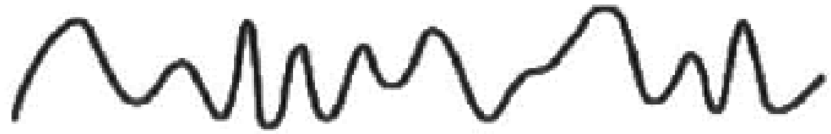
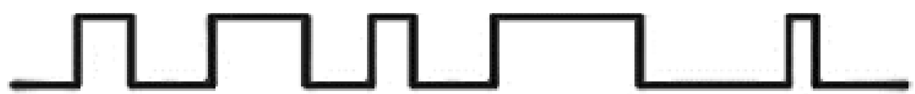
UEC519-Analog and Digital Communication Systems

Unit-2:

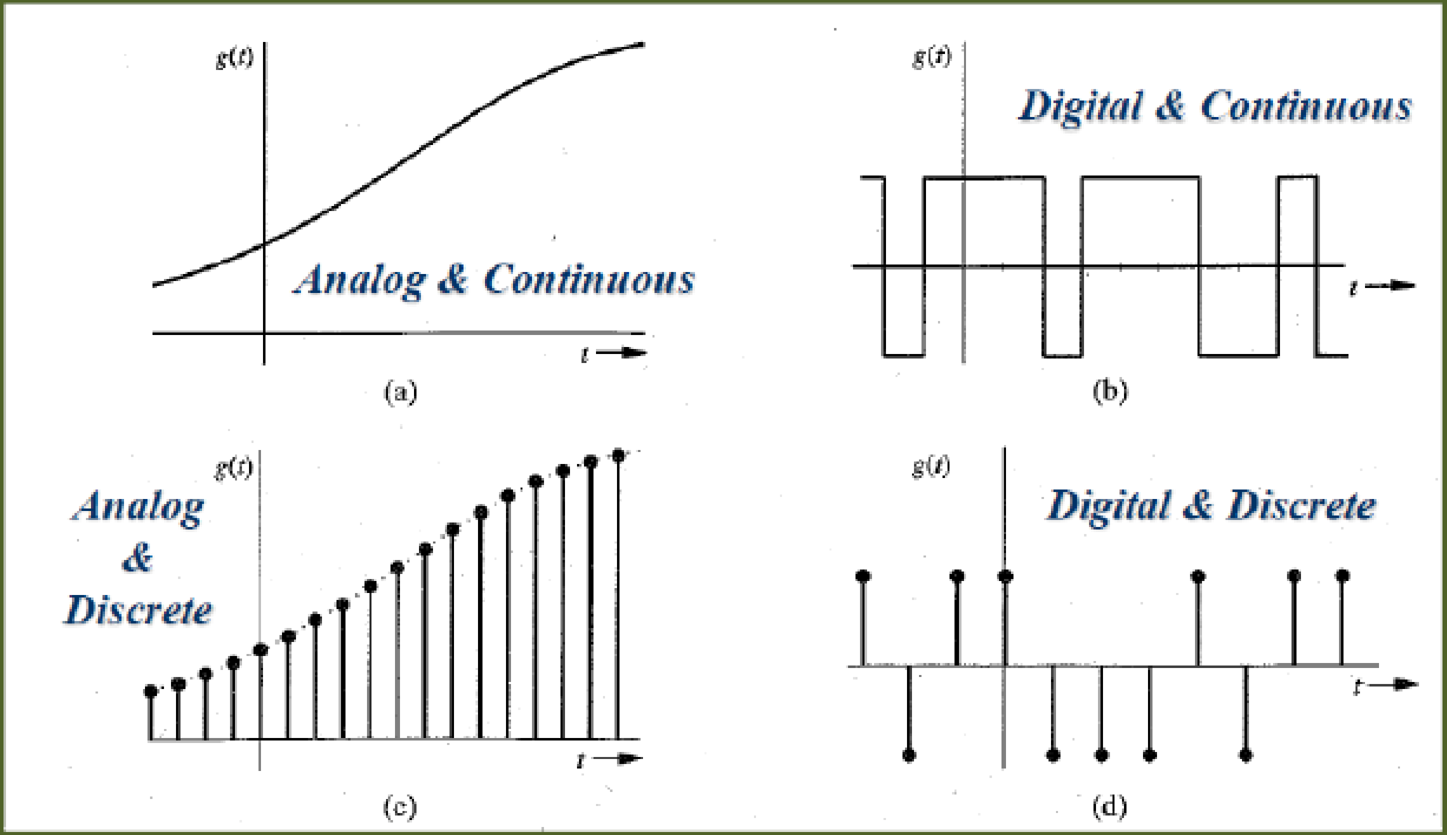
Introduction to Pulse Modulation Systems: Basic model of digital communication system, Bandpass and low pass signal and system representations, low pass equivalent of bandpass signals and system, Pulse modulation. Sampling process, Pulse Amplitude and Pulse code modulation (PCM), Differential pulse code modulation. Delta modulation (DM), Adaptive Delta modulation (ADM), Noise considerations in PCM, Time Division multiplexing.

