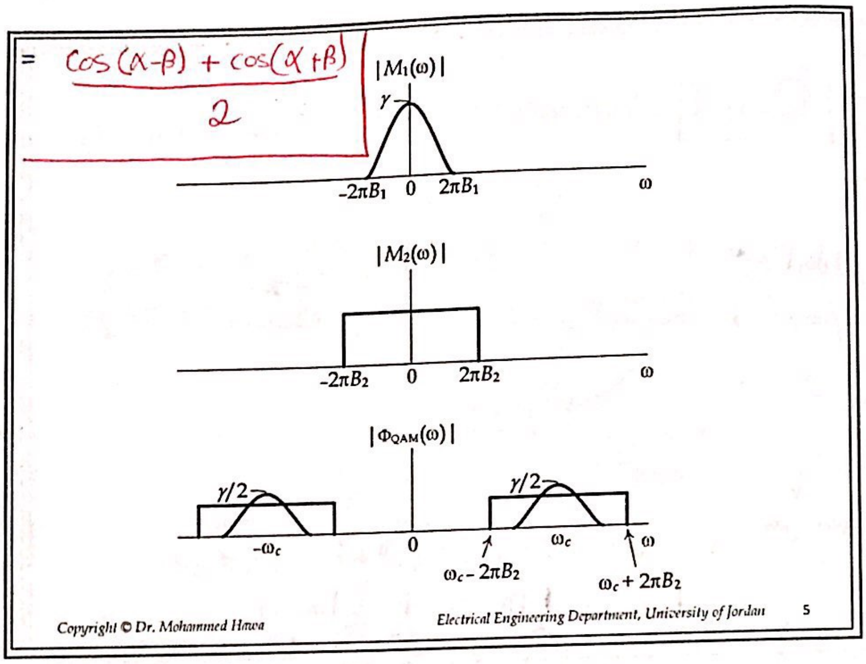
*you have to Know:

3/14/

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

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

③ $\cos\alpha \cos\beta = \frac{\cos(\alpha-\beta) + \cos(\alpha+\beta)}{2}$



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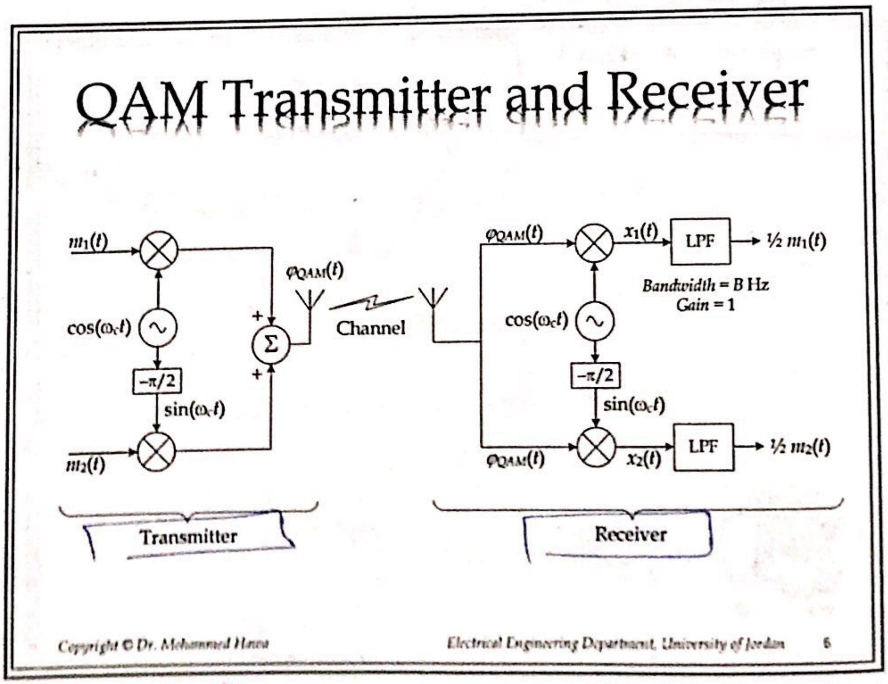
5



QAM Transmitter and Receiver

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Rx: $x_1(t) = \phi_{QAM}(t) \cdot \cos(\omega_c t)$

$= [m_1(t)\cos\omega_c t + w_2(t)\cos\omega_c t]\cos\omega_c t$

$= \frac{1}{2} m_1(t) + \frac{1}{2} m_1(t)\cancel{\cos 2\omega_c t} + \frac{1}{2} m_2 \cancel{\sin 2\omega_c t}$

$\boxed{LPF} \rightarrow y(t) = \frac{1}{2} m_1(t)$

QAM vs. DSB-SC

- **Advantages of QAM:**
  - QAM is more bandwidth efficient than DSB-SC, allowing us to send two signals on the same channel (of bandwidth $2B$).
- **Disadvantages of QAM:**
  - When synchronous detection is used for QAM with errors in synchronization, attenuation, distortion and **co-channel interference** show up.

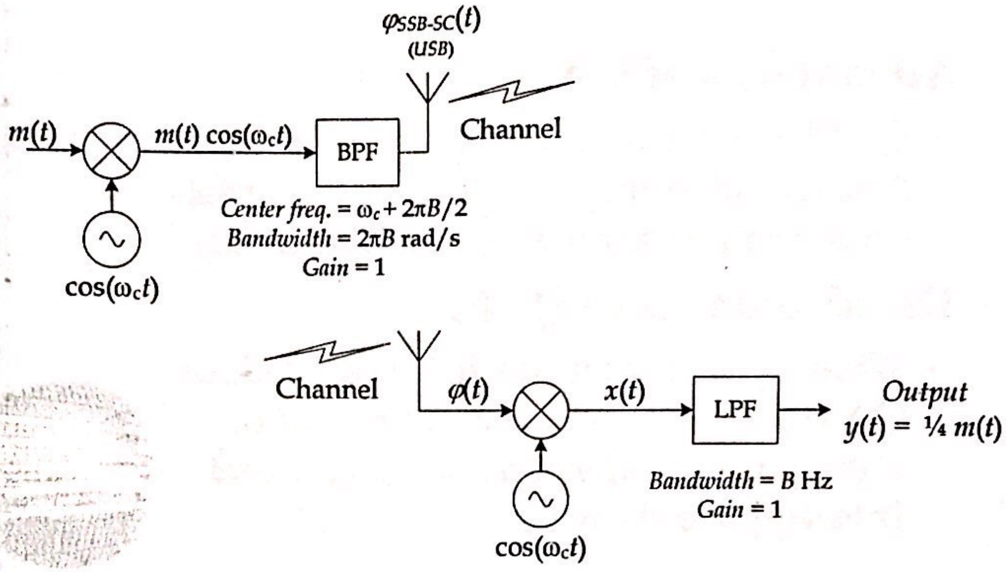
Applications

- Analog QAM is used to carry *chrominance* (color) information in Analog TV broadcasting.
- Digital QAM (to be discussed later) is very popular nowadays: DVB, DAB, Wi-Fi, WiMAX, 3G, 4G, ADSL, etc.
- DSB-SC is used in analog instrumentation, and as part of multiplexing in Stereo FM broadcasting.

3/1

single side band

SSB-SC (USB) Modulation



Center freq. = $\omega_c + 2\pi B/2$
Bandwidth = $2\pi B$ rad/s
Gain = 1

Bandwidth = B Hz
Gain = 1

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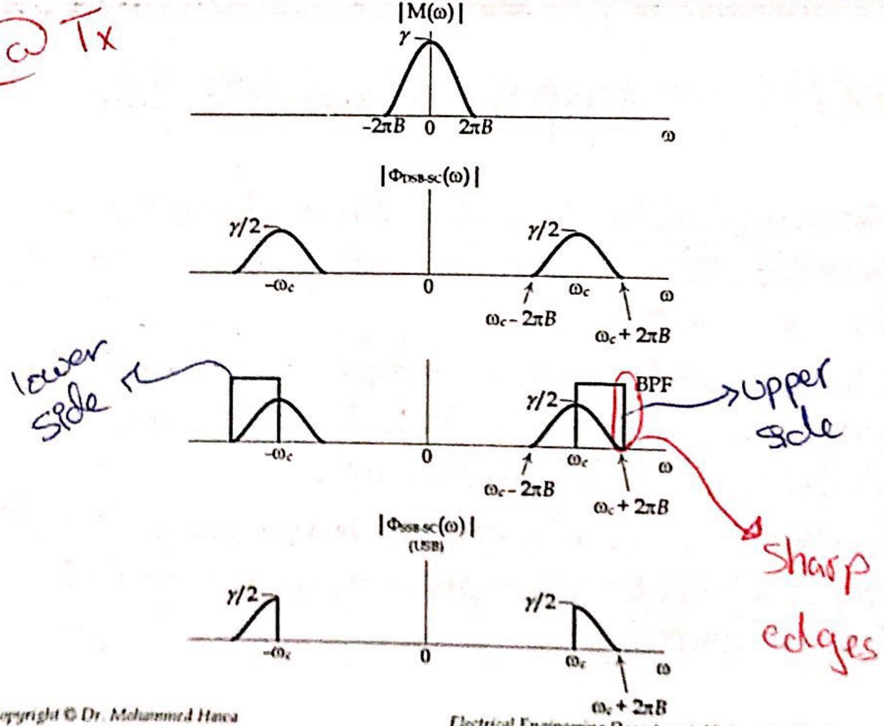
@ Tx



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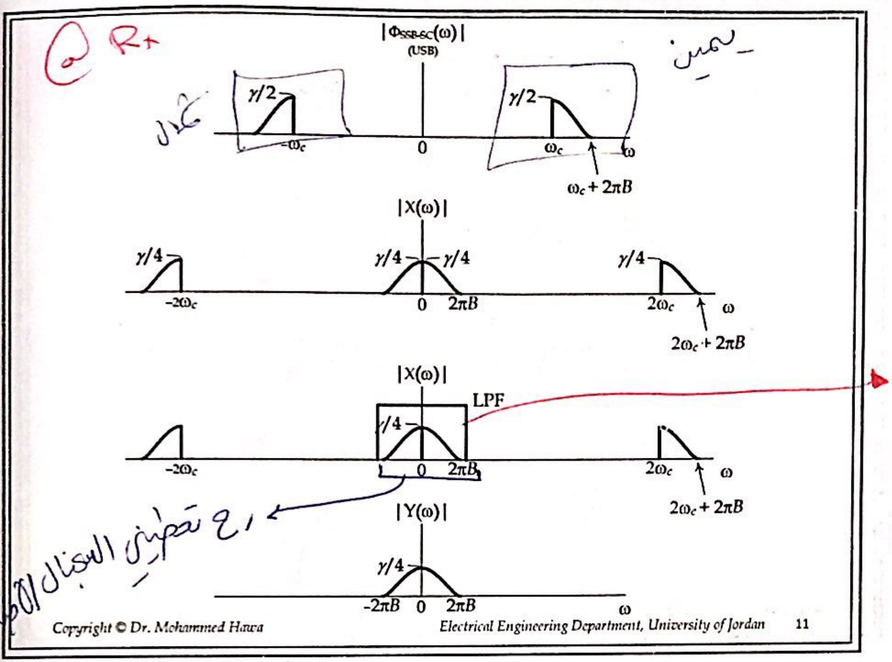
*adv. of SSB-SC & small B.W & small power for amplification on channel

*disadv " & sharp ~~end~~ edges filter



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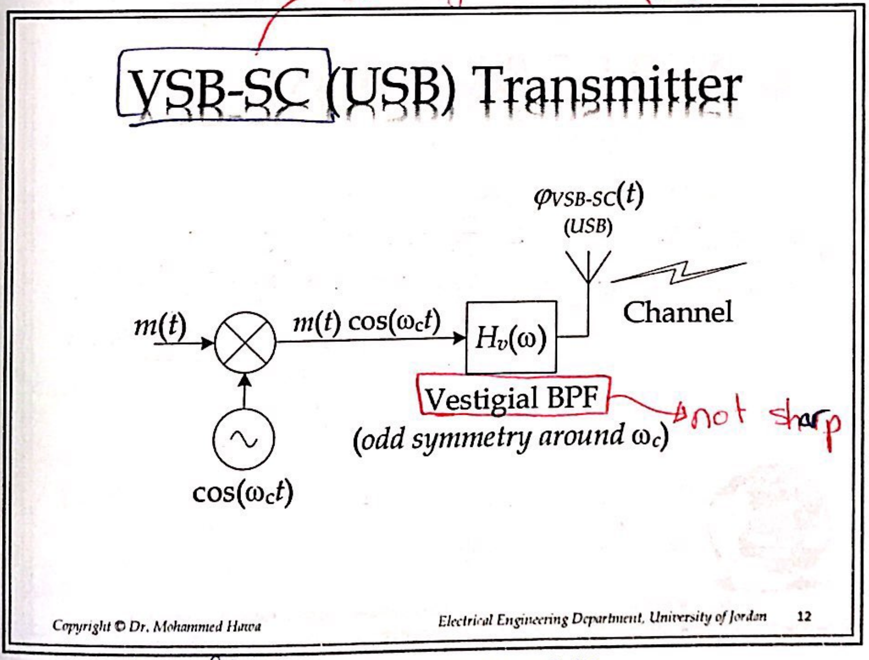
من اللابتوب

اللون الازرق من الي على اليمين والسودا من الي عالشمال

ع تحويش السغنال الاصلية

حل وسط بيقع للـ double & single

VSB-SC (USB) Transmitter



Vestigial BPF
(odd symmetry around ω_c) → not sharp

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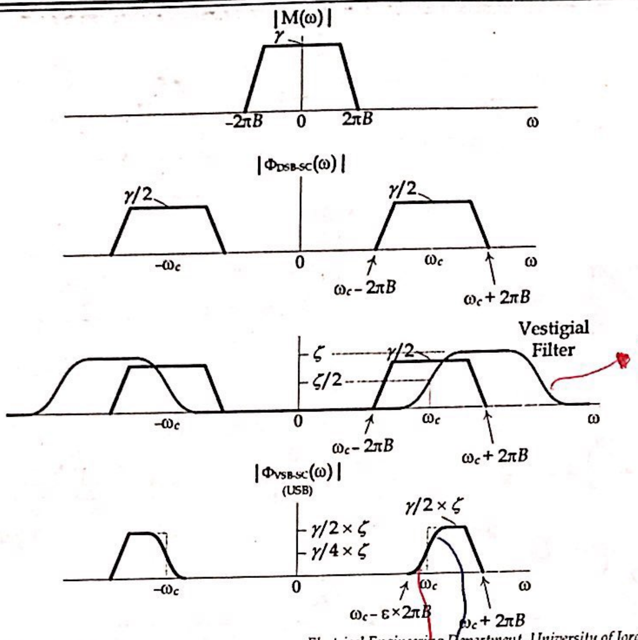
*sharp filter → very expensive

$*BW_{(VSB)} = (1+\epsilon)\beta$ Hz $\rightarrow 0 \leq \epsilon \leq 1$

*typical value of ϵ :
0.1 — 0.5

* if $\epsilon = 0 \rightarrow$ single side --
* if $\epsilon = 1 \rightarrow$ Double side --



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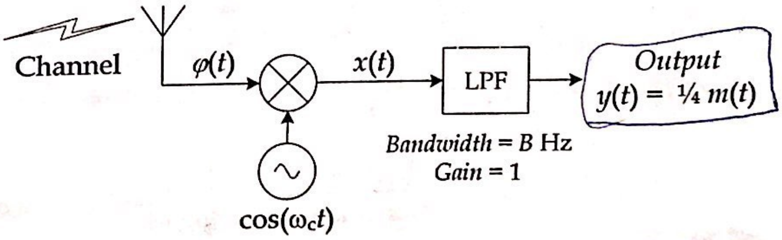
بجوز جز بال lower part

نخسر جزء ال upper part

VSB-SC (USB) Receiver



Output
$y(t) = \frac{1}{4}\,m(t)$

Bandwidth = B Hz
Gain = 1

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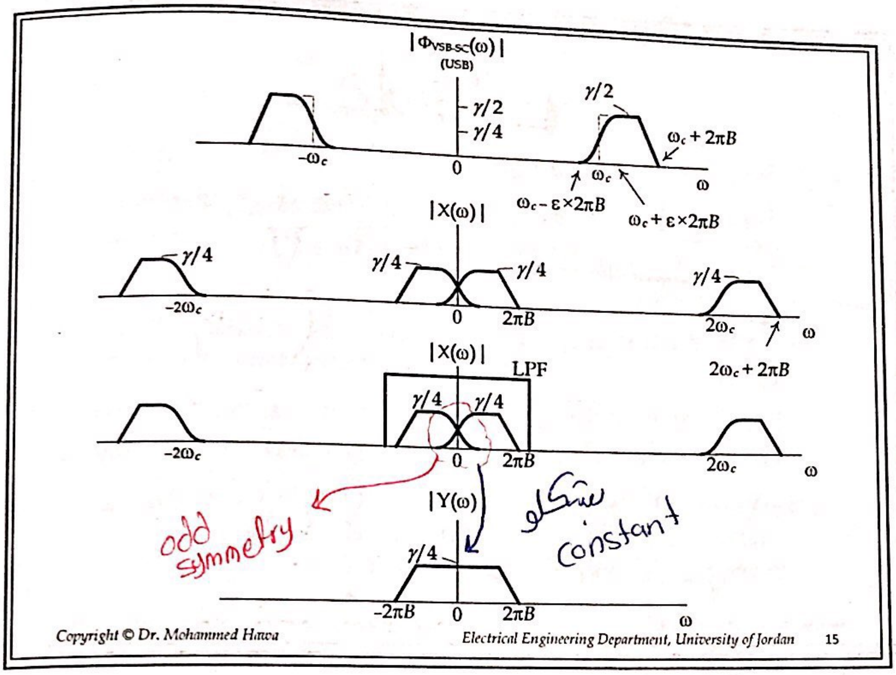

odd symmetry

بشكل constant

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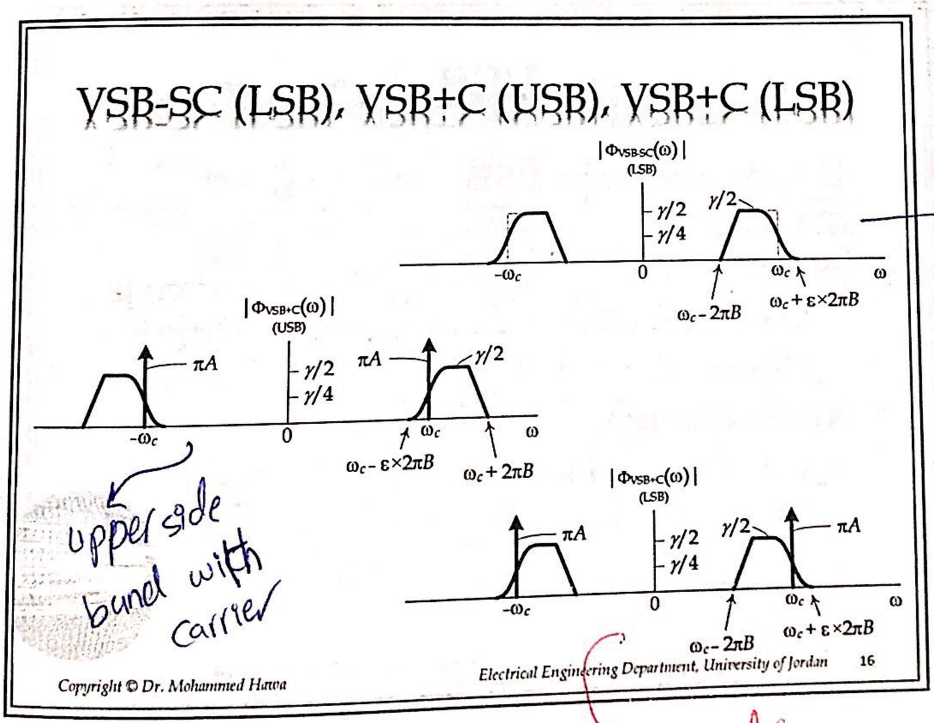

VSB-SC (LSB), VSB+C (USB), VSB+C (LSB)

lower side band

upper side band with carrier

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lower side band with carrier

SSB ↑ best
VSB (freq. selective fading) , (synchro. error) , (B.W)
DSB
QAM ← same B.W
worst

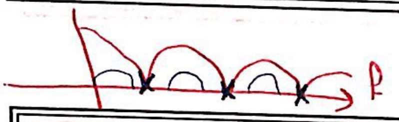
VSB

- **Advantages of VSB:**
  - Simple to generate (no need for sharp filters).
  - Can vary the VSB filter bandwidth (flexibility). ← بتغير بقدر أغير الفلتر ⊕
  - VSB transmission bandwidth is smaller than DSB.
  - Smaller bandwidth means more immunity to frequency-selective fading compared to DSB.
  - ⊖ In case of synchronization errors, VSB-SC suffers less attenuation and distortion compared to DSB-SC.

*freq selective fading

الـ channel بكون فيها freq. معينة بصير fading عليها (بتروح للصفر السجنل)

* وإذا قلت الـ B.W بزيد المقاومة لهاي النقاط



VSB

- **Disadvantages of VSB:** Rx ⟹ complex & expensive
  - ⊖ VSB-SC require synchronous detection.
  - ⊖ VSB+C (which allows envelope detection) is less power efficient compared to AM (since we need $A >> -m(t)_{min}$) ⟹ مناخذه لقدام
- **Applications:**
  - VSB+C is used to send luminance (B & W) information in Analog TV broadcasting. → negative للصورة
  - VSB-SC is used in facsimile (fax) machines.

Summary

- QAM
  - Bandwidth is $2B$ (but we send two signals)
  - Average power is $\overline{\varphi^2(t)} = \frac{1}{2}\overline{m_1^2(t)} + \frac{1}{2}\overline{m_2^2(t)}$
- SSB-SC (USB or LSB)
  - Bandwidth is B (one signal)
  - Average power is $\overline{\varphi^2(t)} = \frac{1}{4}\overline{m^2(t)}$
- VSB-SC (USB or LSB)
  - Bandwidth is $(1 + \epsilon)B$ (one signal)
  - Average power is $\overline{\varphi^2(t)} = \frac{1}{4}\overline{m^2(t)}$ → disadv انه توصل أقل Power

adv. ⇒ انه الpower الي بدي اياها بـ ال channel أقل

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Analog Television Standards

	U.S. Standard	European Standard
Analog TV	**NTSC:** National Television System Committee (VSB+C, QAM, FM; FDM)	**PAL:** → Jordan Phase Alternating Line (VSB+C, QAM, FM; FDM)
Digital TV	**ATSC:** Advanced Television System Committee (MPEG-2; VSB-8 or QAM; TDM+FDM)	**DVB-T, DVB-S, DVB-S2, …:** Digital Video Broadcasting (MPEG-2; QPSK, QAM; TDM+FDM)

ح نركز عليها د التعابير

T → trestial
البث الأرضي

S → satellite

S2 → version2 of satellite

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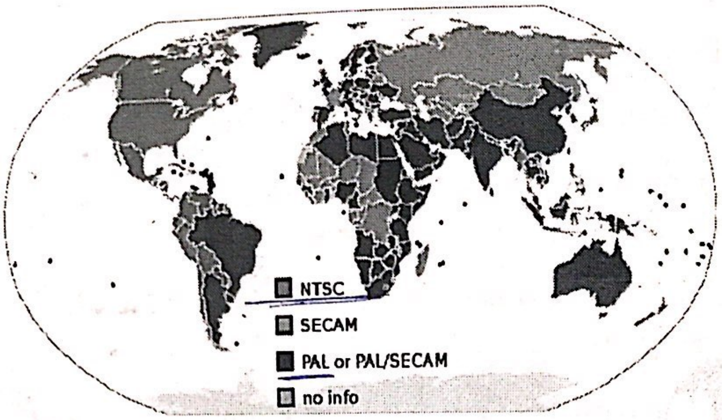
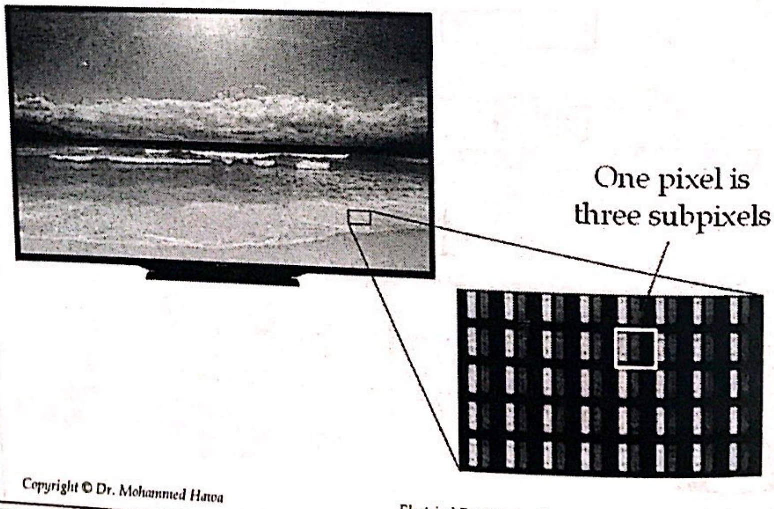
DVB-H → hand held

معلومة *

Analog Television (PAL/NTSC)



Television and Pixels


One pixel is three subpixels

Screen TV ⟶ pixels
↓
3 subpixels
(red, blue, green)

Tx

Y signal ⇒ Luminance (B&W) — NTSC 4M, Pal 6M

U(I) " ⇒ Chrominance 1 — 1 MH

V(Q) " ⇒ Chro " 2 — 1 MHz

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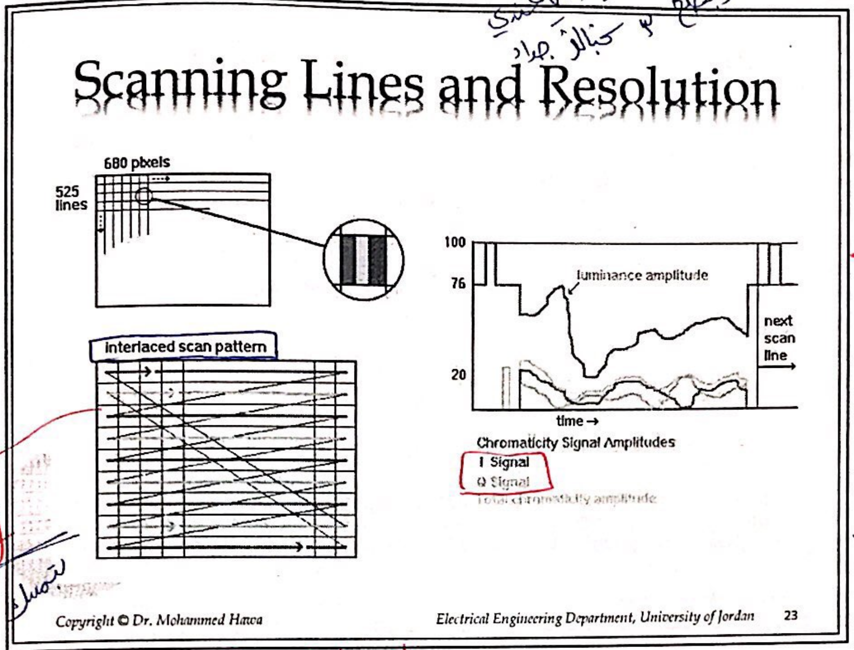
microphone ⇒ FM modulation (0.5 MHz)

هاي ماتركس بضربها بالسجنالز الأصلية وبطلع ٣ سجنالز جداد



Scanning Lines and Resolution

680 pixels

525 lines

interlaced scan pattern

100

76

20

luminance amplitude

next scan line

time →

Chromaticity Signal Amplitudes

I Signal

Q Signal

Total chromaticity amplitude

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عملية Scanning

تشمل odd lines

بعدين even lines

* Y signal

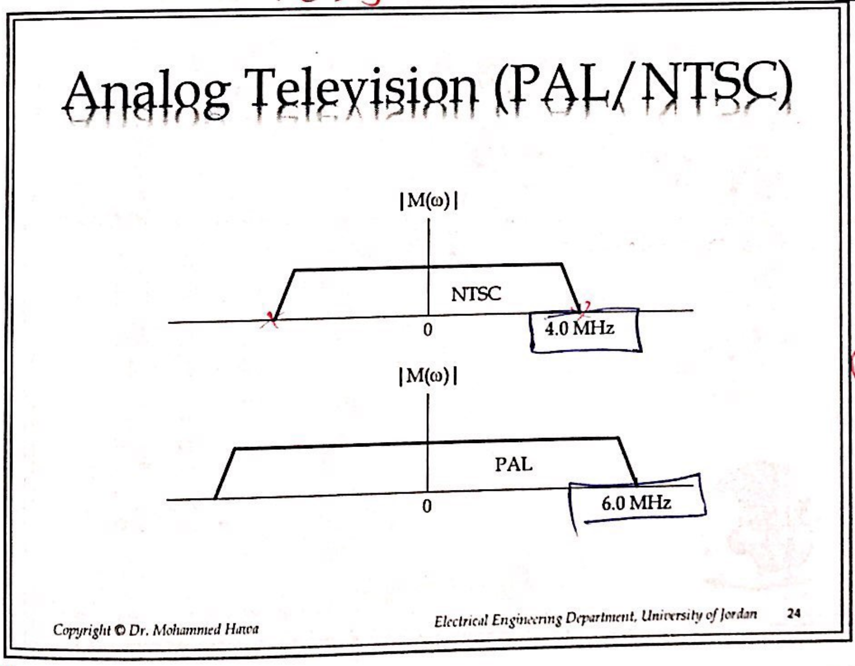
برسلها من خلال

→ VSB + C mod

5 MHz (NTSC)

7 MHz (Pal)

* U(I) } برسلهم
Y(Q) } ⇒ QAM modu. ⇒ (2 MHz)



Analog Television (PAL/NTSC)

|M(ω)|

NTSC

0

4.0 MHz

|M(ω)|

PAL

0

6.0 MHz

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* advantage

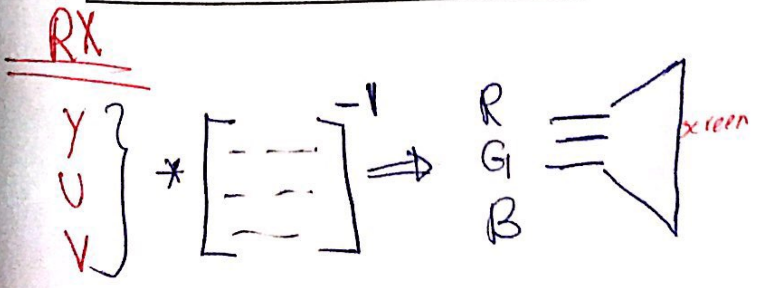
تحويل من Red, blue, green

→ Y, U, V 8

① reduce Bandwidth

② backward Compatibility

RX



TV شرح signals

3/1

مش مهم

Standard Definition (SDTV)

Resolution		Aspect ratio	Pixel shape	Form of scanning	Frame Rate (Hz)
Vertical	Horizontal				
480	640	4:3	square	interlaced	30 (60 fields/s)
				progressive	24 30 60
	704	4:3 or 16:9	non-square	interlaced	30 (60 fields/s)
				progressive	24 30 60

- Many other profiles and frame rates are supported by ATSC and DVB, but the above are the most popular and the most likely to be supported by a digital TV set (monitor). The monitor profile name is called 480i and 480p.

*480 i
480 → vertical lines
i → interlaced

*480 P
P → progressive

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High Definition (HDTV)

Resolution		Aspect ratio	Pixel shape	Form of scanning	Frame Rate (Hz)
Vertical	Horizontal				
720	1280	16:9	square	progressive	24 30 60
1080	1920	16:9	square	interlaced	25 (50 fields/s) 30 (60 fields/s)
				progressive	24 25 30
2160	3840	16:9	square	progressive	30 60 120

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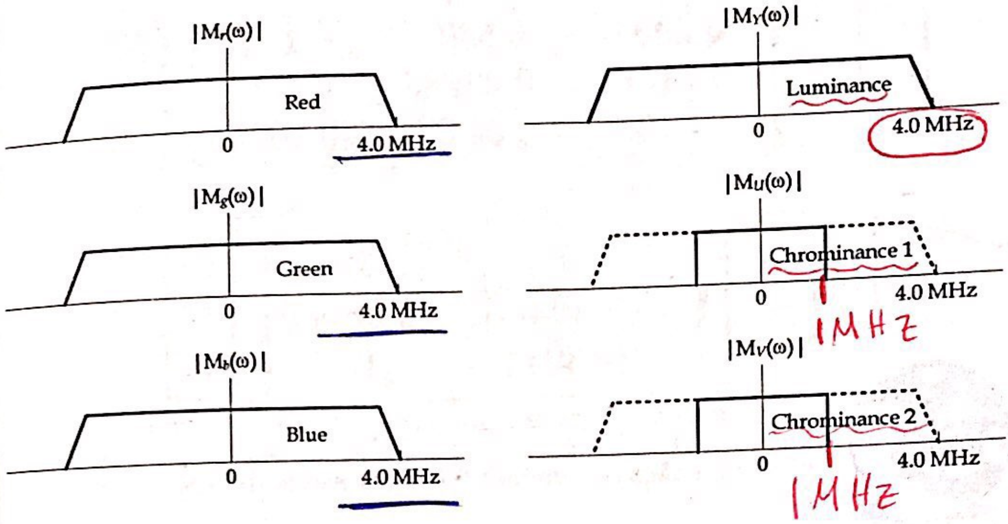
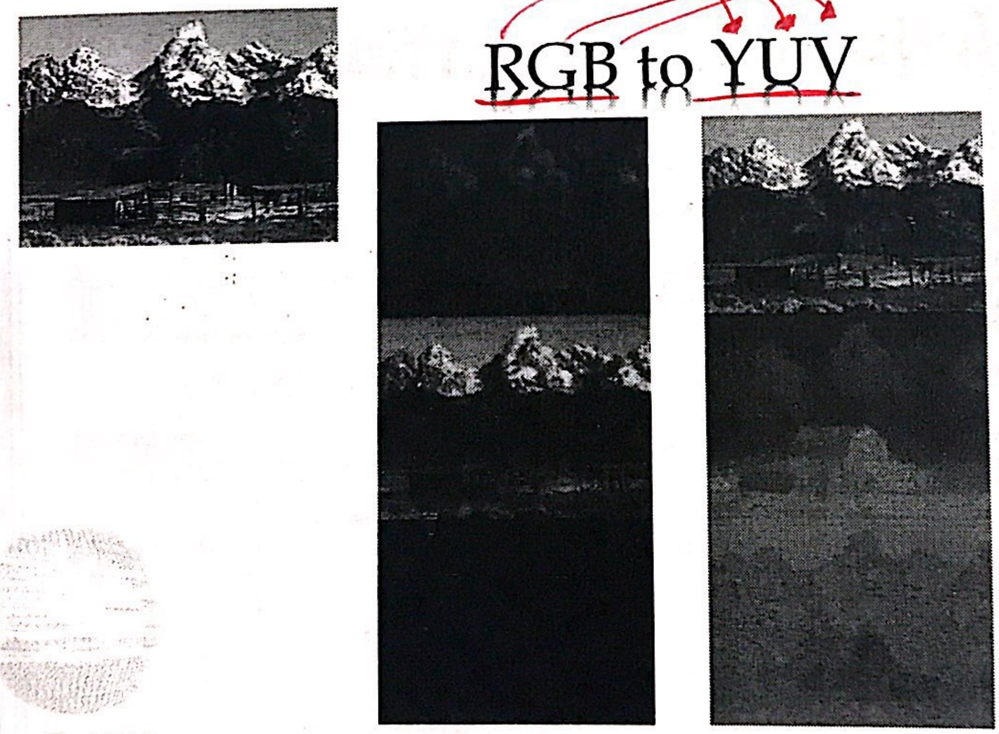
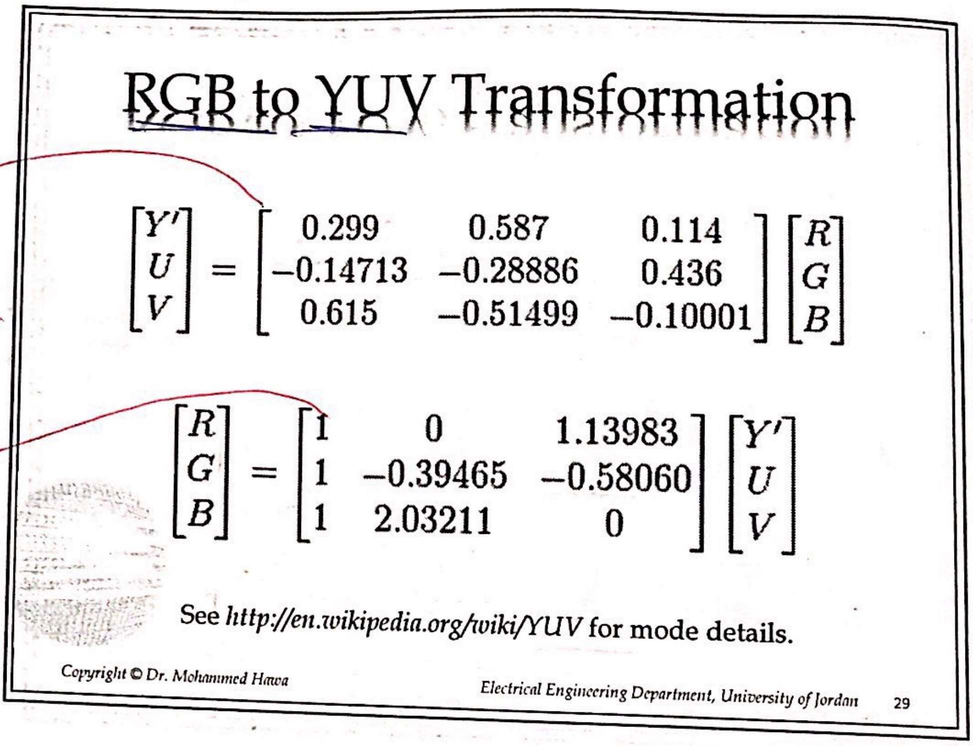
Luminance & Chrominance



RGB to YUV





RGB to YUV Transformation

الماتركس الما

عند Tx

$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & -0.51499 & -0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

عند Rx

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.13983 \\ 1 & -0.39465 & -0.58060 \\ 1 & 2.03211 & 0 \end{bmatrix} \begin{bmatrix} Y' \\ U \\ V \end{bmatrix}$$

See *http://en.wikipedia.org/wiki/YUV* for mode details.

Noticeable only in sharp images

Red, Green, blue

Tx عند

@ Rx

الفرق بكون بس عند

~~shap~~ sharpes

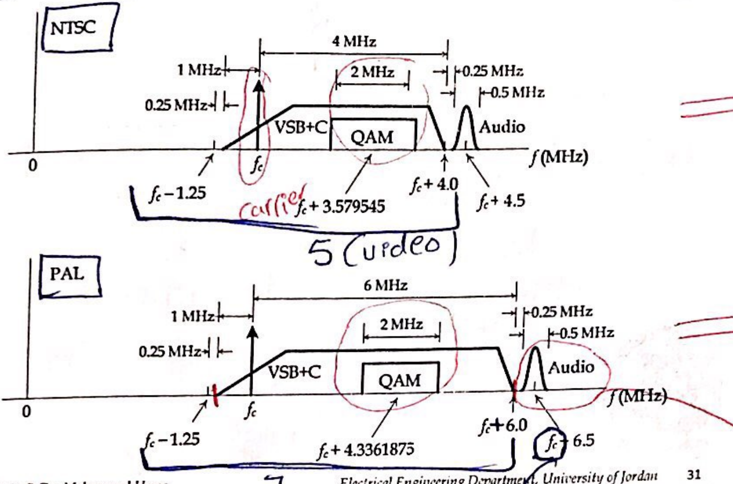
ومش واضح

* اذا طلب BW اكتب 5,7 Video

QAM = 2MHz

*carrier → simple reciever → less cost

Analog TV(VSB+C & FM & QAM)



$0.25 + 1 + 4 + 0.25 + 0.5 = 6MHz$ video + Audio

$0.25 + 6 + 1 + 0.25 + 0.5 = 8MHz$

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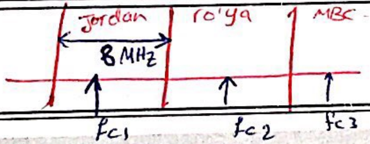
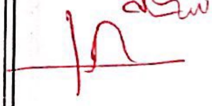


fc ⇒ كل channel الها رقم معين

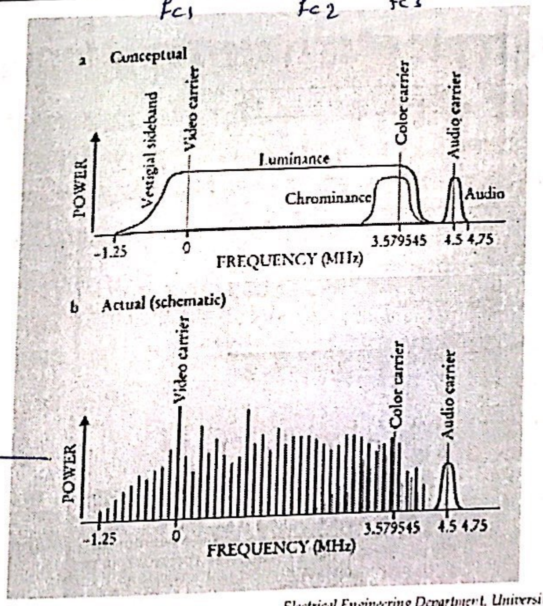
ليش ال guardband لهاد الشكل ؟؟؟

مشان ال practical BPF

هيك شكله



مشان ما يسوي distortion



periodic تقريباً

periodic بس مش

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* for Y signal ⇒ VSB + C

$BW\ (PAL) = 7\ MHz = \beta(1+\epsilon)$, $\beta = 6$

$7 = 6(1+\varepsilon)$

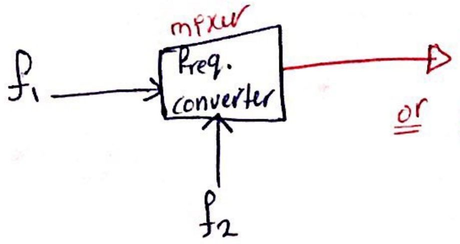
$\epsilon = \frac{1}{6}$

BW(NTSC)

$5 MHz = 4M(1+\epsilon)$

$\epsilon = \frac{1}{4}$

3/14



$f_{o_1} = f_1 + f_2$
or $f_{o_2} = f_1 - f_2$ } heterodyne freq.

*heterodyne: multiple freq.

*homodyne: Single freq.

its called: Freq. conversion

Lecture 7: Heterodyning
(Up & Down Frequency Converter)

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EE421: Communications I

Heterodyne: Multiple Frequencies

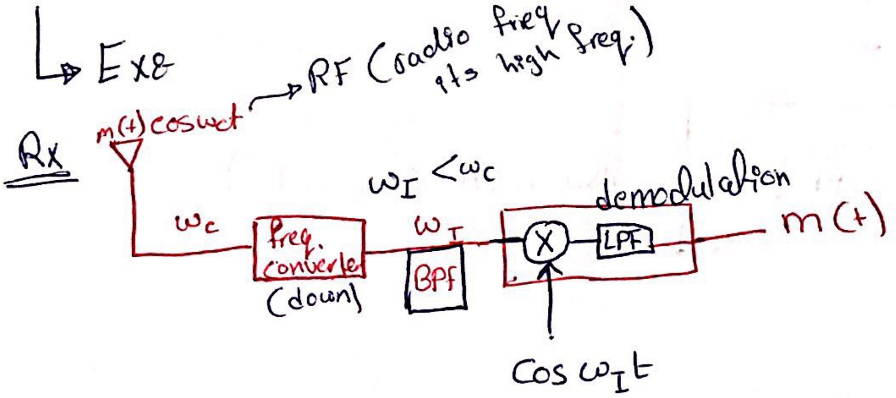
- Typical **transmitters** do not modulate immediately from baseband to carrier frequency ω_c. Rather, they modulate to an *intermediate frequency* ω_I, then an up-converter shifts the frequency to the higher frequency ω_c.
- Also, real-life **receivers** do not demodulate immediately from carrier frequency ω_c to baseband. Rather, they use a down-converter to shift the modulated signal to an *intermediate frequency* ω_I, then demodulate to baseband.
- This has advantages, especially in FDM systems and digital systems (see: super-heterodyne receiver).

