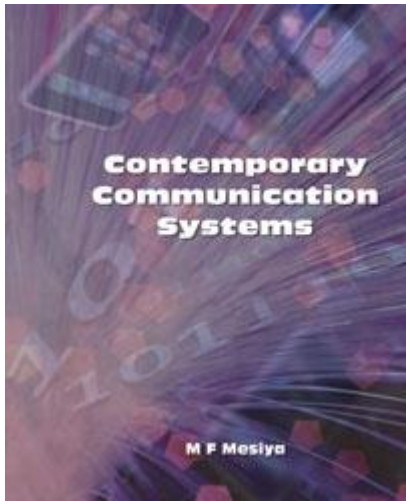
01236258 Principles of Communications
การสื่อสารพื้นฐาน



Introduction

รศ.ดร.ชวลิต เบญจางคประเสริฐ

What is Communication?

การสื่อสาร คือ อะไร

- การสื่อสาร คือ กระบวนการหรือกรรมวิธีที่ใช้แลกเปลี่ยนข้อมูล (สารสนเทศ) หรือการถ่ายโอนข้อมูล(สารสนเทศ) เป้าหมายสำคัญ คือ เครื่องรับจะต้องรับสัญญาณได้ถูกต้องแม่นยำ
- Communication is the process of exchanging information or transfer of information
  - The goal is to reproduce as accurately as possible at the *receiver* a *message* sent from the *transmitter*.
- การสื่อสารข้อมูลจะใช้สัญญาณแม่เหล็กไฟฟ้าในการรับส่ง
- Electrical communication systems convey or transmit information in the form of an electromagnetic signal.
  - For example, we can download a Web page with a click of the mouse from anywhere on the globe.

Types of Message Signals

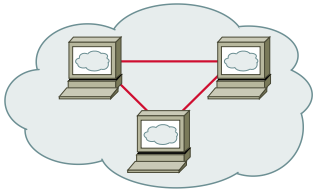
- Speech

- Music

- Image

- Video

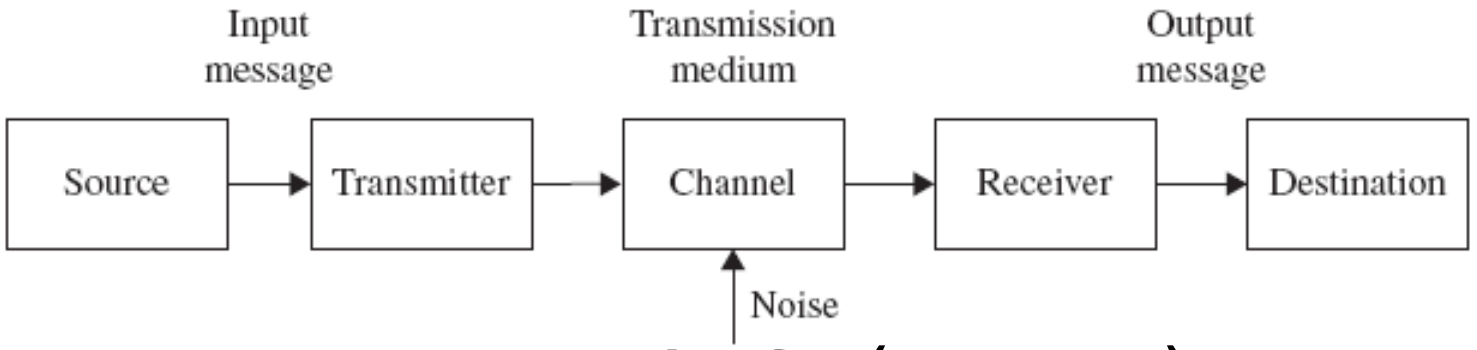
- Data



Elements of a Communication System

องค์ประกอบของระบบสื่อสาร

- A typical communication system consists of (ประกอบด้วย)
  - **Transmitter** – converts the message into a signal that is suitable for transmission over a physical medium or channel.
  - **Transmission medium or channel** – conveys the energy of the signal from the transmitter to a receiver.
  - **Receiver** – recovers the original message from the attenuated/distorted and noisy received signal.