Types of Information

Information:	Type(s):	Example(s):
Message	Analog	Temperature, voice, image, etc.
	Digital	English text, teletype (Morse-coded) text, etc.
Signal	Analog	
	Digital	
Data	Digital only	011000101001011111010 …

Bits
(Binary Digits)

Graphical Representation of various types of signals



➢ Advantages of using digital communication over analog communication

- Can combine different signal types – **data, voice, text, image, video** etc.

- Data communication in **computers** is **digital in nature** whereas **voice communication** between people is **analog in nature**

- The **two** different types **(data/voice/text/image/video)** of signal communication are difficult to **combine** over the **same medium** in the **analog domain**.

- Using digital techniques, it is **possible** to **combine** both format for transmission through a **common medium.**

- **Encryptio**n and **privacy techniques** are easier to implement

- **Better** overall **performance**

- Digital communication is inherently **more efficie**nt than analog in realizing the exchange of **SNR** for **bandwidth**.

- Digital signals can be coded to yield extremely **low rates** and **high fidelity** as well as **privacy**.

- **Hardware is more flexible**

  - Digital hardware implementation is **flexible** and permits the use of **microprocessors**, mini-processors, digital switching and **VLSI**

  - **Shorter** design and production cycle

  - Low **cost:** The use of LSI and VLSI in the design of components and systems have resulted in **lower cost**

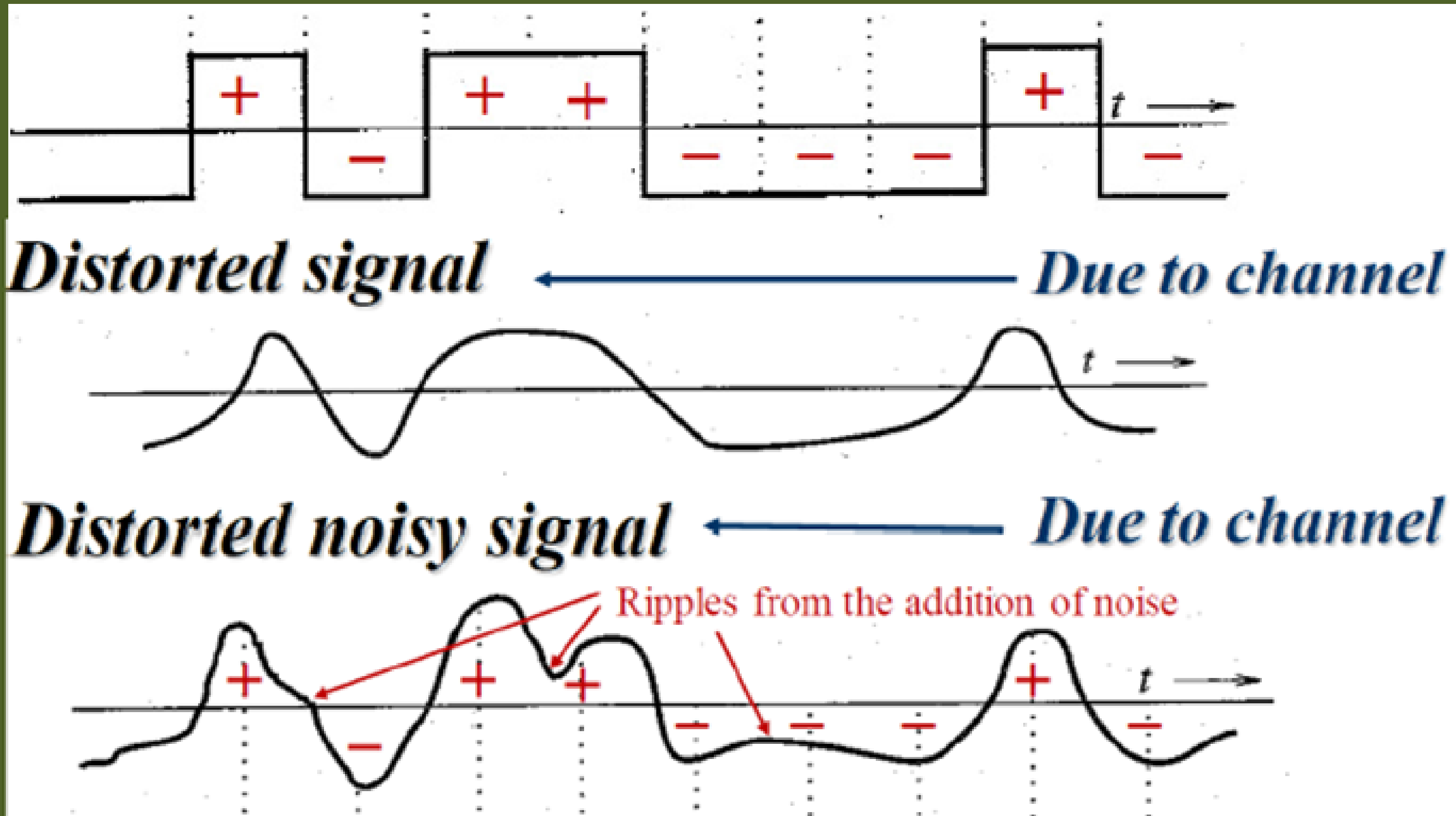
- **Easier and more efficient to multiplex several digital signals**