* Com 14.3.2019 / LEC 7

* advantages (applications) of heterodyning

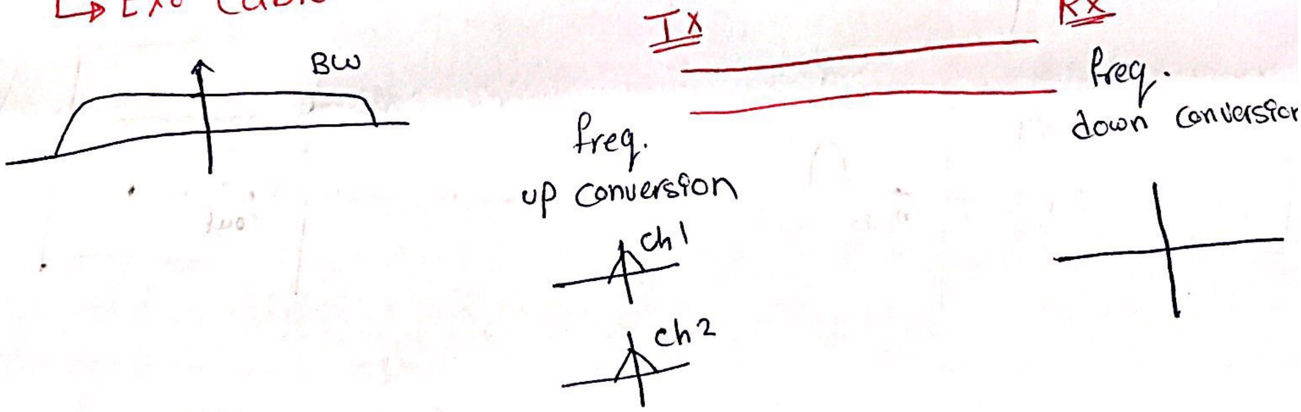
① the dvices H.w used in low freq. range are cheap

↳ Ex:

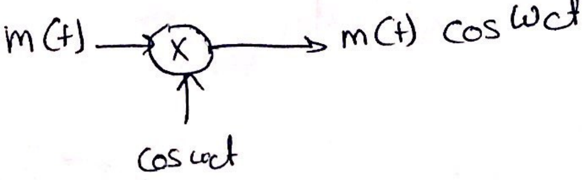


② FDM

↳ Ex: Cable TV



③ super-heterodyne reciever



Tx

$0 \rightarrow \omega_c$ X

$0 \rightarrow \underline{\underline{\omega_I}} \rightarrow \omega_c$ ✓

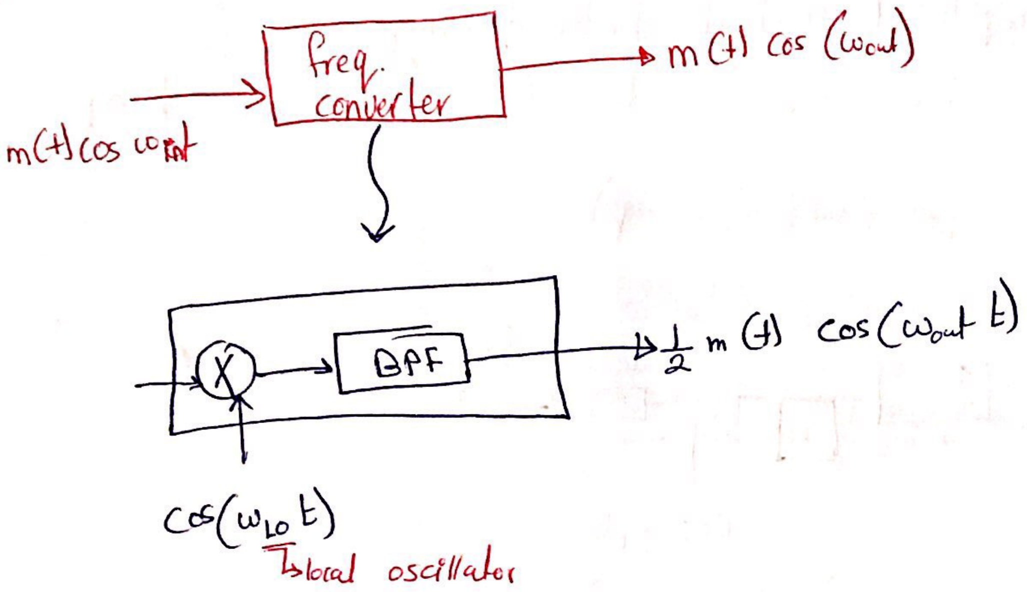
Rx

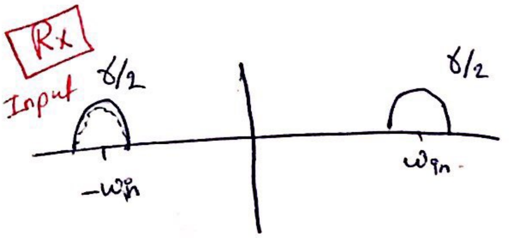
$\omega_c \rightarrow 0$ X

$\omega_c \rightarrow \underline{\underline{\omega_I}} \rightarrow 0$ ✓

لازم أمر من خلال ω_I عشان أقلل freq

*slide 5

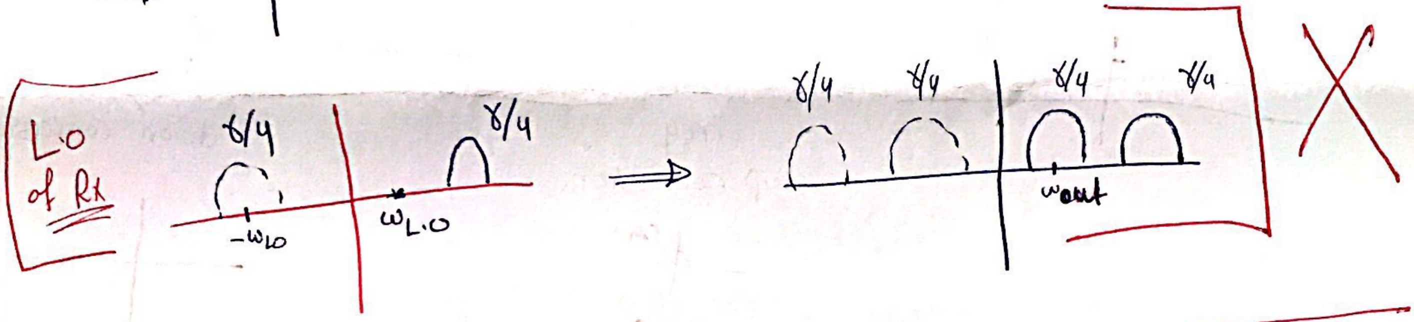


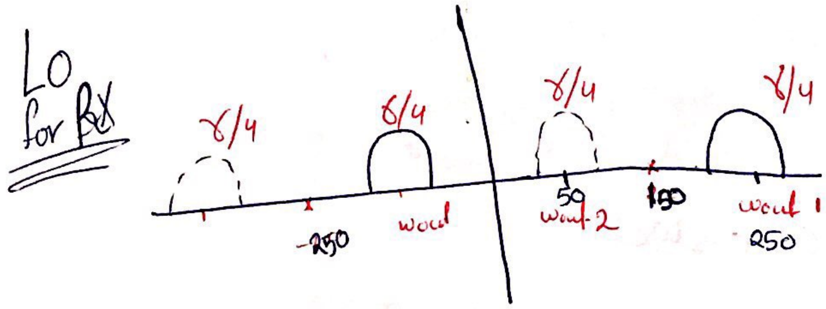


*مثلا فرض

$\omega_{in} = 100$ Hz

$\omega_{LO} = 150$ Hz



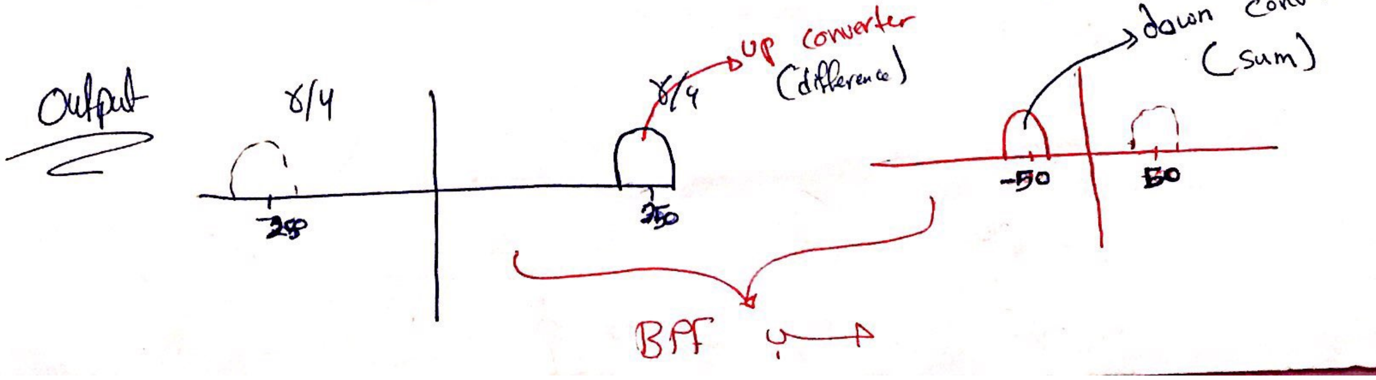


يميز بين up, down من خلال وين الاشي منتقلة

يميز بين difference, sum

$\omega_{LO} = \omega_{out} - \omega_{in}$

$\omega_{LO} = \omega_{out} + \omega_{in}$



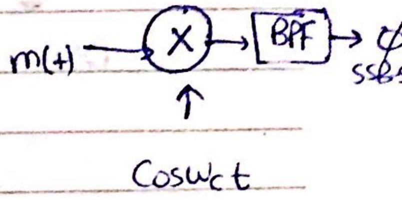
Homework 1 Slide 11.

*Up converter (sum):

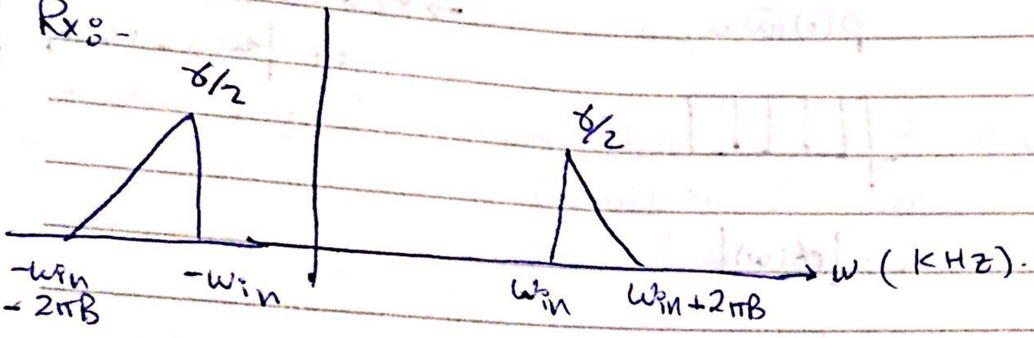
ω_{in} = 100 KHZ.

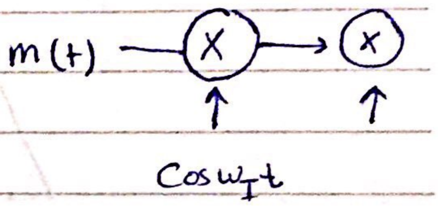
ω_{out} = 300 KHZ

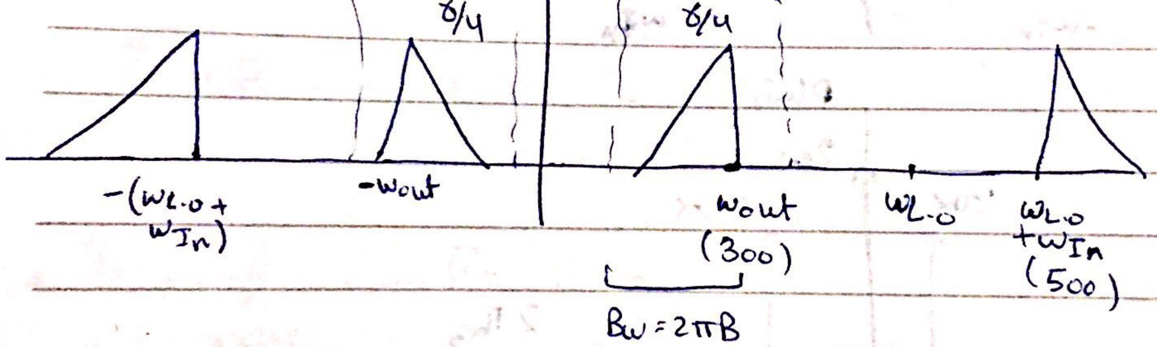
$\omega_{L.O}$ = 400 KHZ.



Rx:-







~~BP~~ BPF: G = 1

$B_W = 2\pi B$

~~Cet~~ Centre Frequency: ~~ωc~~ $\omega_{out} - \frac{2\pi B}{2}$.

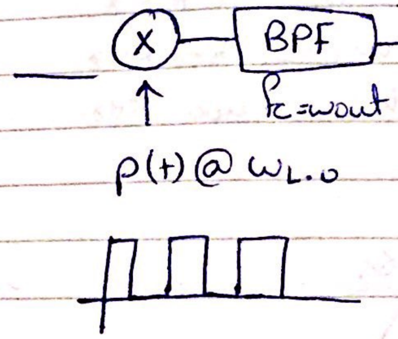
Homework 2 Slide 12

Rx

$\phi(t) = m(t) \cos w_{in} t$

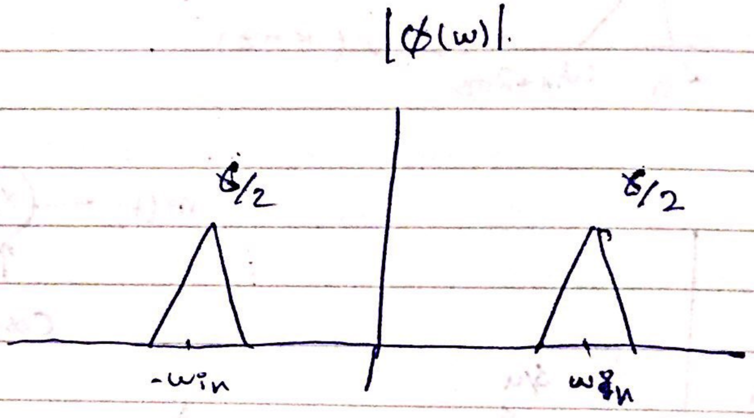
↓

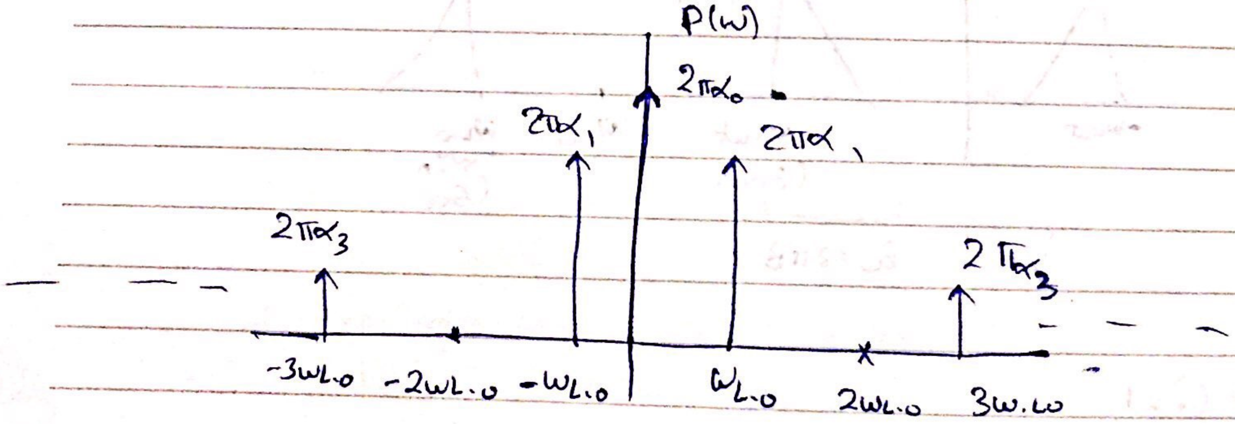
DSB-SC

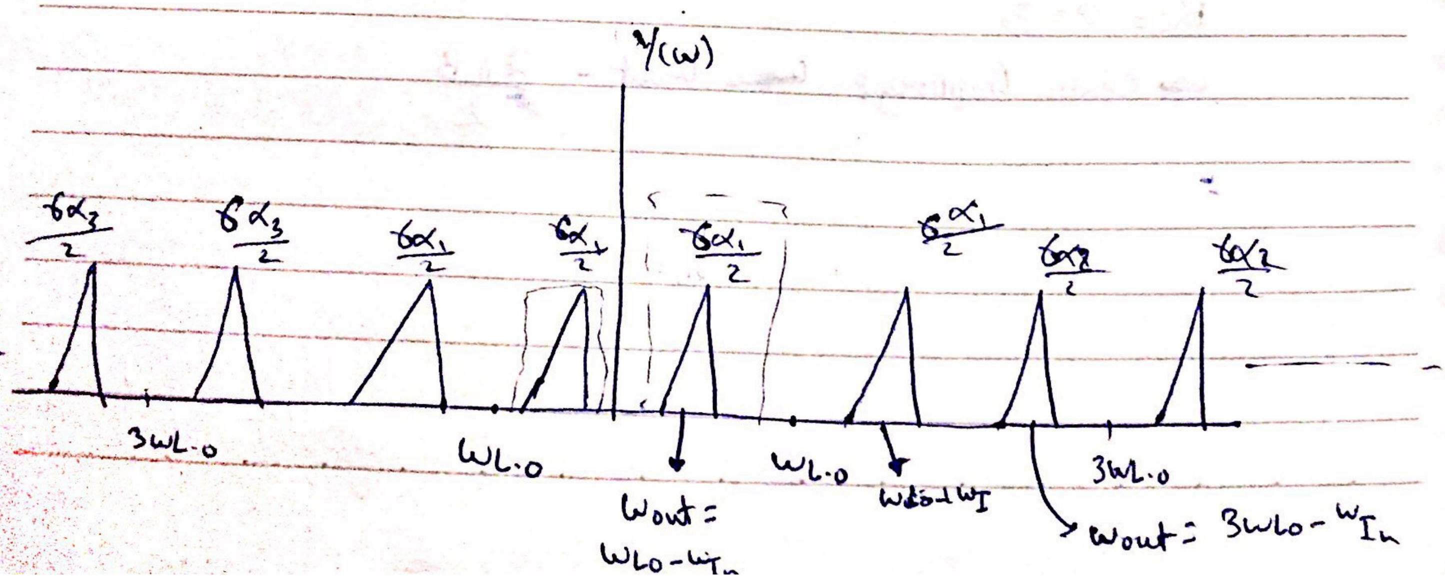


y(t) = k m(t) cos w_{out} t

$\to w_{L.o} = w_{in} \pm w_{out}$ or $|w_{in} - w_{out}|$







Lecture 8

كلما كانت SNR أعلى يكون أفضل

* BER: bit error rate.

* Good digital communication system if BER $\leq 10^{-6}$

↲ Probability of error is 1 from million.

10^{-7} أحسن

10^{-4} أسوء

$\uparrow$ SNR $\rightarrow \downarrow$ BER

* Tx ——$\overset{}{e}$—— Rx (SNR)

noise ↑

↲ بقيسه بال Rx

* $SNR = \frac{P_x}{P_n}$

$$SNR\ dB = 10 \log_{10} \left(\frac{P_x}{P_n} \right) dB$$

$$= 10 \log_{10} (P_x) - 10 \log_{10} (P_n)$$

$$SNR = \frac{P_x}{P_n}$$

$$= \frac{V_x^2/R}{V_n^2/R} = \frac{V^2_x}{V^2_n} \begin{matrix} \rightarrow rms \\ \rightarrow rms \end{matrix}$$

$$SNR\ (dB) = 10 \log_{10} \left(\frac{P_x}{P_n}\right)$$

$$= 10 \log_{10} \left(\frac{V_x}{V_n}\right)^2$$

$$= 20 \log_{10} \left(\frac{V_x}{V_n}\right)$$

* Attenuation = 5

Gain = - 5

$-5 = \log \left(\frac{P_o}{P_i}\right)$.

* dBm →

Ex 1W → ? dBm

Sol 1W → 10^3 mW → 10 log (10^3) dBm

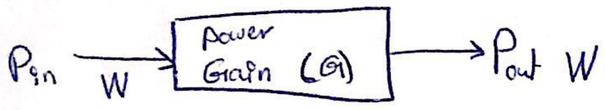
= 30 dBm.

1W → ? dBW

1W → 1W → 10 log (1) dBW

= 0 dBW

Ex



$G = \frac{P_o}{P_{in}}$ (unitless)

$G = 10 \log_{10} \frac{P_o}{P_i}$ dB

$G(db) = \underbrace{10 \log_{10} P_o}_{\text{dbm or dbW}} - \underbrace{10 \log_{10} P_{in}}_{\text{dbm or dbW}}$

P_o(in mW) ← dbm

P_o(in (W)) ← dbW

(*) if $P_i = 5$ W , $P_o = 10$W

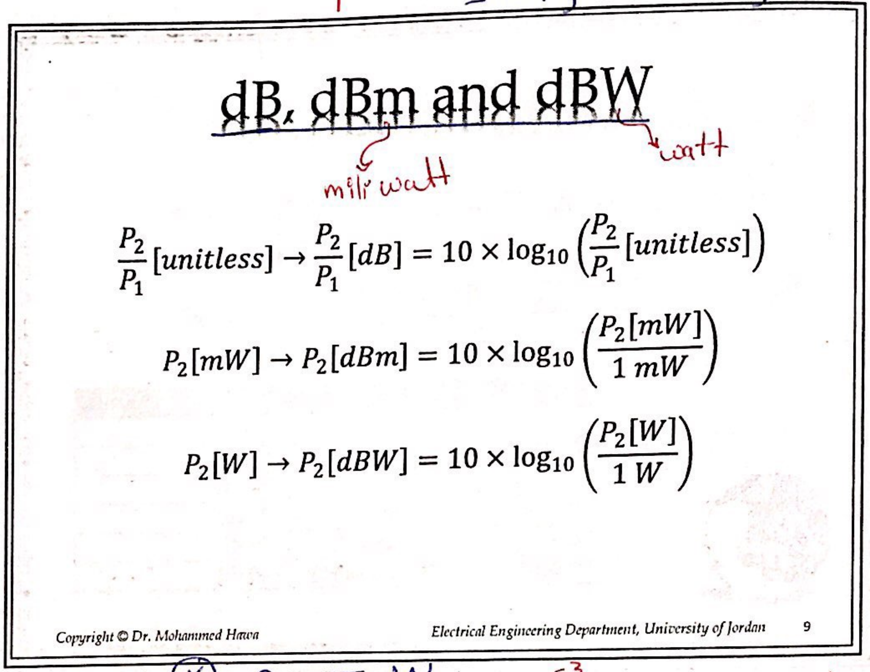
$G = \frac{10}{5} = 2 \rightarrow 10 \lg_{10} 2 = 3$dB

3/1

$\boxed{\text{or}}$

$G(dB) = P_o(dBW) - P_i(dBW)$

$= 10 \log 10 - 10 \log 5 = 3$dB



dB, dBm and dBW

mili watt

watt

$$\frac{P_2}{P_1}[unitless] \rightarrow \frac{P_2}{P_1}[dB] = 10 \times \log_{10}\left(\frac{P_2}{P_1}[unitless]\right)$$

$$P_2[mW] \rightarrow P_2[dBm] = 10 \times \log_{10}\left(\frac{P_2[mW]}{1\,mW}\right)$$

$$P_2[W] \rightarrow P_2[dBW] = 10 \times \log_{10}\left(\frac{P_2[W]}{1\,W}\right)$$

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(*) $P_i = 5$ W

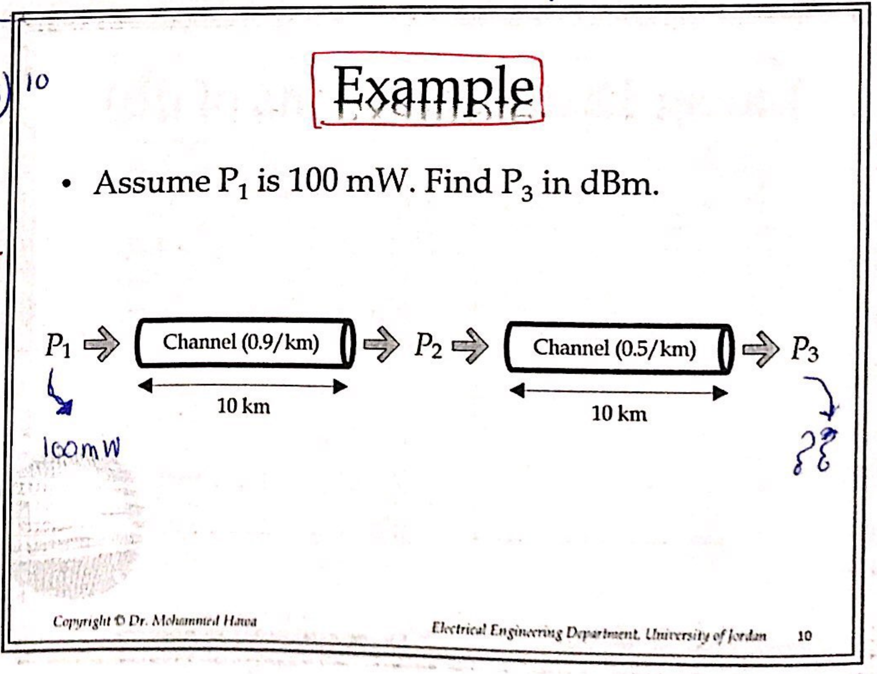
$= 5 \times 10^3$ m W 10^{-3}

*check paper

Sol 1

$P_3 = \underbrace{P_1 (0.9)^{10}}_{P_2} (0.5)^{10}$

$= 0.0341$ mW



Example

- Assume P_1 is 100 mW. Find P_3 in dBm.

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Sol 2

P_3(dBm) =

P_1(dBm) + attenuation Ch (dB)

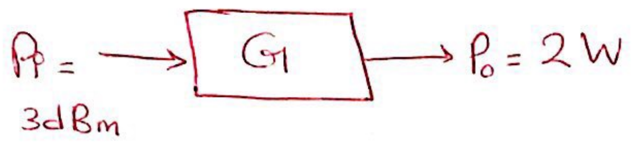
+ attenuation Ch2 (dB

$P_3 = 10\log_{10} 100 + (10 \log_{10} (0.9)) * 10 + (10\log_{10} (0.5)) * 10$

20 dBm − 4.6 dB − 30 dB = −14.6 dBm ≡ 0.0341 m W

Com 21. Mar

EX1 slide 9



G?? in dB & unitless

Sol 1

3 dBm ⟶ W

$3\,dBm = 10 \log_{10} P_i\ (mW)$

$P_i = 10^{3/10}\ mW$

$= 10^{3/10} * 10^{+3}\ W$

$\Rightarrow G = \cancel{\frac{10^{3/10} * 10^{-3}}{2}} = \frac{2}{10^{3/10} * 10^{-3}}$

Unitless ⟶

$* \ 10 \log_{10} \left(\frac{2}{10^{3/10} * 10^{-3}} \right) dB$

sol 2

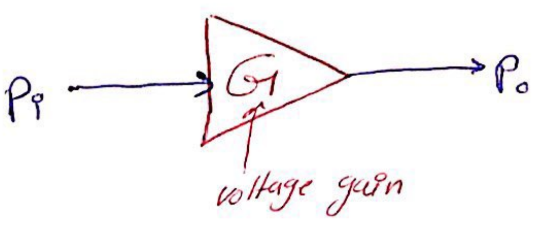
$P_o = 2W \longrightarrow dBm$

$P_o = 10 \log_{10} (2 \times 10^3)\ dBm$

$G(dB) = P_o(dBm) - P_i(dBm)$

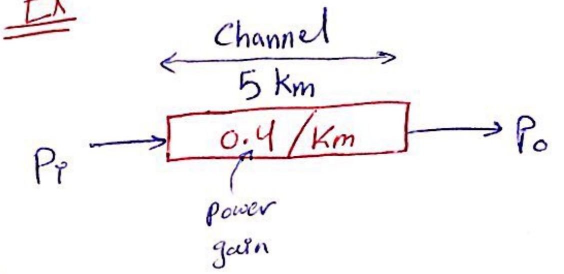
$= 10 \log_{10} (2 * 10^3) - 3$

EX 2



$$\boxed{P_o = G^2 P_i}$$

Ex

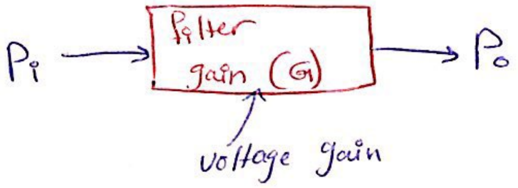


Power gain

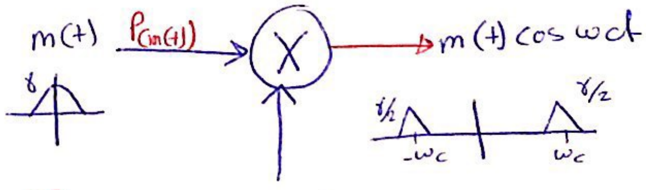
$P_o = P_i \underbrace{(0.4)}_{G}^5$

* اذا معاك
Voltage gain
لازم تربع

EX



$P_o = P_i G^2$

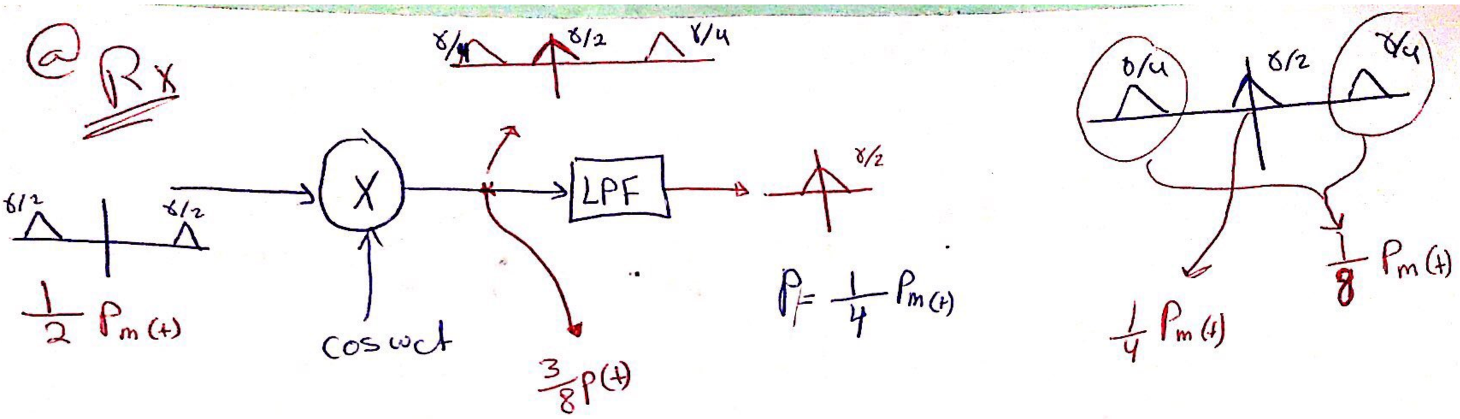


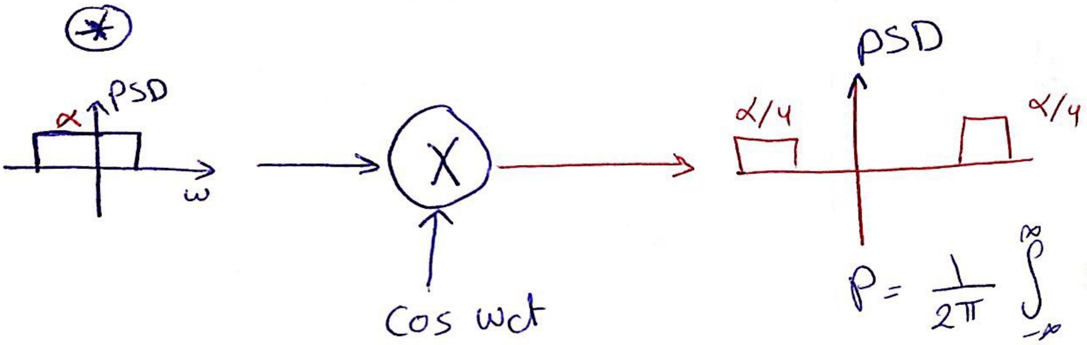
@ TX

$P_o = \frac{1}{2} P_m(t)$

⟶

@ Rx





$$P = \frac{1}{2\pi}\int_{-\infty}^{\infty} PSD \, d\omega$$

*Noise

↳ PSD نشوفها من

* Bit error rate = 10^{-5} → bad
= 10^{7} → good .

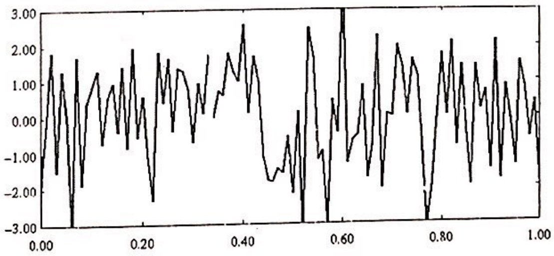
عند Rx بقيسه

SNR vs. Quality

- For **voice** signals:
  - محفظ – SNR = 5 dB to 10 dB at the receiver output implies a barely intelligible signal.
  - SNR = 25 dB to 35 dB is telephone quality signal.
  - **Summary:** If SNR ≥ 30 dB, good quality voice.
- محفظ For **video** signals:
  - **Summary:** If SNR ≥ 50 dB, good quality video.
- محفظ For **digital** signals:
  - Need enough SNR for BER ≤ 10^{-6}, good quality.

Noise in Time Domain

- Noise is a purely **random** signal.
- Cannot be written as a deterministic equation.



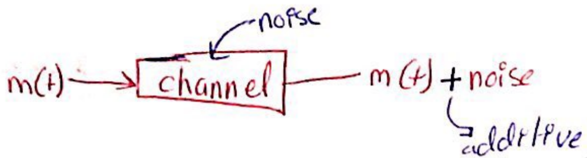
*Noise
random signal

في عنا
internal & external

ch!

* The most used model for noise is AWGN

- AWGN → additive white gaussian noise



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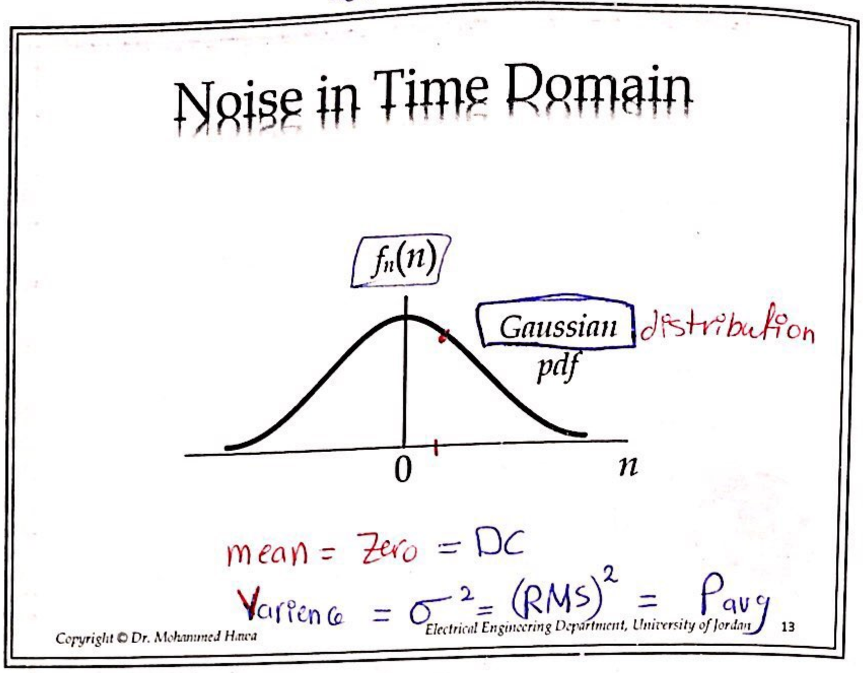

Noise in Time Domain

mean = Zero = DC

Varienc = $\sigma^2 = (RMS)^2 = P_{avg}$

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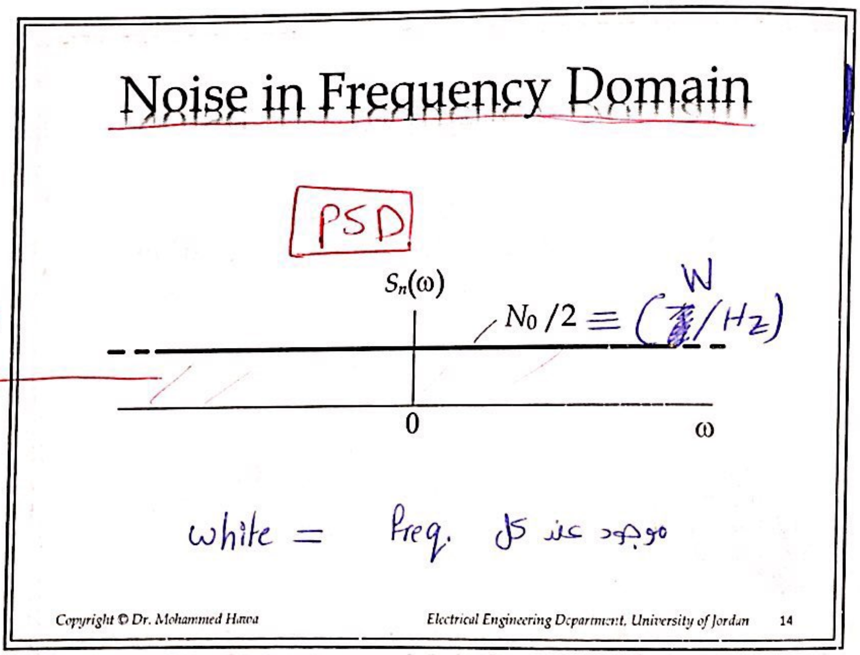

Noise in Frequency Domain

PSD

noise are in all spectrums

white = freq. موجود عند كل

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* where $N_0 = 4KT$ → T: tem preture in Kelvin

K: Boltzman constant

Example

- A voice signal $m(t)$ is transmitted without modulation through a 10 km long baseband channel with AWGN noise. Assume:
  - Average power in $m(t)$ at the TX is 1 kW
  - Channel Attenuation = –5 dB/km
  - $S_n(\omega) = 2 \times 10^{-9}$ W/Hz = $N_0 / 2$
- Show the block diagram of the receiver.
- Determine $SNR_{channel}$ and SNR_{out}.

$B N_0 (G)^2_{LPF}$

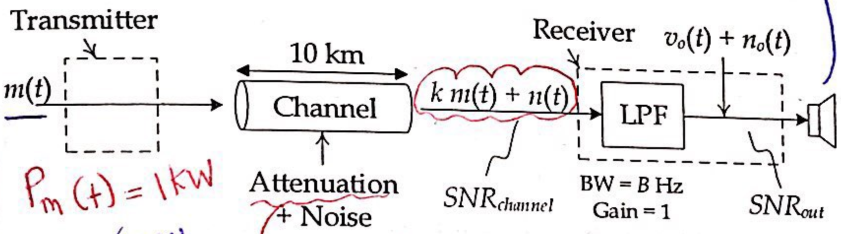
$P_{nois} = \frac{1}{2\pi}(4\pi B * \frac{N_0}{2} * G^2$

–5 dB/Km

= 10 $\log_{10}$ (att unitless)

= $10^{-0.5}$

Solution



$P_m(t) = 1KW$

$= 1*10^6$ mW

–5dB/km

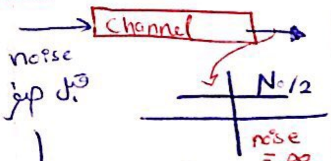
$$SNR_{channel} = \frac{k^2\overline{m^2(t)}}{\overline{n^2(t)}}$$

$$\boxed{SNR_{out} = \frac{\overline{v_o^2(t)}}{\overline{n_o^2(t)}}}$$

$\frac{10mW}{B N_0 G^2_{LPF}}$

voice 4K

*noise



noise [illegible]

SNR = ∞

SNR = Zero = –∞dB

$P_{out} = P_i * G = P_m(t) * \underbrace{(10^{-0.5})^{10}}_{channel} * \underbrace{\cancel{(G_{LPF})^2}}_{filter}$ 1

$= 10^6 * (10)^{-5}$

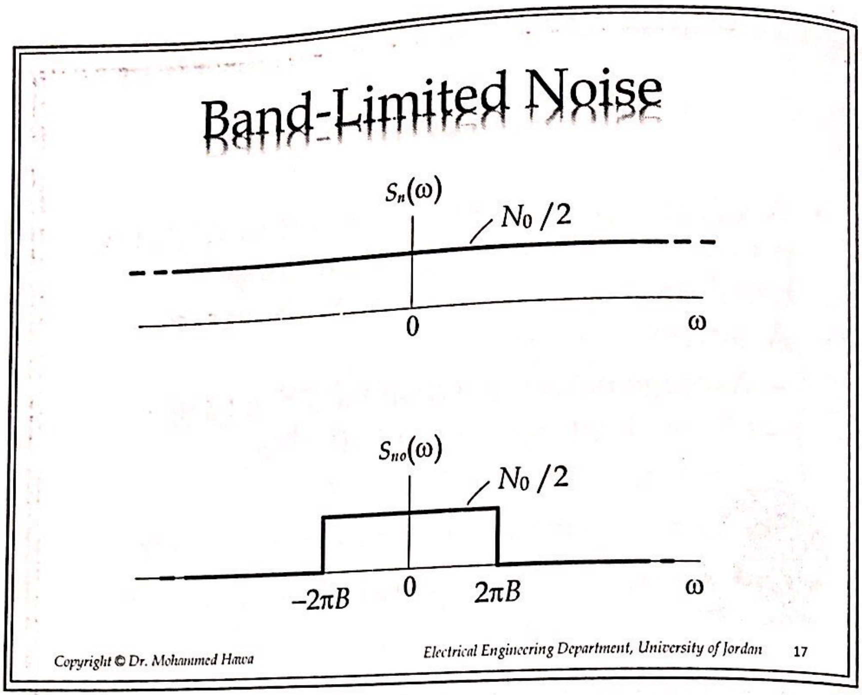
$= 10$ mW

$P_{channel} = P_m(t) * (10^{-0.5})^{10} = 10$mW

$SNR_{out} = \frac{10mW}{B N_0 G^2} = 625$

$= 27.96$ dB

3/14/



Band-Limited Noise

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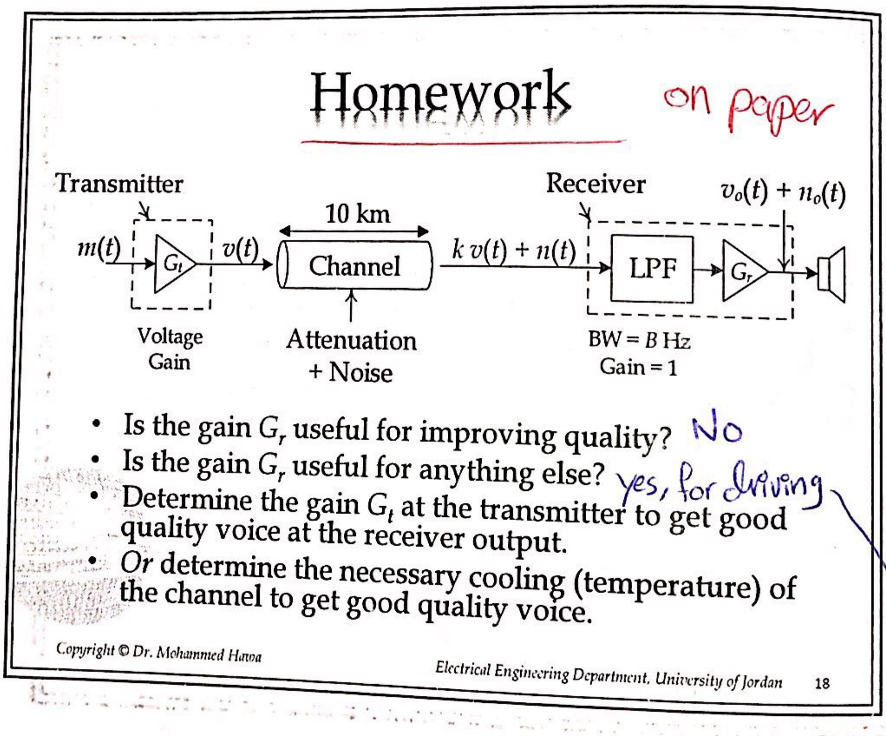

Homework

on paper

- Is the gain G_r useful for improving quality? No
- Is the gain G_r useful for anything else? yes, for driving
- Determine the gain G_t at the transmitter to get good quality voice at the receiver output.
- *Or* determine the necessary cooling (temperature) of the channel to get good quality voice.

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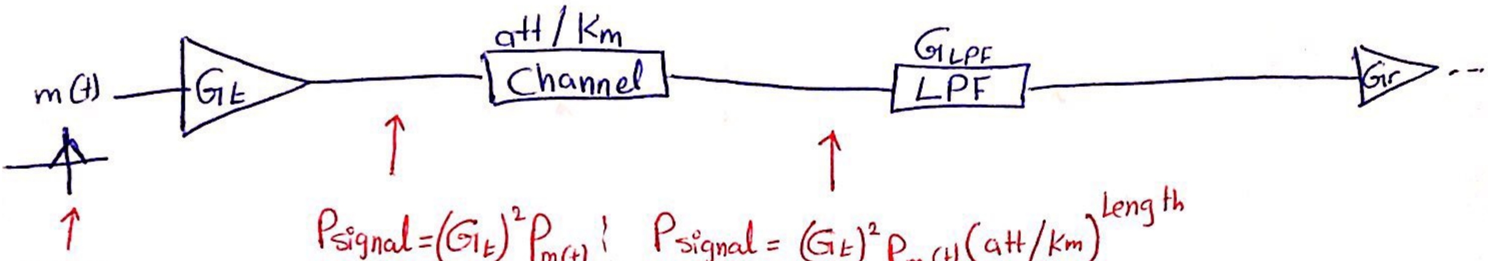
electronic
devices after Gr

*Com

sol H.W slide 18



$P_m(t)$

$P_{signal} = (G_t)^2 P_{m(t)}$

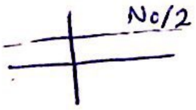
$P_{noise} = Zero$

$SNR = \infty$

$= \infty\, dB$

$P_{signal} = (G_t)^2 P_{m(t)} (att/Km)^{Length}$

$P_{noise} = \frac{1}{2\pi} \int_{-\infty}^{\infty} PSD$



$= \infty$

$SNR = 0 = -\infty\, dB$

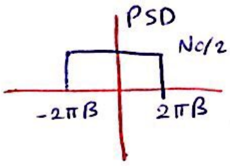
—

تكملة

$P_{signal} = (G_t)^2 P_{m(t)} (att/Km)^{Length} * (G_{LPF})^2$

$P_{noise} = (G_{LPF})^2 N_o B$

$P = \frac{1}{2\pi} \int_{-2\pi B}^{2\pi B} \frac{N_o}{2}\, d\omega$



$= B N_o$

$$\Rightarrow SNR = \frac{P_{m(t)} (G_t)^2 (G_{LPF})^2 (att/Km)^{length}}{(G_{LPF})^2 N_o B}$$

$P_{sig} = (G_t)^2 P_{m(t)} (att/Km)^{length} (G_r)^2 (G_{LPF})^2$

$P_{noise} = (G_{LPF})^2 (G_r)^2 N_o B$

$\Rightarrow SNR_{out} = \frac{P_{sig}}{P_n}$

—

الجواب

Q1: No

Q2: yes, for driving the electronic devices after Gr

Q3: $SNR_{out}\, dB \geq 30\, dB$

Q4: $N_o = 4KT$

on paper

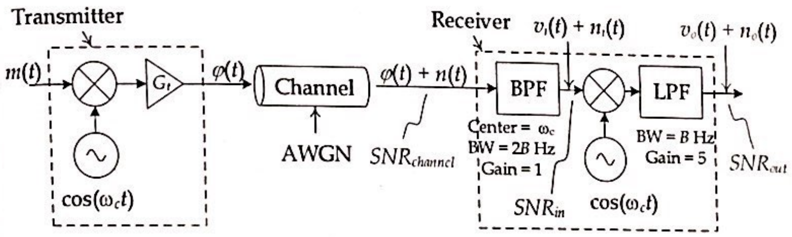
Example 2

- A DSB-SC signal is sent though a channel with no attenuation. The channel is affected by AWGN noise. At the receiver side:
- Show the block diagram of the receiver.
- Determine $SNR_{channel}$.
- Determine SNR_{in}.
- Determine SNR_{out}.
- Determine NF for the demodulator.