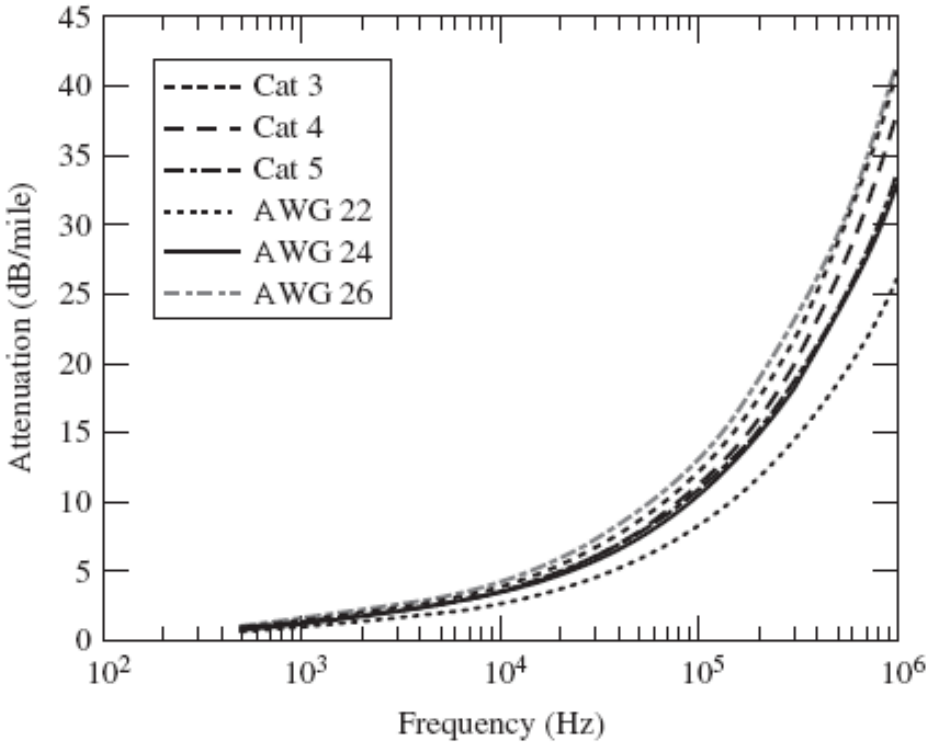
AWGN (สัญญาณรบกวน)

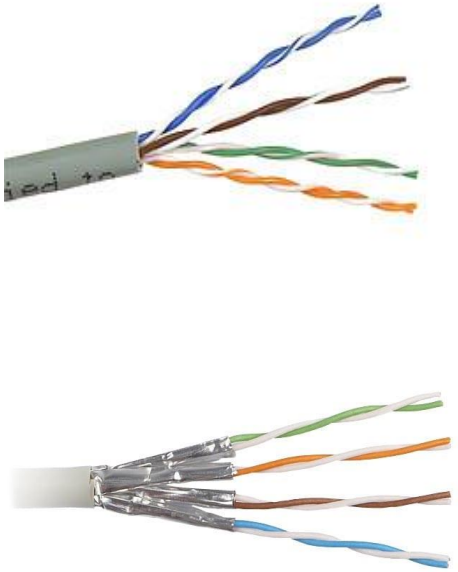
Communication Channels ช่องสัญญาณสื่อสาร

- There are two basic types of communication channels:
  - **Wired media (สื่อมีสาย)**– the signal energy is contained and guided within a solid medium
    - Provide **point-to-point** connectivity. Users communicate via a point-to-point physical link or channel.
    - Examples: Twisted wire pairs, coaxial cable, optical fibers.
  - **Wireless media (สื่อไม่มีสาย หรือ ไร้สาย)**– the signal energy propagates in the form of unguided electromagnetic waves
    - Examples: radio and infrared light.
    - Generally operate in a **broadcast** mode, i.e., the medium is *shared*.

Wired media : Twisted Wire Pair (TWP) สายคู่บิดเกลียว

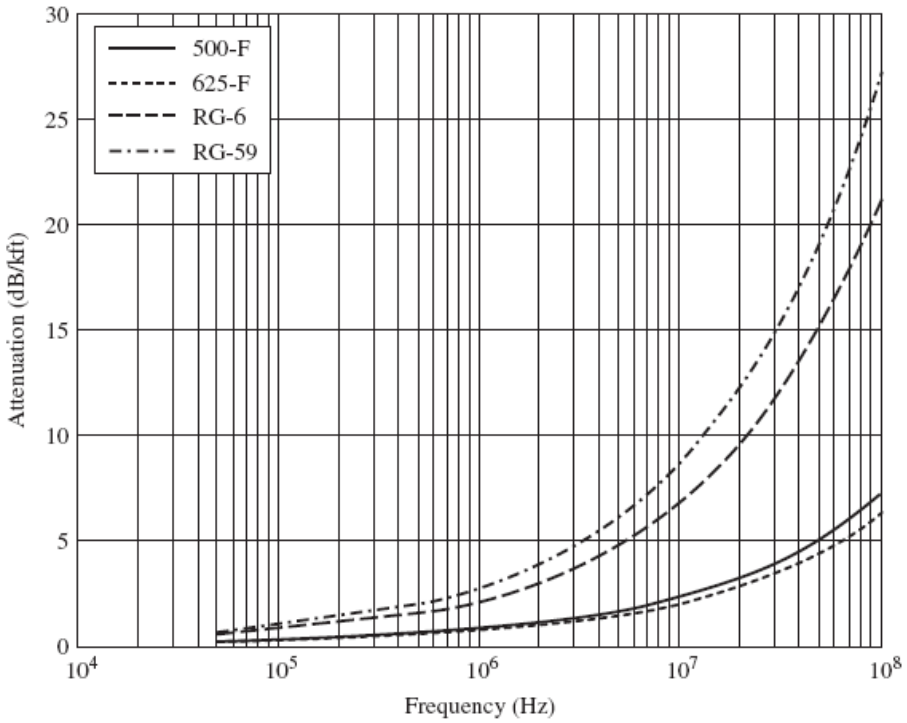
- Two insulated wires (Copper or copper clad steel) twisted in a regular spiral pattern
  - UTP = Unshielded Twisted Pair สายคู่บิดเกลียวแบบไม่ป้องกันสัญญาณรบกวน
  - STP = Shielded Twisted Pair (to reduce interference)