- Easier and more efficient **Multiple Access** Technique like **TDMA**, **FDMA**, **CDMA** etc.

Challenges in Digital Communications

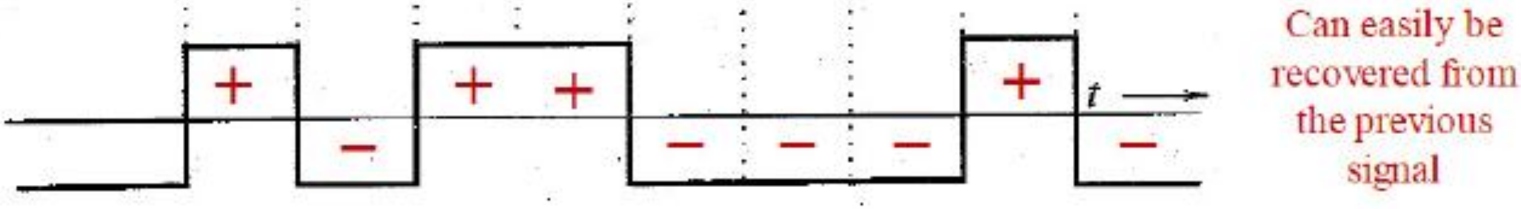
- Requires reliable "**synchronizatio**n"
  - Requires A/D conversions at **high rate**
- Requires **larger bandwidth**

Noise Immunity of Digital Signals

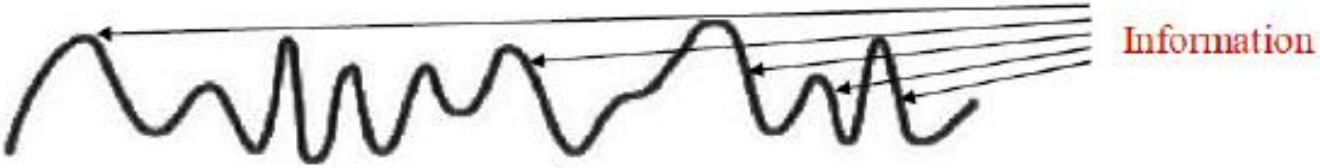


The data can be recovered correctly as long as the distortion and the noise are within limits.

Continued…



In contrast, the waveform (signal shape) in analog messages is so important, as even a small distortion or interference can cause error in the received signal



Clearly, a digital communication system can better withstand (resist) noise and distortion, thus it is more immune to noise.