$SNR_{in} - SNR_{out} = -3dB \longrightarrow$ good demodulator

adv. of synchroniz reciever (coherence)

Solution



$$SNR_{channel} = 0\,,\ SNR_{in} = \frac{\overline{m^2(t)}}{4N_0B}\ ,\quad SNR_{out} = \frac{\overline{m^2(t)}}{2N_0B}$$

$$NF = SNR_{in}\ dB - SNR_{out}\ dB$$

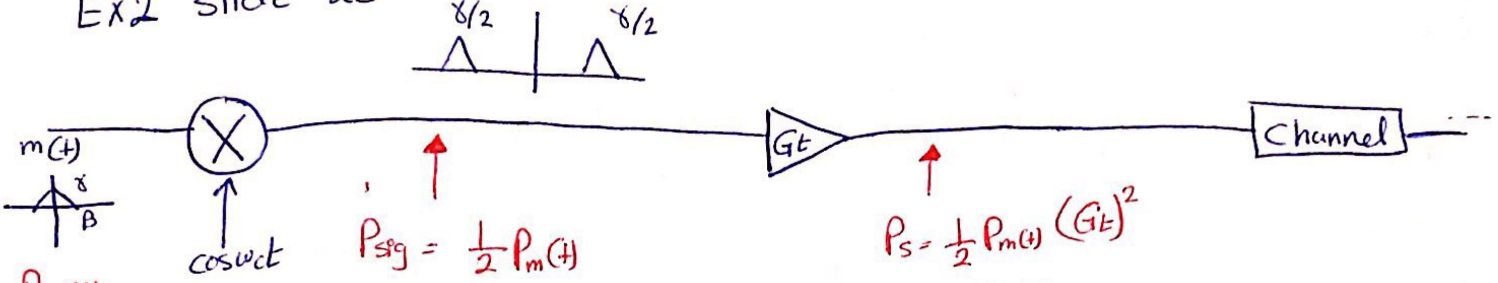
$$= 10\log_{10}\left(\frac{\overline{m(t)^2}}{4N_oB}\right) - 10\log_{10}\left(\frac{\overline{m(t)^2}}{2N_o B}\right)$$

$$= \cancel{10\log_{10}\overline{m(t)}^2} - 10\log_{10} 4N_oB - \left[\cancel{10\log_{10}\overline{m(t)}^2} - 10\log_{10} 2N_oB\right]$$

$$= 10\log_{10} 2N_oB - 10\log_{10} 4N_oB = 10\log 10\left(\frac{2\cancel{N_oB}}{4\cancel{N_oB}}\right) = \underline{-3dB}$$

* Com

Ex2 slide 20



$P_{m(t)}$

$P_{sig} = \frac{1}{2} P_{m(t)}$

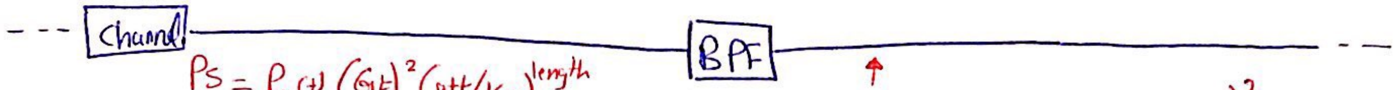
$P_{noise} = 0$

$SNR = \infty = \infty dB$

$P_s = \frac{1}{2} P_{m(t)} (G_t)^2$

$P_n = Zero$

$SNR = \infty$



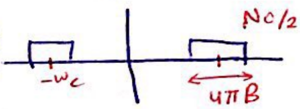
$P_S = P_{m(t)} (G_t)^2 (att/Km)^{length}$

$P_n = \infty$

$SNR = 0 = -\infty dB$

$P_s = \frac{1}{2} P_m (G_t)^2 (att/Km) (G_{BPF})^2$

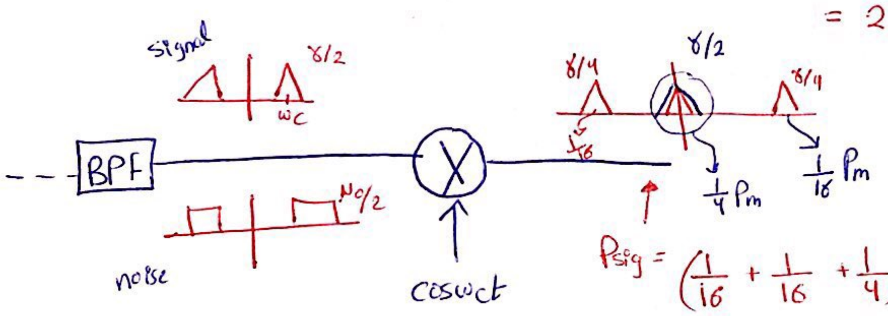
$P_n = 2\left(\frac{1}{2\pi} \int_{-2\pi B}^{2\pi B} No/2 \, d\omega\right)$



$= \frac{1}{\pi} \frac{No}{2} (4\pi B)$

$= 2BNo$

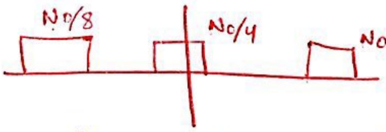
$* \ SNR = \frac{P_m}{4BN_o}$



$P_{sig} = \left(\frac{1}{16} + \frac{1}{16} + \frac{1}{4}\right) P_m = \frac{3}{8} P_{m(t)}$

signal

بس اضرب ب cos
بقسم ع 2



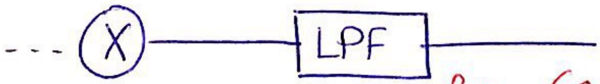
noise

بس اضرب ب cos
بقسم ع 4

Note

$P_{m(t)} = \overline{m(t)^2}$

$P_{noise} = \frac{1}{2\pi}\left[4\pi B\left(\frac{No}{8} + \frac{No}{8} + \frac{No}{4}\right)\right] = NoB$

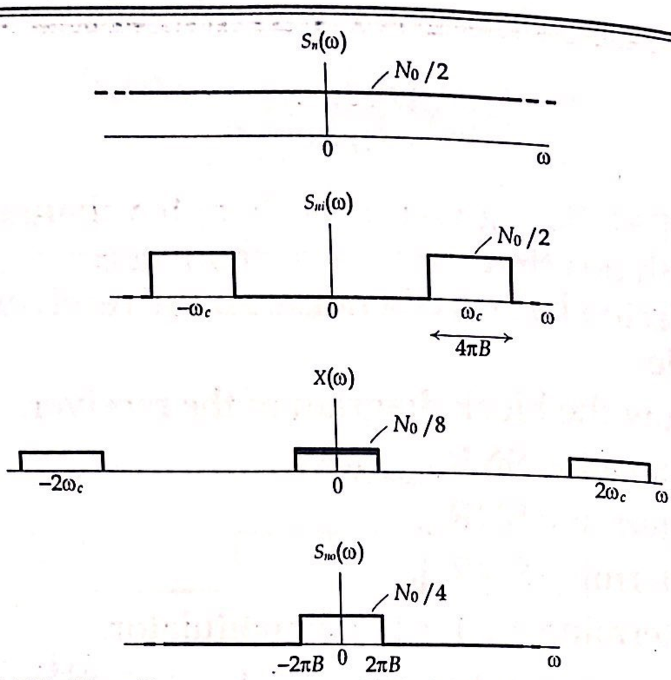


$P_{sig} = (G_{LPF})^2 \left(\frac{1}{4} P_{m(t)}\right)$

$P_n = \frac{1}{2\pi}\left[4\pi B \frac{No}{4}\right] (G_{LPF})^2$

$= \frac{NoB}{2} G^2$

$* \ SNR_{out} = \frac{\frac{1}{4} P_{m(t)}}{\frac{NoB}{2}}$

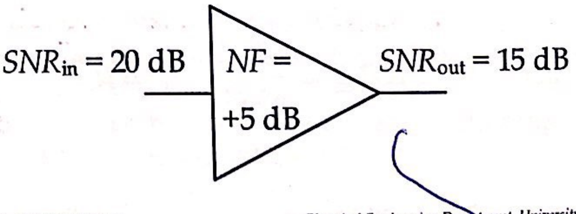


بتقيس لأي device
الـ input
& output

Noise Figure, *NF*

- A number by which the performance of a device can be specified. It measures the *degradation* of the quality (SNR) caused by components in this device.

$$NF \triangleq SNR_{in}(dB) - SNR_{out}(dB)$$



NF → negative → good system

لأنه قيمة SNR_{out} اكبر من SNR_{in}

which is good.

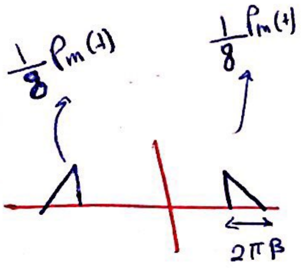
bad sys.

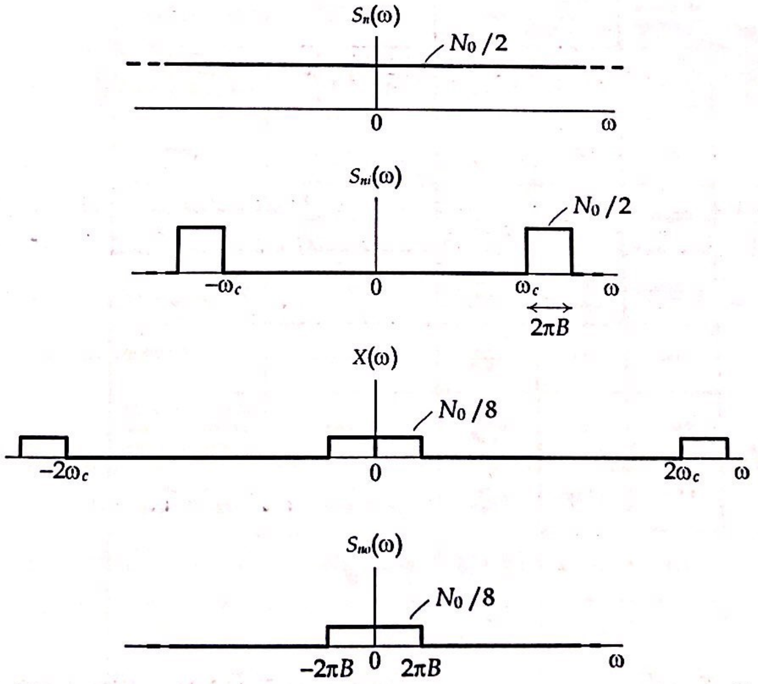
لأنه $SNR_{in} > SNR_{out}$

نفس طريقة
الحل

Homework 1

- A SSB-SC (USB) signal is sent though a channel with no attenuation. The channel is affected by AWGN noise. At the receiver side:
- Show the block diagram of the receiver.
- Determine $SNR_{channel}$.
- Determine SNR_{in}.
- Determine SNR_{out}.
- Determine NF for the demodulator.





$* P_{sig} = \frac{1}{4} P_m(t$

3/14/2

Homework 2

- A QAM signal is sent though a channel with no attenuation. The channel is affected by AWGN noise. At the receiver side:
- Show the block diagram of the receiver.
- Determine $SNR_{channel}$.
- Determine SNR_{in}.
- Determine SNR_{out}.
- Determine NF for the demodulator.

نفسُ / على

cos و sin

مهم — حفظ

Modulation Technique	Modulated Signal Bandwidth	SNR_{out}	Noise Figure NF, dB	Typical Applications
DSB-SC	$2B$	$\frac{S_{in}}{N_0B}$	$\boxed{-3}$	Analog instrumentation; multiplexing as part of FM stereo
SSB-SC	B	$\frac{S_{in}}{N_0B}$	$\boxed{0}$	Point-to-point voice
VSB-SC	$B\sim2B$	$\frac{S_{in}}{N_0B}$	$-3\sim0$	Facsimile (Fax machines)
QAM	$2B$ for two signals	$\frac{S_{in,effective}}{N_0B}$	0	Transmit color information in TV broadcasting; digital data
AM	$2B$	$\eta\frac{S_{in}}{N_0B}$	$-10\log(2\eta)$	Broadcast AM radio; point-to-point voice
SSB+C	B	$\eta\frac{S_{in}}{N_0B}$	$-10\log(\eta)$	Multiplexing in old telephony systems; point-to-point voice
VSB+C	$B\sim2B$	$\eta\frac{S_{in}}{N_0B}$	$-10\log(2\eta)\sim-10\log(\eta)$	Analog Television broadcasting
FM	$2\Delta f+2B$	$\left(\frac{3\beta^2}{k_m^2}\right)\frac{S_{in}}{N_0B}$	$10\log\left(\frac{k_m^2}{6(\beta+1)\beta^2}\right)$	Broadcast FM radio; analog microwave links
PM	$2\Delta f+2B$	$\left(\frac{(\Delta\theta)^2}{k_m^2}\right)\frac{S_{in}}{N_0B}$	$10\log\left(\frac{k_m^2B}{2(\Delta\theta)^2(\Delta f+B)}\right)$	Telemetry; digital data

*φ_{AM} → always without carrier

Lecture 10: Amplitude Modulation (Double Sideband Large Carrier, DSB-LC or AM)

↳ with carrier

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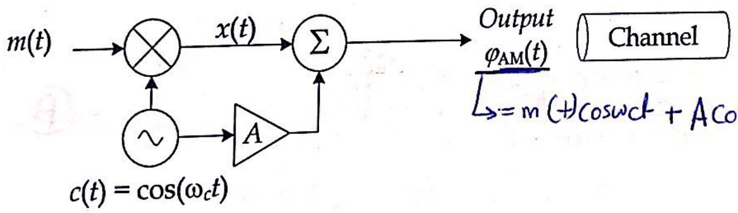
EE421: Communications I. For more information read Chapter 4 in your textbook or visit http://wikipedia.org/.

① DSB-SC
② SSB-SC
③ VSB-SC
④ φ_{AM}
⑤ DSB-LC (DSB with C)
⑥ SSB- LC
⑦ VSB- LC

AM Modulator (*Method #1*)

→ [illegible]



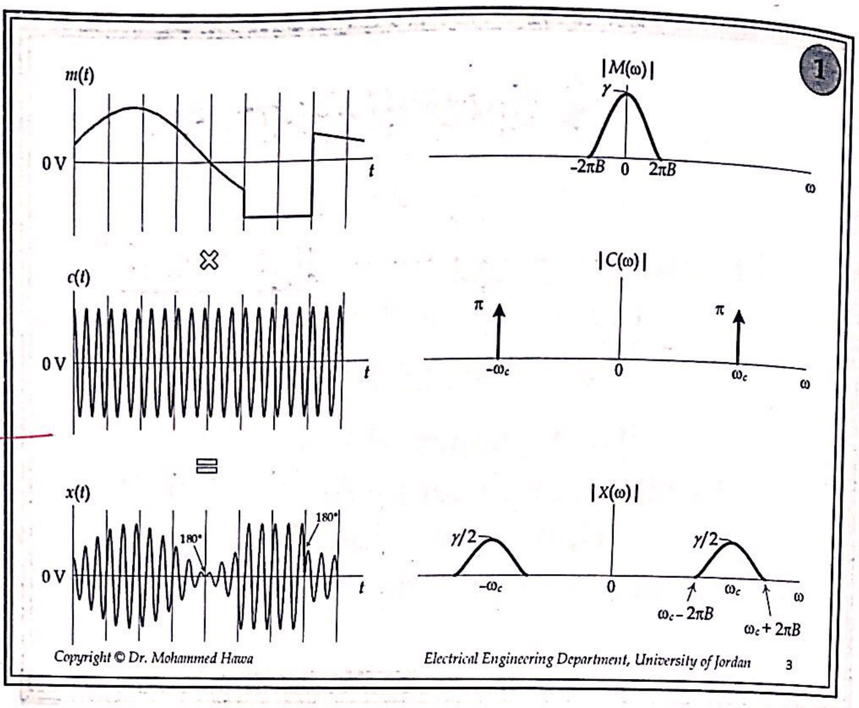
↳ $= m(t)\cos\omega_c t + A\cos\omega_c t$

- Three possibilities (based on the value of *A*):
  - *Under* modulation; $m < 1$
  - *Critical* modulation; $m = 1$
  - *Over* modulation; $m > 1$

adv. of $A\cos\omega_c t$
* simple Rx (asynch. Rx)

*disadv of $A\cos\omega_c t$
more power for carrier

$$\varphi_{DSB-LC} = \underbrace{m(t)\cos\omega_c t + \overset{\substack{\downarrow \\ \text{extra carrier (constant)}}}{A\cos\omega_c t}}_{\text{method 1}} = \underbrace{[m(t) + A]\cos\omega_c t}_{\text{method 2}}$$



m(t) cosωct

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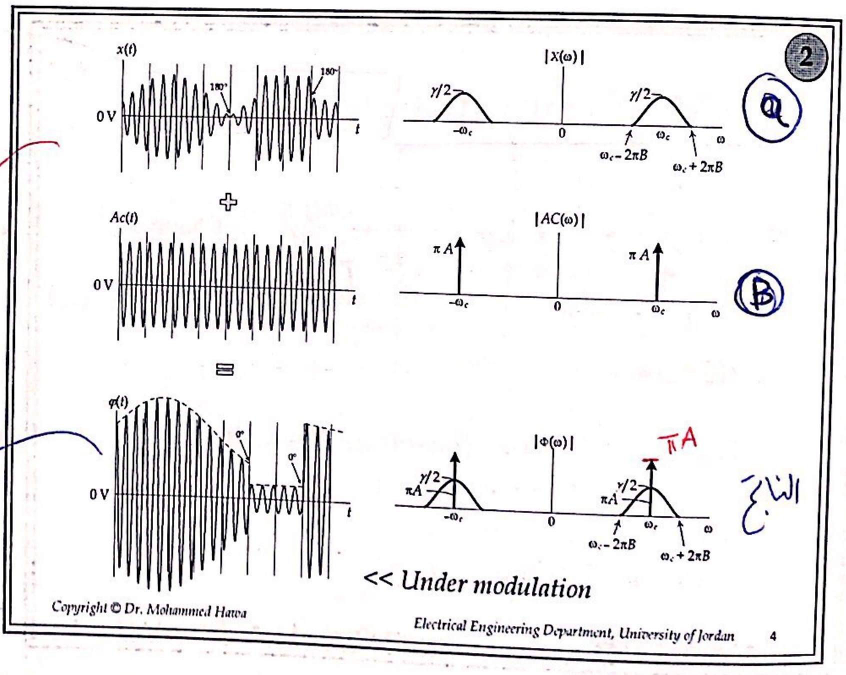

Acoswct

جيب الها من
method 1 بال
time domain

<< Under modulation

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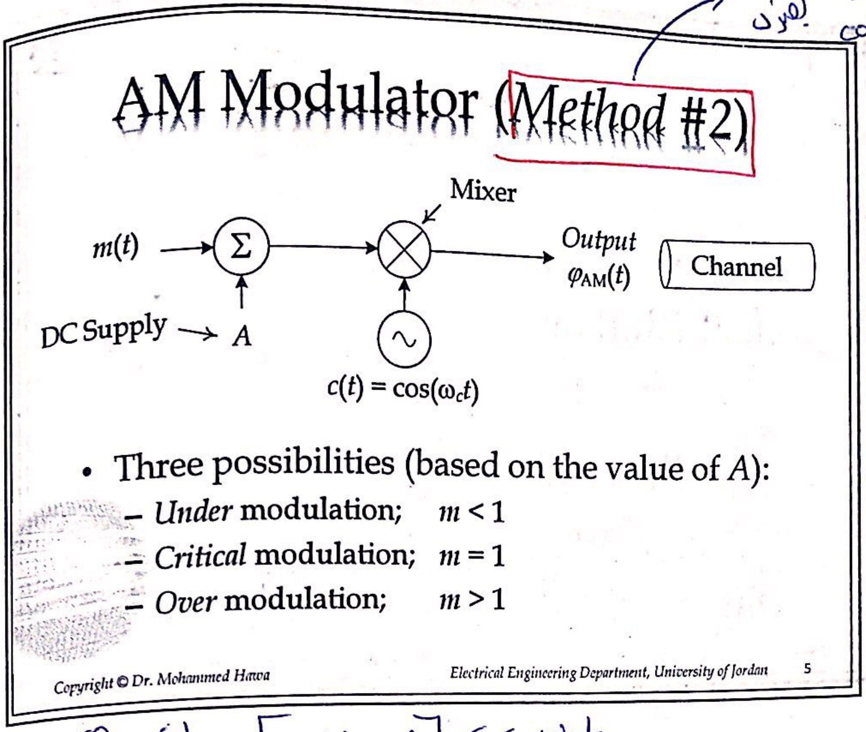
$$\Phi_{Am}(\omega) = \mathcal{F}\left\{m(t)\cos w_c t\right\} + \mathcal{F}\left\{A\cos w_c t\right\}$$

$$= \underbrace{\frac{1}{2}\left[M(\omega-w_c) + M(\omega+\omega_c)\right]}_{a} + \underbrace{A\pi\,\delta(\omega-\omega_c) + A\pi\,\delta(\omega+\omega_c)}_{b}$$

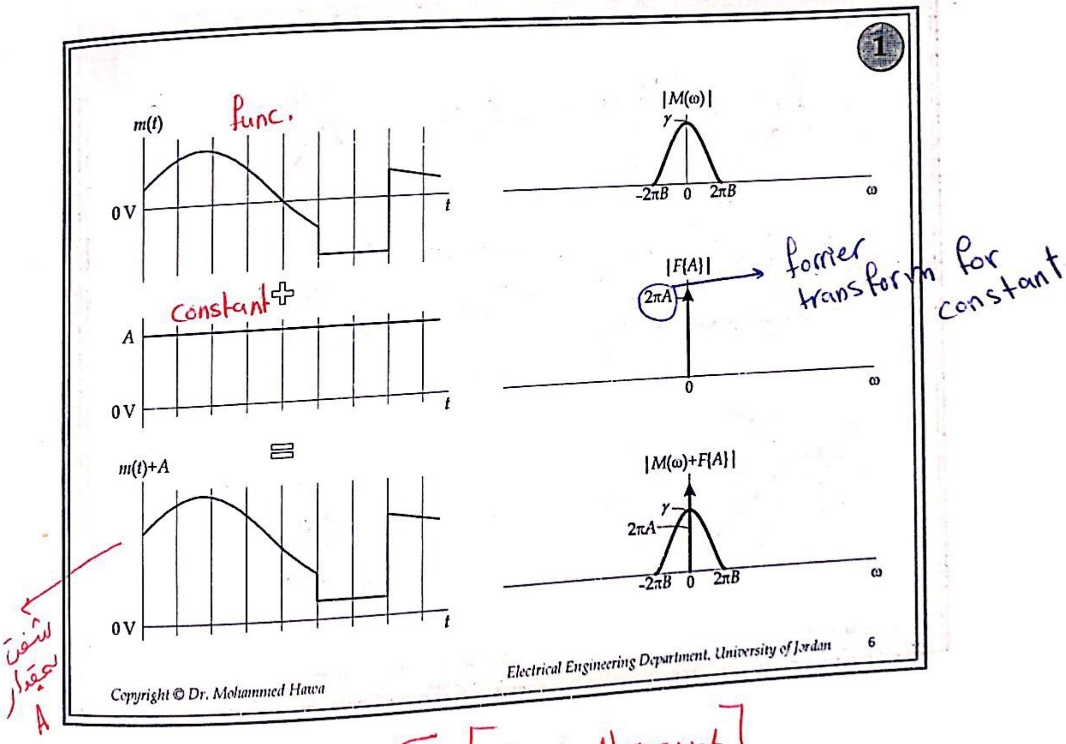
إضافة A لـ m(t) بعدين بضرب cos ؟



AM Modulator (Method #2)

- Three possibilities (based on the value of *A*):
  - *Under* modulation; $m < 1$
  - *Critical* modulation; $m = 1$
  - *Over* modulation; $m > 1$

$$\varphi_{AM}(t) = [m(t) + A] \cos \omega_c t$$

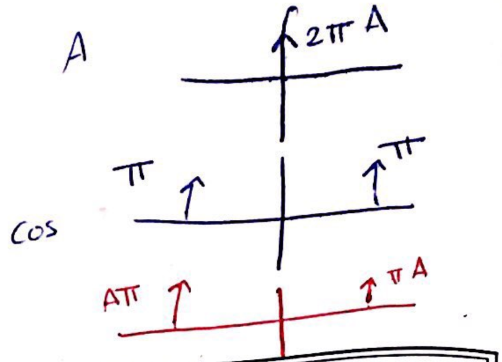


forrier transform for constant

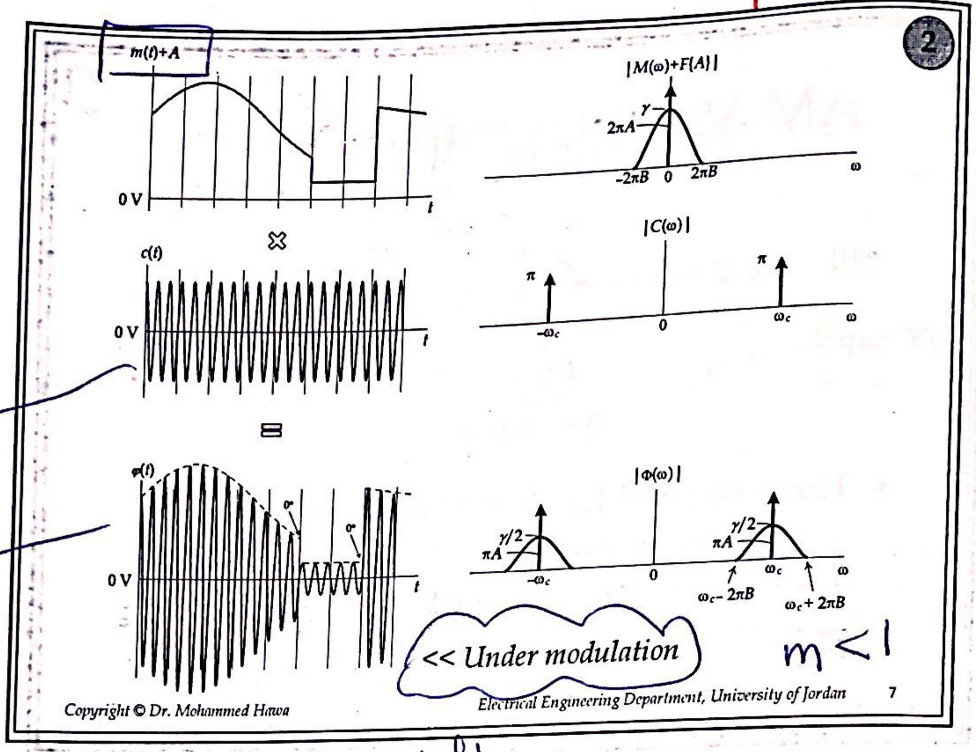
$$\varphi_{Am}(\omega) = \mathcal{F}\left[(m(t)+A)\cos \omega_c t\right]$$

$$\frac{1}{2\pi}\left[2\pi A * \pi\right] \Leftarrow$$

$$= \pi A$$



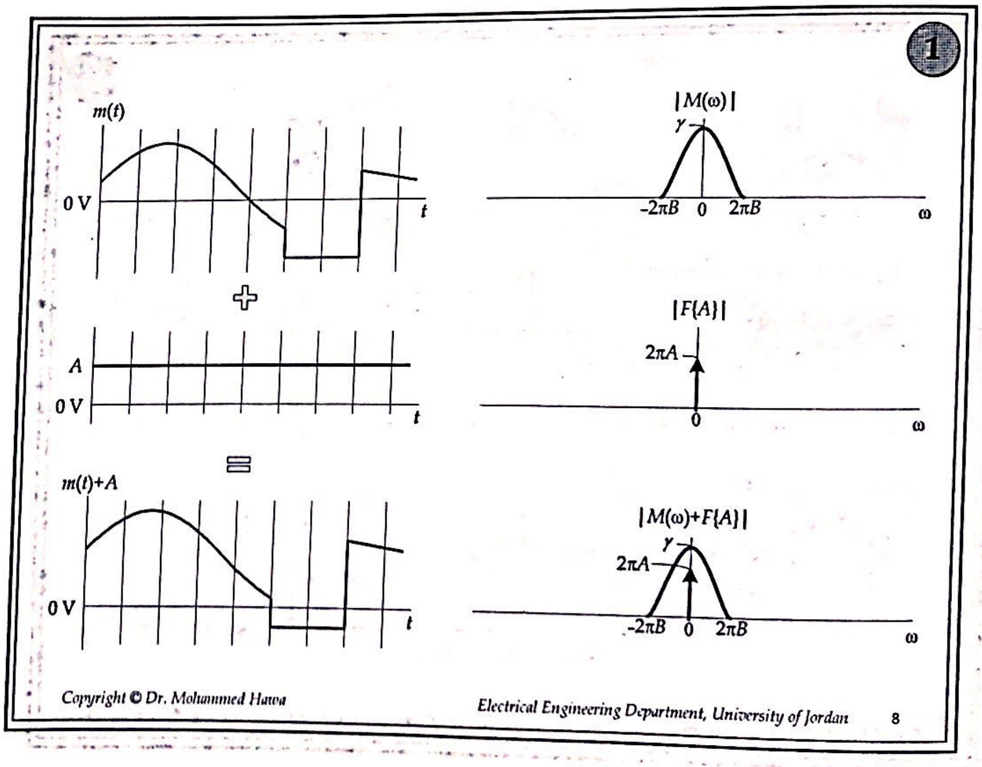
3/14/20



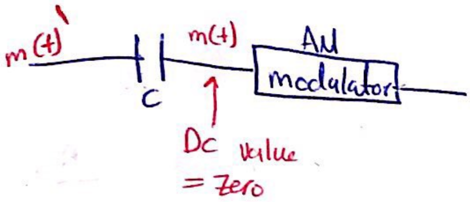
Coswct

mirror on X-axis بجل وبدخل cos

nophase shift



* Note
in Am



لا Dc يمرر

open
circuit

* modulation index

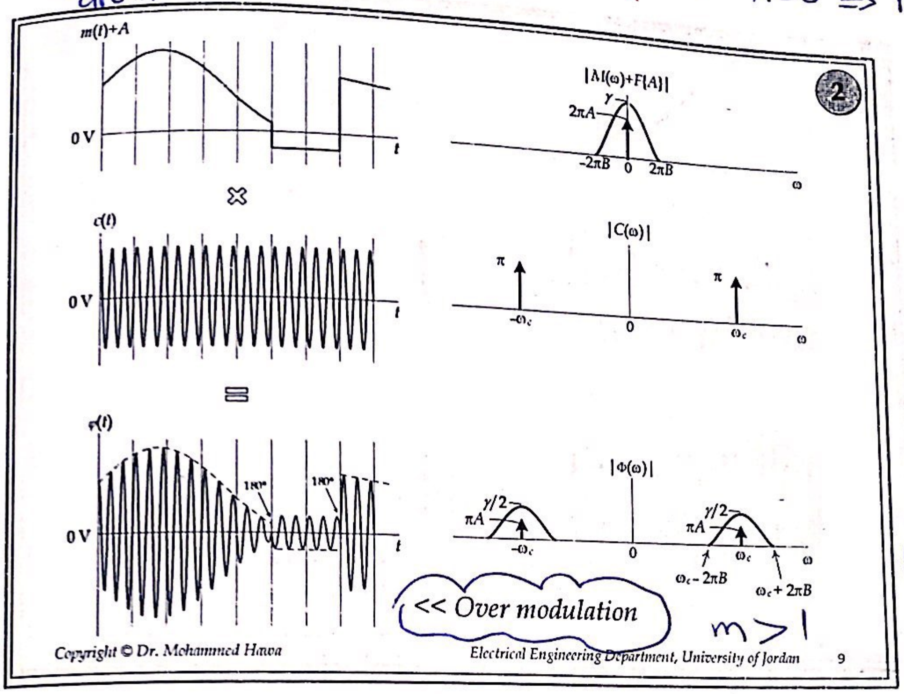
$$m = \frac{-m(t)_{min}}{A}$$

3/14/2017

* if A=0 ⇒ m=∞ ⇒ over modulation

↓

DSB-SC



<< Over modulation

m > 1

phase shift

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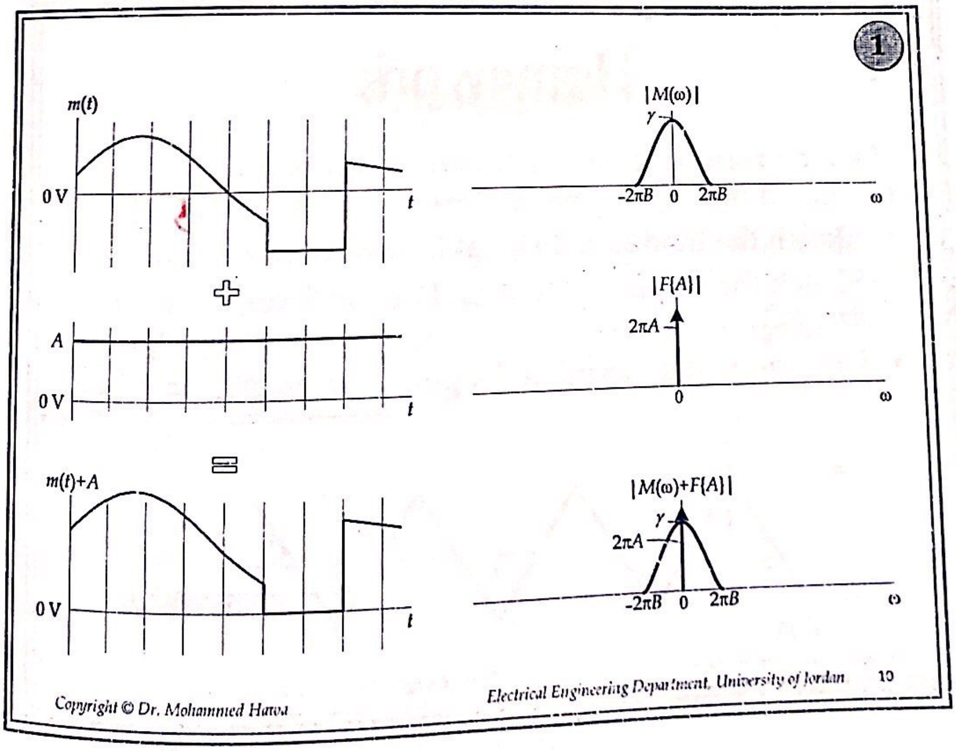

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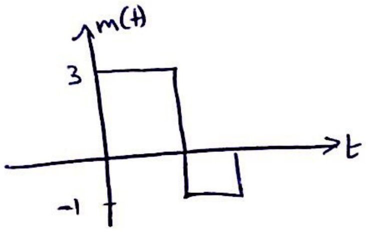
Ex

slide 7 Lec 10

$$\boxed{m = \frac{-m(t)_{min}}{A}}$$

Given

m (t) =



$\boxed{\text{Case 1}} \rightarrow A > -m(t)_{min}$

A = 4 , Draw $\varphi_{AM}(t)$?

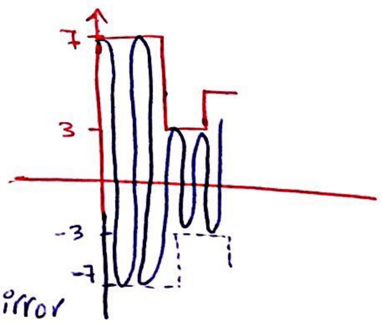
$\boxed{\text{under modulation}}$

* $m < 1$

* we can use synch or a synch. Rx

sol

1- make shift by 4



2-mirror

*note no phase shift

لانه السيقنل بس علت shift بمقدار A

صارت كلها فوق الصفر

3- cos بدخل

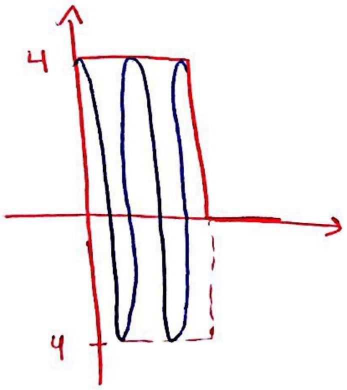
$\boxed{\text{Case 2}}$

if A = 1 → A = -m(t) min

$\boxed{\text{critical modulation}}$

* m = 1

* we can use synch or asynch Rx



*no phase shift

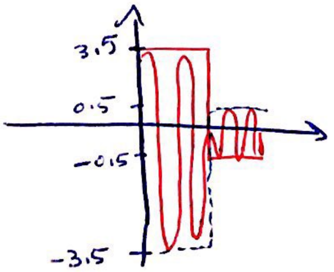
$\boxed{\text{Case 3}} \rightarrow A < -m(t)_{min}$

if A = 0.5

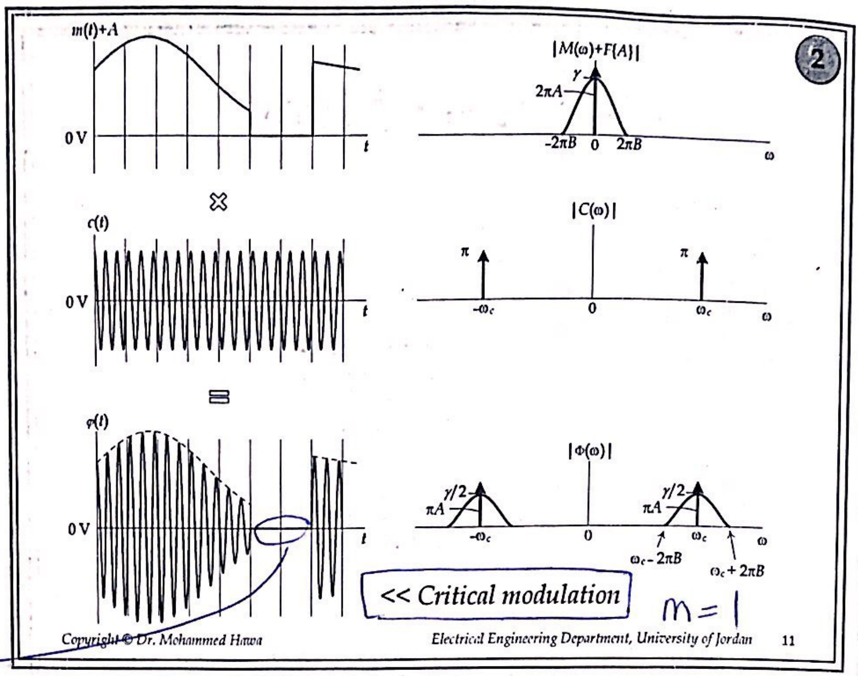
$\boxed{\text{over modulation}}$

* $m > 1$

* we can only synch Rx



phase shift by 180°



<< Critical modulation

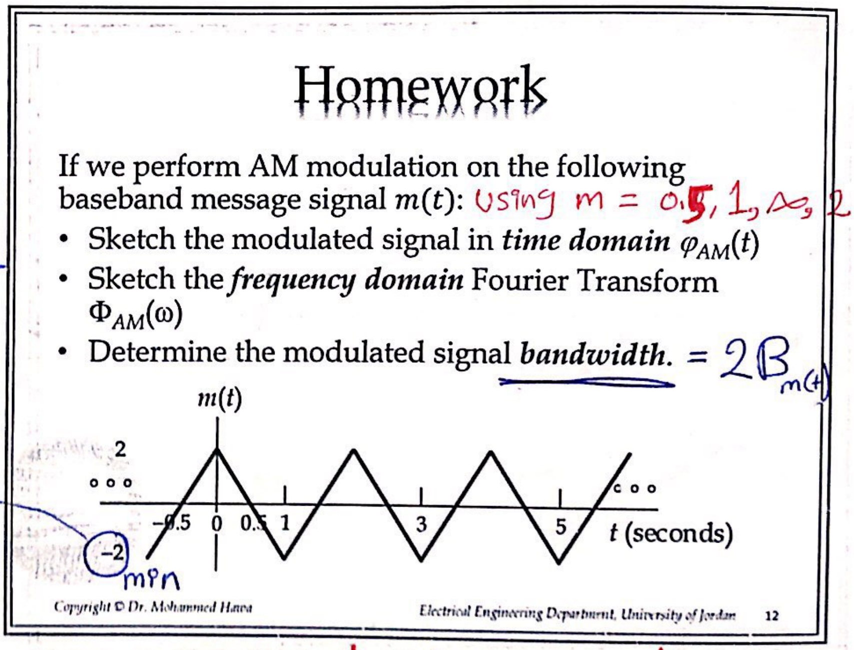
m = 1

بكون فيها جزء

zero

saw tooth *

time domain نركز على



Homework

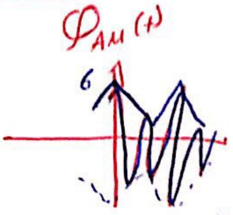
If we perform AM modulation on the following baseband message signal $m(t)$: using m = 0.5, 1, ∞, 2

- Sketch the modulated signal in *time domain* $\varphi_{AM}(t)$
- Sketch the *frequency domain* Fourier Transform $\Phi_{AM}(\omega)$
- Determine the modulated signal **bandwidth.** = $2B_{m(t)}$

$$\overset{0.5}{\cancel{m}} = \frac{-(\overset{-2}{\min})}{A}$$

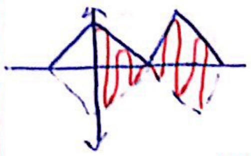
$\boxed{A = 4}$

$\boxed{m = 0.5}$



no phase shift (under mod.)

m = 1
A = 2



no phase shift (Critical)

m = ∞
A = 0
DSB_SC

phase shift 180 (over mod.)

m = 1 ⇒ for one Tx and multiple Rxs

m = ∞ ⇒ for one or more Tx and single Rx

AM Modulation Index, m

$$m \triangleq \frac{-m(t)_{min}}{A}$$

More power needed from transmitter (Larger A)

$m < 1$

$m = 1$

Asynchronous receiver can demodulate. (Very simple and very inexpensive) simple Rx (m=1) + (Am radio)

أفضل نقطة critical

$m > 1$

$m = \infty$

Only a synchronous receiver can demodulate. This RX requires using a PLL @ Rx (Expensive)

without carrier (DSB-SC)

*m = 1

Tx → disadv.

Rx → adv.

* m = ∞

Rx → disadv. (PLL)

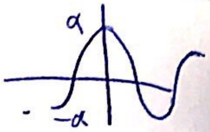
Tx → adv.

Example

Sketch the AM modulated signal in *time domain* $\varphi_{AM}(t)$ and *frequency domain* $\Phi_{AM}(\omega)$, then calculate the modulated signal ***bandwidth, average power, power efficiency***. Assume the case of *tone modulation*, and:

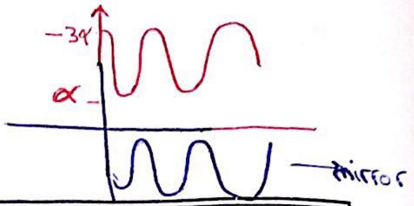
- $m = 0.5$
- $m = 1$
- $m = 2$
- $m = \infty$

* for tone modulation $\Rightarrow m(t) = \alpha \cos \omega_m t$



if $m = 0.5 \Rightarrow m = \frac{-(-\alpha)}{A}$

↳ $A = 2\alpha$ →



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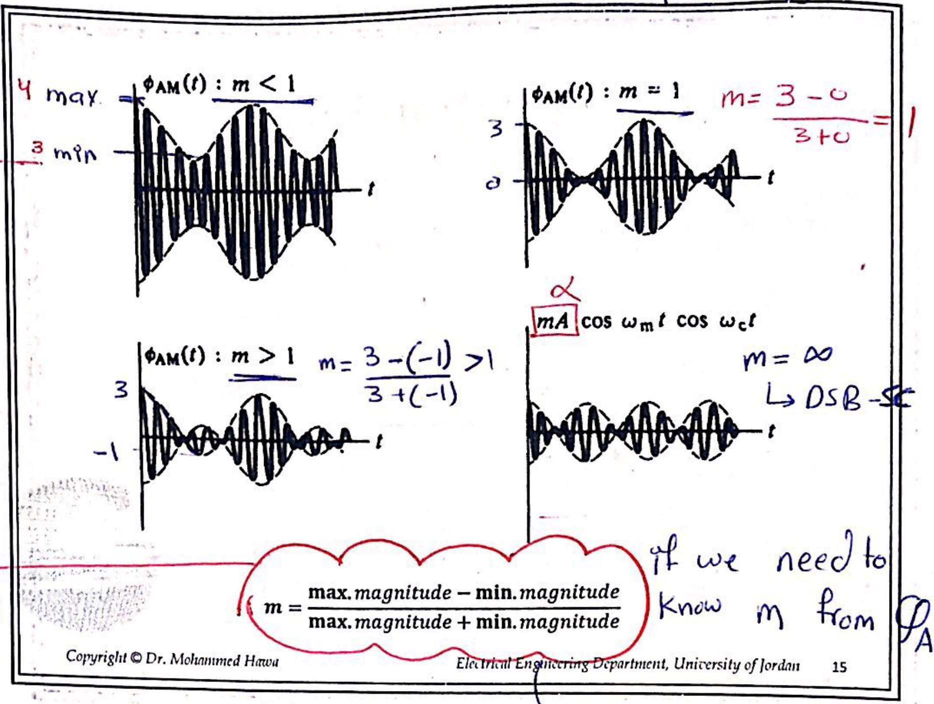

$\phi_{AM}(t)$: $m < 1$

$m = \frac{4-3}{7} < 1$

$\phi_{AM}(t)$: $m = 1$

$m = \frac{3-0}{3+0} = 1$

$\phi_{AM}(t)$: $m > 1$

$m = \frac{3-(-1)}{3+(-1)} > 1$

$\overset{\alpha}{\boxed{mA}} \cos \omega_m t \cos \omega_c t$

$m = \infty$

↳ DSB-SC

for tone modulation

$$m = \frac{\textbf{max.}\,magnitude - \textbf{min.}\,magnitude}{\textbf{max.}\,magnitude + \textbf{min.}\,magnitude}$$

if we need to know m from $\phi_{AM}(t)$

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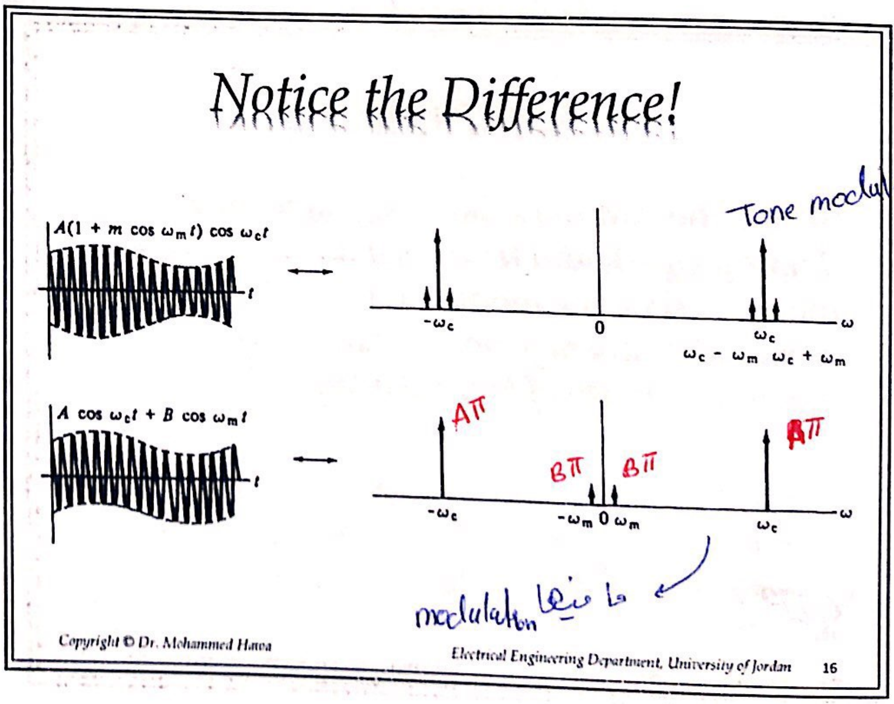
ازا عطني اياه tone, طلع m



Notice the Difference!