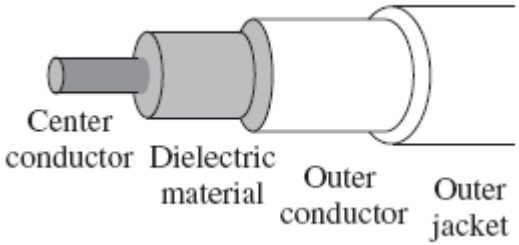


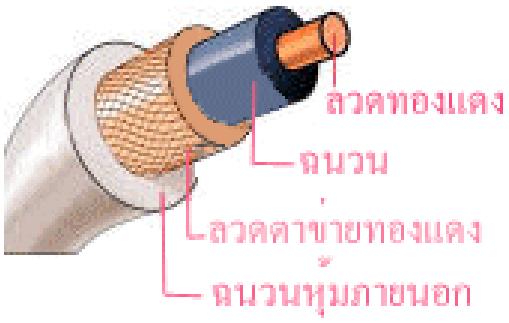


Coaxial Cable สายโคแอกเชียล

- Solid center conductor located coaxially within a cylindrical outer conductor; separated by a solid dielectric material.
- Excellent noise immunity; but not as immune as fiber.

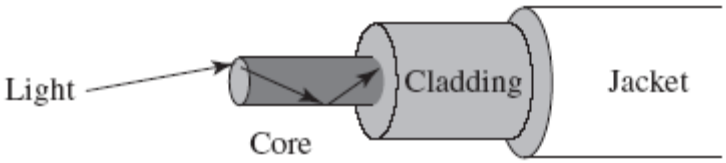


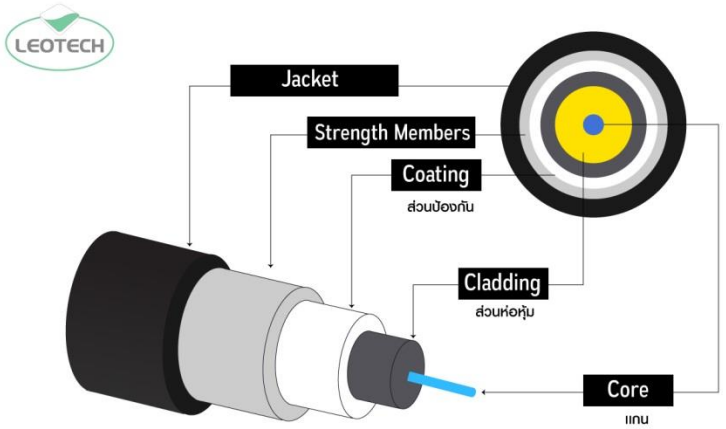




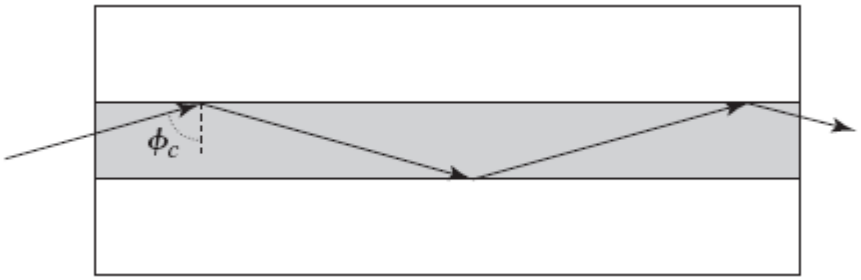
Optical Fibers เส้นใยแก้วนำแสง

- Optical fiber consists of a cylindrical glass *core* surrounded by a concentric layer of glass called *cladding* as shown in Figure.