Regenerative Repeaters

In digital systems:

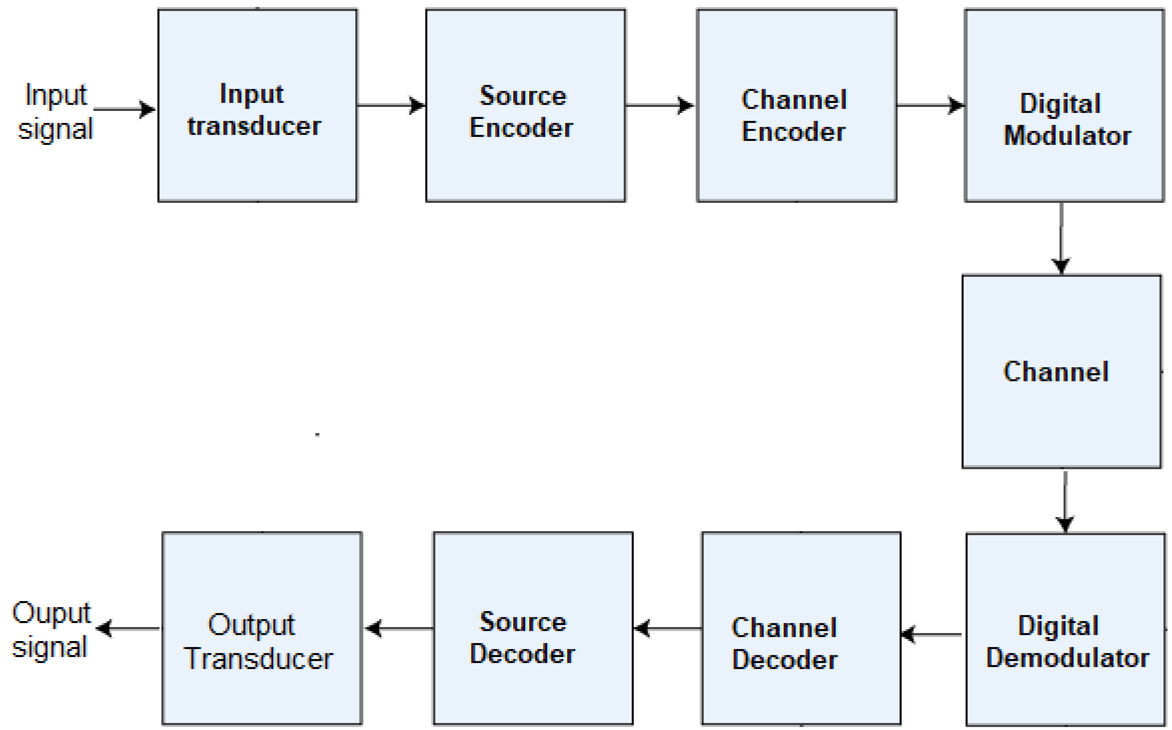
- Repeater stations are placed along the communication path at distances short enough to ensure that noise and distortion remains within a limit.
- At each repeater station:
  - ❖ The incoming pulses are detected.
  - ❖ New clean pulses are generated.
  - ❖ The new pulses are transmitted to the next repeater station.
- This process prevents the accumulation of noise and distortion along the path by cleaning the pulses periodically at the repeater station.

Shortcomings of Analog Communication Systems

In analog systems:

- There is no way to avoid accumulation of noise and distortion along the path.
- Amplification is of little help, because it enhances the signal and noise in the same proportion (as discussed earlier).
- Signal quality can be improved by <u>filtering</u> the signal then <u>amplifying</u> it.
- Repeaters used in analog systems basically consist of filters and then amplifiers (they are not "regenerative" repeaters).