$A(1 + m \cos \omega_m t) \cos \omega_c t$ ⟷

Tone modulation

$A \cos \omega_c t + B \cos \omega_m t$ ⟷

ما فيها modulation

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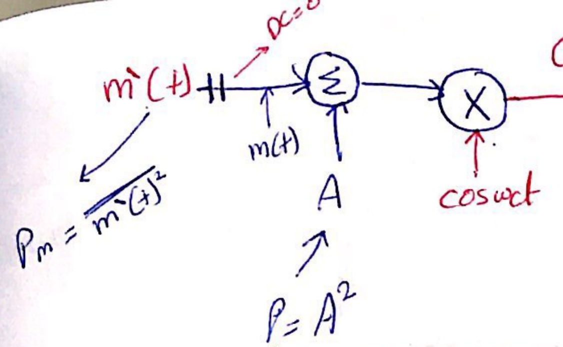

$\varphi_{AM} = [A + m(t)]\cos\omega_c t = A\cos\omega_c t + m(t)\cos\omega_c t$

$P_{Am} = \frac{1}{2}\overline{m(t)^2} + \frac{1}{2}A^2 + A\,\overline{m(t)}$

$= P_s + P_c + A\overline{m(t)}$

P_s: $\boxed{m(t)\cos\omega c t}$ P_c: $\boxed{A\cos\omega c t}$

AM Average Power

$$P_{\varphi_{AM}(t)} = \overline{\varphi^2_{AM}(t)} = \lim_{T\to\infty}\frac{1}{T}\int_T \varphi^2_{AM}(t)dt$$

$$\overline{\varphi^2_{AM}(t)} = \overline{[m(t)\cos(\omega_c t) + A\cos(\omega_c t)]^2}$$

$$\overline{\varphi^2_{AM}(t)} = \overline{m^2(t)\cos^2(\omega_c t) + A^2\cos^2(\omega_c t) + 2Am(t)\cos^2(\omega_c t)}$$

$$\overline{\varphi^2_{AM}(t)} = \overline{m^2(t)\cos^2(\omega_c t)} + A^2\,\overline{\cos^2(\omega_c t)} + 2A\overline{m(t)\cos^2(\omega_c t)}$$

$$\overline{\varphi^2_{AM}(t)} = \frac{1}{2}\overline{m^2(t)} + \frac{A^2}{2} + A\overline{m(t)} = P_s + P_c + 0$$

→ DC for m(t) = Zero

$* \ \overline{\cos^2(\omega_c t)} = \frac{1}{2}$

AM Power Efficiency

power effic

$$\boxed{\eta = \frac{Useful\ power}{Total\ power}} = \frac{P_s}{P_t} = \frac{P_s}{P_s + P_c}$$

→ m(t)cosωct

→ مجموع

$$\eta = \frac{\frac{1}{2}\overline{m^2(t)}}{\frac{1}{2}\overline{m^2(t)} + \frac{A^2}{2}} \quad (general)$$

P_s

$$\boxed{\eta = \frac{m^2}{m^2 + 2}} * 100\% \ (tone\ modulation)$$

m	n
0.5	11.11%
1	33.33%
2	66.66%
∞	100%

DSB-SC ← ∞

كل ما زاد mod. index
efficiency بزيد
احسن

$P_c = 40KW = \frac{\frac{1}{2}A^2}{R}$ / $m = 0.707$ / tone $= \alpha \cos \omega_m t$ / $R = 50\ \Omega$

sol

ⓐ $\eta = \frac{m^2}{m^2+2} = 20\%$

ⓑ $P_T = \cancel{P_s} + \cancel{P_c} = 50Kw$; P_s: 10K ; P_c: 40Kw

$\eta = \frac{P_s}{P_s + P_c}$

$\hookrightarrow P_s = 10Kw$

ⓒ $C(t) = A \cos \omega_c t$ V

$\cancel{P_c} = \frac{A^2/2}{50}$; P_c: 40k ; 50 → R

$A = 2000V$

3/14/2017

Homework #1

- A given AM (DSB-LC) broadcast station transmits an average carrier power, P_c, of 40 kW and uses a modulation index, m, of 0.707 for *tone* modulation. *Assuming* the antenna is represented by a 50 Ω resistive load, calculate:
  - a – The transmission efficiency (η).
  - b – The total average power output (P_t).
  - c – The *extra carrier* amplitude (A).
  - d – The peak amplitude of the output signal.
  - – *Answers*: 20%; 50 kW; 2000 V; 3414 V.

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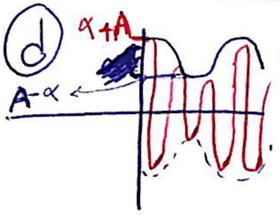
ⓓ



$m = \frac{-(-\alpha)}{A}$

$\boxed{\alpha = mA}$

$\hookrightarrow \alpha = 1414 \Rightarrow max = A + \alpha$
$= 3414$

طريقة ثانية

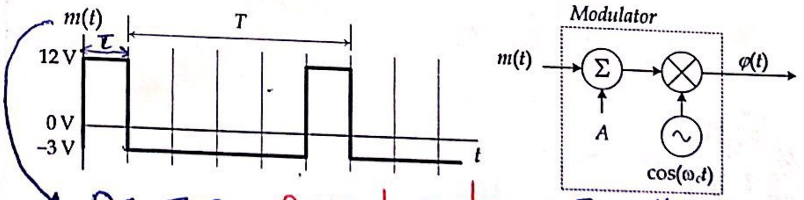
α

$P_s = \frac{1}{2} P_m$

$50k = \frac{1}{2} \frac{\alpha^2/2}{R}$

Homework #2

- The baseband signal $m(t)$ shown is passed through the following modulator. Assume the power efficiency is 90% (η), $T = 60$ μs (period) and $f_c = 40$ MHz. Determine:



DC = Zero , $Bw = \frac{1}{\tau} = \frac{1}{\frac{T}{5}} = \frac{5}{60 \mu sec}$ Hz

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sol

② $B.W_{\varphi_{Am}} = 2 BW_{m(t)} = 2 * \frac{5}{60\mu} = 166.67$ KHz

③ $P_s = \frac{1}{2} P_m(t) = \frac{1}{2}\left[\frac{1}{60\mu}\int_0^{\tau\ 12\mu} (12)^2 + \frac{1}{T}\int_{12\mu}^{60\mu} (-3)^2\right]$

④ $P_c \rightarrow \eta = 0.9 = \frac{P_s}{P_s + P_c} \rightsquigarrow P_c = 2W$

⑤ $m = \frac{-m(t)_{min}}{A} = \frac{-(-3)}{2} = 1.5$ / $A \Rightarrow P_c = \frac{1}{2}A^2$ $A=2$

Tone mod. مش

⑥ $|\varphi_{AM}(\omega)| = ?$ @ $\omega = \omega_c - \frac{2\pi}{T} = \boxed{\omega_c - \omega_0}$ ω_0

$m(t) \longrightarrow M(\omega) = \left[\sum_{n=-\infty}^{\infty} \frac{2\pi A\tau}{T} \operatorname{sinc}\left(\frac{n\omega_0\tau}{2\pi}\right) e^{-j\omega_0 \frac{T}{2}} \delta(\omega-\omega_0)\right] - 2\pi(3)\delta\omega$

$\mathcal{F}$(rect Shifted)

shift right

shift

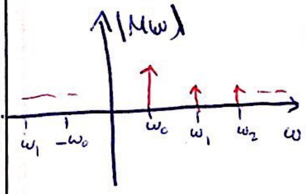
shift down

من الرسمة

Homework #2

1 - Type of the modulated signal $\varphi(t)$? AM (DSB-LC)
2 - Bandwidth of the modulated signal?
3 - Average power in the sidebands P_s?
4 - Average power in the extra carrier P_c?
5 - Modulation index of the modulated signal?
6 - Magnitude spectrum density of the modulated signal $|\Phi(\omega)|$ at $\omega=\omega_c-2\pi/T$?
- *Answers*: AM; 166.67 kHz; 18 W; 2 W; 1.5; $2\pi\times1.403\ \delta(\omega-\omega_c+2\pi/T)$;

$\omega_0 = \frac{2\pi}{T}$



$B\omega = \frac{1}{\tau}$ (first null)

$\tau = \frac{1}{5}T$

AM vs. DSB-SC

- Both require the same transmission bandwidth (equal to 2B).
- DSB-SC allows for a more efficient *transmitter* (power savings). → no carrier
- AM allows for a cheaper *receiver* (asynchronous demodulator), while DSB-SC only works with synchronous detection.

In general shift ال ,ولو rect ازا كان عشي

$\mathcal{F}(\text{rect}) = \left[\sum_{-\infty}^{\infty} \frac{2\pi A\tau}{T} \operatorname{sinc}\left(\frac{n\omega_0\tau}{2\pi}\right) e^{-j\omega_0(\Delta t)} \delta(\omega-\omega_0)\right] - 2\pi(\Delta a)\delta(\omega)$

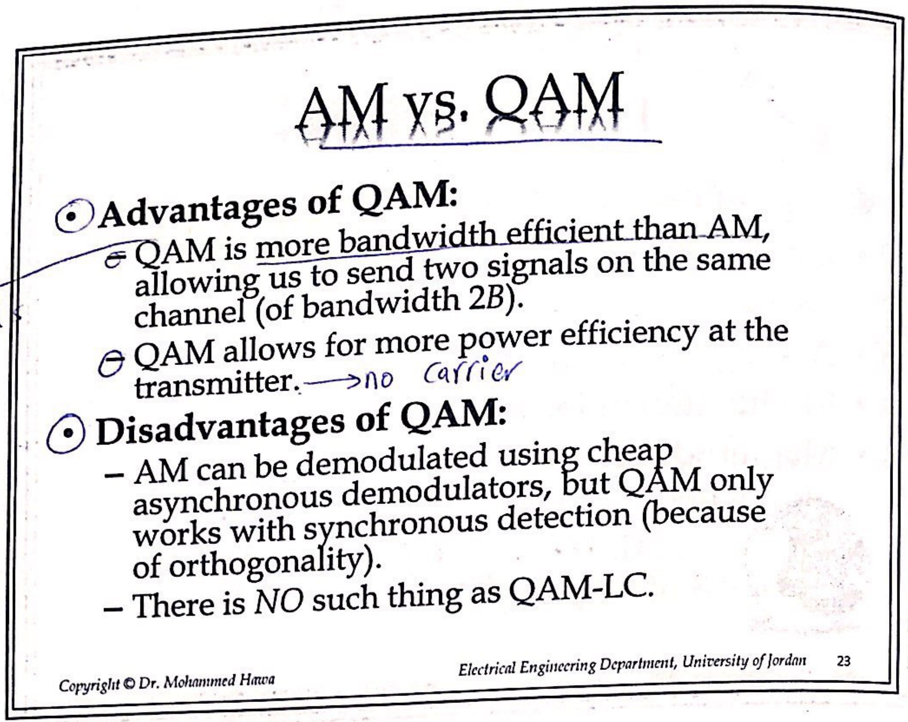
down shift

* for our example

$\sum_{-\infty}^{\infty} \frac{2\pi * \cancel{15}_{3} * \frac{1}{\cancel{5}}\cancel{T}}{\cancel{T}} \operatorname{sinc}\left(\frac{n * \frac{2\pi}{\cancel{T}} * \frac{1}{5}\cancel{T}}{\cancel{2\pi}}\right) e^{-j\omega_0\frac{T}{2}} \delta(\omega-\omega_0) - 2\pi * 3 * \delta\omega$ ⟶

3/14/

because we sent 2 signal



AM vs. QAM

- **Advantages of QAM:**
  - QAM is more bandwidth efficient than AM, allowing us to send two signals on the same channel (of bandwidth 2*B*).
  - QAM allows for more power efficiency at the transmitter. → no carrier
- **Disadvantages of QAM:**
  - AM can be demodulated using cheap asynchronous demodulators, but QAM only works with synchronous detection (because of orthogonality).
  - There is *NO* such thing as QAM-LC.

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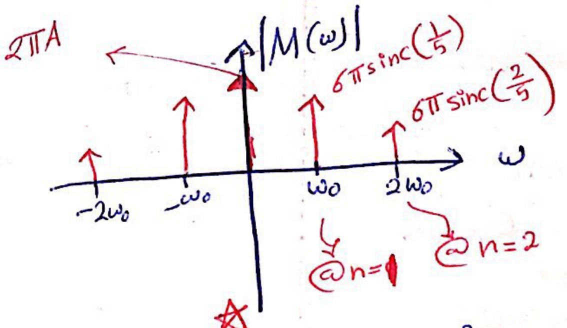
* تكملة فرع ٦ في المثال السابق

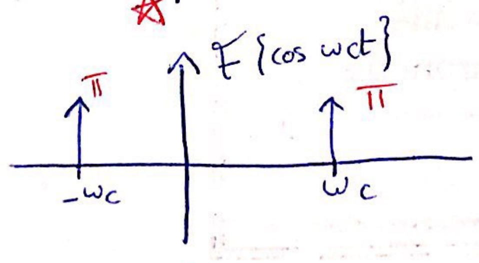
$$|M(\omega)| = \sum_{-\infty}^{\infty} 6\pi \operatorname{sinc}\left(\frac{n}{5}\right) \delta(\omega - n\omega_0) - 6\pi\delta(\omega)$$



⊛ for A ⇒ $\mathcal{F}\{A\} = 2\pi A\delta(\omega)$

بنجمع مع $M(\omega)$

بعدين بنعمل shift مع cos



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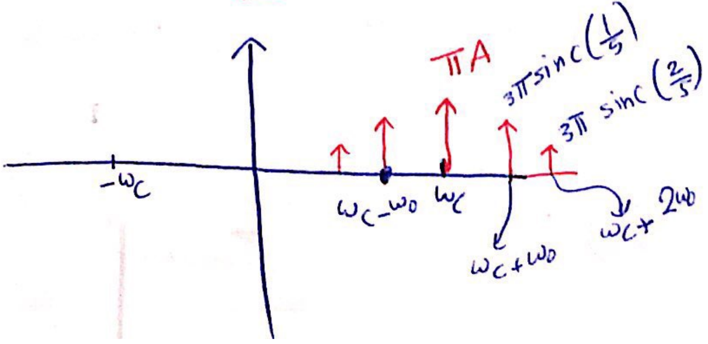

* المطلوب عند $\boxed{\omega_c - \omega_0}$

$$|\phi(\omega)| = 3\pi \operatorname{sinc}\left(\frac{1}{5}\right)$$

$$= 3\pi \frac{\sin(\pi/5)}{\pi/5} \rightarrow \text{rad}$$

$$= 8.812$$

Lecture 11: AM Hardware

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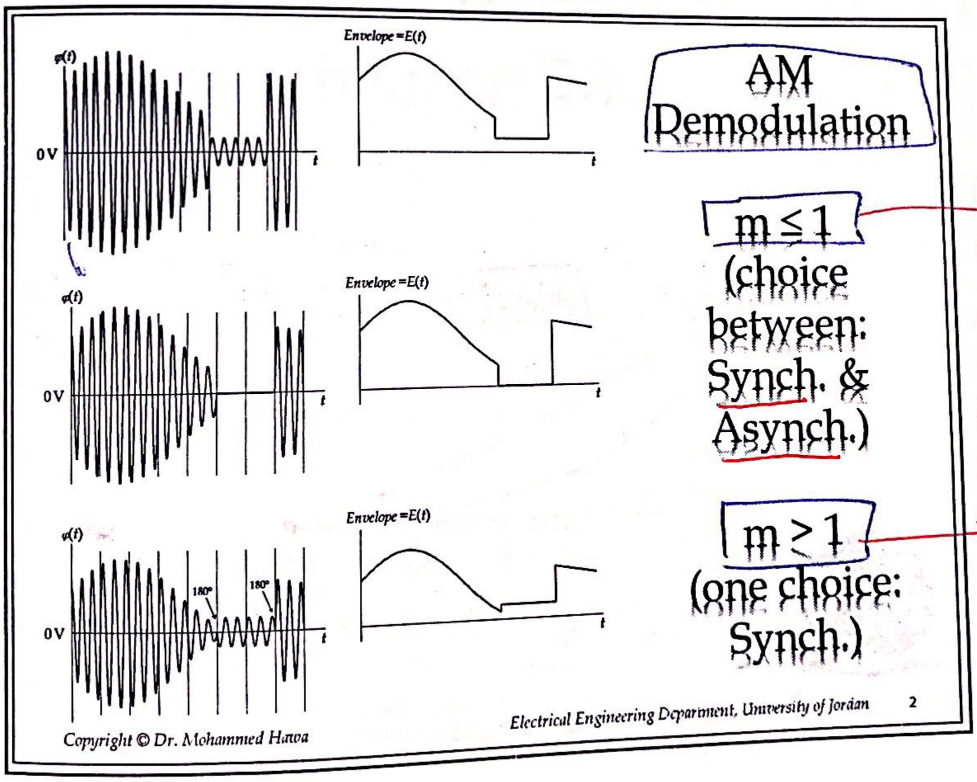
EE421: Communications I. For more information read Chapter 4 in your textbook or visit http://wikipedia.org/.



AM Demodulation

$m \leq 1$ (choice between: Synch. & Asynch.)

under & critical

$m \geq 1$ (one choice: Synch.)

over

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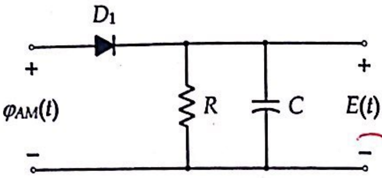
design for demodulator

4/10/

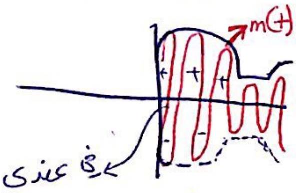
Design #A: Envelope Detector

one diode, R, C



→ half wave rectifier.

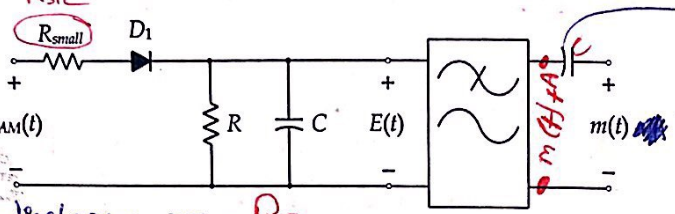
السگنل الواصلة



عندي 2 →
positive , negative cycles

(+) : diode on
→ charging capacitor
$V_C = V_{in} = V_o$

if V_{in} ↓ (+) ⇒ diode off
→ discharging



shift بشيل A

LPF
Gain = 1
Bandwidth = B Hz

* discharging $\tau = R_sC$
* charging $\tau = R_sC$

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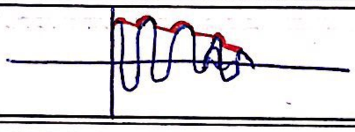
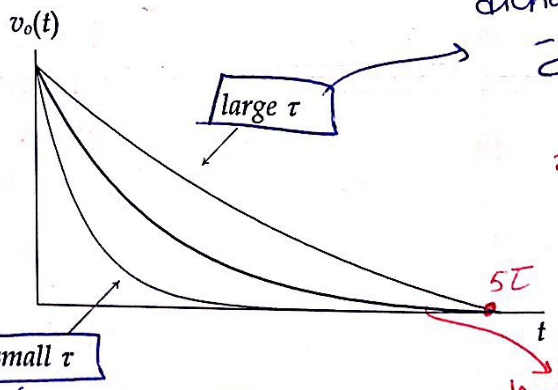


First-order RC circuit dischage



dichar. عملية بطيئة → تبطئ عملية discharge

اكل الوسط

سريعة

بنزل كثير

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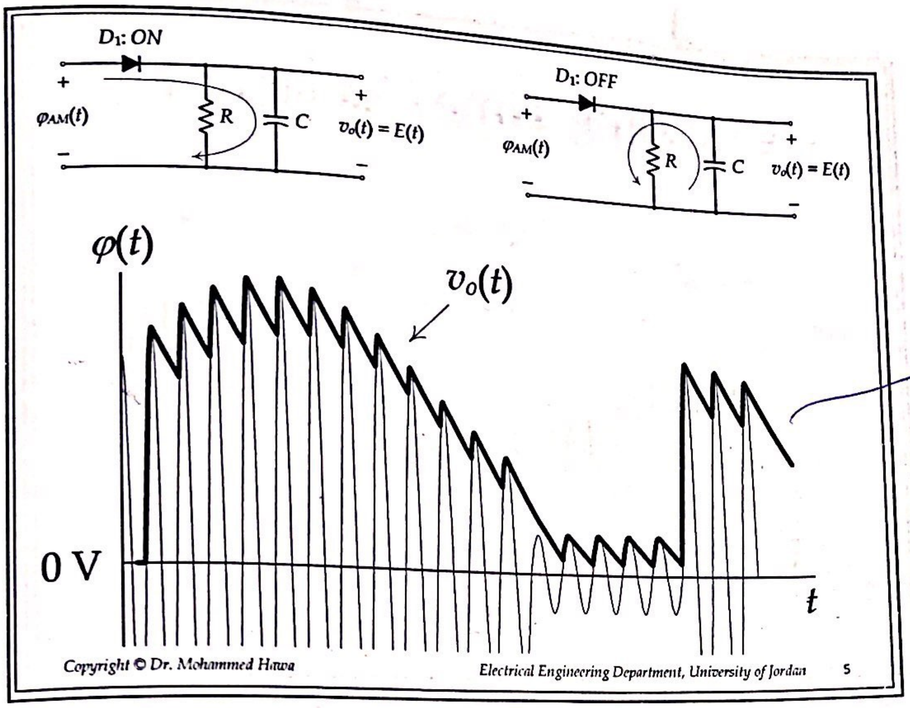

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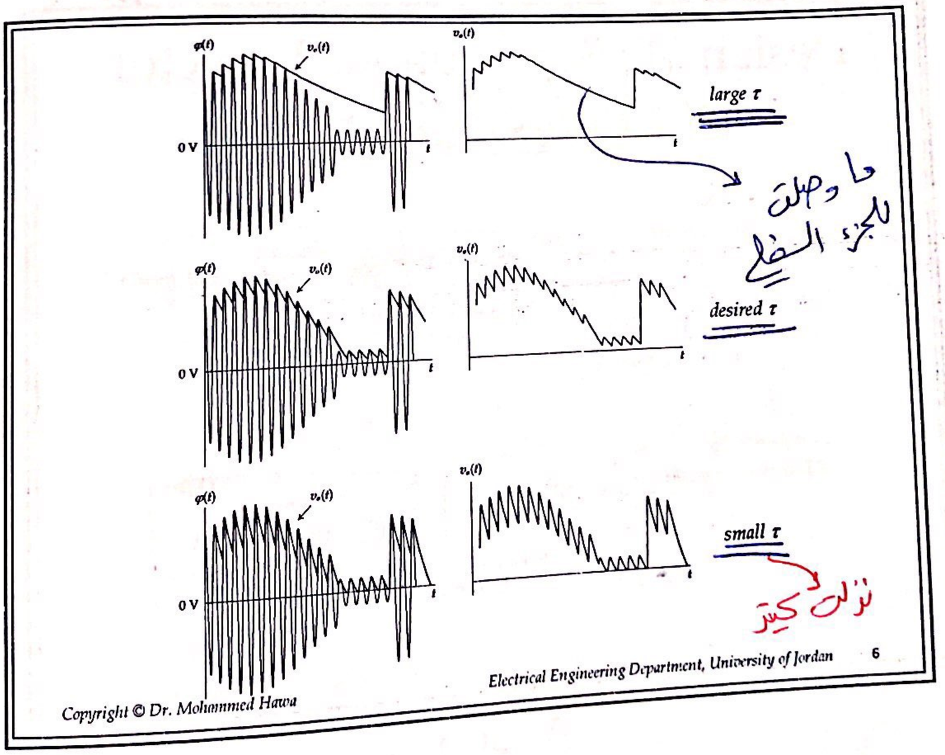
عشان اتخلص من
ripples هدول.
~~BPF~~
LPF



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ما وصلت
للجزء السفلي

نزلت كتير

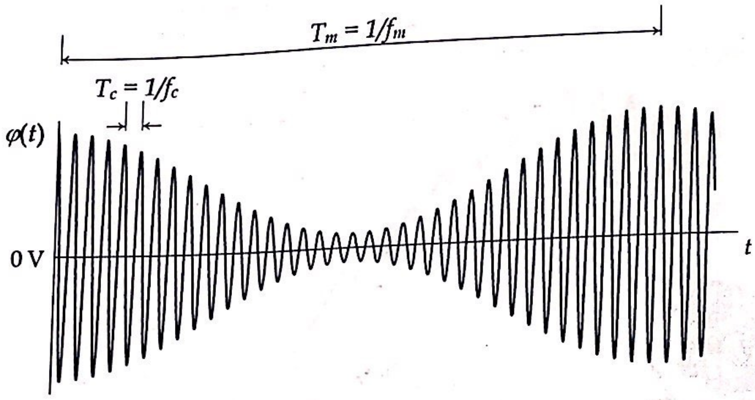
$$\frac{1}{f_c} \ll \tau \ll \frac{1}{f_m}$$

for tone modulation

$$T_c \ll \tau \ll T_m$$

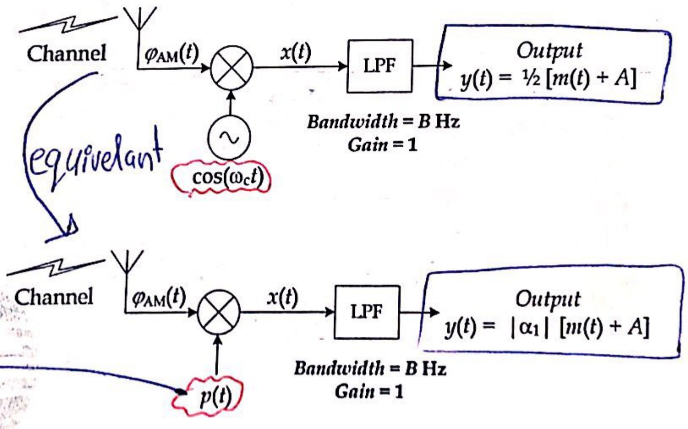
4/10/2017

Choosing Time Constant τ



(*) In general: $\frac{1}{f_c} \ll \tau \ll \frac{1}{B} \rightarrow$ BW of m(t) in Hz

Design #B: Synchronous Detector (aka Product Detector)



rect fun

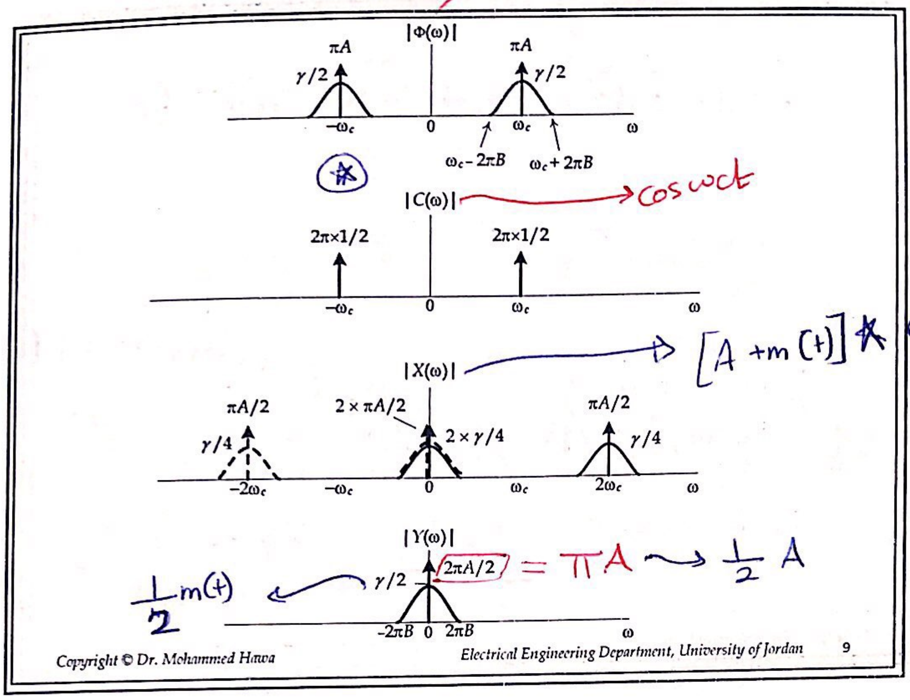
* عشان أشيل ال A حط capacitor

بعد LPF

* دائماً كاباسيتور بشيل ال DC

2πA , γ ⊙—— m(t) التسنيل الأصلية

$[A+m(t)]$ ~~cos~~



$\cos\omega_c t$

$[A+m(t)] * \cos\omega_c t$

$\boxed{2\pi A/2} = \pi A \rightsquigarrow \frac{1}{2} A$

$\frac{1}{2} m(t)$

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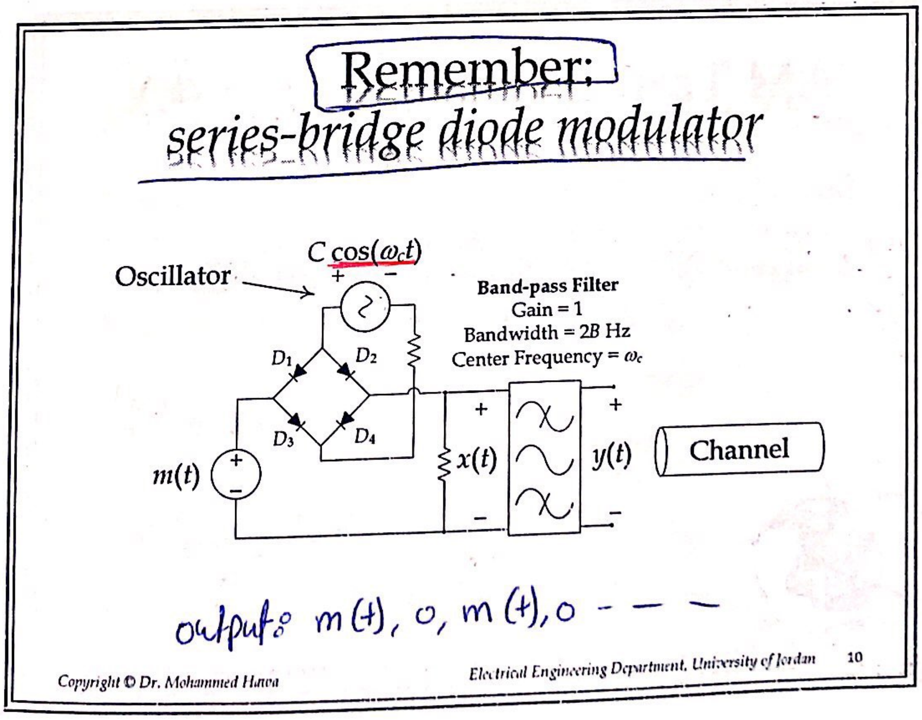
Remember:
series-bridge diode modulator

output: m(t), 0, m(t), 0 - - -

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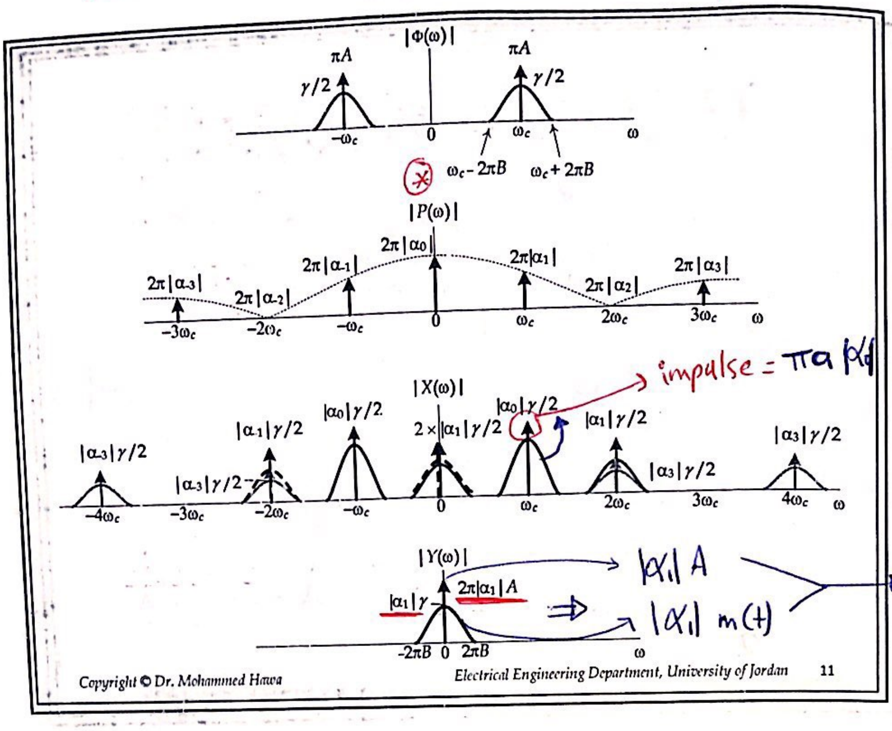
* لو ضربت ب P(t) ـــ عبارة عن rect func.



impulse = πa |α|

$|\alpha_1| A$

$\Rightarrow$

$|\alpha_1|\, m(t)$

$\rightarrow |\alpha_1| [A + m(t)]$

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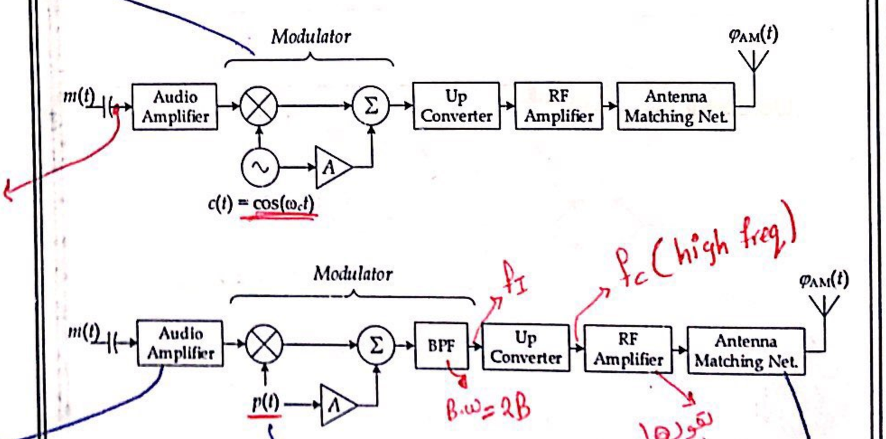
11

AM Transmitters: Design #A



هون بس بكون عندي 2 copies بس أضرب ب cos ωct

بشيل الـ DC من m(t)

f_I

f_c (high freq.)

B.ω = 2B

بقويها

بتعامل مع freq. قليلة

(بكبر signal الي freq ها قليلة)

بس أضرب ب p(t) بطلع عندي signal طويلة لـ ∞ فبحط BPF.

for max. power transfer

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A .نفس الشي بس ضيف

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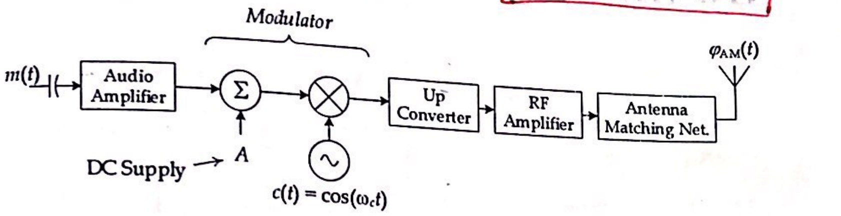
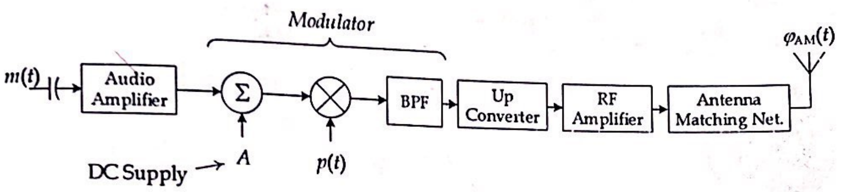
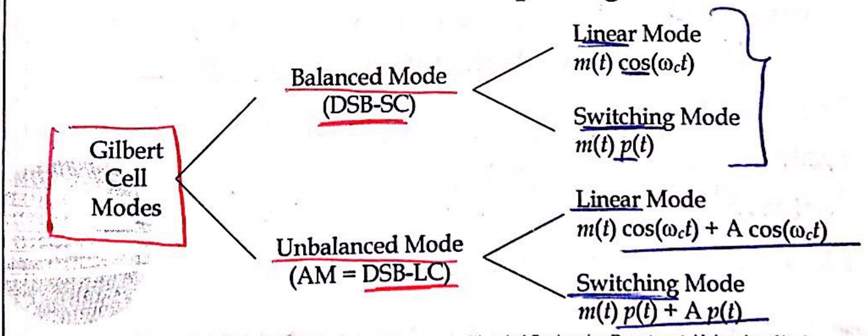
AM Transmitters: Design #B





AM Transmitters: Design #C

- Use the Gilbert Cell (MC1496) in the unbalanced mode, in which the gain of the top two differential amplifiers is unbalanced, which adds a residual carrier in the output signal.


Gilbert Cell Modes

Balanced Mode (DSB-SC)

Linear Mode $m(t)\cos(\omega_c t)$

Switching Mode $m(t)\,p(t)$

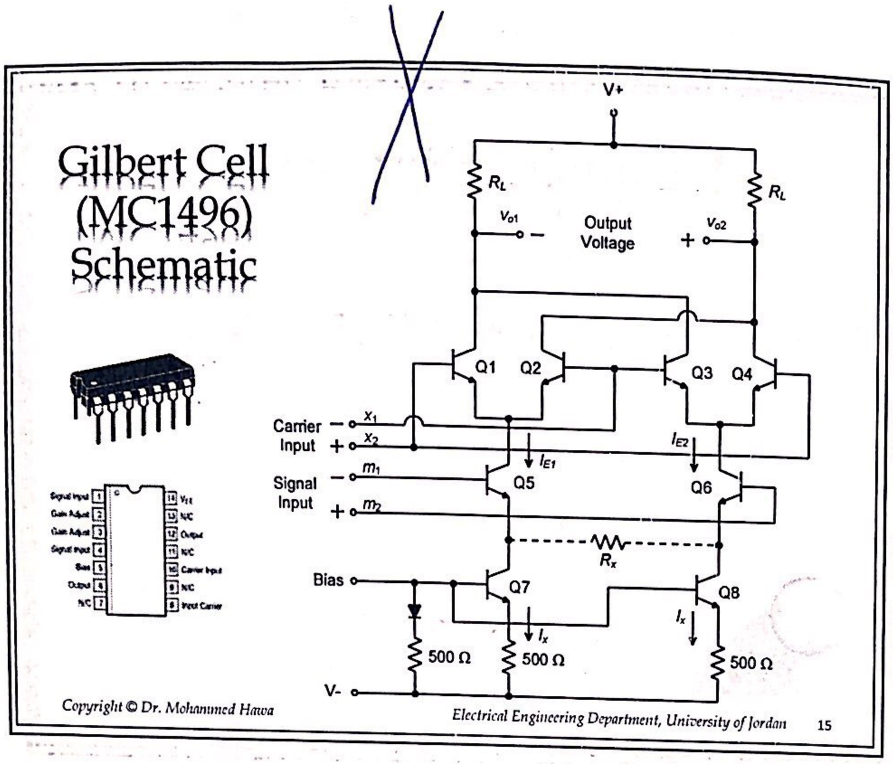
Unbalanced Mode (AM = DSB-LC)

Linear Mode $m(t)\cos(\omega_c t) + A\cos(\omega_c t)$

Switching Mode $m(t)\,p(t) + A\,p(t)$

note مهم

signal	power
$m(t)$	$\overline{m^2(t)}$
$\frac{1}{2} m(t)$	$\frac{1}{4} \overline{m^2(t)}$
DC	DC^2



~~Gilbert Cell (MC1496) Schematic~~

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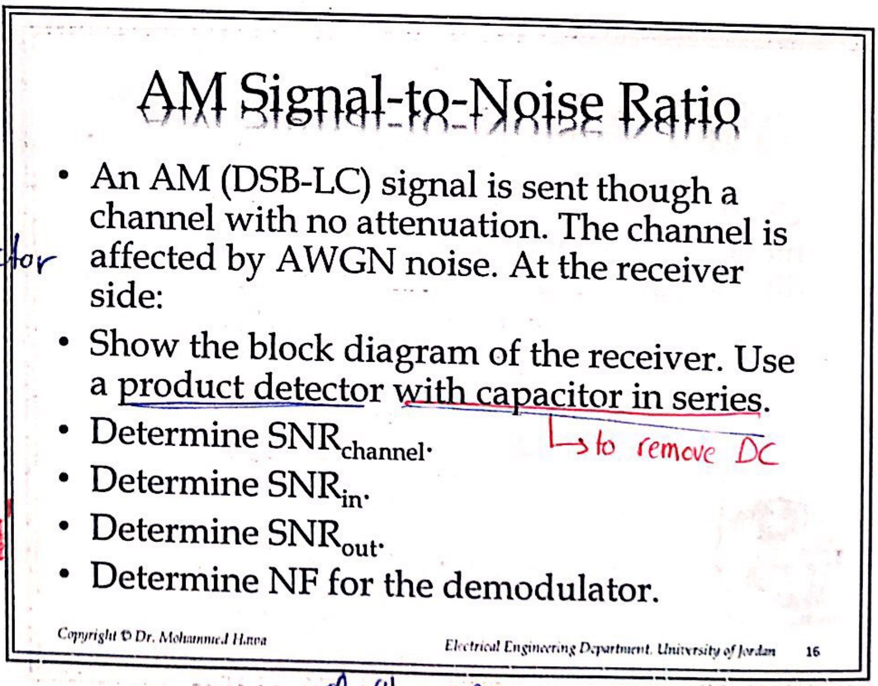

AM Signal-to-Noise Ratio

* ما بفرق أستخدم product او envelope detector

* بس product
كل

- An AM (DSB-LC) signal is sent though a channel with no attenuation. The channel is affected by AWGN noise. At the receiver side:
- Show the block diagram of the receiver. Use a product detector with capacitor in series.
  ↳ to remove DC
- Determine $SNR_{channel}$.
- Determine SNR_{in}.
- Determine SNR_{out}.
- Determine NF for the demodulator.

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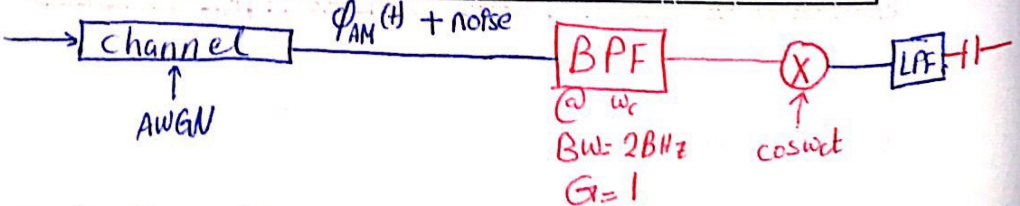
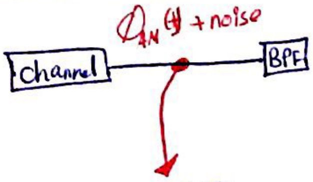


الحل على الورقة

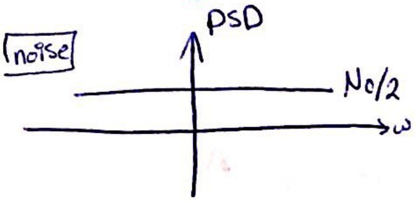
Slide 16

Lec 11

@

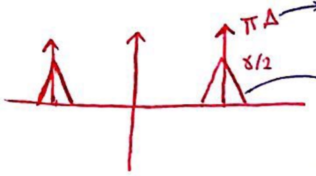


noise



$$P_n = \frac{1}{2\pi}\int_{-\infty}^{\infty}\frac{N_0}{2}d\omega = \infty$$

signal

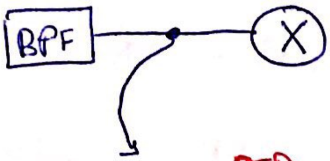


πA → $P = A^2/4$

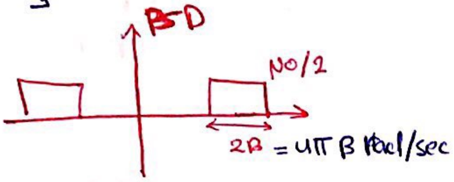
γ/2 → $P = \frac{1}{4}\overline{m^2(t)}$

$$P_{sig} = \underbrace{\frac{1}{2}\overline{m^2(t)}}_{P_s} + \underbrace{\frac{1}{2}A^2}_{P_c}$$

$$SNR_{chan} = \frac{P_{sig}}{P_n} = Zero = -\infty\, dB$$



noise



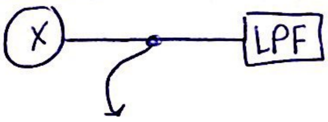
$$P_n = \frac{1}{2\pi}\left[4\pi B * \frac{N_0}{2}\right] * 2 = 2N_0B$$

signal

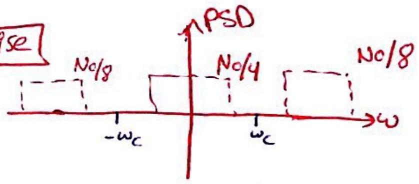
$$P_{sig} = \frac{1}{2}\overline{m^2(t)} + \frac{1}{2}A^2$$

$$SNR_{in} = \frac{\frac{1}{2}\overline{m^2(t)} + \frac{1}{2}A^2}{2N_0B}$$

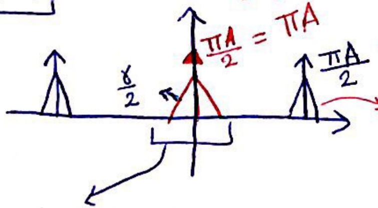
@



noise



signal



2copy جمع

$\frac{\pi A}{2} = \pi A$

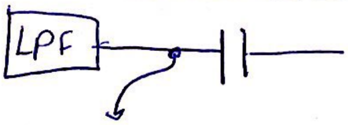
$\frac{\pi A}{2} \rightarrow P = \frac{A^2}{16}$

$\frac{\gamma}{4} \rightarrow P = \frac{1}{16}\overline{m^2(t)}$

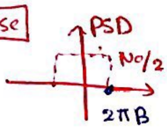
$\frac{1}{4}\overline{m^2(t)}$, $\frac{A^2}{4}$

$$P_{sig} = 2\left(\frac{1}{16}A^2 + \frac{1}{16}m^2(t)\right) + \frac{1}{4}m^2(t) + \frac{1}{4}A^2$$

$$= \frac{3}{8}\left(A^2 + \overline{m^2(t)}\right)$$

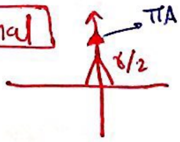


noise



$$P_n = \frac{1}{2\pi}\left[4\pi B * \frac{N_0}{2}\right] = \frac{BN_0}{2}$$

signal

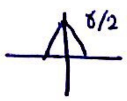


$P_{sig} =$ - - - -

@

noise → same up = $\frac{BN_0}{2}$

signal



$\gamma/2 = \frac{1}{2}m(t)$

$- P_{sig} = \frac{1}{4}\overline{m^2(t)}$

$$SNR_{out} = \frac{\frac{1}{2}\overline{m^2(t)}}{BN_0} = \frac{\eta S_{in}}{BN_0}$$

$$NF = SNR_{in}\,(dB) - SNR_{out}\,(dB)$$

$$= 10\log_{10}\frac{SNR_{in}}{SNR_{out}}$$ unitless

$$= 10\log_{10}\frac{\frac{S_{in}}{2N_0B}}{\eta\frac{S_{in}}{N_0B}} = 10\log_{10}\frac{1}{2\eta} = -10\log_{10}2\eta$$

Note

$$\eta = \frac{\frac{1}{2}\overline{m^2(t)}}{\frac{1}{2}\overline{m^2(t)} + \frac{1}{2}A^2} = \frac{\frac{1}{2}\overline{m^2(t)}}{S_{in}}$$

$$\boxed{\eta S_{in} = \frac{1}{2}\overline{m^2(t)}}$$

Solution

$$SNR_{out} = \eta \frac{S_{in}}{N_0 B}$$

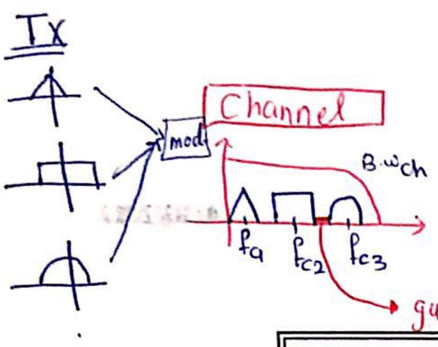
$$S_{in} = \frac{1}{2}\overline{m^2(t)} + \frac{A^2}{2}$$

$$NF = -10\log(2\eta)$$

Modulation Technique	Modulated Signal Bandwidth	SNR_{out}	Noise Figure NF, dB	Typical Applications
DSB-SC	$2B$	$\frac{S_{in}}{N_0B}$	-3	Analog instrumentation; multiplexing as part of FM stereo
SSB-SC	B	$\frac{S_{in}}{N_0B}$	0	Point-to-point voice
VSB-SC	B~$2B$	$\frac{S_{in}}{N_0B}$	-3~0	Facsimile (Fax machines)
QAM	$2B$ for two signals	$\frac{S_{in,effective}}{N_0B}$	0	Transmit color information in TV broadcasting; digital data
AM	$2B$	$\eta\frac{S_{in}}{N_0B}$	$-10\log(2\eta)$	Broadcast AM radio; point-to-point voice
SSB+C	B	$\eta\frac{S_{in}}{N_0B}$	$-10\log(\eta)$	Multiplexing in old telephony systems; point-to-point voice
VSB+C	B~$2B$	$\eta\frac{S_{in}}{N_0B}$	$-10\log(2\eta)$~ $-10\log(\eta)$	Analog Television broadcasting
FM	$2\Delta f + 2B$	$\left(\frac{3\beta^2}{k_m^2}\right)\frac{S_{in}}{N_0B}$	$10\log\left(\frac{k_m^2}{6(\beta+1)\beta^2}\right)$	Broadcast FM radio; analog microwave links
PM	$2\Delta f + 2B$	$\left(\frac{(\Delta\theta)^2}{k_m^2}\right)\frac{S_{in}}{N_0B}$	$10\log\left(\frac{k_m^2 B}{2(\Delta\theta)^2(\Delta f + B)}\right)$	Telemetry; digital data

* مهم كتير

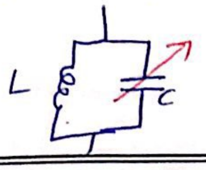
Tx



Rx

we use tuneable BPF + Demodulator

variable center freq.