Block Diagram of Digital Communication System



Block Diagram

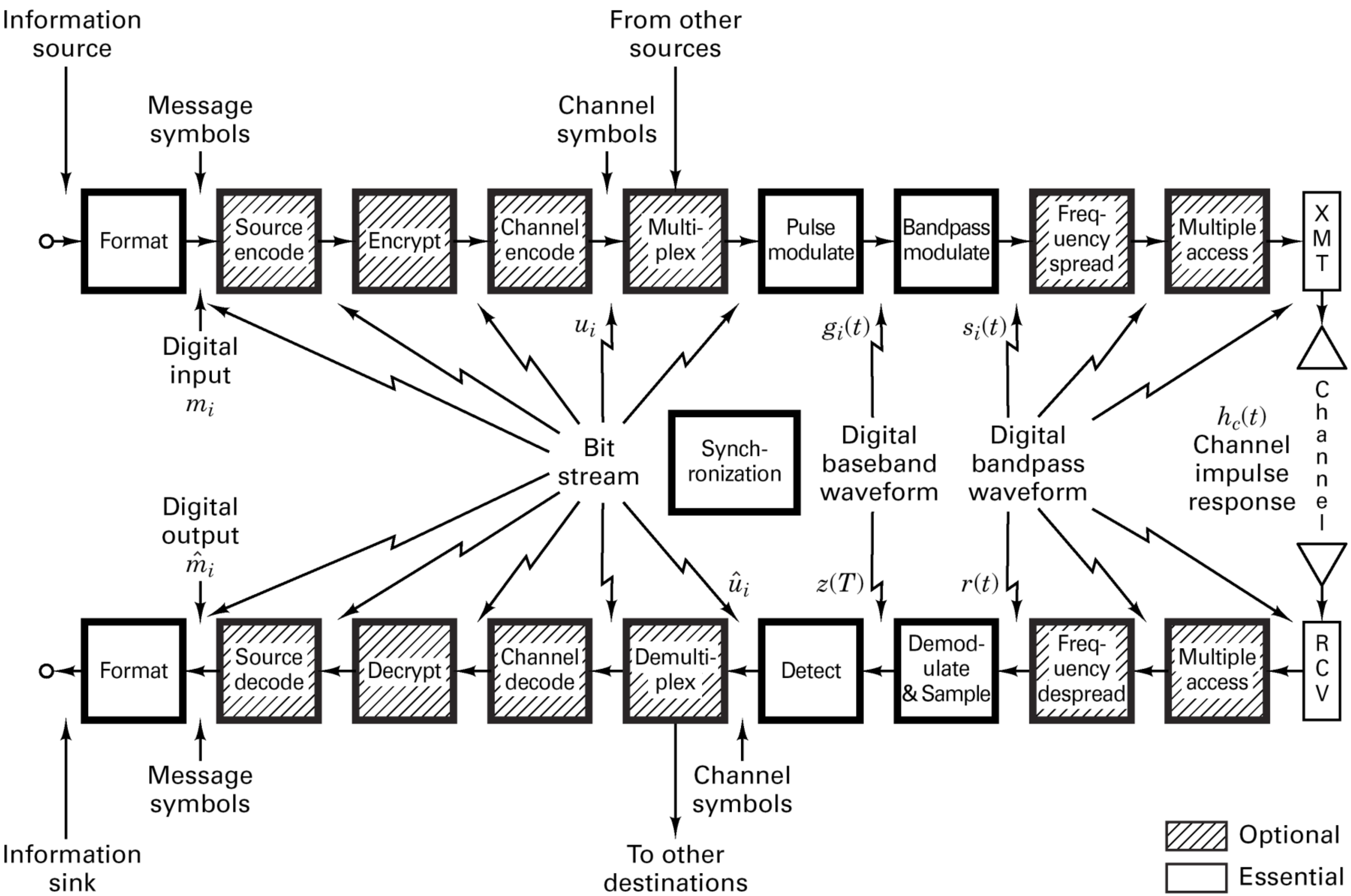
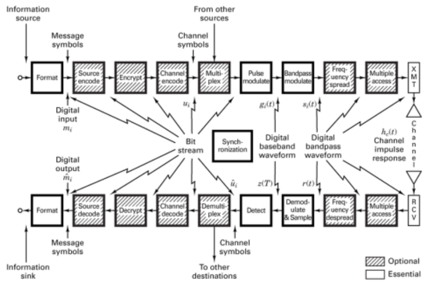


Figure 1.2 Block diagram of a typical digital communication system.

Methods and techniques



Formatting
- Character coding
- Sampling
- Quantization
- Pulse code modulation (PCM)

Source Coding
- Predictive coding
- Block coding
- Variable length coding
- Synthesis/analysis coding
- Lossless compression
- Lossy compression

Baseband Signaling
- PCM waveforms (line codes)
  - Nonreturn-to-zero (NRZ)
  - Return-to-zero (RZ)
  - Phase encoded
  - Multilevel binary
- *M*-ary pulse modulation
  - PAM, PPM, PDM

Equalization
- Maximum-likelihood sequence estimation (MLSE)
- Equalization with filters
  - Transversal or decision feedback
  - Preset or Adaptive
  - Symbol spaced or fractionally spaced

Bandpass Signaling

Coherent
- Phase shift keying (PSK)
- Frequency shift keying (FSK)
- Amplitude shift keying (ASK)
- Continuous phase modulation (CPM)
- Hybrids

Noncoherent
- Differential phase shift keying (DPSK)
- Frequency shift keying (FSK)
- Amplitude shift keying (ASK)
- Continuous phase modulation (CPM)
- Hybrids

Channel Coding

Waveform
- *M*-ary signaling
- Antipodal
- Orthogonal
- Trellis-coded modulation

Structured Sequences
- Block
- Convolutional
- Turbo

Synchronization
- Frequency synchronization
- Phase synchronization
- Symbol synchronization
- Frame synchronization
- Network synchronization

Multiplexing/Multiple Access
- Frequency division (FDM/FDMA)
- Time division (TDM/TDMA)
- Code division (CDM/CDMA)
- Space division (SDMA)
- Polarization division (PDMA)

Spreading
- Direct sequencing (DS)
- Frequency hopping (FH)
- Time hopping (TH)
- Hybrids

Encryption
- Block
- Data stream

Figure 1.3 Basic digital communication transformations.

Fourier Transform

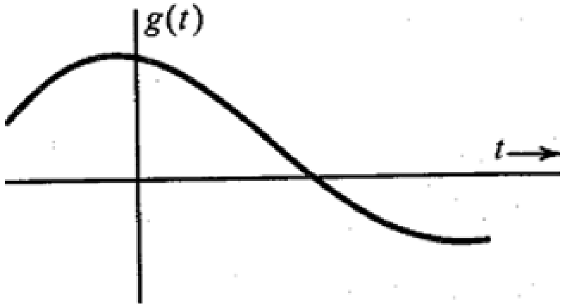
Short Table of Fourier Transforms

	$g(t)$	$G(\omega)$	
1	$e^{-at}u(t)$	$\dfrac{1}{a+j\omega}$	$a>0$
2	$e^{at}u(-t)$	$\dfrac{1}{a-j\omega}$	$a>0$
3	$e^{-a\|t\|}$	$\dfrac{2a}{a^2+\omega^2}$	$a>0$
4	$te^{-at}u(t)$	$\dfrac{1}{(a+j\omega)^2}$	$a>0$
5	$t^n e^{-at}u(t)$	$\dfrac{n!}{(a+j\omega)^{n+1}}$	$a>0$
6	$\delta(t)$	1	
7	1	$2\pi\delta(\omega)$	
8	$e^{j\omega_0 t}$	$2\pi\delta(\omega-\omega_0)$	
9	$\cos\ \omega_0 t$	$\pi[\delta(\omega-\omega_0)+\delta(\omega+\omega_0)]$	
10	$\sin\ \omega_0 t$	$j\pi[\delta(\omega+\omega_0)-\delta(\omega-\omega_0)]$	