$\omega_c = \frac{1}{\sqrt{LC}}$

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* اذا ما سويت modula.
بصير بينهم interferance

- بمنعهم يتداخلو
وعشان بال Rx
+ تخدم practical filter

Lecture 14: FDM, AM Radio, and the Superheterodyne Receiver

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EE421: Communications I: Lecture 14. For more information read Chapter 4 in your textbook or visit http://wikipedia.org/.

* tuenable BPF:

1- C.f

2- Bω

3- roll-off (sharpness)

Multiplexing: FDM

- Frequency Division Multiplexing (**FDM**) is a process that allows the transmission of several signals over the same channel at the same time.
- This is achieved by modulating the different signals on different carriers with different **carrier frequencies**.
- The receiver isolates one signal from the rest using a **tuneable BPF**.

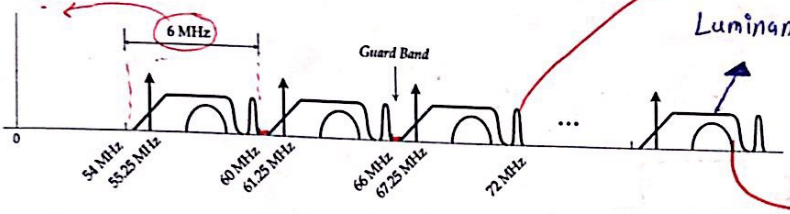
* adv. small guard band
↳ save B.ω

*disad. of small gaurdband
↳ sharp filter → expensive

* Applications of FDM:

1- TV broadcasting

TV Broadcasting (FDM)



PAL

حسب

Audio signal (FM)

Luminance signal (B&Y) (VSB-LC)

Chrominance (U, V) (ΦAM)

[illegible]

يعني 2 signal U, V

- For an FDM system, you need to know:
  - *Broadcast frequencies* for the stations (i.e., allocated spectrum).
  - *Bandwidth* of each station.
  - *Guardband* between adjacent stations.

for both PAL, NTSC = 0.25 MHz

TV Broadcasting

VHF

UHF

- Terrestrial TV uses broadcast frequencies within the ranges:

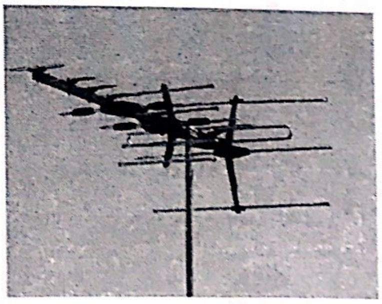
ارضي

- VHF (Very High Frequency): 30 MHz to 300 MHz

station

- UHF (Ultra High Frequency): 300 MHz and 3 GHz.

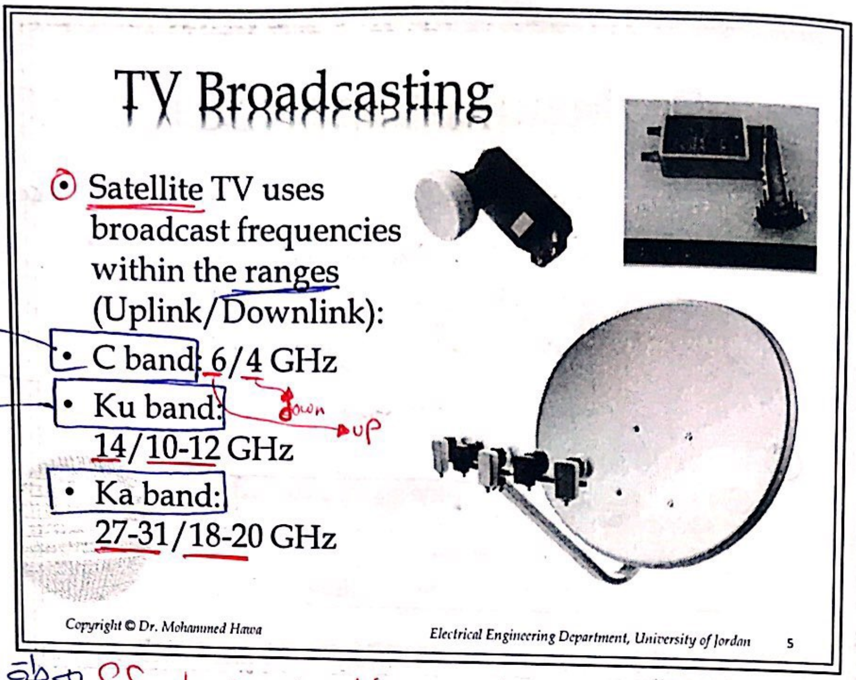
حفظ الأرقام



$$f\uparrow \rightarrow \lambda\downarrow \Rightarrow L_{antenna}\downarrow = \frac{\lambda}{2}$$

$f\uparrow \Rightarrow$ attenuation $\uparrow$

→ ال UHF فيها اعلى attenuation



TV Broadcasting

- Satellite TV uses broadcast frequencies within the ranges (Uplink/Downlink):
  - C band: 6/4 GHz
  - Ku band: 14/10-12 GHz
  - Ka band: 27-31/18-20 GHz

dish small

bigger dish

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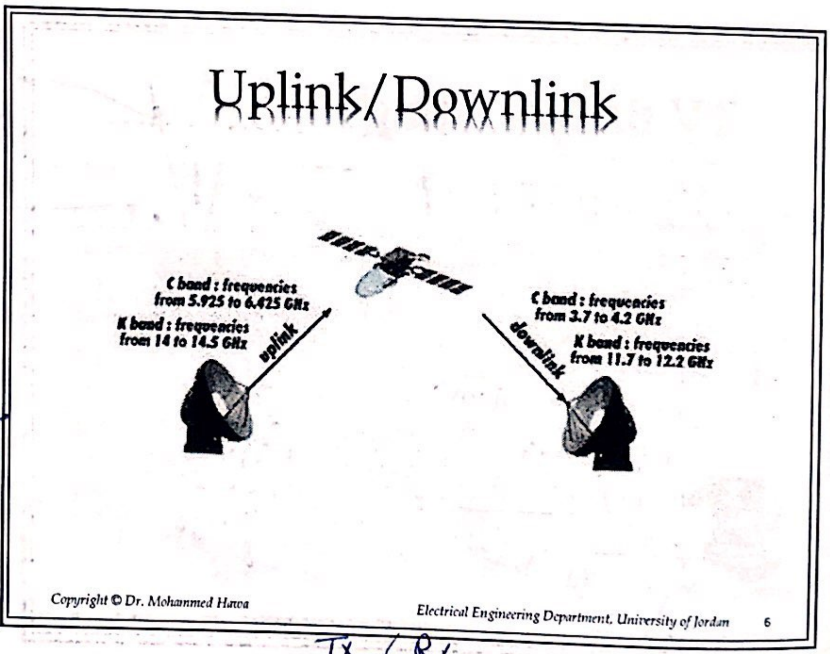
* ليش قيمة ال uplink أعلى من downlink ؟؟

محطة الارسال الارضي
ما فيها مشكلة بالبور
فنبعث عالي Freq.
وعادي يصير attenuation
* لكن القمر الصناعي
ما في بور كتير
فبرسل Freq. اقل
مشان ما يصير atten.
عليها

* لكن الموبايل العكس



Uplink/Downlink

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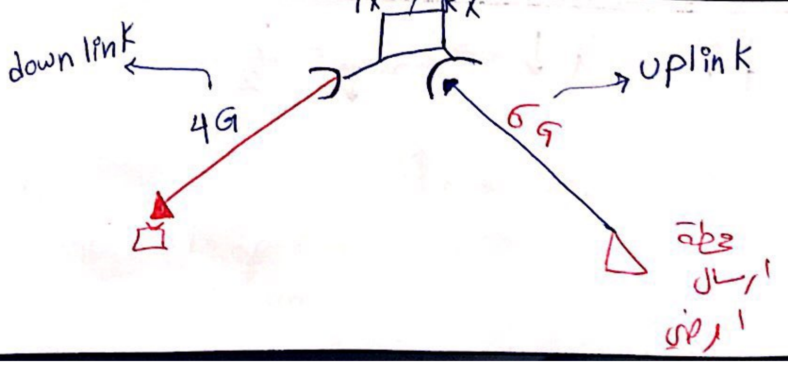
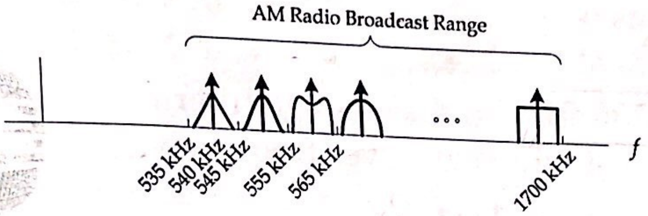


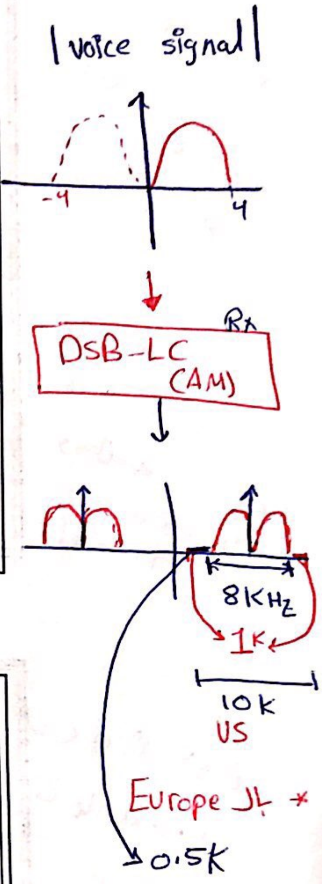
Application ② AM radio broadcasting

→ voice signal

AM Radio Broadcasting

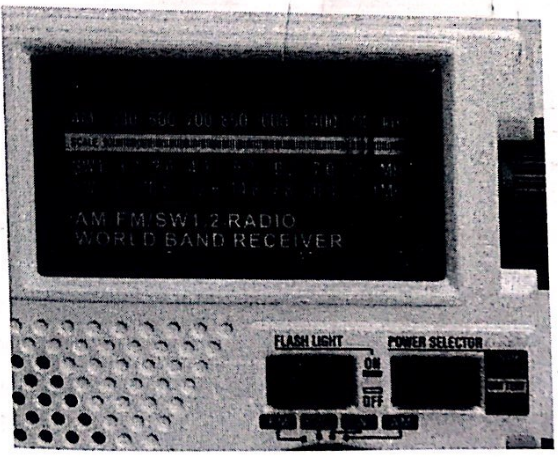
- Each station is an AM modulation of human voice.
- FDM is used to multiplex signals on the air waves.
- **US:** Each station occupies a bandwidth of 10 kHz.
- **Europe:** Each station occupies a bandwidth of 9 kHz.



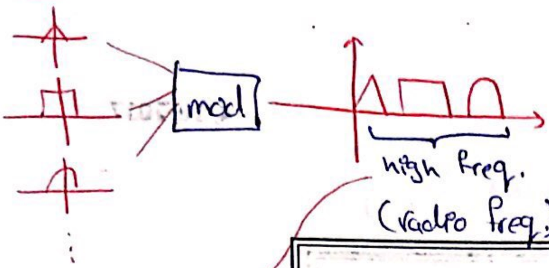


*range of AM radio broadcast ≈ 1 MHz

HW: Look at Your Radio Dial



*problem of FDM:



① sharp / narrow → ~~[illegible]~~ B.W

Rx we need highly selective (sharp) tuenable BPF

due to Small guardband (1K or 0.5K)

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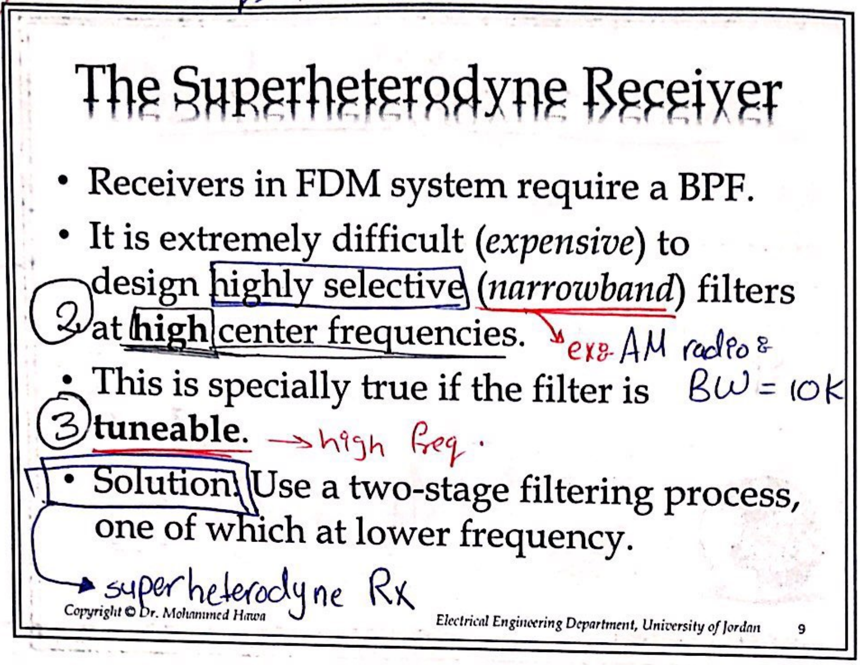
very difficult * هلأ بالـ ②
and expensive

مشان بال Rx يكون عنا small antena



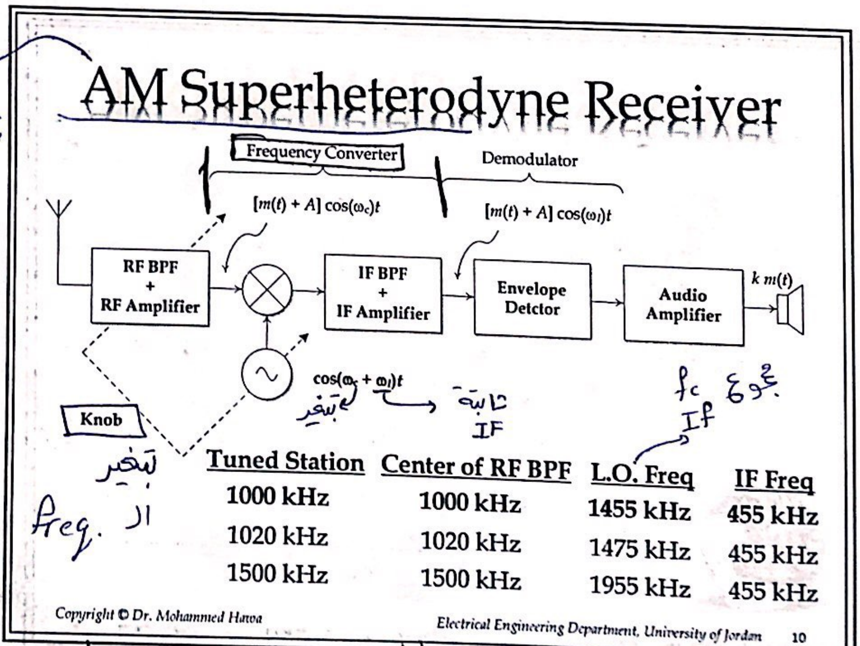
The Superheterodyne Receiver

- Receivers in FDM system require a BPF.
- It is extremely difficult (*expensive*) to design ② highly selective (*narrowband*) filters at high center frequencies. → ex: AM radio & BW = 10K or 9K
- This is specially true if the filter is ③ **tuneable**. → high freq.
- Solution: Use a two-stage filtering process, one of which at lower frequency. → superheterodyne Rx

الثلاث شروط لازم يتحققو ولكن ← very expensive & difficult

لازم يكون tuenable & high centre freq.

* لكن اول شرط مش ضروري يتحقق



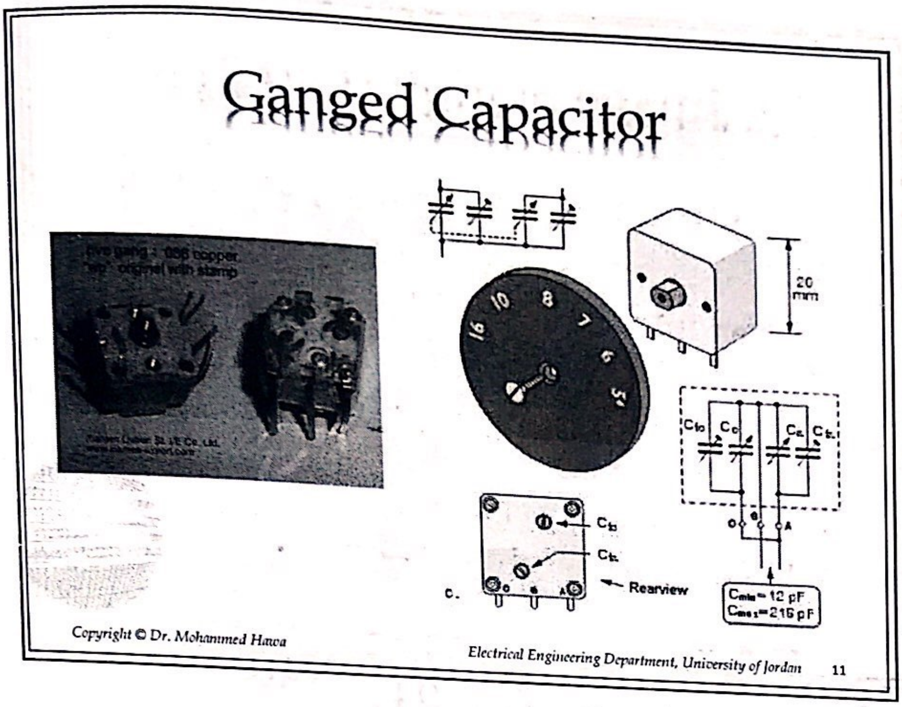
AM Superheterodyne Receiver

Tuned Station	Center of RF BPF	L.O. Freq	IF Freq
1000 kHz	1000 kHz	1455 kHz	455 kHz
1020 kHz	1020 kHz	1475 kHz	455 kHz
1500 kHz	1500 kHz	1955 kHz	455 kHz

الجزء هاد متغير من خلال Knob

الجزء هاد ثابت → مفيد بال envelop detector

$$\frac{1}{f_I} \ll \tau \ll \frac{1}{Bw\,(m(t))}$$



Ganged Capacitor

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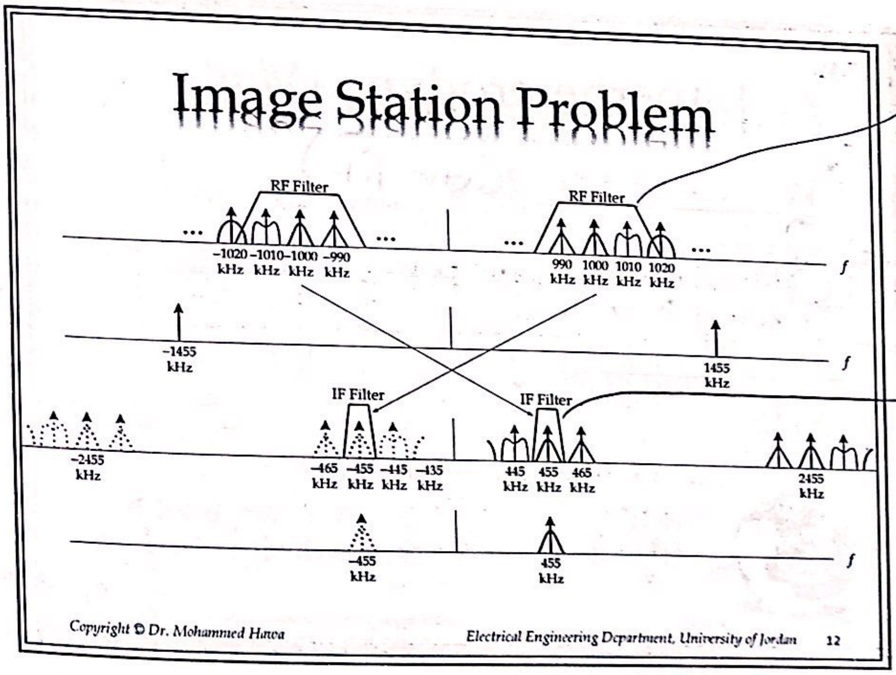

Image Station Problem

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tuenable
freq يغير ال

not
tuenable
& doesn't
work in
high freq
⇓
not expensive + freq ما يغير ال

4/10/2

فيه سمعها

1000 - بس اجيها 1455 → 455

* المشكلة 1910 بس اطرح منها 1455 → 455

image station

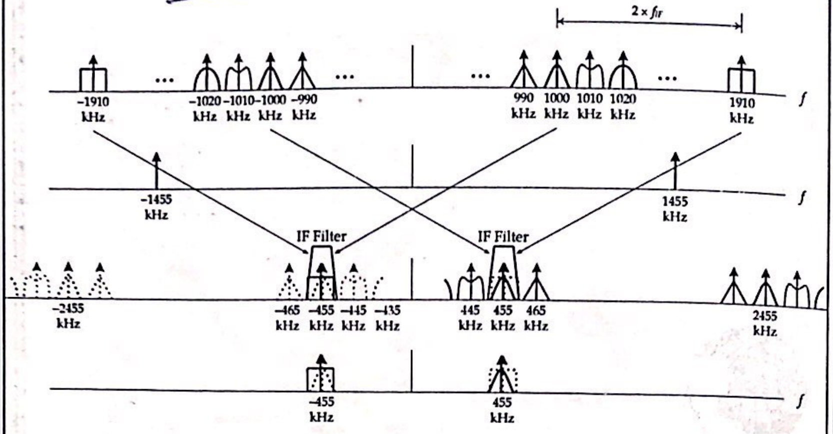
⇓

2 signals interferance

اكل ما اطرح 1910 معهم في نفس الفلتر.

*. كيف

Image Station (*Part* 2)



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$f_{Image} - f_{L.O} = f_I$

$f_{Image} - (\underset{\downarrow f\ station}{f_c} + f_I) = f_I \Rightarrow f_{image} = f_c + 2f_I \rightarrow 455$

Superheterodyne *Why*'s

- *Why* the RF Filter? (adv. RF)
  - Eliminates the *image station.*
  - Reduces the amount (power) of noise that enters the receiver.
- *Why* the IF Stage (heterodyning)?
  - With its high-selectivity and lower price, the IF filter isolates the desired radio station from all others sent using FDM.
  - Since the IF frequency does not change with the tuned station, it is easier to design the E.D.

envelop detector

freq نزلنا وربطنا هاي

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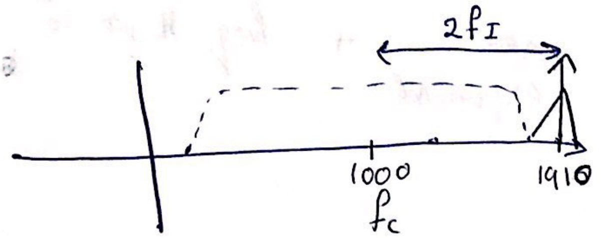
* 1910 = 1000 + 2 * 455

$BW_{(max)\,BPF} = 2(2f_I - B_{Image})$

$= 4f_I - 2B_{Image}$



Range of AM station is (540 —— 1700 KHz)

if we use differance down converter ⇒ $f_{L.O}$ = 540 − 455 = 85 KHz

1700 − 455 = 1245 KH

4/10/2017

" " " sum " " " ⇒ $f_{L.O}$ = 540 + 455 = 995 KHz

1700 + 455 = 2155 KHz

Superheterodyne Why's

- *Why* the sum, not difference?

ليش جمعنا f_c ع f_I ??

- The sum (as opposed to the difference) in the receiver results in a smaller tuning range ratio, which requires a smaller tuning capacitor for the local oscillator.
- Hence, this solution is cheaper.

sum : cheap & simple hardware

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H.ω حل 7

* sum

ratio (1:2)

* differance

ratio (1:14)

Homework

- Now design a superheterodyne receiver, but this time using the difference for L.O.:

1 – If you want to listen to the station at 1000 kHz what settings should you choose for the RF BPF, the oscillator, and the IF BPF?

2 – Repeat the same problem if you want to listen to the 1020 kHz and 1500 kHz stations.

3 – What is the frequency of the image station if you are listening to the station at 1000 kHz?

↳ 1910 K

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ع فرض انها

voice signal

sol 1 $f_{station}$ = 1000 KHz ⟶ RF BPF : Centre freq. = 1000 KHz

$BW_{max} = 4f_I - 2B_{image}$

= 4 * 455 − 2(4K) 8

$f_{L.O}$ = 1000 − 455 = 545 K Hz

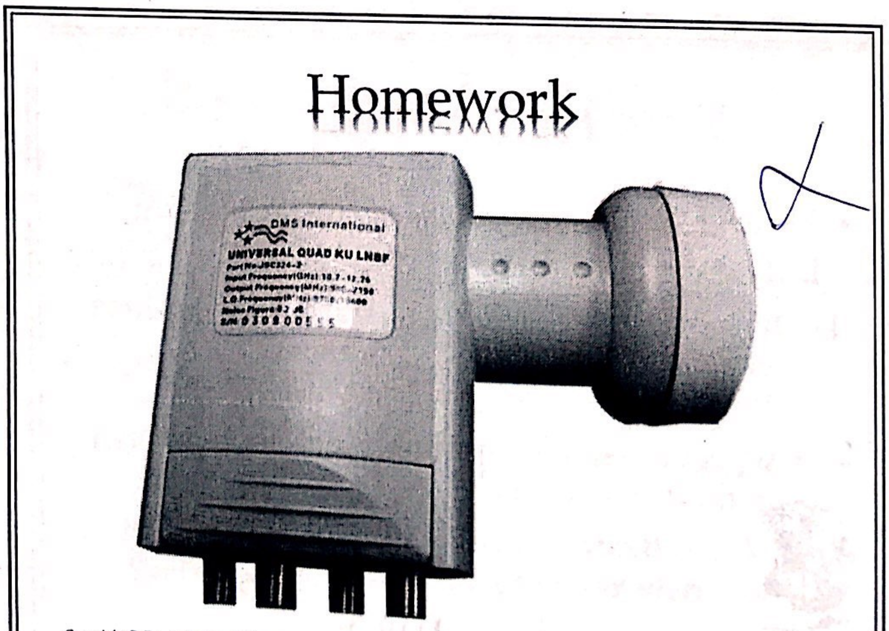
IF : c.f = 455 KHz

الي بدي ا ⟵ B.W = 2 × 4 = 8 kHz (voice signal)

استخدامات

Superheterodyne *Everywhere!*

- The superheterodyne receiver is much more popular nowadays compared to the homodyne receiver.
- It is used in many communication systems including: FM Radio, Analog and Digital TV broadcasting, Cellular phones, WiMAX, Satellite and Microwave systems, GPS, etc.
- Some popular IF frequencies:
  - AM radio receivers: 455 kHz
  - FM radio receivers: 10.7 MHz
  - Analogue television receivers: 45.75 MHz



Homework

4/10/20

Lecture 15: Frequency and Phase Modulation (FM and PM)

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EE421: Communications I: Lecture 15. For more information read Chapter 5 in your textbook or visit http://wikipedia.org/.

الاستاذ الي رح ناخذها
نكاد الشابتر

Just like *earlier*…

- Time domain expression.
- Time domain *sketch*.
- Average power of modulated signal.
- Frequency domain representation.
- *Bandwidth* of modulated signal.
- Signal-to-Noise Ratio and Quality.
- Practical Applications.
- Modulators and Demodulators (hardware).

Angle Modulation (FM and PM)

$$\varphi_{unmodulated}(t) = A\cos(\underbrace{\omega_c t + \theta_0}) \rightarrow \text{angle or argument}$$

$$\varphi_{FM\ or\ PM}(t) = A\cos\theta(t)$$

$$\boxed{\omega_i(t) \triangleq \frac{d\theta(t)}{dt}} = \omega_c$$

$$\boxed{\theta_i(t) \triangleq \theta(t) - \omega_c t} = \theta_0$$

→ بالنسبة للسيجنال اللي فوق

- $\theta(t)$ is **generalized angle** of the modulated signal.
- $\omega_i(t)$ is **instantaneous frequency** of modulated signal.
- $\theta_i(t)$ is **instantaneous phase** of modulated signal.

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Frequency Modulation (FM)

- The *instantaneous frequency* of the modulated signal changes in proportion to the message.

$$\omega_{i_{FM}}(t) = \omega_c + k_f m(t)$$

$$\theta_{FM}(t) = \omega_c t + k_f \int_{-\infty}^{t} m(t)dt$$

حفظ

$$\boxed{\varphi_{FM}(t) = A\cos\left(\omega_c t + k_f \int_{-\infty}^{t} m(t)dt\right)}$$

k_f → constant

$$\theta_{i_{FM}}(t) = k_f \int_{-\infty}^{t} m(t)dt$$

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→ for this signal

linearly بتأثر عليها $m(t) \leftarrow \omega_i(t) = \omega_c + m(t).K_f \leftarrow$ FM

$$\theta_f(t) = K_f \int_{-\infty}^{t} m(t)\cdot dt$$

4/10/2017

for this signal.

$\omega_i(t) = \omega_c + K_p m'(t)$

$\theta_i(t) = K_p m(t) \longrightarrow$ PM

لانه m(t) اثرت مباشرة (بدون اشتقاق) على الفيز

Phase Modulation (PM)

- The *instantaneous phase* of the modulated signal changes in proportion to the message.

$$\theta_{i_{PM}}(t) = k_p m(t)$$

$$\theta_{PM}(t) = \omega_c t + k_p m(t)$$

مهم

$$\boxed{\varphi_{PM}(t) = A\cos\left(\omega_c t + k_p m(t)\right)}$$

$$\omega_{i_{PM}}(t) = \omega_c + k_p \frac{dm(t)}{dt} = \omega_c + k_P m'(t)$$

FM and PM Equivalence

- FM
  - Constant amplitude A
  - Constant carrier frequency ω_c
  - Variable *instantaneous* frequency $\omega_i \propto m(t)$
  - Variable *instantaneous* phase $\theta_i \propto \int m(t)dt$
- PM
  - Constant amplitude A
  - Constant carrier frequency ω_c
  - Variable *instantaneous* frequency $\omega_i \propto m'(t)$
  - Variable *instantaneous* phase $\theta_i \propto m(t)$

تشابه

اختلاف

$$\varphi_{FM}(t) = A\cos\left(\omega_c t + K_f \int_{-\infty}^{t} m(t)\,dt\right)$$

$$\omega_i = \omega_c + K_f\, m(t)$$

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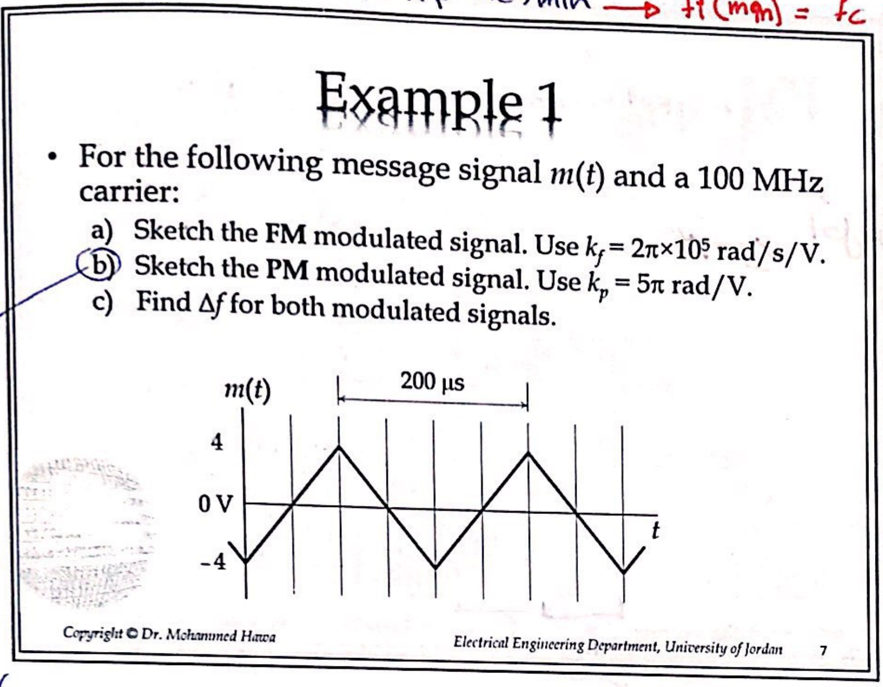
$$\omega_{i(max)} = \omega_c + K_f\, m(t)_{max} \longrightarrow f_{i(max)} = f_c + \frac{K_f}{2\pi} m(t)_{max} \quad (Hz)$$

$$\omega_{i(min)} = \omega_c + K_f\, m(t)_{min} \longrightarrow f_{i(min)} = f_c + \frac{K_f}{2\pi} m(t)_{min}$$



Example 1

- For the following message signal $m(t)$ and a 100 MHz carrier:
  a) Sketch the **FM** modulated signal. Use $k_f = 2\pi\times10^5$ rad/s/V.
  b) Sketch the **PM** modulated signal. Use $k_p = 5\pi$ rad/V.
  c) Find Δf for both modulated signals.

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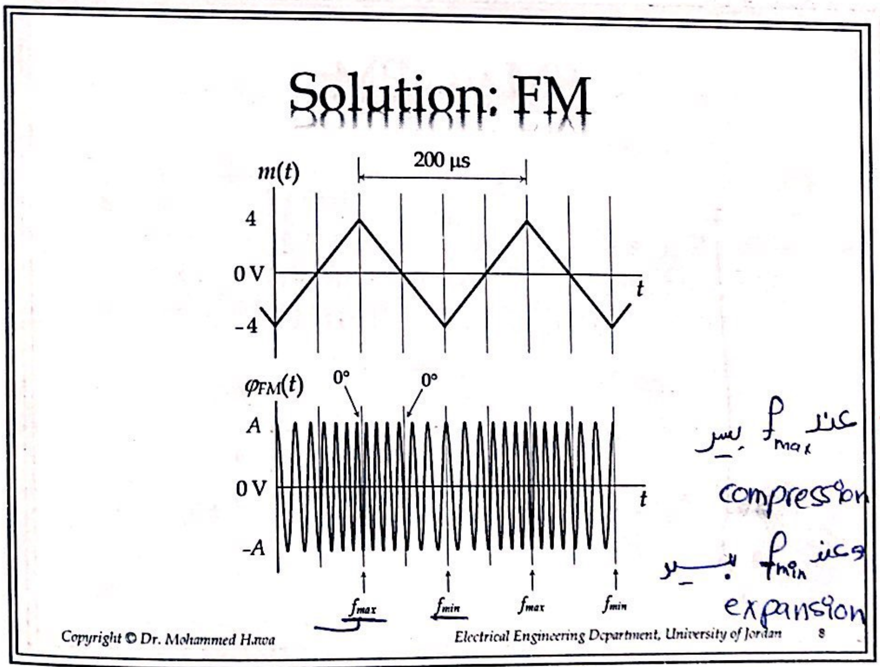
اول شي بجيب المشتقة بعدين بنرسم كالعادة



Solution: FM

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عند f_{max} بصير compression **

وعند f_{min} بصير expansion

ⓐ $f_{i(max)} = 100M + \frac{2\pi \times 10^5}{2\pi}(4)\ Hz = 100.4 Hz$

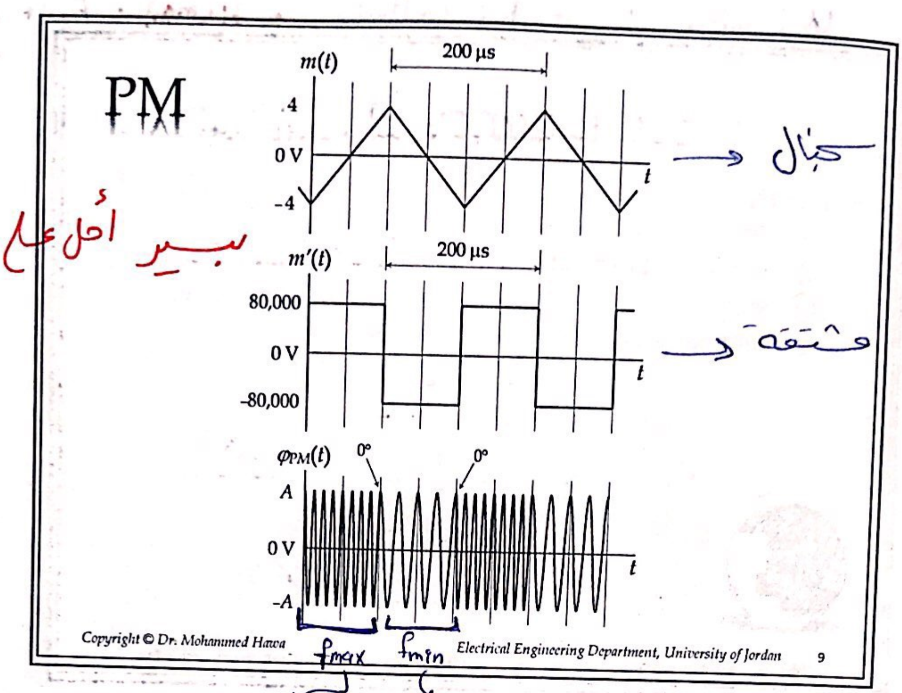
$f_{i(min)} = 100M + \frac{\overset{2}{\cancel{2}}\pi \times 10^5}{2\pi}(-4) = 99.6\ HZ$

ⓑ $\longrightarrow$

ⓑ $f_{i(max)} = f_c + \frac{k_p}{2\pi} m'(t)_{max}$

$= 100M + \frac{5\pi}{2\pi}(80\,000) = 100.2\ MHz$

$f_{i(min)} = f_c + \frac{k_p}{2\pi} m'(t)_{min} = 99.8\ MHz$



PM

بيسير أول على المشتقة

سجنال

مشتقة

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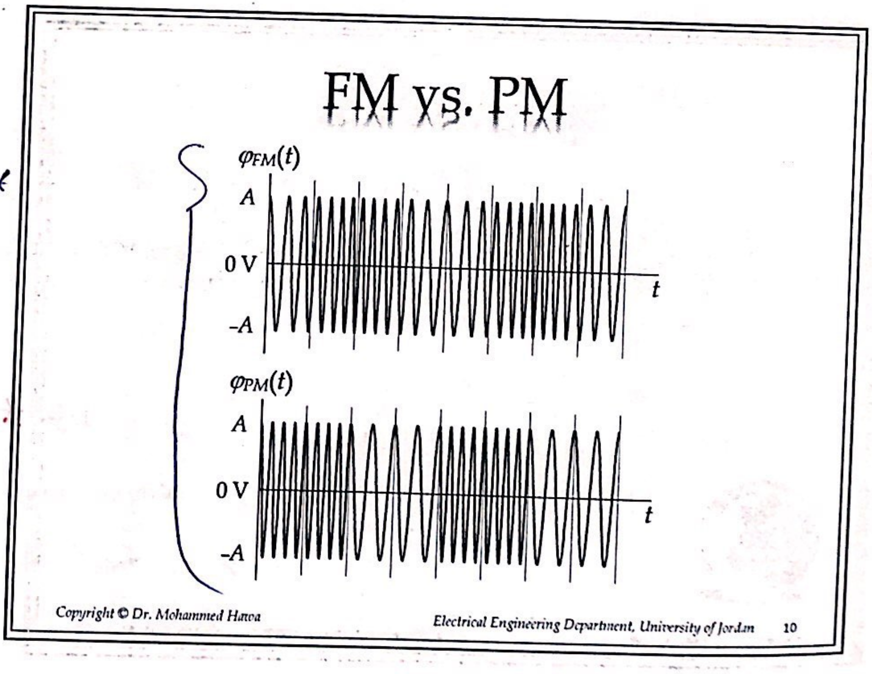
fmax → compression

fmin → expansion



FM vs. PM

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* احنا اشتغلنا على freq.

* لكن في تغيير ضمني على instantenuous. phase

ⓒ ΔF for FM = 0.4 MHz

ΔF " PM = 0.2 MHz

Peak Frequency Deviation

مهم

- **For FM:**

$$\Delta f \triangleq \frac{f_{max} - f_{min}}{2} = \frac{k_f}{2\pi} \times \frac{m(t)_{max} - m(t)_{min}}{2}$$

$$\boxed{\Delta f = \frac{k_f}{4\pi} \times m(t)_{pk-pk} \quad [Hz]} \rightarrow 8$$

للسؤال السابق

- **For PM:**

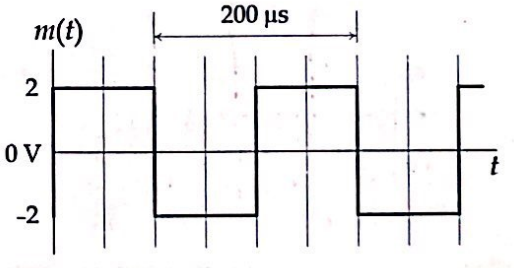
$$\Delta f \triangleq \frac{f_{max} - f_{min}}{2} = \frac{k_p}{2\pi} \times \frac{m'(t)_{max} - m'(t)_{min}}{2}$$

$$\boxed{\Delta f = \frac{k_p}{4\pi} \times m'(t)_{pk-pk} \quad [Hz]} \rightarrow 160.000$$

~~Kp = π~~

Example 2

- For the following message signal $m(t)$ and a 100 MHz carrier:
  - a) Sketch the **FM** modulated signal. Use $k_f = 2\pi \times 10^5$ rad/s/V.
  - b) Sketch the **PM** modulated signal. Use $k_p = \pi/4$ rad/V.
  - c) Find Δf for both modulated signals.