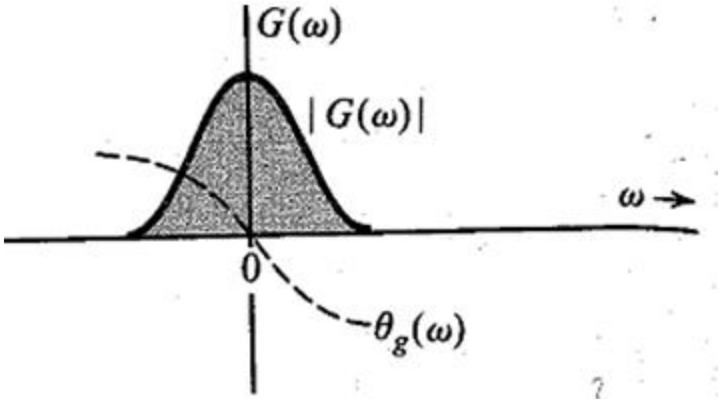
Time domain

Frequency domain

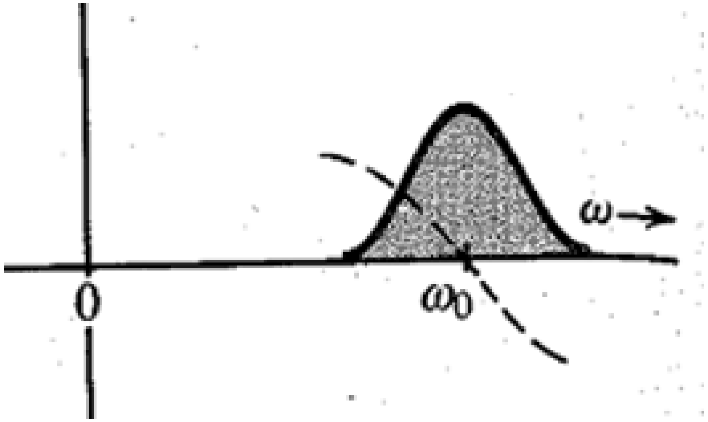
Time limited signal



Baseband signal



Band pass signal



Frequency Shifting Property of Fourier Transform

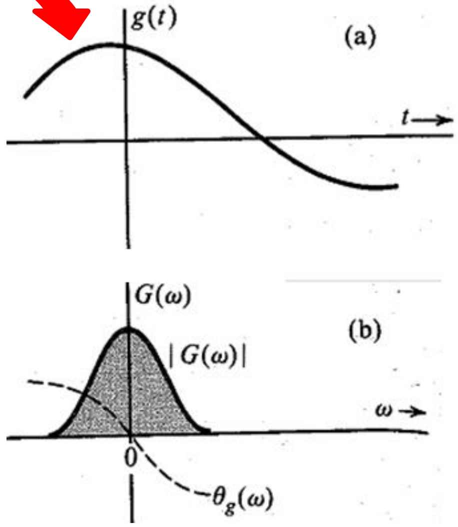
Show that:

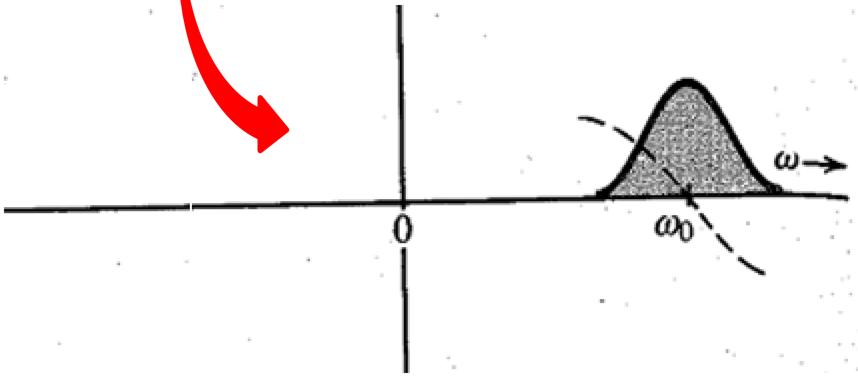
If

$$g(t) \Longleftrightarrow G(\omega)$$

then

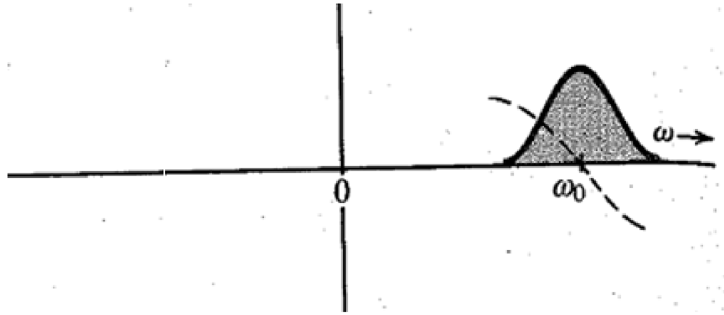
$$g(t)e^{j\omega_0 t} \Longleftrightarrow G(\omega - \omega_0)$$





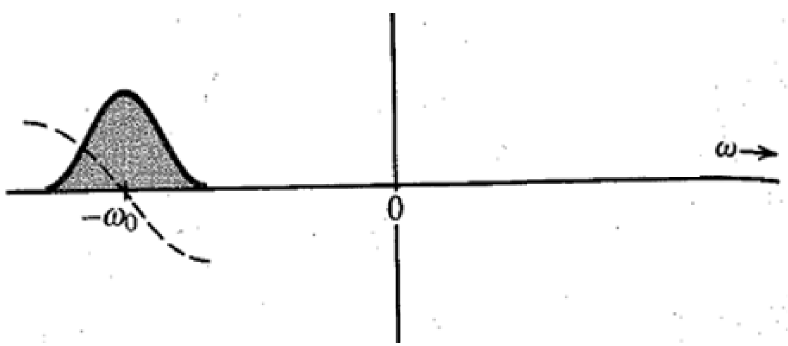
Proof: By definition,

$$\mathcal{F}[g(t)e^{j\omega_0 t}] = \int_{-\infty}^{\infty} g(t)e^{j\omega_0 t}e^{-j\omega t}\,dt = \int_{-\infty}^{\infty} g(t)e^{-j(\omega-\omega_0)t}\,dt = G(\omega-\omega_0)$$



This property states that multiplication of a signal by a factor $e^{j\omega_0 t}$ shifts the spectrum of that signal by $\omega = \omega_0$.