$W_{i\,max} = f_c + K_f * (2)$

$W_{i\,min} = f_c + K_f * (-2)$

بمعنى

منطقتين وحدة

فيها compression

وحدة Expansion

* BPSK:

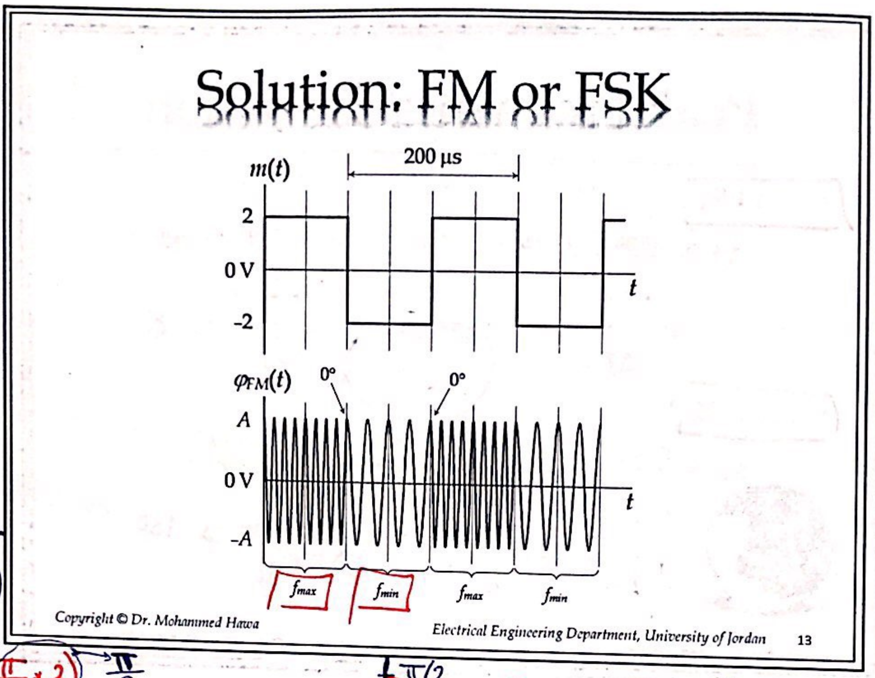
4/10/2017

⊛ if m(t) is polar NRZ + FM = FSK

analog Mod → digital modulation

⊛ " " " " " + PM = BPSK → بيكون عندي 2 phases

⊛ " " " " " + AM = ASK



Solution: FM or FSK

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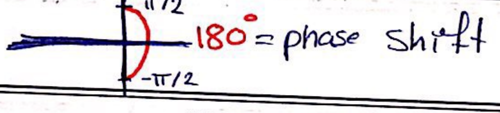
$\varphi_{PM}(t) = A\cos(\omega_c t + k_p m(t))$

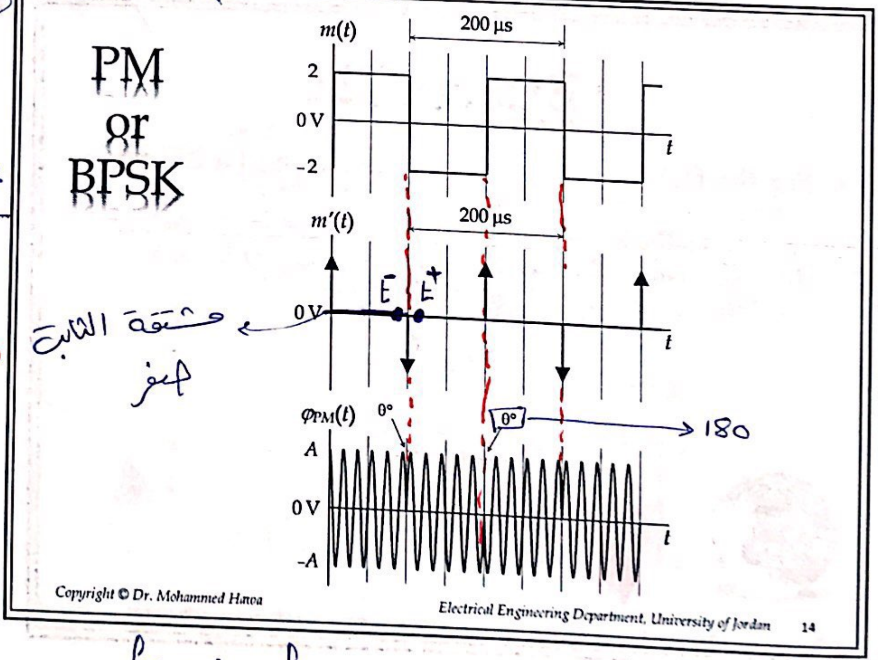
$\varphi_{PM}(t^-) = A\cos(\omega_c t + \frac{\pi}{4} * 2) \rightarrow \frac{\pi}{2}$

$\varphi_{PM}(t^+) = A\cos(\omega_c t + \frac{\pi}{4} * (-2)) \rightarrow -\frac{\pi}{2}$

*مشان اطلع وين phase shift



180° = phase shift



PM or BPSK

0° → 180

مشتقة الثابتة صفر

لكن في sharp edge

مشتقتها impulse

⇓

phase shift

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$f_i(max) = f_c$

$f_i(min) = f_c$

ما بيصير هيك

لكن في phase shift

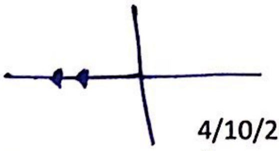
جاي من

sudden change

* for example 2

if $K_p = \frac{\pi}{2}$ $\quad \varphi_{PM}(t^-) = A\cos(\omega_c t + \pi)$

$\varphi_{PM}(t^+) = A\cos(\omega_c t - \pi)$



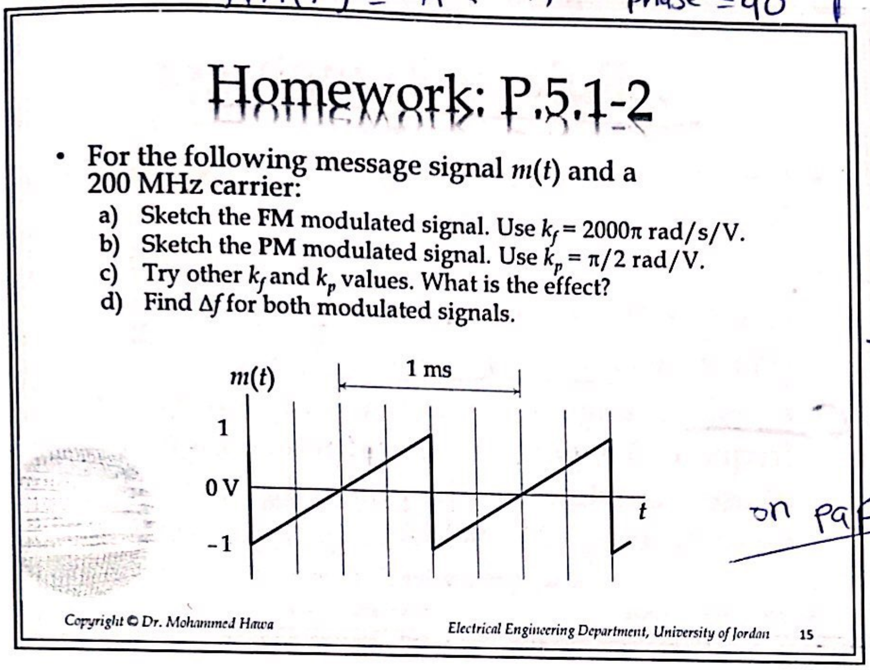
4/10/2017

if $K_p = \frac{\pi}{8}$ $\quad \varphi_{PM}(t^-) = A\angle \pi/4$

$\varphi_{PM}(t^+) = A\angle -\pi/4$ $\quad$ phase $= 90$

No phase shift → بنتصورها

in practical cases we need phase-shift $< 2\pi$ to avoid phase ambiguaty



Homework: P.5.1-2

- For the following message signal $m(t)$ and a 200 MHz carrier:
  a) Sketch the FM modulated signal. Use $k_f = 2000\pi$ rad/s/V.
  b) Sketch the PM modulated signal. Use $k_p = \pi/2$ rad/V.
  c) Try other k_f and k_p values. What is the effect?
  d) Find Δf for both modulated signals.

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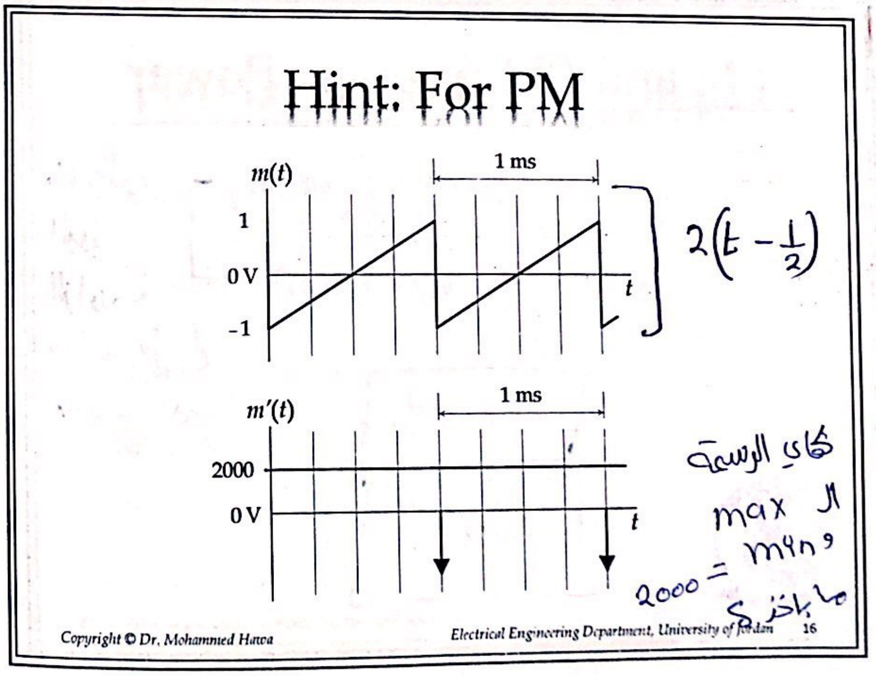
on paper



Hint: For PM

$2\left(t - \frac{1}{2}\right)$

كاي الرسمة

ال max

و min

2000 =

ما باخذ

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homework slide 15 lec 15

PAGE

DATE

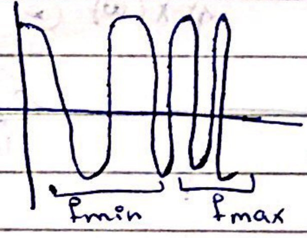
A. $\phi_{FM}(t) = A\cos(\omega_c t + K_f \int_{-\infty}^{t} m(\tau).d\tau$

$f_{i(max)} = f_c + \frac{K_f}{2\pi} m(t)_{max} = 200.001 \text{ MHz}$

$f_{i(min)} = f_c + \frac{K_f}{2\pi} m(t)_{min} = 199.999 \text{ MHz}$

$\Delta f = \frac{f_{max} - f_{min}}{2} = 1000 \text{ Hz}$ $\boxed{OR}$ $\frac{K_f\, m(t)}{4\pi} = 1000 \text{ Hz}$

$\theta_i(t) = K_f \int_{-\infty}^{t} m(\tau).dt$



for $0 < t < 1$ msec

$m(t) = 2(t - \frac{1}{2}) = 2t - 1$

$\theta_i(t) = K_f \int_{-\infty}^{t} 2\tau - 1\, d\tau = K_f(t^2 - t) \xrightarrow{\text{نشتق}} 2t - 1 = 0 \rightarrow t = \frac{1}{2}$

$\theta_{i\,min}$ @ $t = \frac{1}{2} \rightarrow$ [illegible] $\frac{-K_f}{4}$

$\Big\{ \theta_{i\,max} =$ @ $t=0$ & $t=0$

$= Zero$ مساحة فوق وتحت متساوية

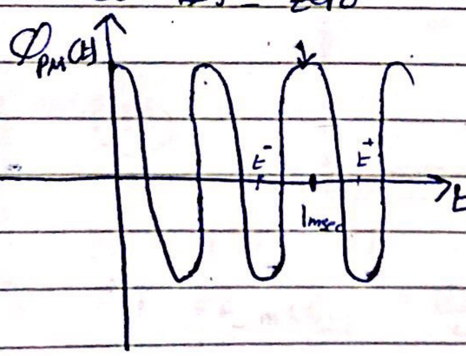
b. $\phi_{PM}(t) = A\cos(\omega_c t + K_p\, m(t))$

$\Delta f = \frac{K_p}{4\pi} m'(t)_{p-p}$

$f_{i(max)} = f_c + \frac{K_p}{2\pi} \overset{2000}{\cancel{m'(t)_{max}}} = 200 \times 10^6 + 500 \text{ Hz}$

$f_{i(min)} = f_c + \frac{K_p}{2\pi} \underset{2000}{\cancel{m'(t)_{min}}} = 200 \times 10^{+6} + 500 \text{ Hz}$

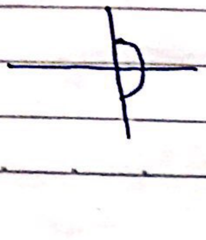
So $\Delta f = Zero$



قيمة m(t) عند t^-

$\phi_{PM}(t^-) = A\cos(\omega_c t^- + K_p\, \overset{\nearrow}{1}) = A\angle\frac{\pi}{2}$

$\phi_{PM}(t^+) = A\cos(\omega_c t^+ + K_p(-1)) = A\angle\frac{-\pi}{2}$



phase-shift $= \underline{\underline{180^\circ}}$

* بنقدر نحل زي هيك بدون جدول الرولز

Rules of Thumb

- Smooth change in frequency means smooth change in phase *always.*
- Sudden change in frequency (i.e., unit step change) *does not* mean a sudden change in phase, i.e., it means 0° phase shift.
- *Impulse* change in frequency (i.e., infinity frequency) *might* cause a sudden change in phase. To determine the phase shift (or lack thereof) see $k_p m(t)$ for PM or $k_f \int m(t)dt$ for FM.

FM and PM Average Power

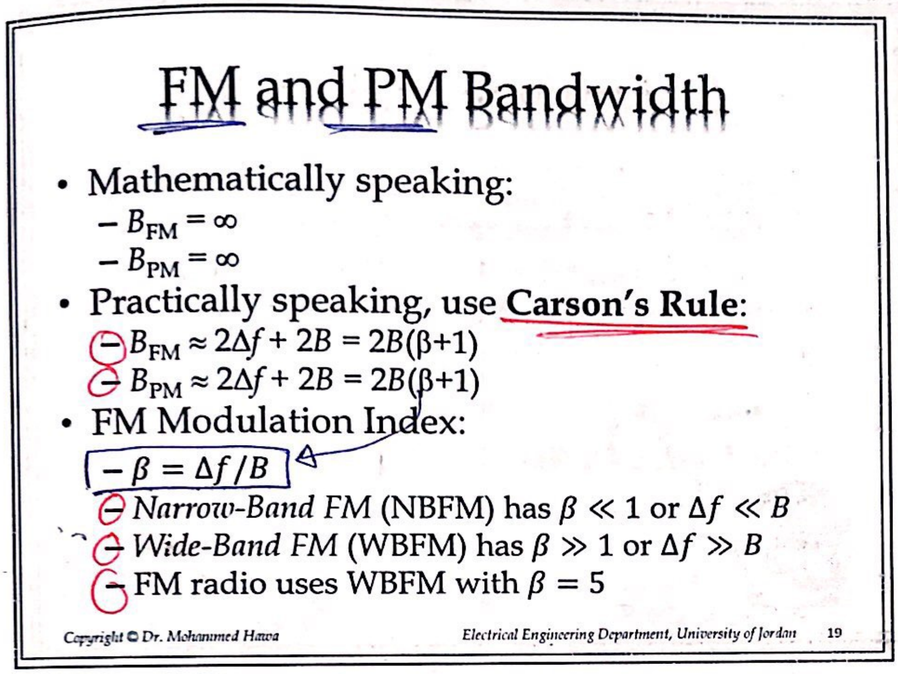
$$\phi_{FM}(t) = A\cos\left(\omega_c t + k_f \int_{-\infty}^{t} m(t)dt\right)$$

$$\phi_{PM}(t) = A\cos\left(\omega_c t + k_p m(t)\right)$$

[illegible] البور
الزاوية
ما بتأثر على
حساب البور

$$\boxed{\overline{\varphi_{FM}^2(t)} = \frac{A^2}{2}}$$

$$\boxed{\overline{\varphi_{PM}^2(t)} = \frac{A^2}{2}}$$



FM and PM Bandwidth

- Mathematically speaking:
  - $B_{FM} = \infty$
  - $B_{PM} = \infty$
- Practically speaking, use **Carson's Rule**:
  - $B_{FM} \approx 2\Delta f + 2B = 2B(\beta+1)$
  - $B_{PM} \approx 2\Delta f + 2B = 2B(\beta+1)$
- FM Modulation Index:
  - $\boxed{\beta = \Delta f / B}$
  - *Narrow-Band FM* (NBFM) has $\beta \ll 1$ or $\Delta f \ll B$
  - *Wide-Band FM* (WBFM) has $\beta \gg 1$ or $\Delta f \gg B$
  - FM radio uses WBFM with $\beta = 5$

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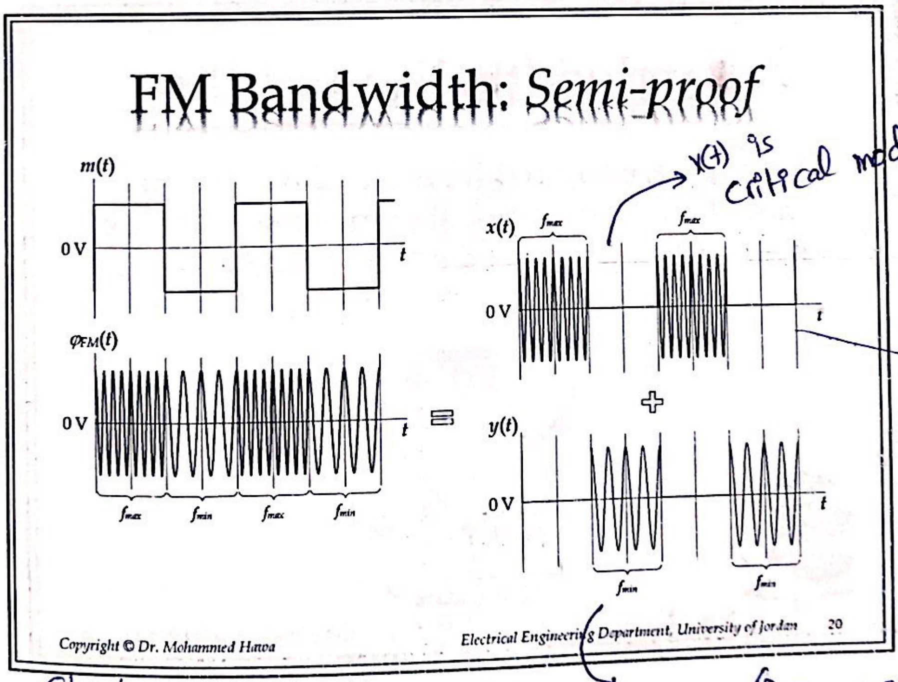

FM Bandwidth: *Semi-proof*

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x(t) is critical modulation @ $f_c = f_{max}$

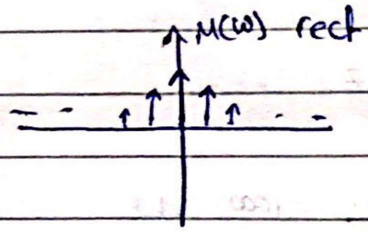
عنده
تردد صفر
[illegible]

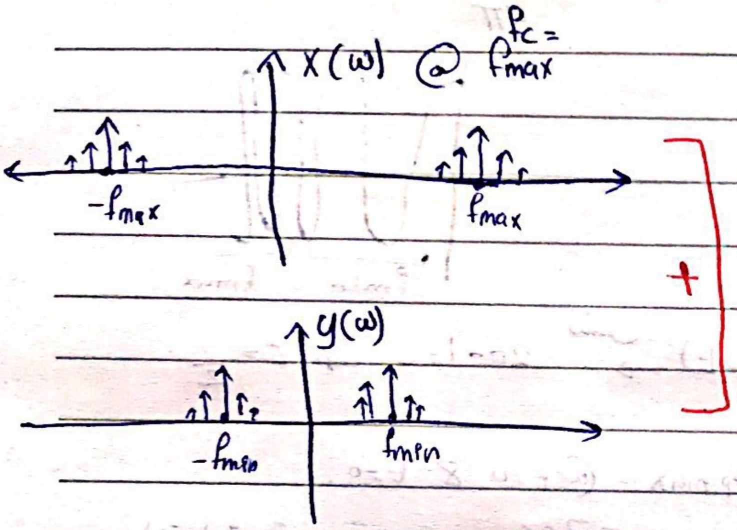
DSB-LC

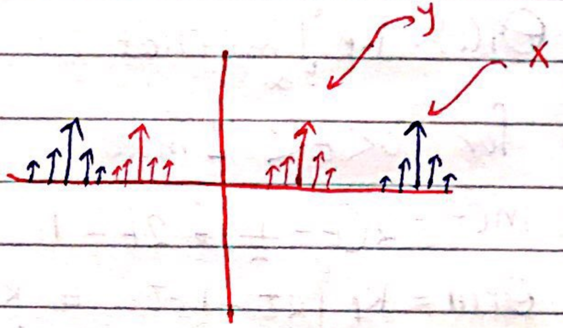
y(t) is (DSB-LC)
critical modulation @ $f_c = f_{min}$

Check paper

Lec 15 slide 20

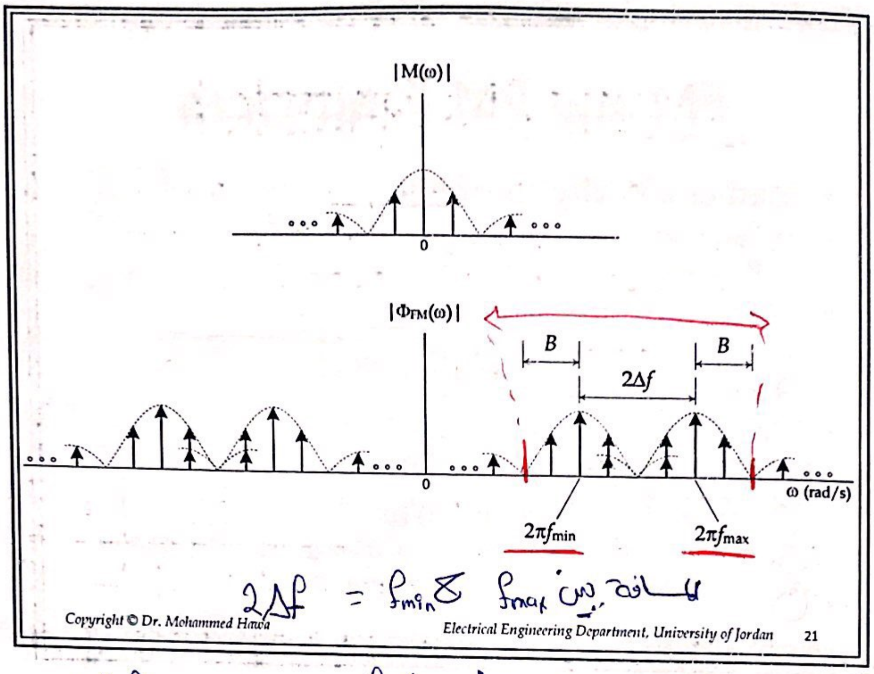






$\varphi_{FM}(t) = x(t) + y(t)$

$|\varphi_{FM}(\omega)| = X(\omega) + Y(\omega)$



$2\Delta f = f_{min}$ & f_{max} المسافة بين

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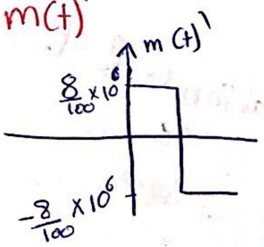
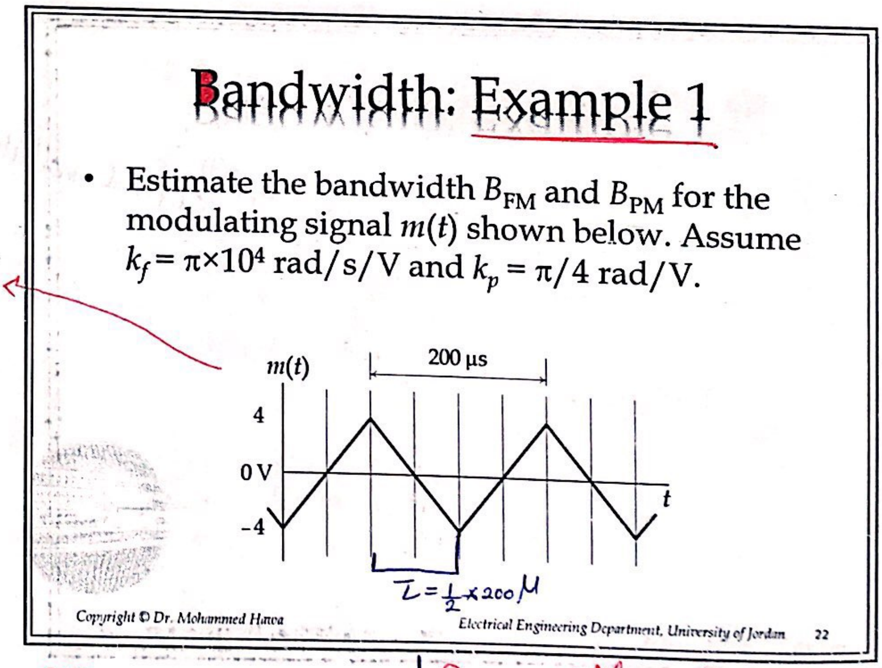
$2\Delta f + 2B$ = first nulls الكلي المسافة بين





Bandwidth: Example 1

- Estimate the bandwidth B_{FM} and B_{PM} for the modulating signal $m(t)$ shown below. Assume $k_f = \pi\times10^4$ rad/s/V and $k_p = \pi/4$ rad/V.

$\tau = \frac{1}{2} \times 200\mu$

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sol

$B_{FM} = 2\Delta f + 2B$

$\Delta f = \frac{K_f}{4\pi} m(t)_{p-p} = \frac{\pi \times 10^4}{4\pi} 8 = 20KHz$

$B_{m(t)} = \frac{1}{\tau} = \frac{1}{100\mu} = 10KH$

$\therefore B_{FM} = 60KHz$

$B_{PM} = 2\Delta f + 2B$

$\Delta f = \frac{K_P}{4\pi} m'(t)_{p-p} = 10 KHz$

$B_{PM} = 40KHz$

sol ① $B_{FM} = 2\Delta f + 2B$

$\Delta f = \frac{K_f}{4\pi} m(t)_{pp} = 100\,KHz$

$B = \frac{1}{\tau} = 10\,KHz$

$B\omega_{FM} = 220\,KHz$

$B_{PM} = \cancel{2\Delta f} + 2B = 20\,KHz$

Zero

const مشتقة

Zero.

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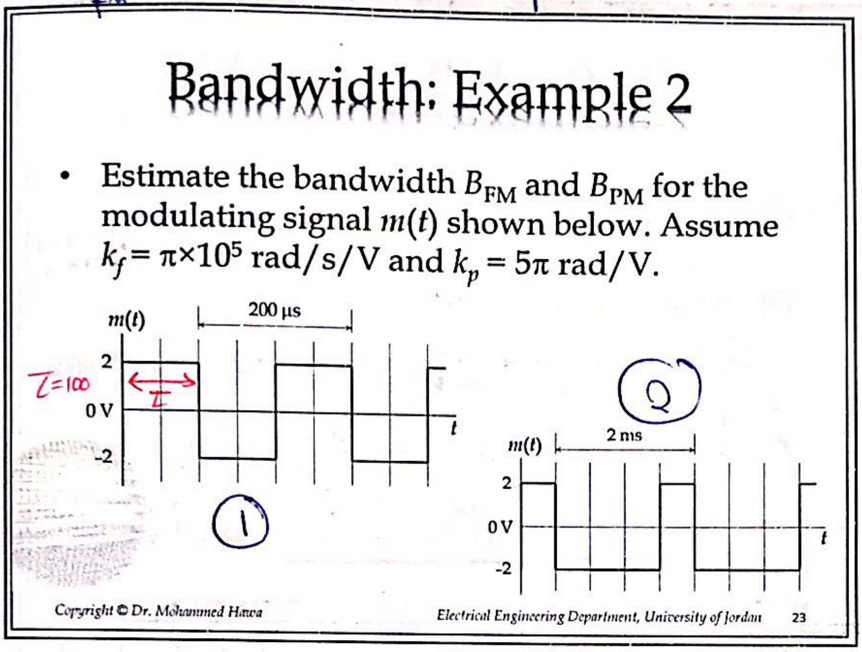

Bandwidth: Example 2

- Estimate the bandwidth B_{FM} and B_{PM} for the modulating signal $m(t)$ shown below. Assume $k_f = \pi\times10^5$ rad/s/V and $k_p = 5\pi$ rad/V.

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FM Signal-to-Noise Ratio

$$SNR_{out} = \left(\frac{3\beta^2}{k_m^2}\right)\frac{S_{in}}{N_0 B}$$

$\beta = 2\Delta f + 2B = 2B(\beta+1)$

$$S_{in} = \overline{\varphi^2(t)} = \frac{A^2}{2}$$

$$k_m^2 = \frac{m_p^2}{\overline{m^2(t)}}$$

↓ Krest factor

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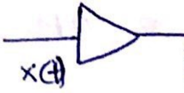
β ↑ ⇒ SNR ↑ ⇒ Quality ↑ (adv.)

⇒ B.w ↑ (disadv.)



$y(t) = a_0 + a_1 x(t) + a_2 x(t)^2 \cdots$ (non linear)

if $x(t) = A\cos(\omega_c t + \psi(t)) \longrightarrow$ FM or PM

then $y(t) = C_0 + \underbrace{C_1 \cos(\omega_c t + \psi(t))} + C_2 \cos(2\omega_c t + \psi\, 2t) \cdots$

using BPF we can get it

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FM مقارنة مع AM

FM (and PM) vs. AM

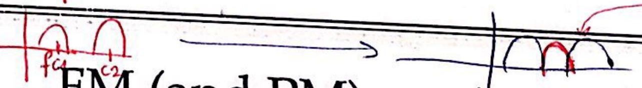
- FM (and PM) Advantages:
  - The constant amplitude of FM makes it less susceptible to nonlinearities. رح يصير فيها distor. اما ال AM signal
  - The constant amplitude of FM gives it a kind of immunity against rapid fading (even with the larger bandwidth). توصل السيجنال من اكثر من مكان وتتجمع
  - Due to the constant amplitude, FM is less vulnerable than AM to adjacent-channel interference.
  - FM is capable of exchanging SNR for bandwidth.

* fading: ↳ variation in freq.

$BW_{PM} = 2B(1+\beta)$ ← بقدر العب ب β

$BW_{AM} = 2B$ (DSB-SC)

$x(t) = \cos\omega_{c2}t$, $\cos\omega_c t$ → non linear channel → $y(t) = x^2(t) = \frac{1}{2} + \frac{1}{2}\cos(2\omega_c t)$



FM (and PM) vs. AM

- FM (and PM) Disadvantages:
  - WBFM (which provides better quality) requires large transmission bandwidth.
  - FM modulators and demodulators are relatively more expensive that AM hardware.
  - PM demodulation requires synchronous detection (relatively expensive).

@ Rx

PLL

wide band FM $\beta \gg 1$

عشان هيك بتجنب PM

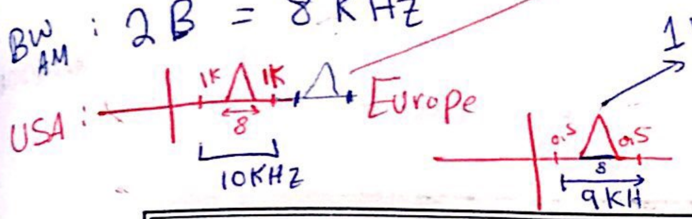
يستخدم بال binary transmission

AN radio:-

m(t): voice signal (4KHz)

BW_{AM} : 2B = 8 KHz

المسافة بين channel = 2K



FM radio :-

m(t) = voice + music (BW = 15K)

$BW_{FM} = 2B(1+\beta) = 180$ KHz

5 Standard

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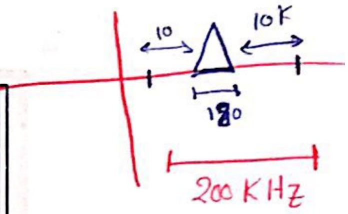
Europe & USA & same



Applications: FM Radio

- FM + FDM
  - The baseband message is 15 kHz
  - With β = 5, the bandwidth of each station is 200 kHz (both U.S. and Europe).
  - The broadcast range is 88 – 108 MHz.
- FM radio sounds better than AM radio:
  - m(t) has a larger bandwidth.
  - WBFM: exchanging SNR for bandwidth.
  - Pre-emphasis/De-emphasis improves SNR.
  - Stereo FM.

المسافة بين Channel, 20 KHz

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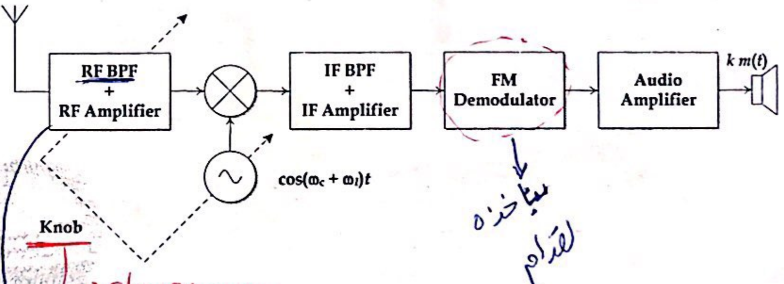
FM Superhetrodyne Receiver

- IF frequency = 10.7 MHz FM ثابتة in AM = 455K
- L.O. frequency = 88 + 10.7 MH to 108 + 10.7 MHz

فكرته بيسوي down converter من 100k [illegible] لـ 10.7



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not sharp filter (cheap)

AM: 535 KHz ⟶ 1700 KHz

FM: 88 MHz ⟶ 108 MHz →

$\boxed{50}$ $\lambda_{FM} < \lambda_{AM}$

$L_{eng.\,FM} < L_{AM}$

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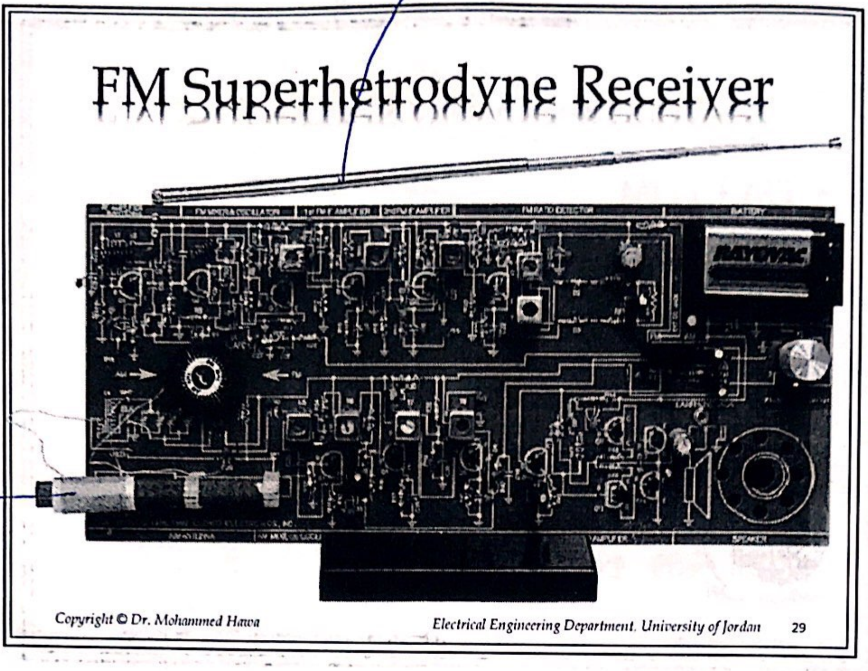
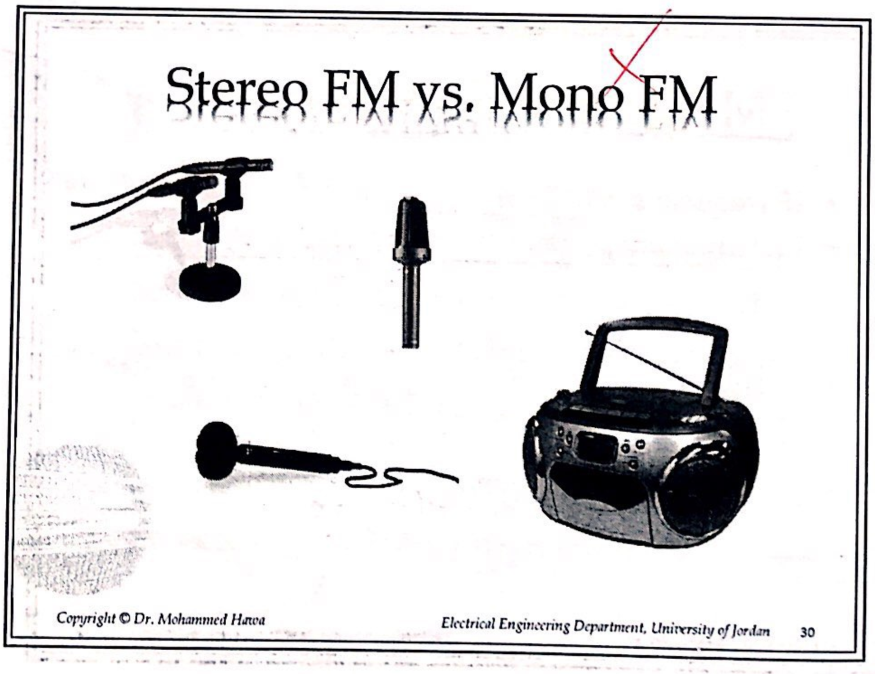
Antenna 1 FM



FM Superhetrodyne Receiver

Antenna 2

AM



Stereo FM vs. Mono FM

Lecture 16: FM Modulators and Demodulators

→ hardware

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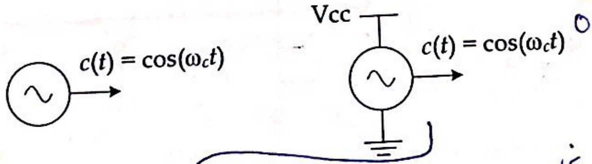
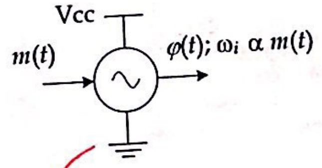
FM Modulator: $\boxed{\text{VCO}}$

↳ Voltage controlled oscilator

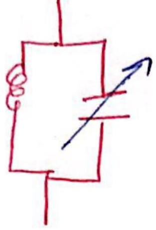


old oscilator → fixed ωi ← كانو يعطوني



بطلع سيجنال ال ωi
الها
↳ related مع m(t)

LC tank:-



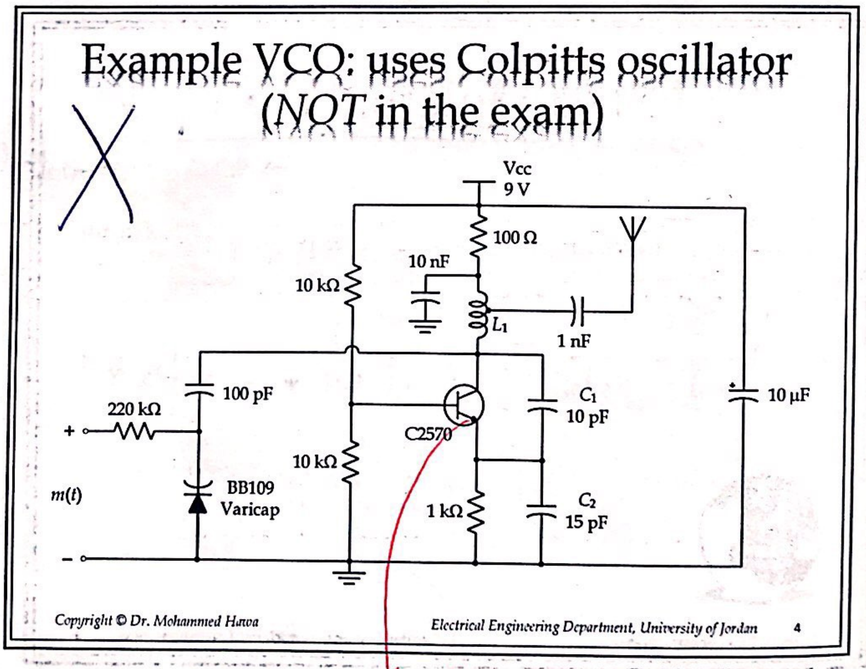
$$\Rightarrow \omega_{res} = \frac{1}{\sqrt{LC}}$$

Oscillator

- To build an oscillator, we require three components:
  - Amplifier
  - Positive feedback
  - LC tank
- The frequency of the oscillator is controlled by the LC tank resonant circuit.
- Many implementations available: Colpitts oscillator, Hartley oscillator, Ring oscillator, etc.

مكون

مسؤول عن ال freq. of oscillator



Example VCO: uses Colpitts oscillator (*NOT* in the exam)

amplifier

*Varicap → Variable capacitor or Varactor

FM Demodulators 3types

- FM Discriminator (also called Slope Detector or Ratio Detector): → Cheapest
  - Convert frequency variations into amplitude variations, then use an envelope detector. ω_f
- Quadrature Detector: expensive but more suitable
  - Convert frequency variations into phase variations, then use a phase-difference detector. → LPF + mixer $\Delta\theta$
- Phase-Locked Loop: expensive but suitable in IC's
  - A phase-difference feedback system. ↳ LPF + mixer

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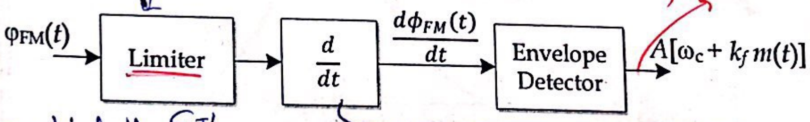
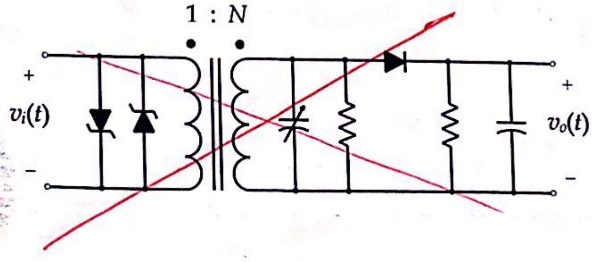
$$\phi_{FM}(t) = \underline{A}\cos\left(\omega_c t + k_f\int_{-\infty}^{t} m(t).dt\right)$$

FM Discriminator



ع شكل [illegible]

بثبت ال amplitude



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$$\frac{d\phi_{FM}(t)}{dt} = -A[\omega_c + k_f m(t)] * \sin\left(\omega_c t + \int_{-\infty}^{t} m(t).dt\right)$$

$$= A[\omega_c + k_f m(t)] * \sin\left(\omega_c t + \int_{-\infty}^{t} m(t).dt\right)$$

envelop

↓

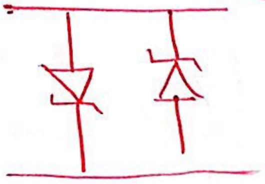
ED

↓

$A\omega_c + A k_f m(t) \rightarrow$ ⊣⊢ $\rightarrow A k_f m(t)$

*Limiter → to make A constant @ Rx

→ 2 Zenor diode



Scanned with CamScanner

٣* Application of LC tank:

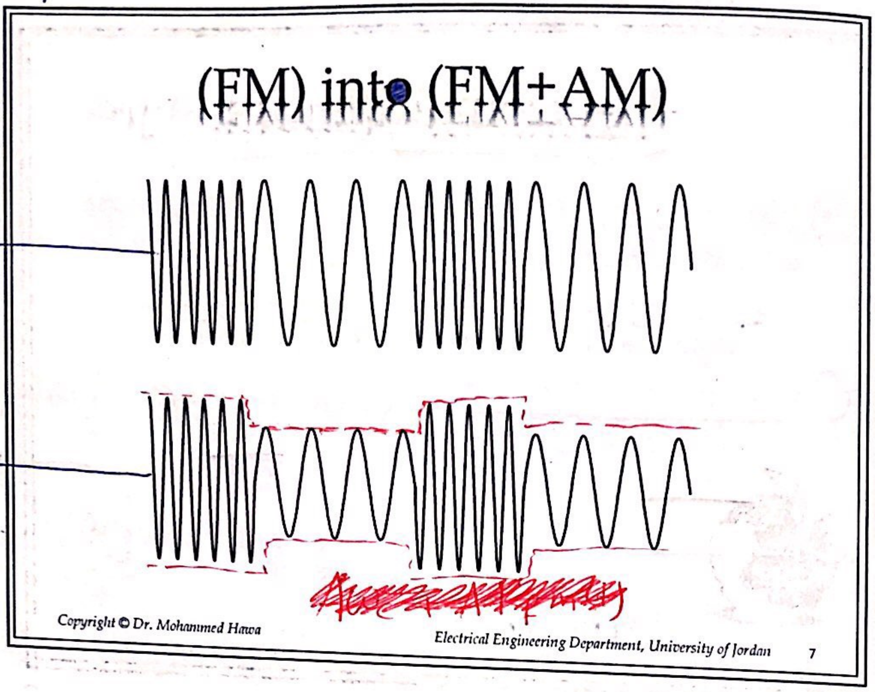
4/10/2017

1- inside oscillator or VCO to control freq.

2- BPF

3- diffrentiator $\left(\frac{d}{dt}\right)$ → discriminator

4- converts freq. variation into phase variation → quadratic



(FM) into (FM+AM)

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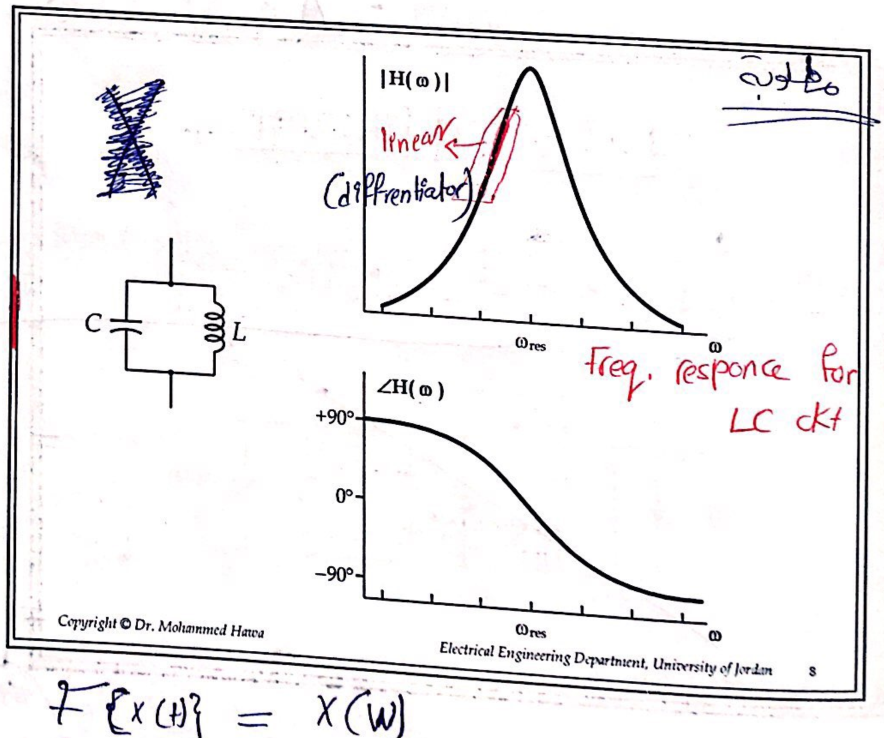
السجنال الاصلية FM

بعد ما استقبلت ودخلتها.