Similarly Changing ω_0 to $-\omega_0$



$$g(t)e^{-j\omega_0 t} \Longleftrightarrow G(\omega+\omega_0)$$

Because $e^{j\omega_0 t}$ is not a real function that can be generated, frequency shifting in practice is achieved by multiplying $g(t)$ by a sinusoid. This can be seen from the fact that

$$g(t)\cos\ \omega_0 t = \frac{1}{2}\left[g(t)e^{j\omega_0 t} + g(t)e^{-j\omega_0 t}\right]$$

We know that

$$g(t)e^{j\omega_0 t} \Longleftrightarrow G(\omega - \omega_0) \tag{3.33}$$

$$g(t)e^{-j\omega_0 t} \Longleftrightarrow G(\omega + \omega_0) \tag{3.34}$$

From Eqs. (3.33) and (3.34), it follows that

$$g(t)\cos\ \omega_0 t \Longleftrightarrow \frac{1}{2}[G(\omega - \omega_0) + G(\omega + \omega_0)] \tag{3.35}$$

This shows that the multiplication of a signal $g(t)$ by a sinusoid of frequency ω_0 shifts the spectrum $G(\omega)$ by $\pm\omega_0$. Multiplication of a sinusoid $\cos\ \omega_0 t$ by $g(t)$ amounts to modulating the sinusoid amplitude. This type of modulation is known as **amplitude modulation**.

Performance Metrics

- **Analog Communication Systems**
  - Metric is **fidelity**: want $\hat{m}(t) \approx m(t)$
  - **SNR** typically used as performance metric

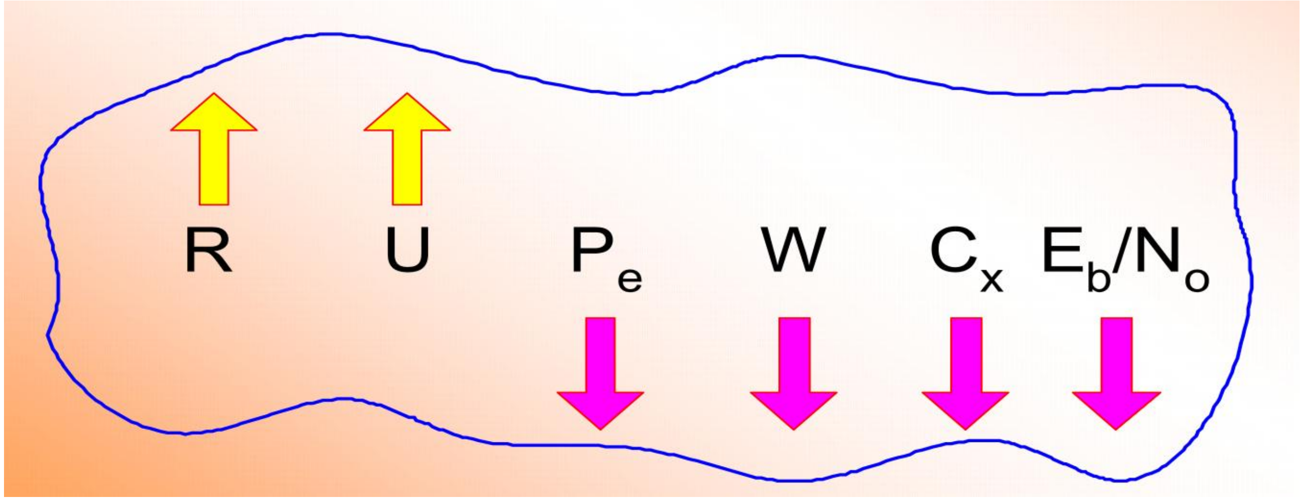
- **Digital Communication Systems**
  - Metrics are **data rate** (R bps) and **probability of bit error** (BER)

$$\left(P_b = p(\hat{b} \neq b)\right)$$

  - Symbols already known at the receiver
  - Without noise/distortion/sync. problem, we will never make bit errors

Goals in Communication System Design

- To maximize transmission rate, ***R***
- To maximize system utilization, ***U***
- To minimize bit error rate, P_e
- To minimize required systems bandwidth, ***W***
- To minimize system complexity, C_x
- To minimize required power, E_b/N_o



Thanks !