~~envelop~~ ~~detector~~

صارت FM و AM



مطلوب

Freq. responce for LC ckt

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diffrentiator

$$\mathcal{F}\{x(t)\} = X(\omega)$$

$$|H(\omega)| = \left|\mathcal{F}\left\{\frac{d\,x(t)}{dt}\right\}\right| = |j\omega\, X(\omega)|$$

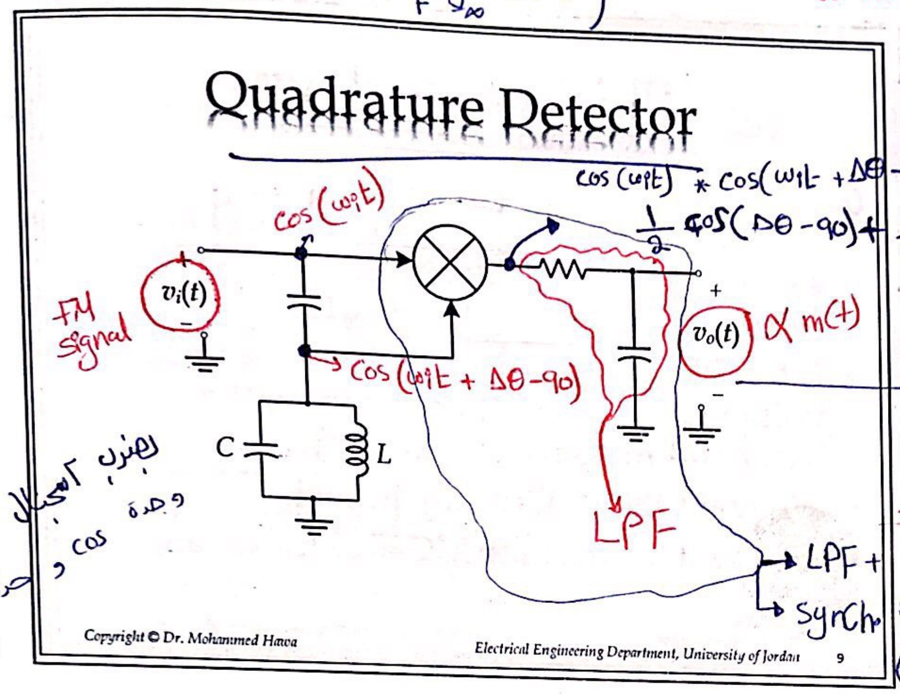
$$|Y(\omega)| = |\omega\, X(\omega)|$$

$$\frac{|Y(\omega)|}{|X(\omega)|} = \omega$$

احتمالاً رح نهملها wi

$$A\cos\left(\underbrace{\omega_c t + K_f\int_{\infty}^{t} m(t)\cdot dt}\right)$$

$\omega i \propto \Delta\theta \propto m(t)$



Quadrature Detector

$\cos(\omega_i t) * \cos(\omega_i t + \Delta\theta - 90) =$

$\frac{1}{2}\cos(\Delta\theta - 90) + \cancel{\frac{1}{2}\cos(\omega_i t + \Delta\theta - 90)} \rightarrow$ LPF

$\rightarrow \frac{1}{2}\sin(\Delta\theta)$

$\approx \frac{1}{2}\Delta(\theta)$

*small $x \rightarrow \sin x = x$

→ LPF + mixer

→ Synch. Rx (phase differance detector)

بضرب امجال وحدة cos و حدة بسويلها shift

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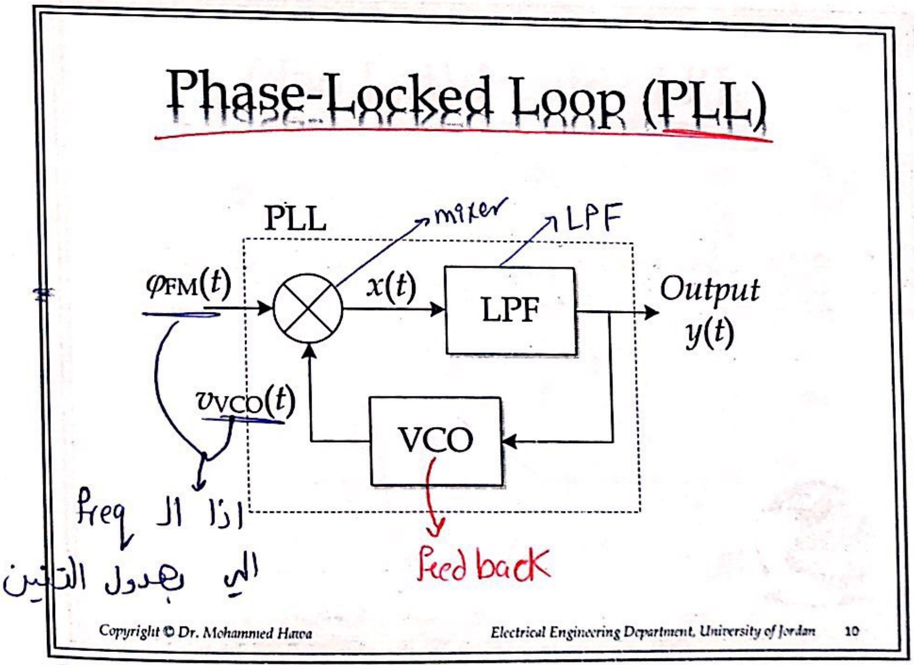

Phase-Locked Loop (PLL)

اذا ال freq الي بجدول التنين

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متساوي بتكون In-LOCK

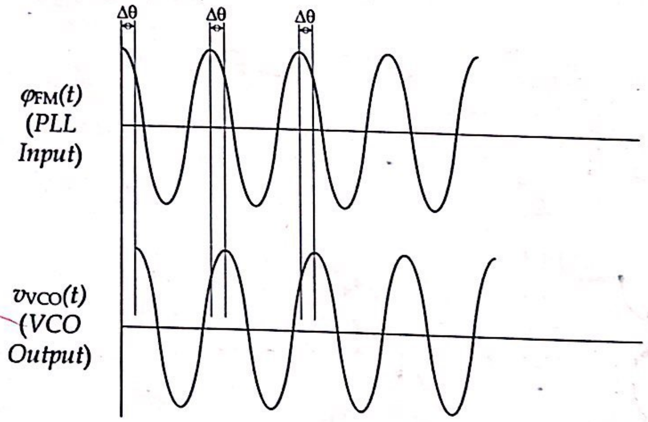
وبكون ال output الها relation مع m(t)

ال feed back بضل يعدل لحتى تساوي ال freq.

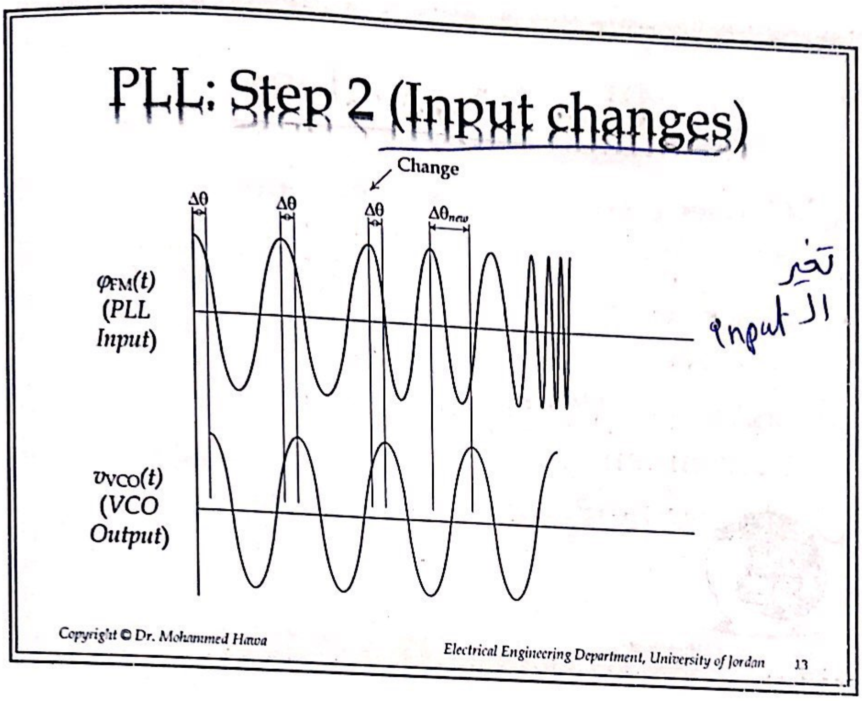
PLL Terminology

- A PLL is said to be **in-lock** if the frequency of the inner VCO $v_{VCO}(t)$ is exactly the *same* as the frequency of the received signal $v_{in}(t) = \varphi_{FM}(t)$.
- If the PLL stays in-lock, then the output voltage $v_{out}(t)$ is proportional to the baseband message signal $m(t)$.
- We want the PLL to stay in-lock.
- See the datasheet for MC4046 for details.

PLL: Step 1 (In Lock)



بنحاول نخليهم
متساويين
بال
freq.



PLL: Step 2 (Input changes)

تغير ال Input

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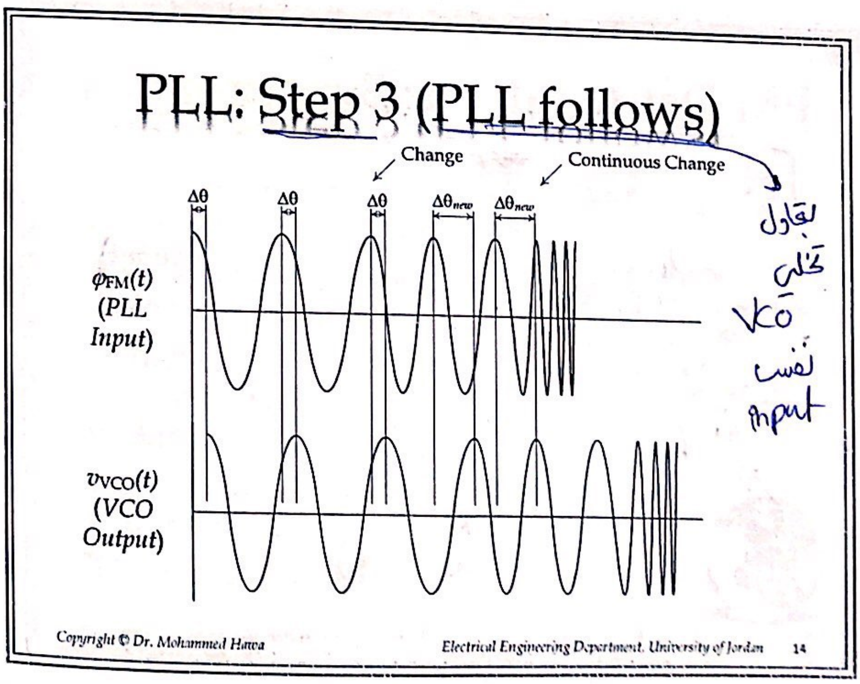

PLL: Step 3 (PLL follows)

بتحاول تخلي VCO نفس input

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مهم

PLL Applications

- Carrier recovery for Synchronous detectors.
- Clock recovery for digital baseband receivers.
- Stabilizing VCO frequencies in FM transmitters.
- FM Demodulator.

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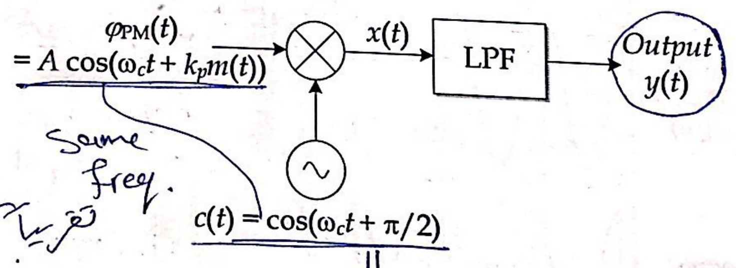
PM Demodulator: Synchronous

تختلف عن FM



same freq.

تقريبا

$c(t) = \cos(\omega_c t + \pi/2)$

$\Downarrow$

$\sin(\omega_c t)$

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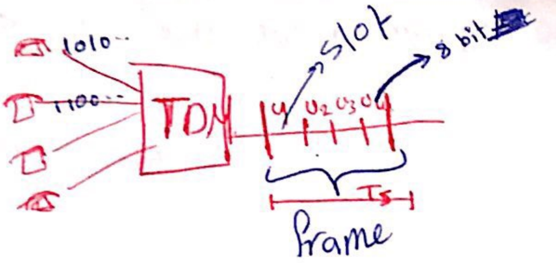
$$x(t) = \frac{A}{2}\left[\cos\left(k_p m(t) + \frac{\pi}{2}\right) + \cos\underbrace{\left(2\omega_c t + k_p m(t) + \frac{\pi}{2}\right)}_{\text{reject by LPF}}\right]$$

$$y(t) = \frac{A}{2}\cos\left(k_p m(t) + \frac{\pi}{2}\right)$$

$$= -\frac{A}{2}\sin\left(k_p m(t)\right)$$

$$\simeq -\frac{A}{2} k_p m(t)$$

Scanned with CamScanner



T_1 = 24 user US

E_1 = 30 user Europe

4/10/2017

TDM → used in digital system

FMD → " " " & Analog "

Lecture 17: Time Division Multiplexing and Telephony

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University of Jordan

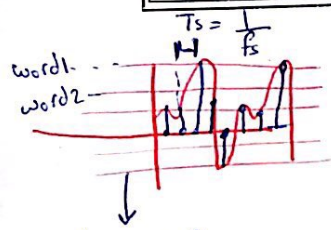
EE421: Communications I. For more information read Chapter 6 in your textbook or visit http://wikipedia.org/.

Multiplexing: TDM

- Time Division Multiplexing (**TDM**) is a process that allows the transmission of several signals over the same baseband channel.
- Achieved by interleaving the bits of the different signals using different **time instants**.
- The receiver isolates one signal from the rest using a **time demultiplexer**.
- TDM is ***not*** limited to PCM or telephony.

يستخدمها
بأشياء ثانية

PCM → pulse code modulation



bw = 2 fm

$2^8 = 256$

A/D
(PCM) →
1. sampling
2. quantization → level كل
ال كود
3. coding

⊛ $f_s \geq 2 f_m$ ← 4 KHz

∴ f_s = 8000 sample/sec

$T_f = T_s$ = 125 μsec

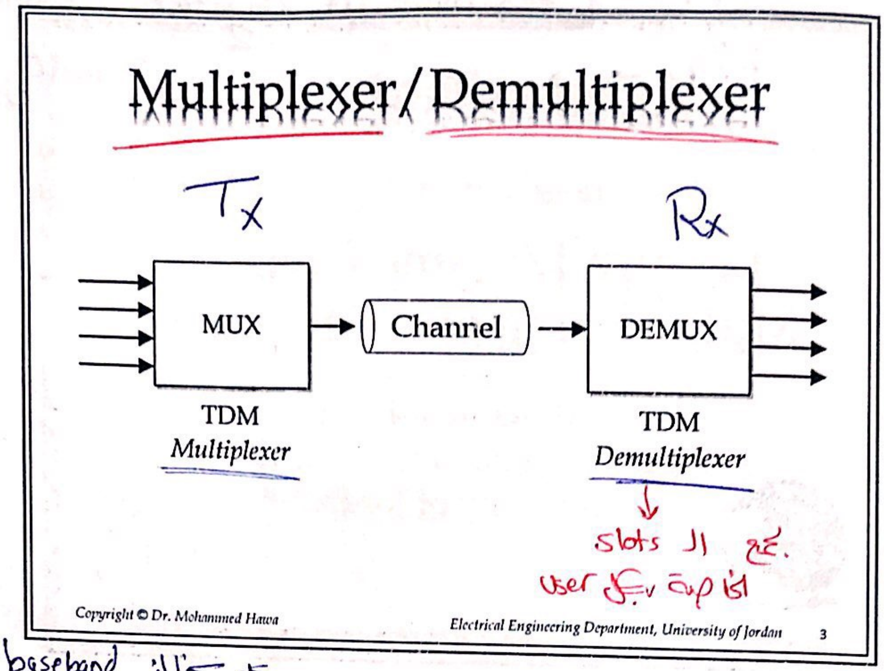
⊛ bit rate (f_o) =
8 * 8000 bit/sec = 64 kbps
≡ bw of digital telephon signal

* In telephone system → we use bipolar line code

↓

b.w = bit rate = f_o

4/10/20



Multiplexer/Demultiplexer

Tx

Rx

MUX → Channel → DEMUX

TDM
Multiplexer

TDM
Demultiplexer

↓

جمع ال slots.

اذا فية بجيب user

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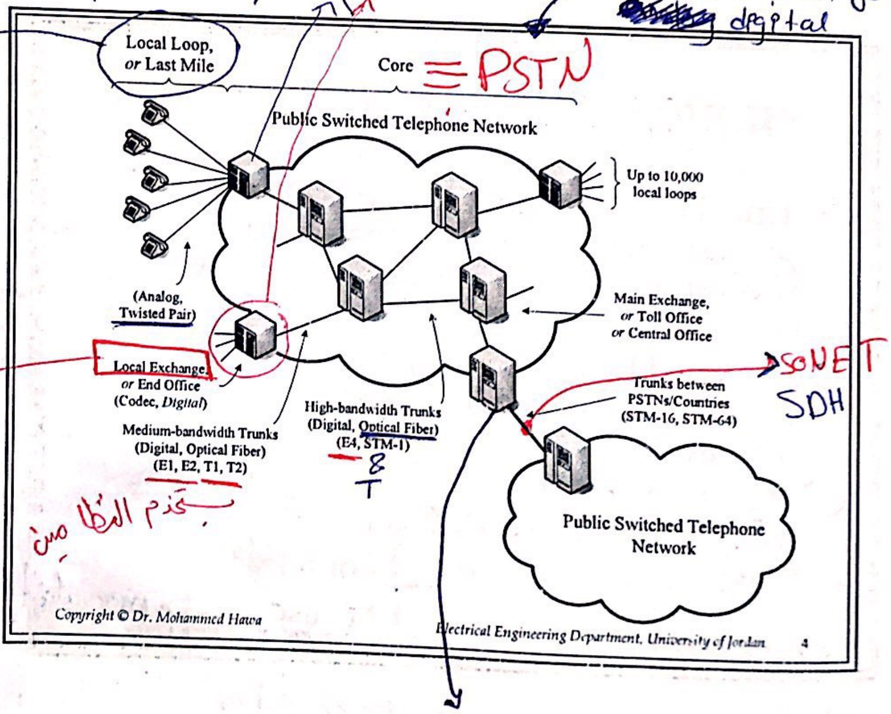
كل سجنالز baseband analog

مقسم

كل السيغنال baseband digital



Local Loop, *or* Last Mile

Core = PSTN

Public Switched Telephone Network

Up to 10,000 local loops

(Analog, Twisted Pair)

Local Exchange, *or* End Office (Codec, *Digital*)

Main Exchange, *or* Toll Office *or* Central Office

Medium-bandwidth Trunks (Digital, Optical Fiber) (E1, E2, T1, T2)

High-bandwidth Trunks (Digital, Optical Fiber) (E4, STM-1)

Trunks between PSTNs/Countries (STM-16, STM-64)

Public Switched Telephone Network

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connection بين ال user مع أول مقسم

المقاسم الي بتشبك مع ال user

بتخدم الخطا مين

E

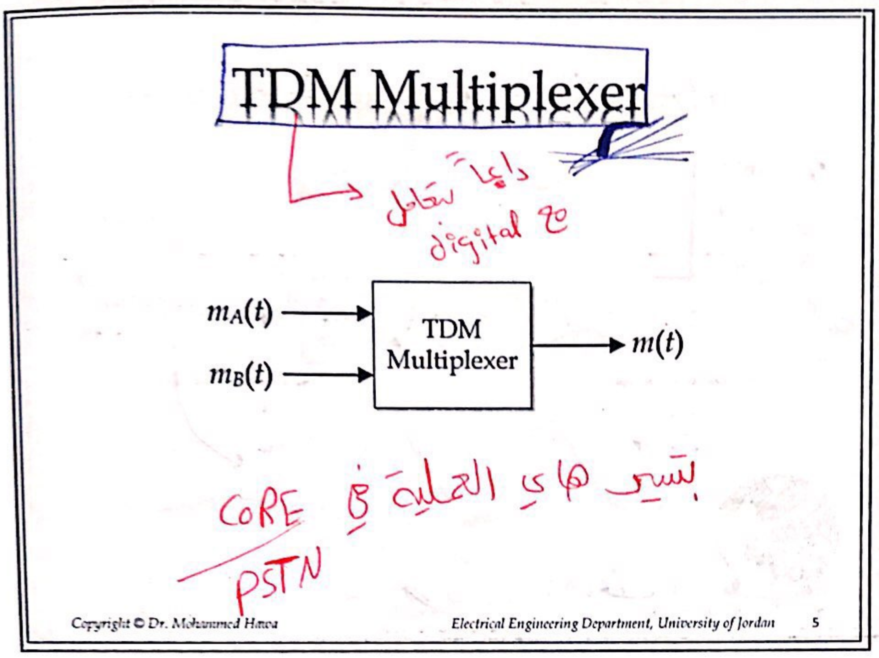
T

SONET
SDH

بشبك مع PSTN ثانية

T_1 rate = 8 * 8000 = 64 Kbps * 24 = $\boxed{}$

user



TDM Multiplexer

دايماً بتعامل مع digital

بتصير هاي العملية في CORE PSTN

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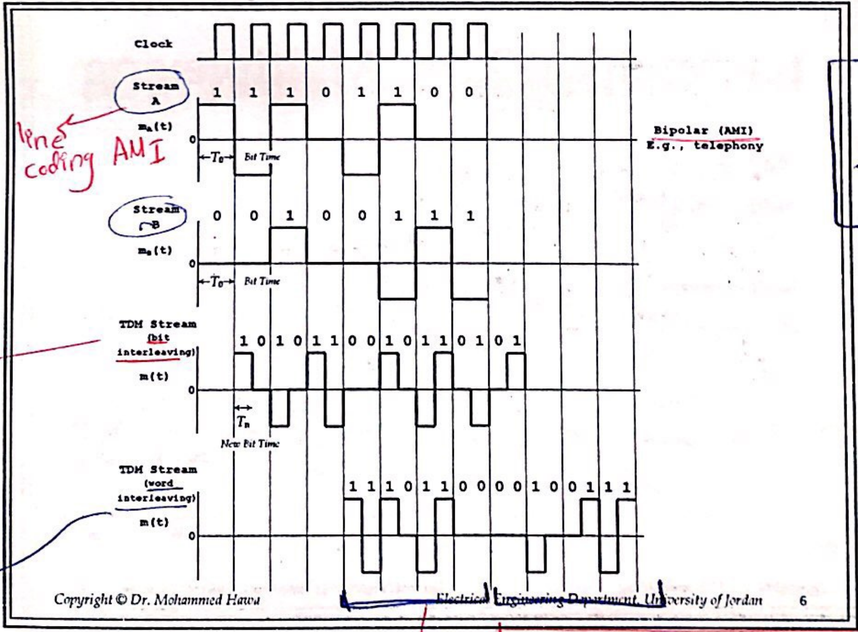

line coding AMI

بياخذ بت بت من كل يوزر

بياخذ word من كل user

8 bit من كل user بالتناوب

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$T_n = \frac{1}{2} T_0$ (2 users)

$T_n = \frac{1}{4} T_0$ (4 users)

In telephone sys.

$T_0 = \frac{1}{64000}$ sec

$= \frac{1}{f_0} \rightarrow 64000$

Ex: in T_1 sys., number of users = 24 user

$T_n = \frac{1}{24} * \frac{1}{64000}$ sec

$f_0 = 24 * 64$ Kbps

≈ 1.5 Mbps

* هل شرط اذا استخدمنا في A bipolar وفي B machester

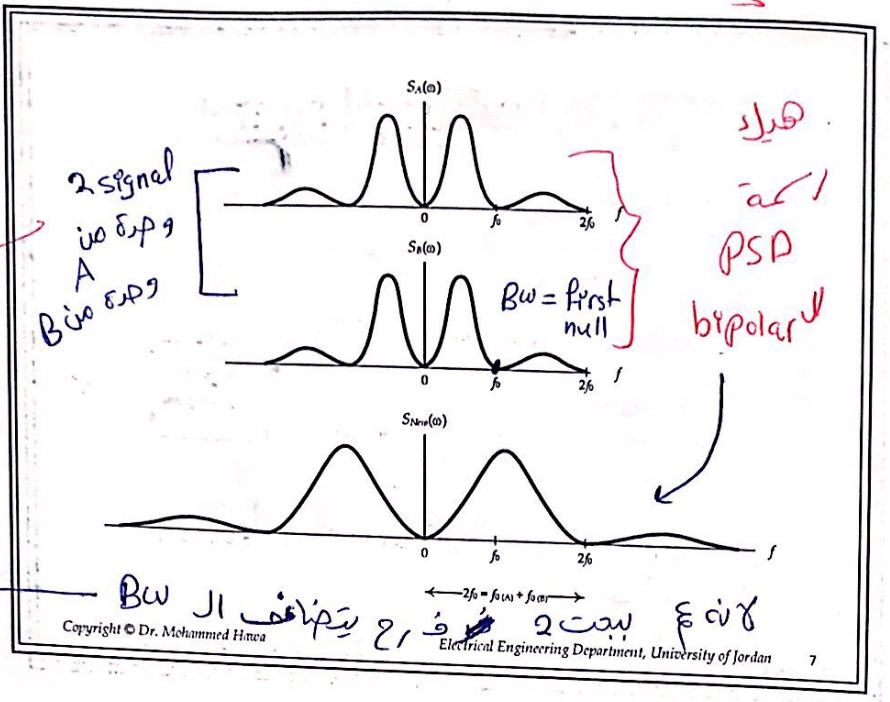
وفي m(t) ← unipolar ؟؟

مثال

اي line code

ليس بشرط

4/10



2 signal واحدة من A وواحدة من B

الشي ← bipolar AMI

هيك اشكال PSD لل bipolar

Bw = first null

لانه ع بجمع 2 ف ، 2 يتضاعف ال Bw ← $f_o(A) + f_o(B)$

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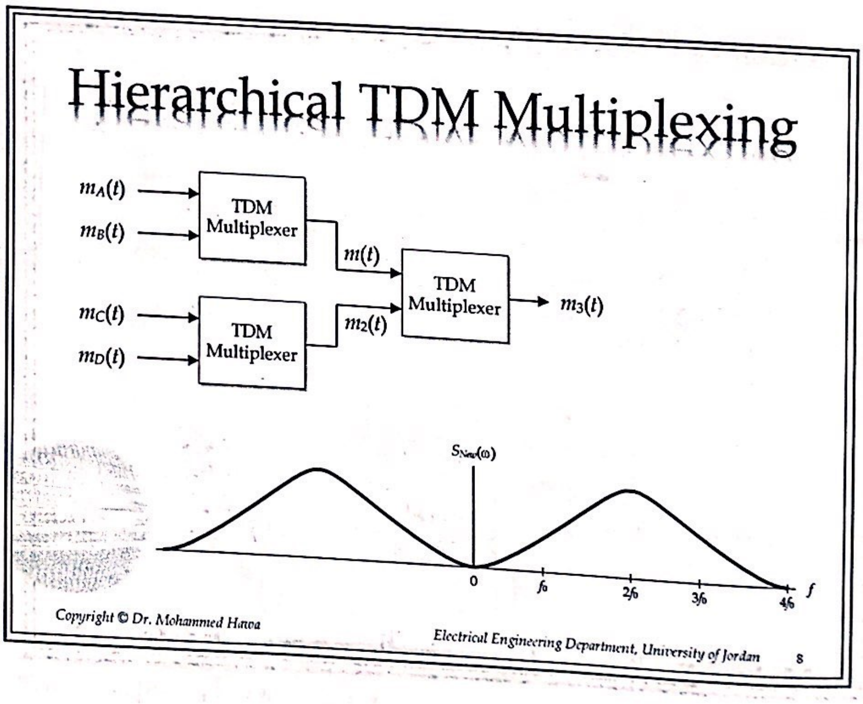
Hierarchical TDM Multiplexing



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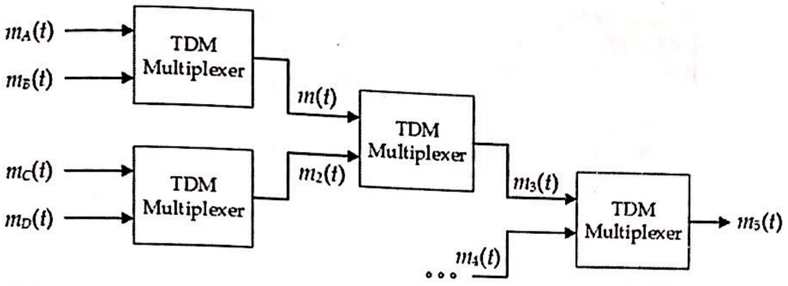
(*) Check paper

Any number of steps!



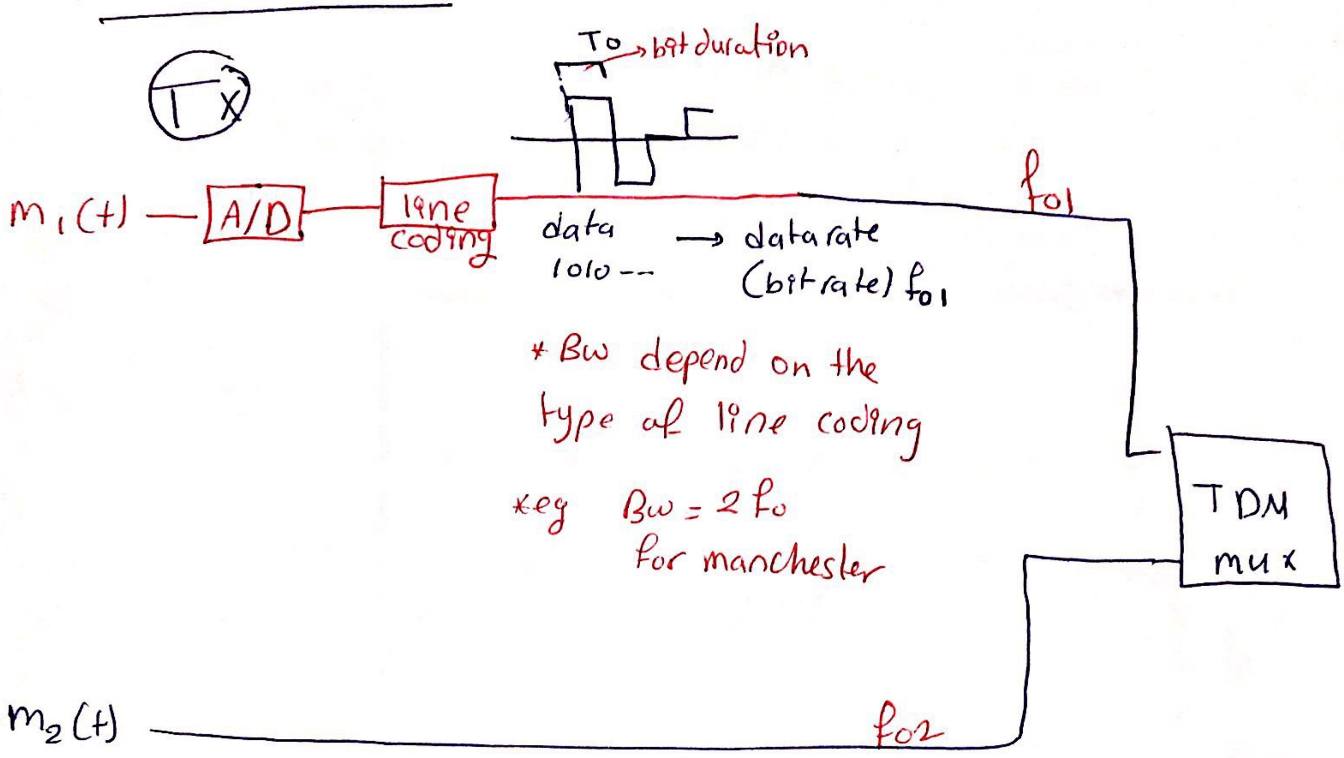
- *Homework*: Show the hardware blocks at the receiver side (Aqaba).

TDM Hierarchy Standard (Tel.)

	U.S. Standard	*European Standard*
Low bit-rate PDH: Plesiochronous Digital Hierarchy	***T1***	***E1***
High bit-rate SDH: Synchronous Digital Hierarchy	***SONET*** (Synchronous Optical Network)	***SDH*** (Synchronous Digital Hierarchy)

TDM Lec 17 slide 9

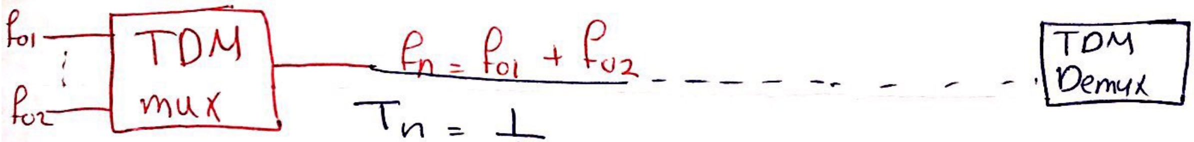
Tx



data → data rate
1010 - - (bit rate) f_{o1}

* Bw depend on the type of line coding

*eg $Bw = 2 f_o$ for manchester

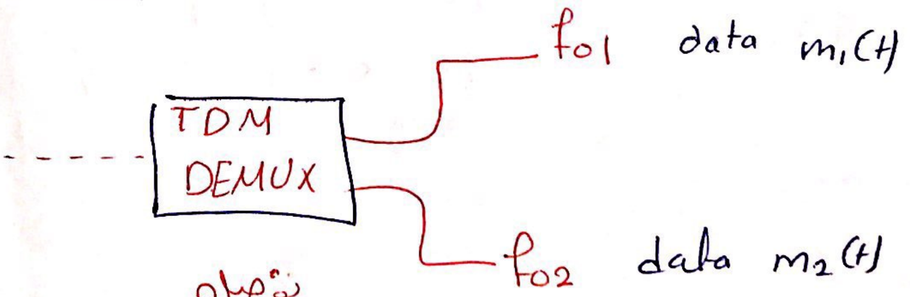


$f_n = f_{o1} + f_{o2}$

$T_n = \frac{1}{f_n}$

Bw depend on line coding

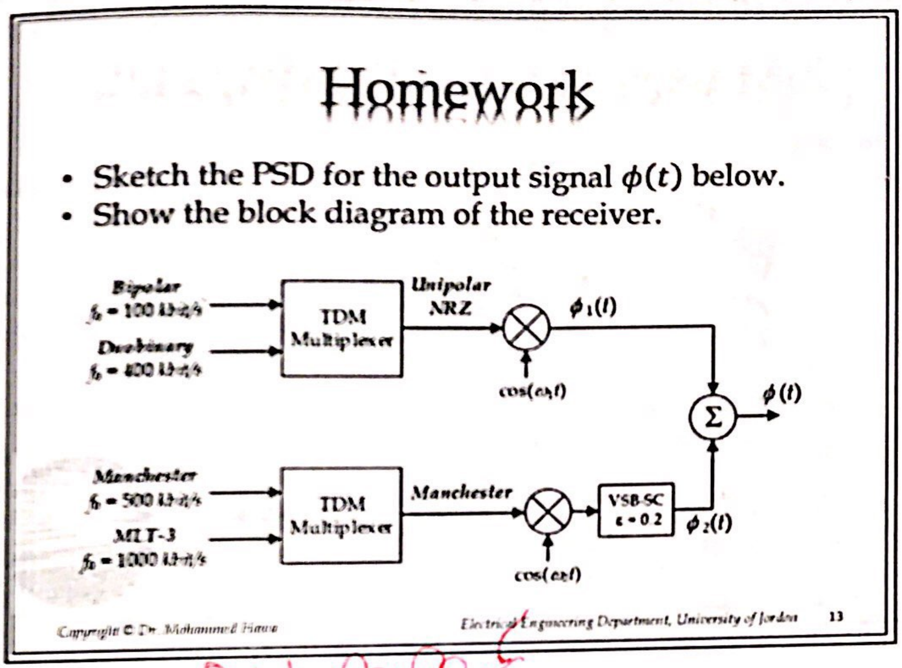
@ Rx



f_{o1} data $m_1(t)$

f_{o2} data $m_2(t)$

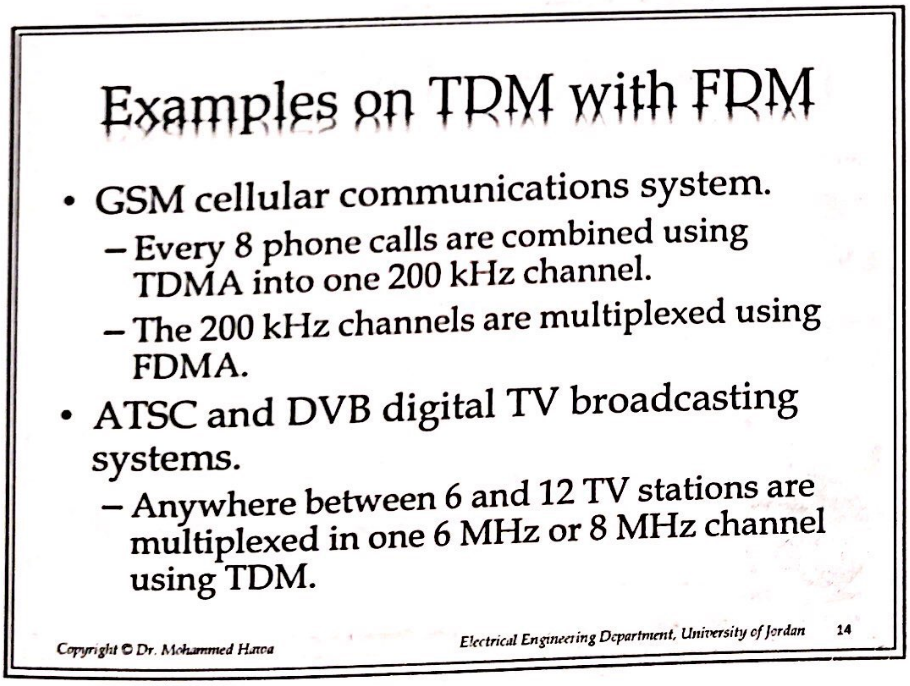
بتطلع



Homework

- Sketch the PSD for the output signal $\phi(t)$ below.
- Show the block diagram of the receiver.

ON Paper

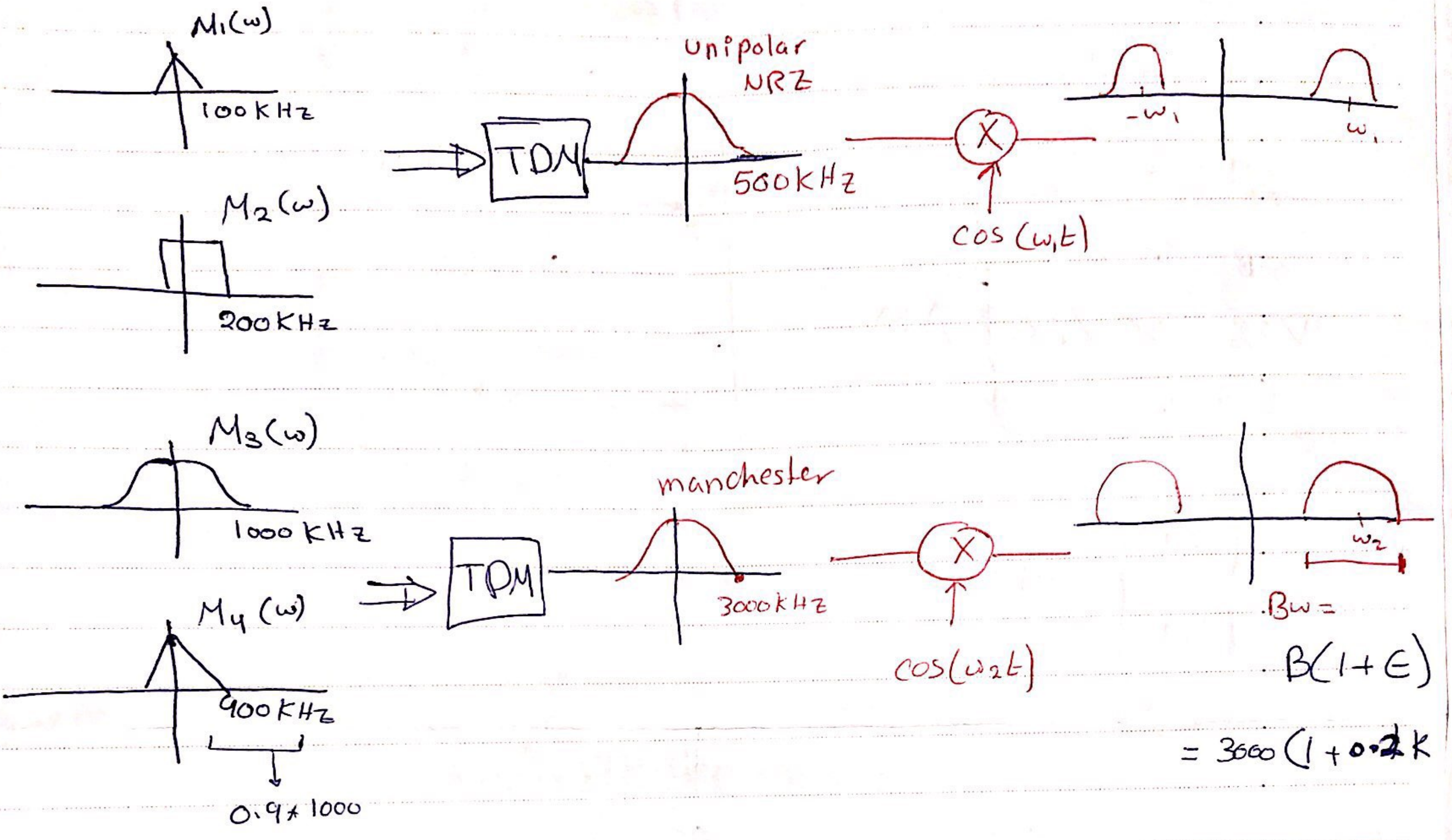


Examples on TDM with FDM

- GSM cellular communications system.
  - Every 8 phone calls are combined using TDMA into one 200 kHz channel.
  - The 200 kHz channels are multiplexed using FDMA.
- ATSC and DVB digital TV broadcasting systems.
  - Anywhere between 6 and 12 TV stations are multiplexed in one 6 MHz or 8 MHz channel using TDM.

/ /

Homework slide 13 Lec 17



Bw =

$B(1+\epsilon)$

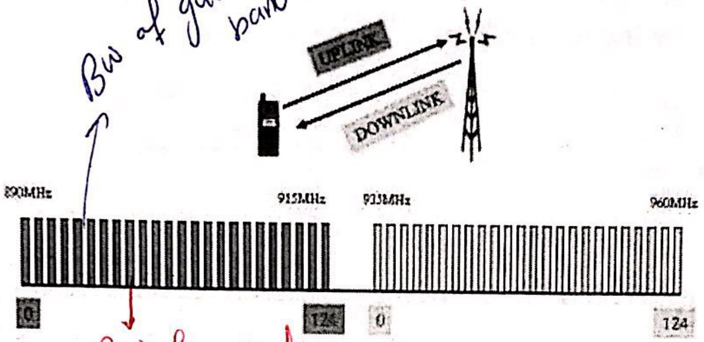
$= 3000(1+0.2)K$

multiple access

كل واحد له
time slot
برسل عليه
دائماً

GSM uses TDMA/FDMA/FDD

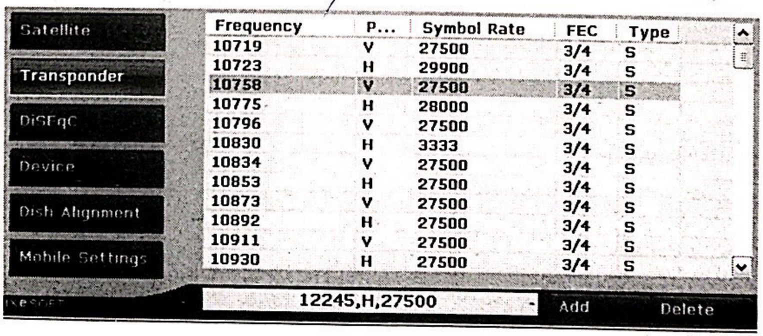
Bw of gaurd band



check it from laptop

Bw for red
200 KH

Homework: Satellite Receiver



Frequency	P...	Symbol Rate	FEC	Type
10719	V	27500	3/4	S
10723	H	29900	3/4	S
10758	V	27500	3/4	S
10775	H	28000	3/4	S
10796	V	27500	3/4	S
10830	H	3333	3/4	S
10834	V	27500	3/4	S
10853	H	27500	3/4	S
10873	V	27500	3/4	S
10892	H	27500	3/4	S
10911	V	27500	3/4	S
10930	H	27500	3/4	S

12245,H,27500

Analog mod	digital mod
DSB-SC/LC SSB-SC/LC VSB-SC/LC	ASK
ΦAM	QAM
FM	FSK
PM	PSK

Lecture 19: Digital Modulation

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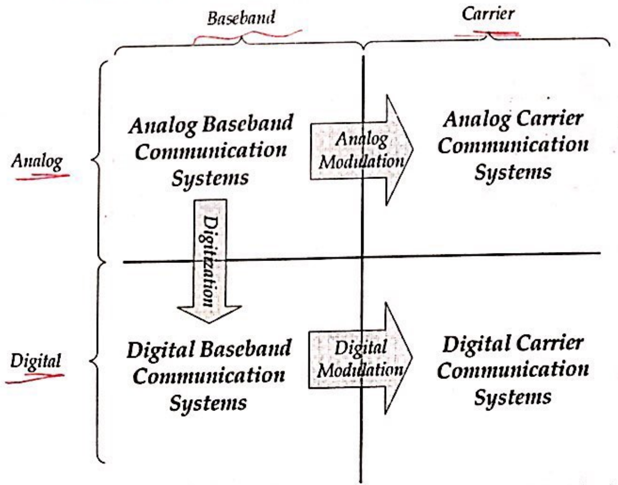
University of Jordan

EE421: Communications I. For more information read Chapters 7 & 10 in your textbook or visit http://wikipedia.org/.

The *Last Piece* of the Puzzle!



Baseband

Carrier

Analog

Analog Baseband Communication Systems

Analog Modulation

Analog Carrier Communication Systems

Digitization

Digital

Digital Baseband Communication Systems

Digital Modulation

Digital Carrier Communication Systems

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* most used PSK, QAM

↳ small BW but synch. PLL

Digital Modulation

- *Four* main modulation techniques:
  - Amplitude-Shift Keying (**ASK**).
  - Frequency-Shift Keying (**FSK**).
  - Phase-Shift Keying (**PSK**).
  - Quadrature Amplitude Modulation (**QAM**).
- PSK and QAM are the most popular nowadays because of their *smaller* bandwidths.
- PSK and QAM require synchronous detection, which is easier nowadays (PLLs).

we use NRZ

we use polar or ~~NRZ~~ Mary

Analog vs. *Digital* Modulation

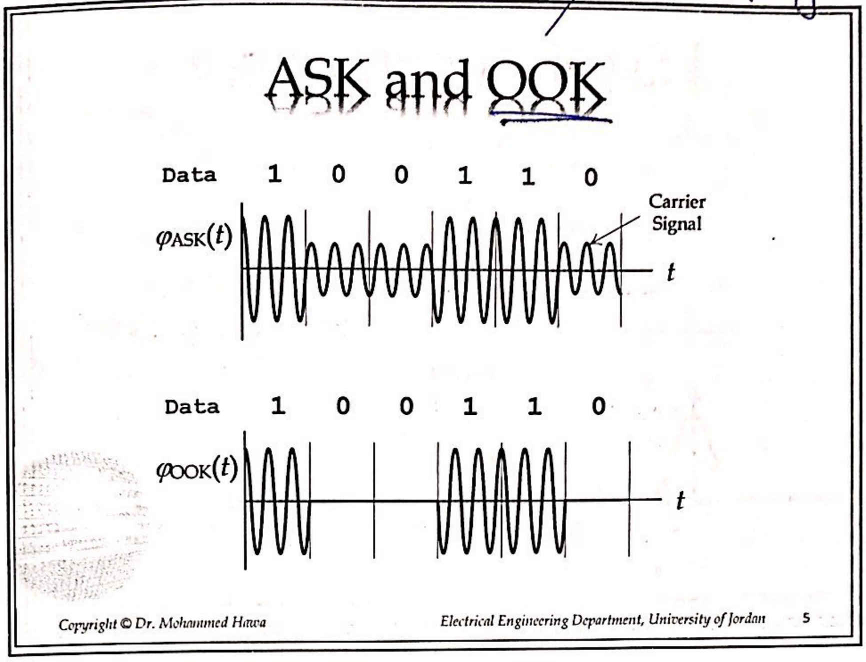
- $m(t)$ *is* Polar NRZ + AM = **ASK**
- $m(t)$ *is* Polar NRZ + FM = **FSK**
- $m(t)$ *is* Polar NRZ + PM = **BPSK**
- $m(t)$ *is* *Q*-ary NRZ + PM = **QPSK**
- $m(t)$ *is* *M*-ary NRZ + PM = **M-PSK**
- $m(t)$ *is* *M*-ary NRZ + QAM = **QAM**
- $m(t)$ *is* *M*-ary NRZ + AM = **M-ASK**

* QAry ≡ Mary

↓ quad.

↳ 4ary

on-off Keying



ASK and OOK

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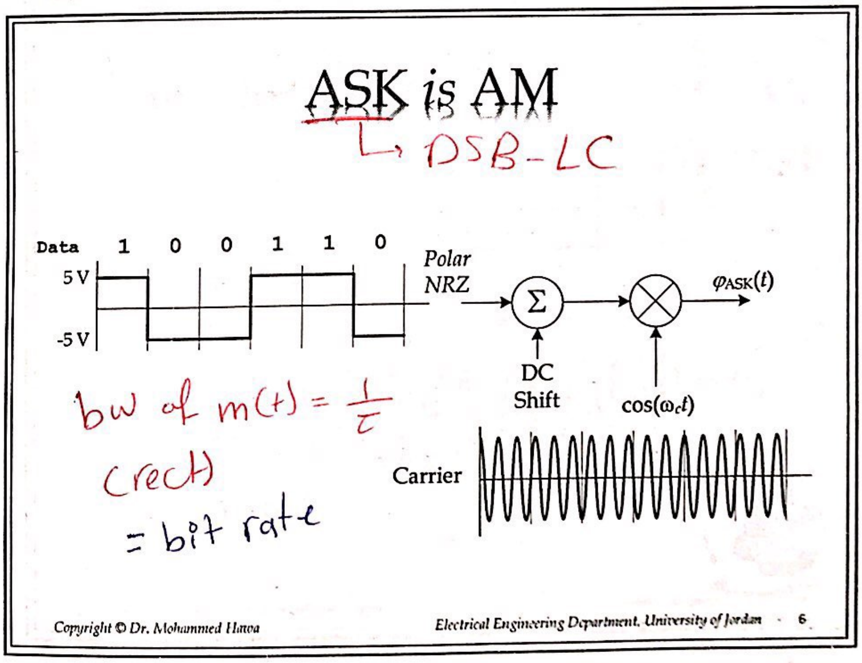

ASK *is* AM

↳ DSB-LC

bw of $m(t) = \frac{1}{\tau}$

(rect)

= bit rate

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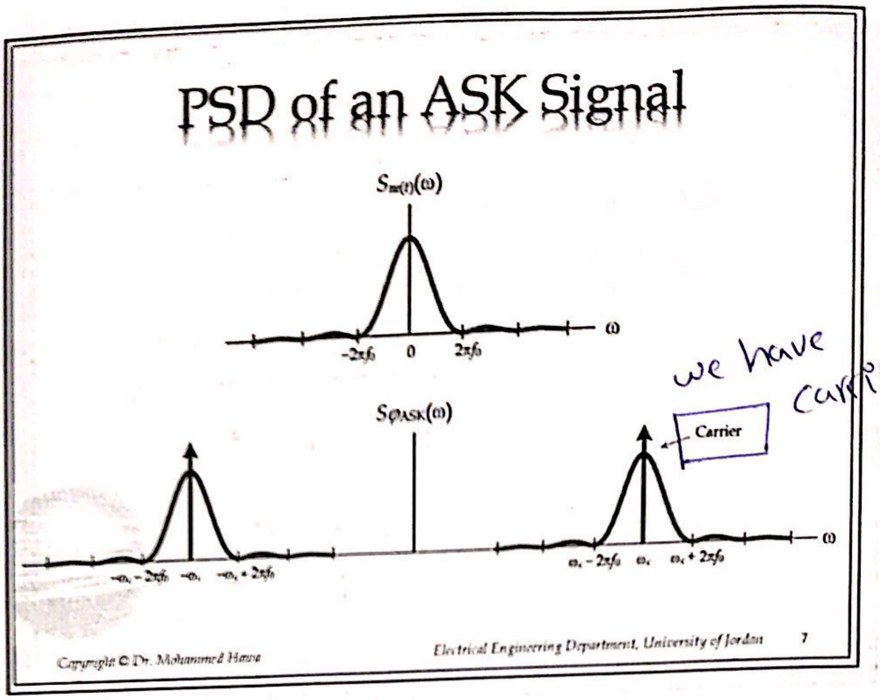

PSD of an ASK Signal

we have carrier from ASK

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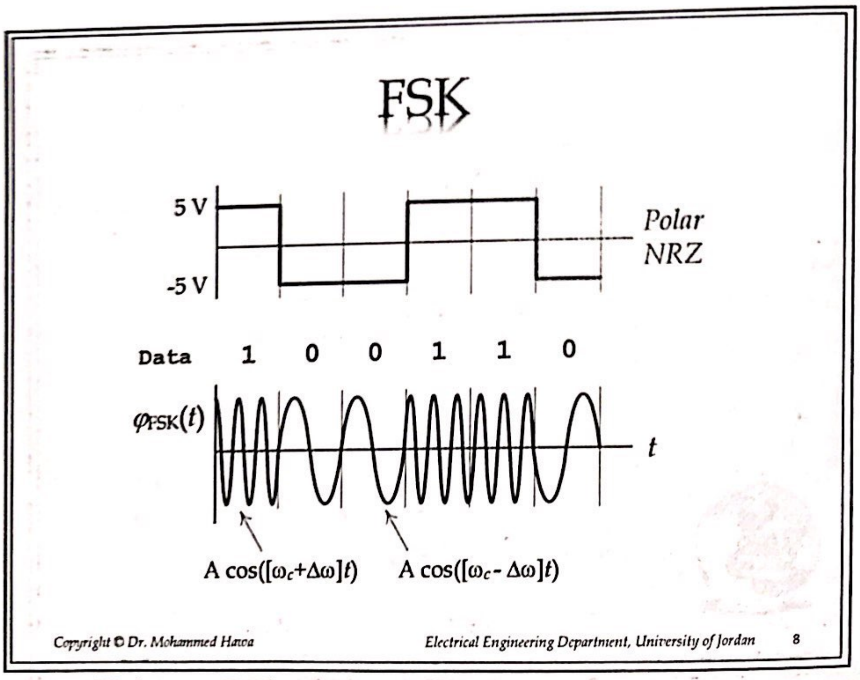
7



FSK

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8

$$B_{FM} = \underbrace{2\Delta f}_{\frac{f_{max} - f_{min}}{2}} + 2\underbrace{B}_{f_0}$$

phase shift

← من ال impulse

لازم يتوزع
phaseshift L
عشان ال Rx
- يحلل السيجنال

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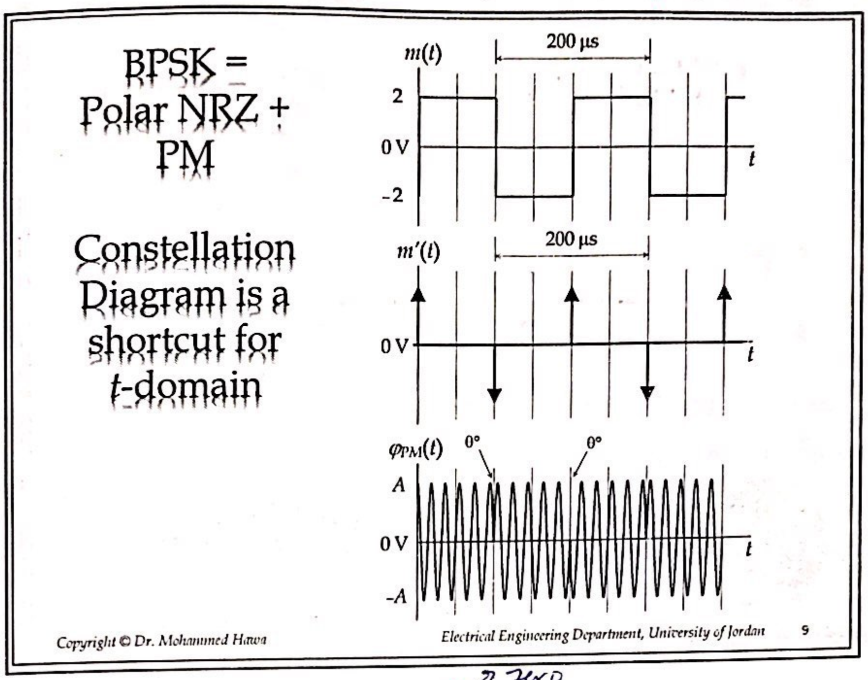

BPSK = Polar NRZ + PM

Constellation Diagram is a shortcut for *t*-domain

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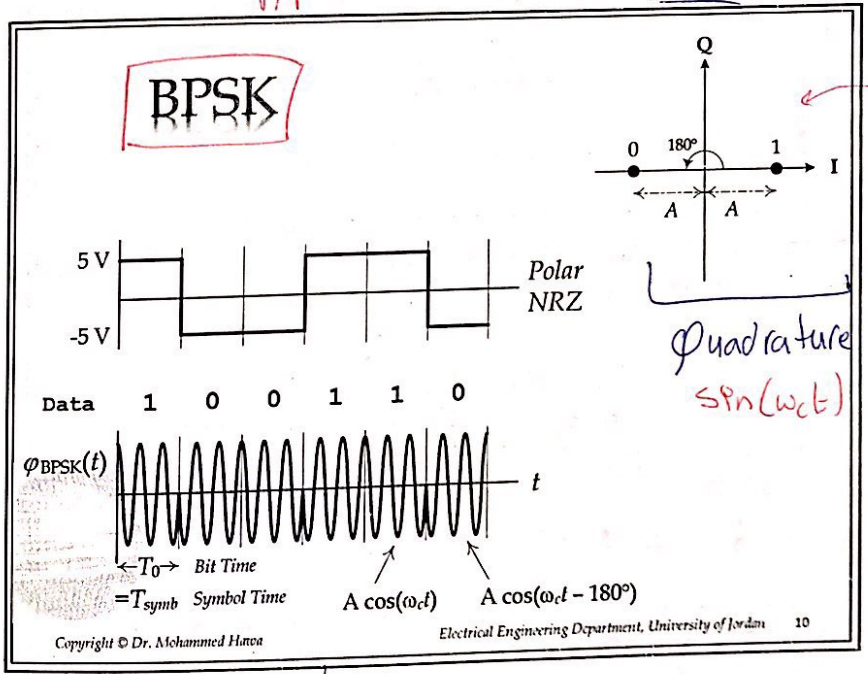
9

$$B_{PM} = 2\overset{\text{zero}}{\cancel{\Delta f}} + 2B = \underline{2B}$$



BPSK

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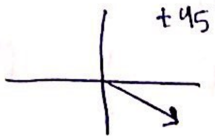
10

ccw

in phase with $\cos(\omega_c t)$

Quadrature $\sin(\omega_c t)$



لأنه A ثابتة فبمشي
عل شكل دائرة

$11 \rightarrow A\cos(\omega_c t - 45)$

$01 \rightarrow A\cos(\omega_c t - 135)$

$10 \rightarrow A\cos(\omega_c t + 45)$

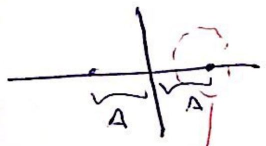
$00 \rightarrow A\cos(\omega_c t - 225)$

4/10/2017

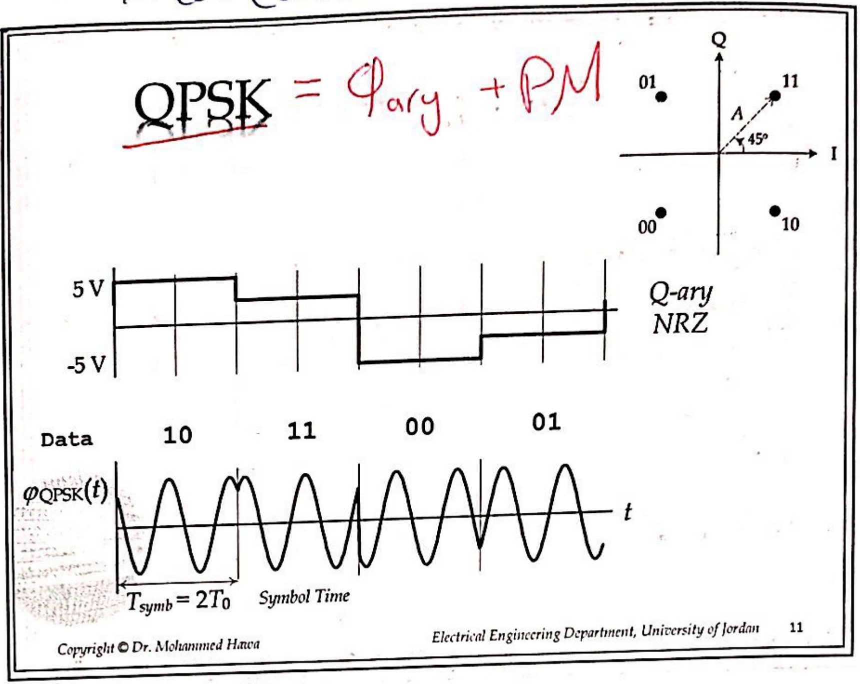
مم كيف نحسب

Bω?

BER?



symbol ↓ in time domain



QPSK = Qary + PM

Q-ary NRZ

Data 10 11 00 01

$T_{symb} = 2T_0$ Symbol Time

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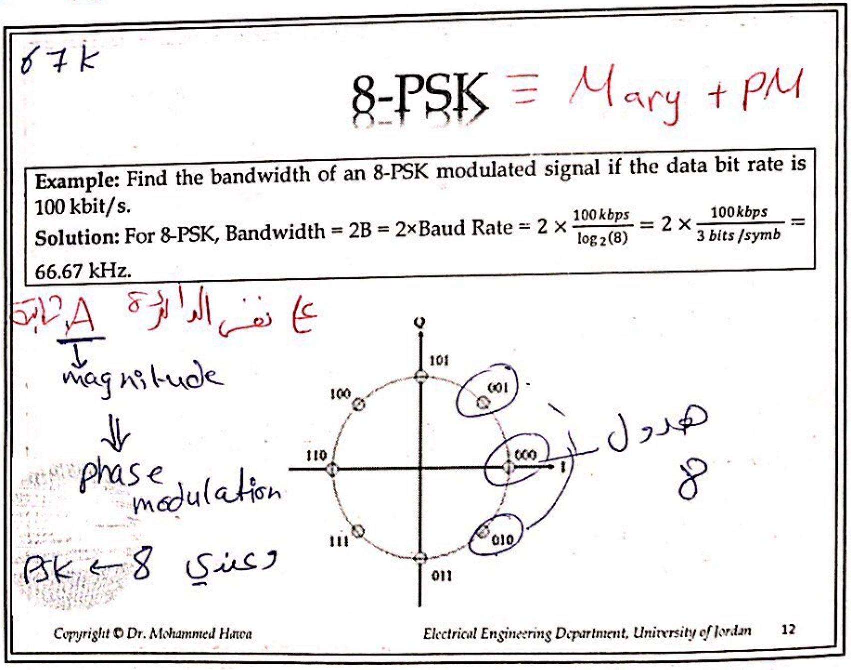
$B\omega = 2\Delta f + 2B\, f_s$

$= 2 * \frac{100}{3} = 66.67k$

* في حاله Mary

دائماً

$B \rightarrow f_s \rightarrow \frac{f_o}{\log_2 M}$



8-PSK ≡ Mary + PM

Example: Find the bandwidth of an 8-PSK modulated signal if the data bit rate is 100 kbit/s.

Solution: For 8-PSK, Bandwidth = 2B = 2×Baud Rate = $2 \times \frac{100\,kbps}{\log_2(8)} = 2 \times \frac{100\,kbps}{3\ bits/symb} =$ 66.67 kHz.

ع نفس الدائرة A ثابتة

↓ magnitude

⇓ phase modulation

ويعني 8 ← PSK

هدول 8

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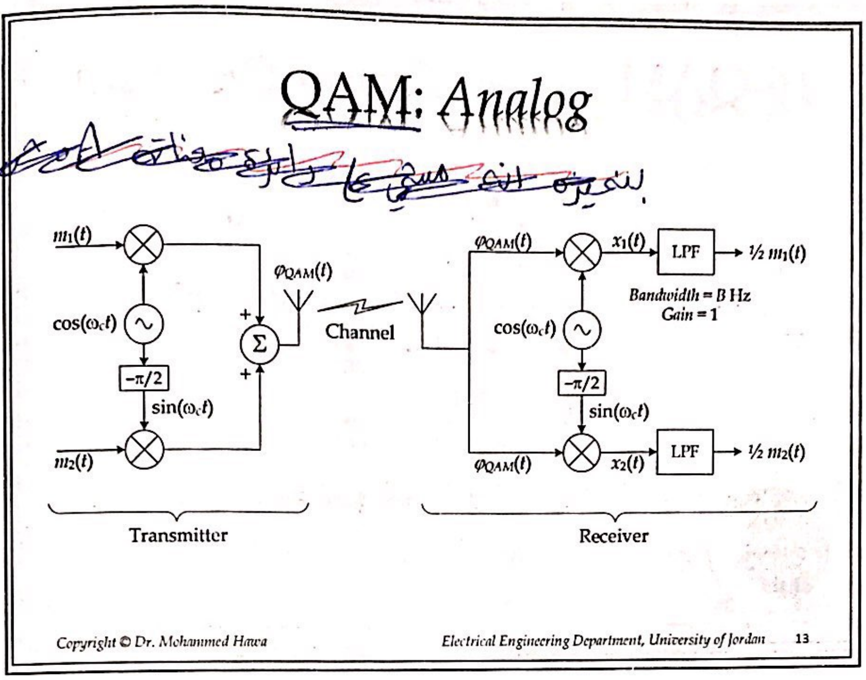
bit rate = f_o = 100 Kbit/s

symbol rate (baud rate) = $f_s = \frac{1}{\cancel{\log_2 8}_{\,3}} f_o = \frac{100}{3} K$



QAM: *Analog*

[illegible]

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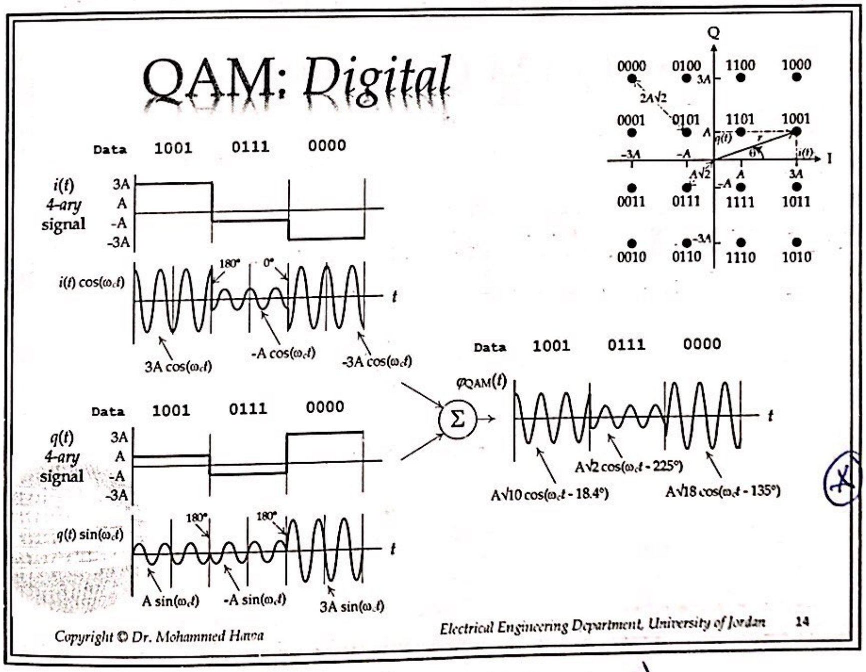
✓



QAM: *Digital*

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Ⓧ $f_b = 8\,\text{Mbps}$

$f_s = \frac{1}{4} \times 8$

$= 2\,\text{M sym/sec}$

Ⓧ BW of QAM

$= 2B = 2f_s$

$= 4\,\text{MHz}$

$1001 = 3A\cos(\omega_c t) + A\sin(\omega_c t)$

$= \sqrt{(3A)^2 + A^2}\ \cos(\omega_c t - \emptyset)$

$\emptyset \to \tan^{-1}\left(\frac{A}{3A}\right)$

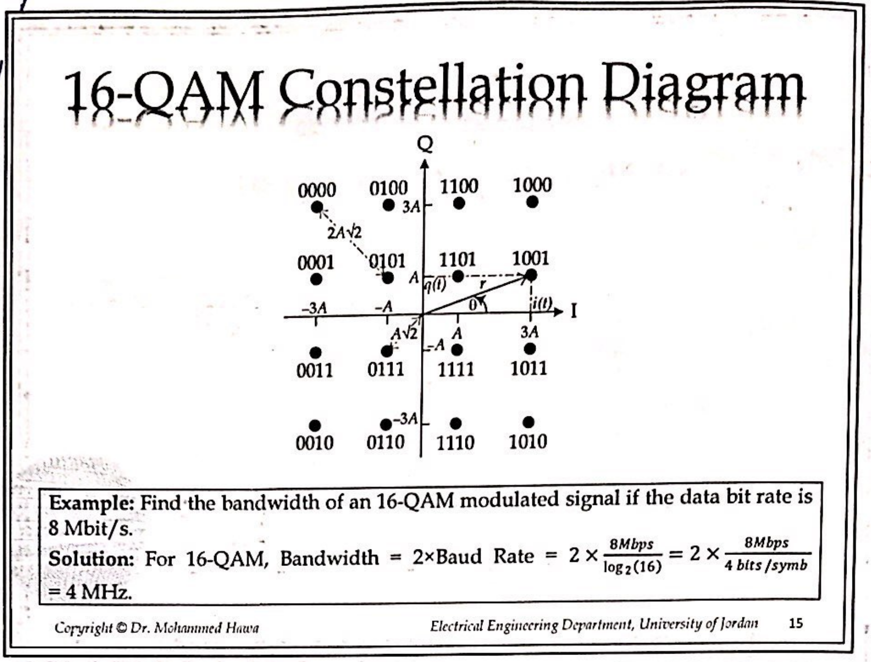
$= A\sqrt{10}$

4/10/2017

* بما انه مش عا دائرة معناته A مش ثابت / مش ١٦ و ٣٢

⇓

16-QAM



16-QAM Constellation Diagram

Example: Find the bandwidth of an 16-QAM modulated signal if the data bit rate is 8 Mbit/s.
Solution: For 16-QAM, Bandwidth = 2×Baud Rate = $2 \times \frac{8Mbps}{\log_2(16)} = 2 \times \frac{8Mbps}{4\ bits/symb}$ = 4 MHz.

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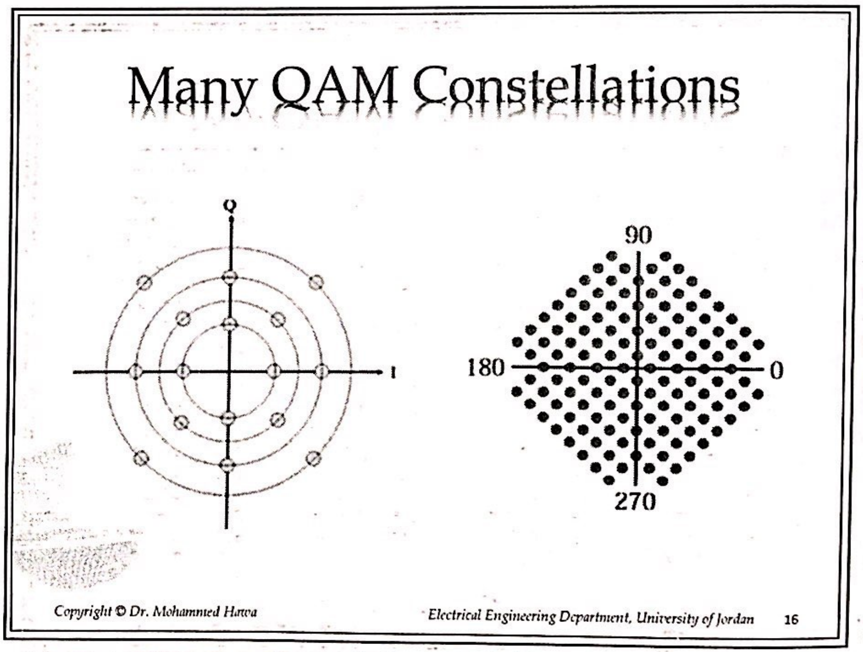

Many QAM Constellations

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خارج للقبل

$\circledast$ 0111 $\Rightarrow -\cancel{3}A\cos(\omega_c t) - A\sin(\omega_c t)$

$= \sqrt{A^2+A^2}\cos(\omega_c - (180+45))$

$\tan^{-1}\frac{A}{A}$

$\circledast$ 0000 $\Rightarrow -3A\cos(\omega_c t) + 3A\sin(\omega_c t)$

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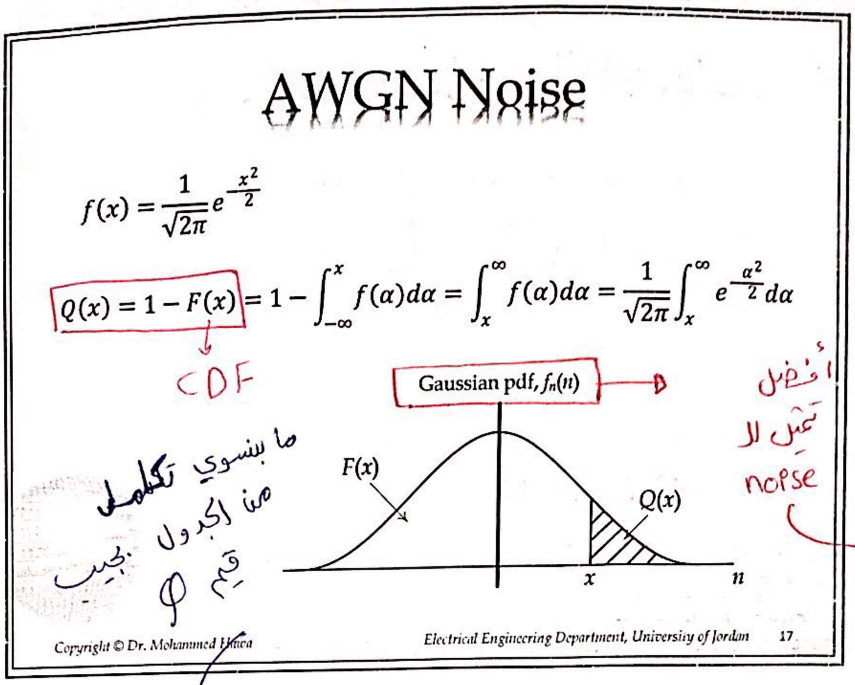

AWGN Noise

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$$

$$\boxed{Q(x) = 1 - F(x)} = 1 - \int_{-\infty}^{x} f(\alpha)d\alpha = \int_{x}^{\infty} f(\alpha)d\alpha = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{\alpha^2}{2}} d\alpha$$

CDF

Gaussian pdf, $f_n(n)$ → أفضل تمثل ال noise since انها random

ما بنسوي تكامل من الجدول بجيب قيم Φ

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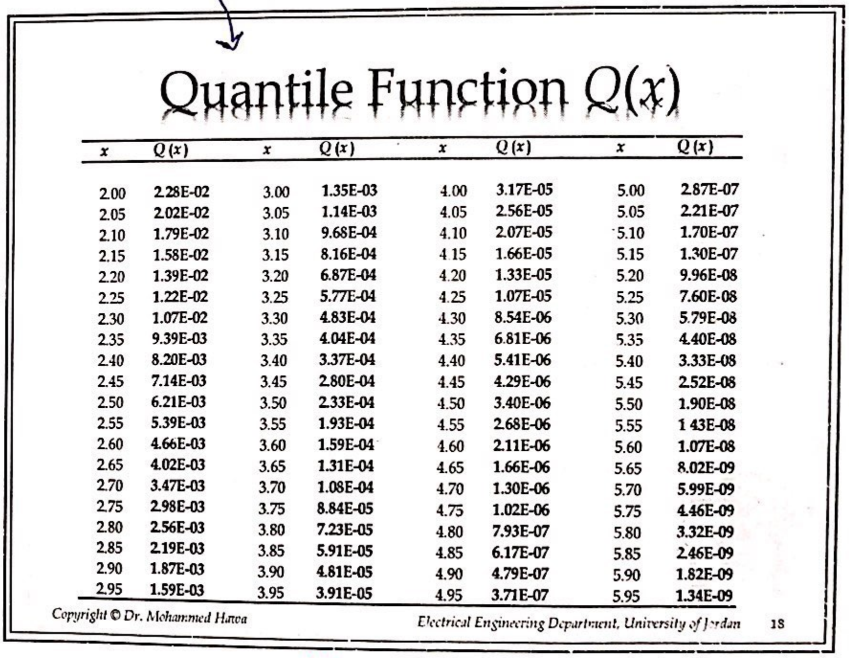
* الاشتقاق مش مطلوب



Quantile Function $Q(x)$

x	Q (x)	x	Q (x)	x	Q (x)	x	Q (x)
2.00	2.28E-02	3.00	1.35E-03	4.00	3.17E-05	5.00	2.87E-07
2.05	2.02E-02	3.05	1.14E-03	4.05	2.56E-05	5.05	2.21E-07
2.10	1.79E-02	3.10	9.68E-04	4.10	2.07E-05	5.10	1.70E-07
2.15	1.58E-02	3.15	8.16E-04	4.15	1.66E-05	5.15	1.30E-07
2.20	1.39E-02	3.20	6.87E-04	4.20	1.33E-05	5.20	9.96E-08
2.25	1.22E-02	3.25	5.77E-04	4.25	1.07E-05	5.25	7.60E-08
2.30	1.07E-02	3.30	4.83E-04	4.30	8.54E-06	5.30	5.79E-08
2.35	9.39E-03	3.35	4.04E-04	4.35	6.81E-06	5.35	4.40E-08
2.40	8.20E-03	3.40	3.37E-04	4.40	5.41E-06	5.40	3.33E-08
2.45	7.14E-03	3.45	2.80E-04	4.45	4.29E-06	5.45	2.52E-08
2.50	6.21E-03	3.50	2.33E-04	4.50	3.40E-06	5.50	1.90E-08
2.55	5.39E-03	3.55	1.93E-04	4.55	2.68E-06	5.55	1.43E-08
2.60	4.66E-03	3.60	1.59E-04	4.60	2.11E-06	5.60	1.07E-08
2.65	4.02E-03	3.65	1.31E-04	4.65	1.66E-06	5.65	8.02E-09
2.70	3.47E-03	3.70	1.08E-04	4.70	1.30E-06	5.70	5.99E-09
2.75	2.98E-03	3.75	8.84E-05	4.75	1.02E-06	5.75	4.46E-09
2.80	2.56E-03	3.80	7.23E-05	4.80	7.93E-07	5.80	3.32E-09
2.85	2.19E-03	3.85	5.91E-05	4.85	6.17E-07	5.85	2.46E-09
2.90	1.87E-03	3.90	4.81E-05	4.90	4.79E-07	5.90	1.82E-09
2.95	1.59E-03	3.95	3.91E-05	4.95	3.71E-07	5.95	1.34E-09

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* مثلاً إذا اعطاني قيمة بين قيمتين بالجدول

$2.80 \longrightarrow 2.56 * 10^{-3}$

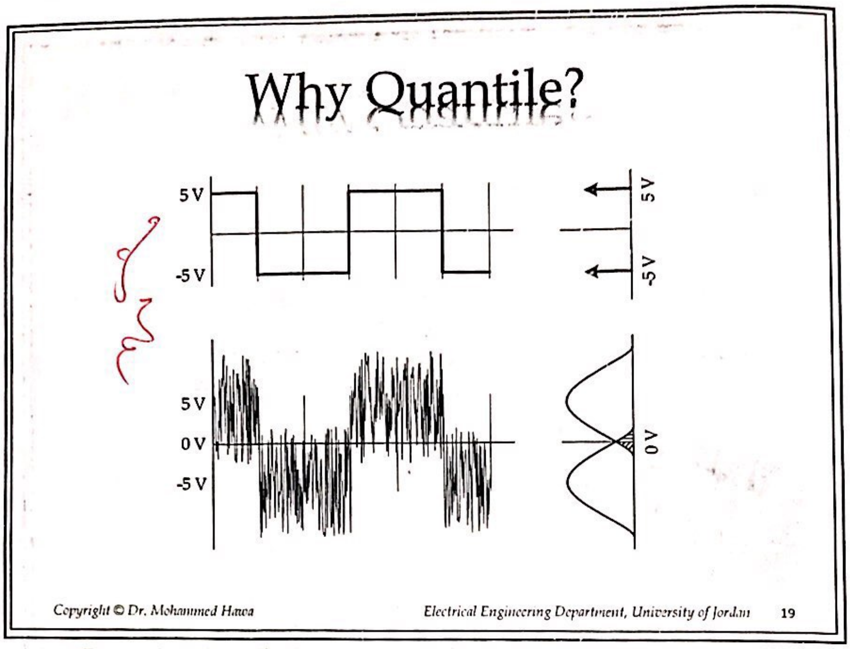
$2.83 \longrightarrow X$

$2.85 \longrightarrow 2.19 * 10^{-3}$

$$\Longrightarrow \frac{2.83 - 2.80}{2.85 - 2.80} = \frac{X - 2.56 \times 10^{-3}}{2.19 \times 10^{-3} - 2.56 \times 10^{-3}}$$

* To Know the BER we need → Q(z)

4/10/201



Why Quantile?

مش مهم

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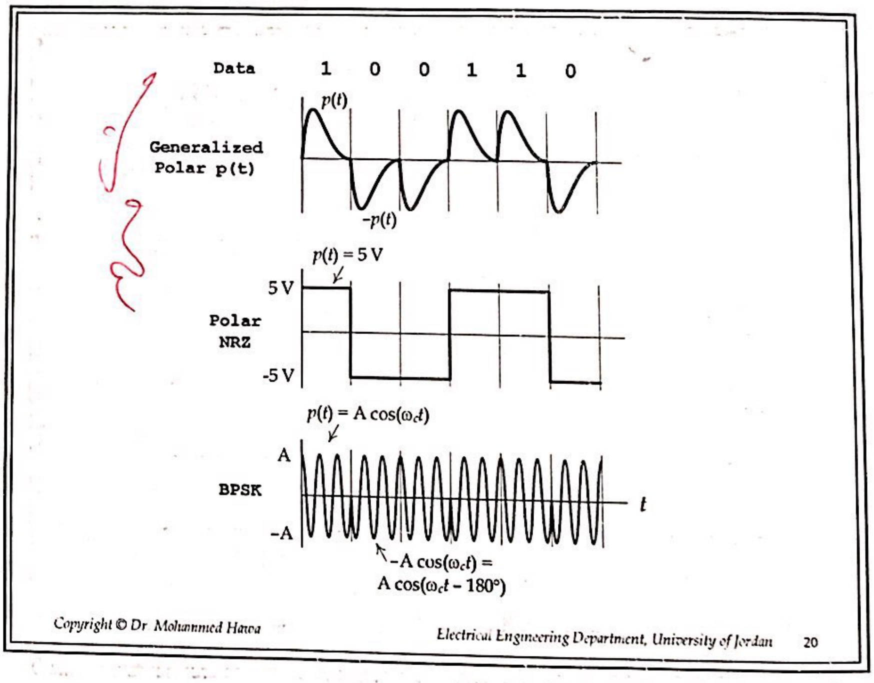

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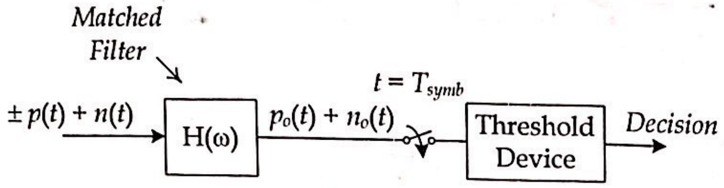
Matched Filter

↳ optimal



مش مهم

Perfromance of Digital Systems

حفظ

Modulation with AWGN	Error Probability
ASK	$BER = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$
FSK	$BER = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$
BPSK	$BER = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$
QPSK	$BER = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$
PSK (order *M*)	$BER \cong \frac{2}{k} Q\left(\sqrt{2k\frac{E_b}{N_0} \times \sin\left(\frac{\pi}{M}\right)}\right)$
QAM (order *M*) (*Rectangular QAM*)	$P_{bc} = \frac{4}{k}\left(1 - \frac{1}{\sqrt{M}}\right) Q\left(\sqrt{\frac{3k}{M-1}\frac{E_b}{N_0}}\right)$ $BER = 1 - (1 - P_{bc})^2$

هدول ازا
اجا سؤال بيعطينا
القانون

4/10/2017

Definitions

For the rest of this document, we will use the following notation:

- M = Number of possible symbols that the modulated signal can assume.
- k = the number of bits sent per transmitted symbol = $\log_2(M)$.
- E_s = *Average* energy-per-transmitted-symbol in the modulated signal (Joule).
- E_b = *Average* energy-per-transmitted-bit in the modulated signal (Joule) = E_s/k.
- $S_n(\omega) = \frac{N_0}{2}$ = Double-sided *noise* power spectral density (*in* W/Hz = Joule).
- T_o = Bit duration.
- T_{symb} = Symbol duration = $k\,T_o$
- BER = Probability of bit-error = bit error rate.

$E_b = \frac{E_s}{K}$

اللي بدنا نحسبه

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ع

Example:
Find the BER for BPSK if we use an *optimal* detector (a matched filter). Assume the amplitude of the carrier is $A = 0.5$ V, data rate is 2 bps, and $N_0 = 2 \times 10^{-2}$ W/Hz.

Solution:
In BPSK there is one symbol per bit (i.e., a total of two symbols that the modulated signal can assume). The two symbols can be written as:

$$s_1 = A\cos(\omega_c t) \qquad s_2 = -A\cos(\omega_c t) = A\cos(\omega_c t - \pi)$$

The energy-per-symbol here is the same as the energy-per-bit and is equal for both possible symbols. Hence, its average is:

$$E_b = E_s = \left(\frac{A^2}{2}T_{symb}\right)\Pr[1] + \left(\frac{A^2}{2}T_{symb}\right)\Pr[0] = \frac{A^2}{2}T_{symb} = \frac{A^2}{2}T_o = \frac{A^2}{2}\frac{1}{f_0}$$

$K=1$

Hence,

$$\text{BER} = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q\left(\sqrt{\frac{A^2}{N_0 f_0}}\right) = Q\left(\sqrt{\frac{0.5^2}{2\times10^{-2}\times 2}}\right) = Q(\sqrt{6.25}) = Q(2.5)$$
$$= 6.21 \times 10^{-3}$$

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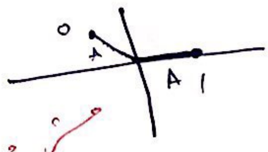
هون ما عندي / كة بس ال BPSK



مش مهمة الزاوية

احتمال كل واحدة = $\frac{1}{2}$

$f_s = \frac{f_o}{\log_2 \cancel{M}_2} = f_o = 0.5$

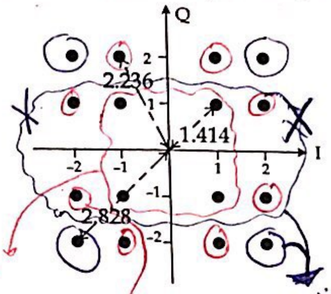
Example

القانون من الجدول

Find the BER for the 16-QAM constellation shown below if we use an *optimal* detector (a matched filter). Assume the data rate is 4 bps, and $N_0 = 5 \times 10^{-2}$ W/Hz.

P_{bc} ---

BER ...



نفس الحجم energy

نفس الحجم energy

الخارجين الهم نفس energy

16- QAM

$\downarrow$

K = 4

M = 16

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Solution:

In this system there are 16 possible symbols, which we assume to be equally probable, i.e., each occurs with a probability of 1/16. Hence, the energy-per-symbol is:

$$E_s = \left(\frac{1.414^2}{2}T_{symb}\right)\left(\frac{4}{16}\right) + \left(\frac{2.236^2}{2}T_{symb}\right)\left(\frac{8}{16}\right) + \left(\frac{2.828^2}{2}T_{symb}\right)\left(\frac{4}{16}\right)$$

الداخلين   برة   خارجين

$$E_s = [0.25 + 1.25 + 1]T_{symb} = 2.5(T_{symb})$$

$$E_b = \frac{E_s}{k} = 2.5\left(\frac{T_{symb}}{k}\right) = 2.5(T_0) = \frac{2.5}{f_0} = \frac{2.5}{4} = 0.625 \text{ J}$$

$$P_{bc} = \frac{4}{k}\left(1 - \frac{1}{\sqrt{M}}\right)Q\left(\sqrt{\frac{3k}{M-1}\frac{E_b}{N_0}}\right) = \frac{4}{4}\left(1 - \frac{1}{\sqrt{16}}\right)Q\left(\sqrt{\frac{3\times4}{16-1}\times\frac{0.625}{0.05}}\right) = \frac{3}{4}Q(\sqrt{10})$$

$$= \frac{3}{4}Q(3.162) = \frac{3}{4}\times 8\times10^{-4} = 6\times10^{-4}$$

$$BER = 1 - (1 - P_{bc})^2 = 1 - (1 - 6\times10^{-4})^2 = 1.2\times10^{-3}$$

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$* Bw = 2B$

$$f_s = \frac{f_0}{\log_2 M} = 1$$

$$\boxed{Bw = 2 \text{ Hz}}$$

To find Es ?

* مثلاً لو اخذ الداخلين

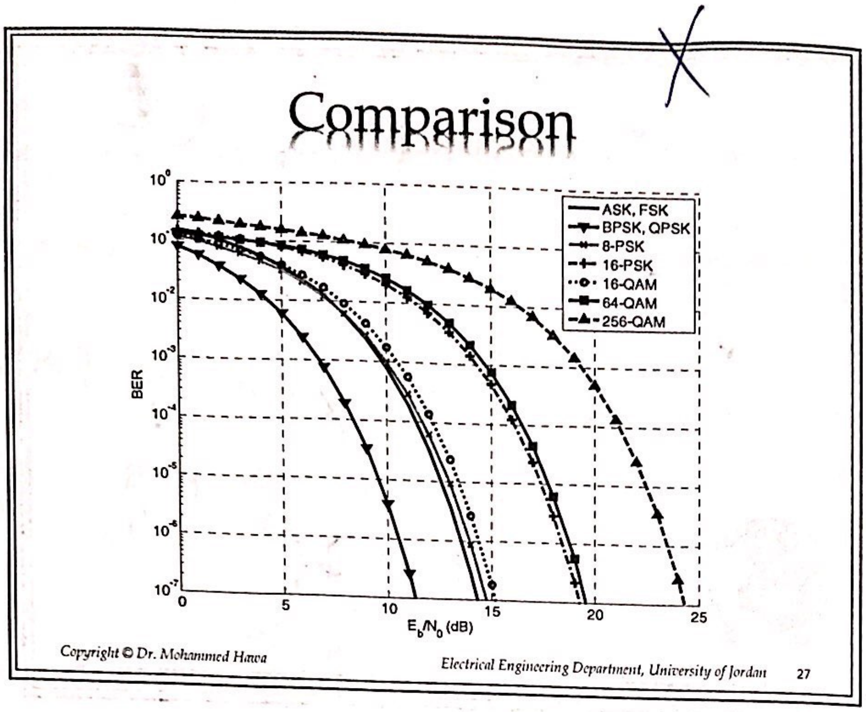
$$E_s = 4 * \frac{1}{16} * \frac{(1.414)^2}{2} * T_{symb} \rightarrow \frac{1}{f_{sy}} = \frac{1}{\frac{f_0}{\log_2 M}}$$

عدد النقاط

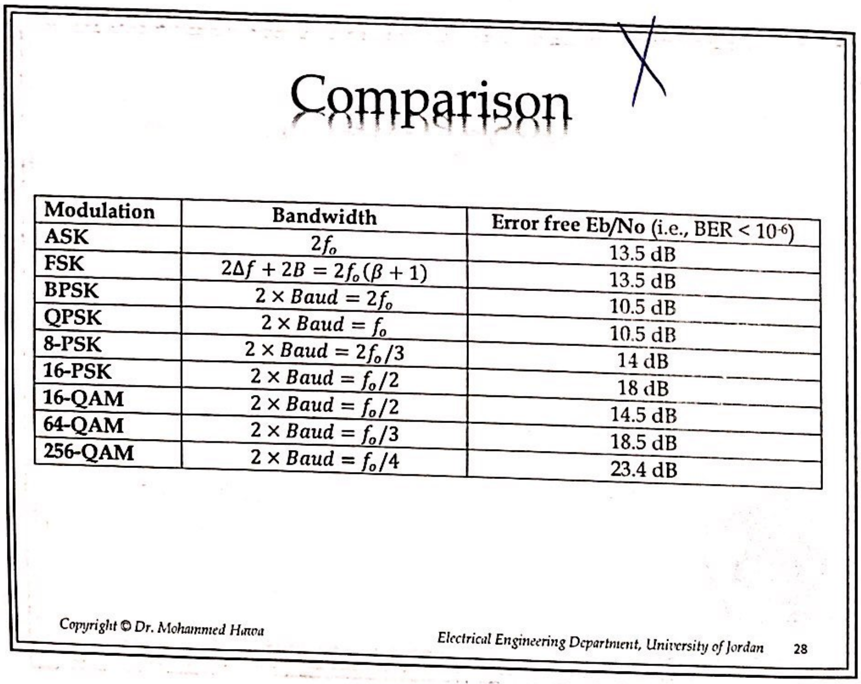
احتمالية كل نقطة

power لكل وحدة

4/10/2017



Comparison



Comparison

Modulation	Bandwidth	Error free Eb/No (i.e., BER < 10^{-6})
ASK	$2f_o$	13.5 dB
FSK	$2\Delta f + 2B = 2f_o(\beta + 1)$	13.5 dB
BPSK	$2 \times Baud = 2f_o$	10.5 dB
QPSK	$2 \times Baud = f_o$	10.5 dB
8-PSK	$2 \times Baud = 2f_o/3$	14 dB
16-PSK	$2 \times Baud = f_o/2$	18 dB
16-QAM	$2 \times Baud = f_o/2$	14.5 dB
64-QAM	$2 \times Baud = f_o/3$	18.5 dB
256-QAM	$2 \times Baud = f_o/4$	23.4 dB

Remember: Digital Modulation

- **Bandwidth** of the channel decides the **baud rate** (symbols per second) you can send.
- **Signal-to-noise ratio** (E_b/N_0) decides the level of modulation you can use while still maintaining a small bit error rate. In other words, it decides the number of **bits you can send per symbol**.
- Hence, the two factors together (bandwidth and SNR) decide the **total bit rate** you can achieve over any single channel.
- Shannon's Limit!

Shannon's Limit

$$C = B_{ch} \times log_2(1 + SNR)$$

- C: Capacity of the channel in bits/second (bps)
- B_{ch}: Channel bandwidth (units of Hz)
- SNR: Signal-to-Noise Ratio (unitless)(*not dB*)