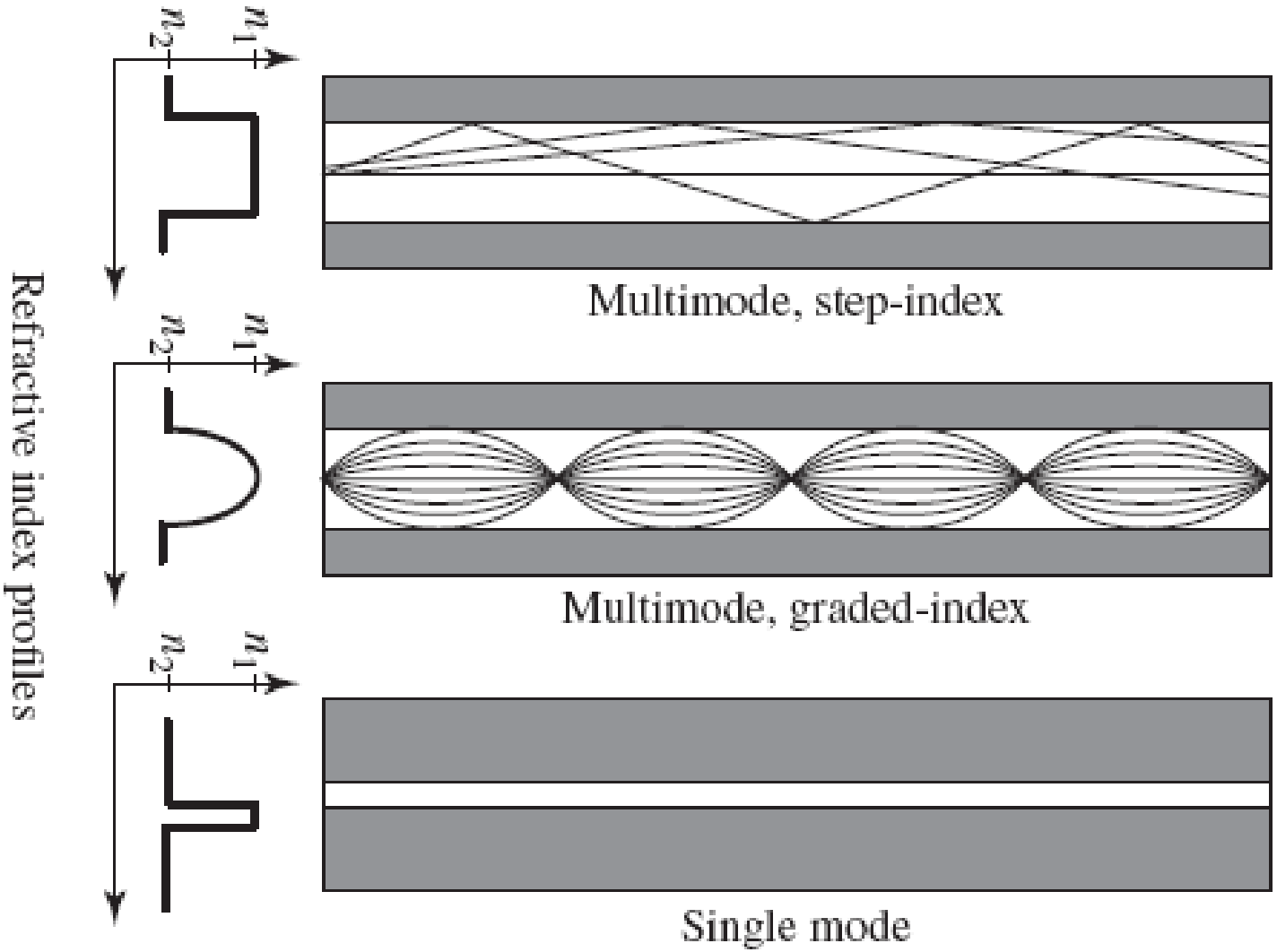
- Light propagates through fiber using *total internal reflection* which is made possible by making refractive index of the core higher than that of cladding.



Types of Fiber

- There are three types of optical fiber as shown in Figure
  - Step-Index Single Mode
  - Step-Index Multimode
  - Graded-Index Multimode

- **Step-index single-mode fiber** allows for only one mode of light ("axial ray") to travel within the fiber
  - Single-mode fibers are used in applications where low signal loss and high data rates are required, such as on long spans in telecommunication networks.


Refractive index profiles
n_1
n_2
Multimode, step-index
Multimode, graded-index
Single mode

Types of Fiber (contd)

The term *multimode* refers to the fact that multiple modes or rays propagate through the fiber.

Step-index multimode fiber has a refractive index profile that undergoes a step change from high to low at the cladding boundary

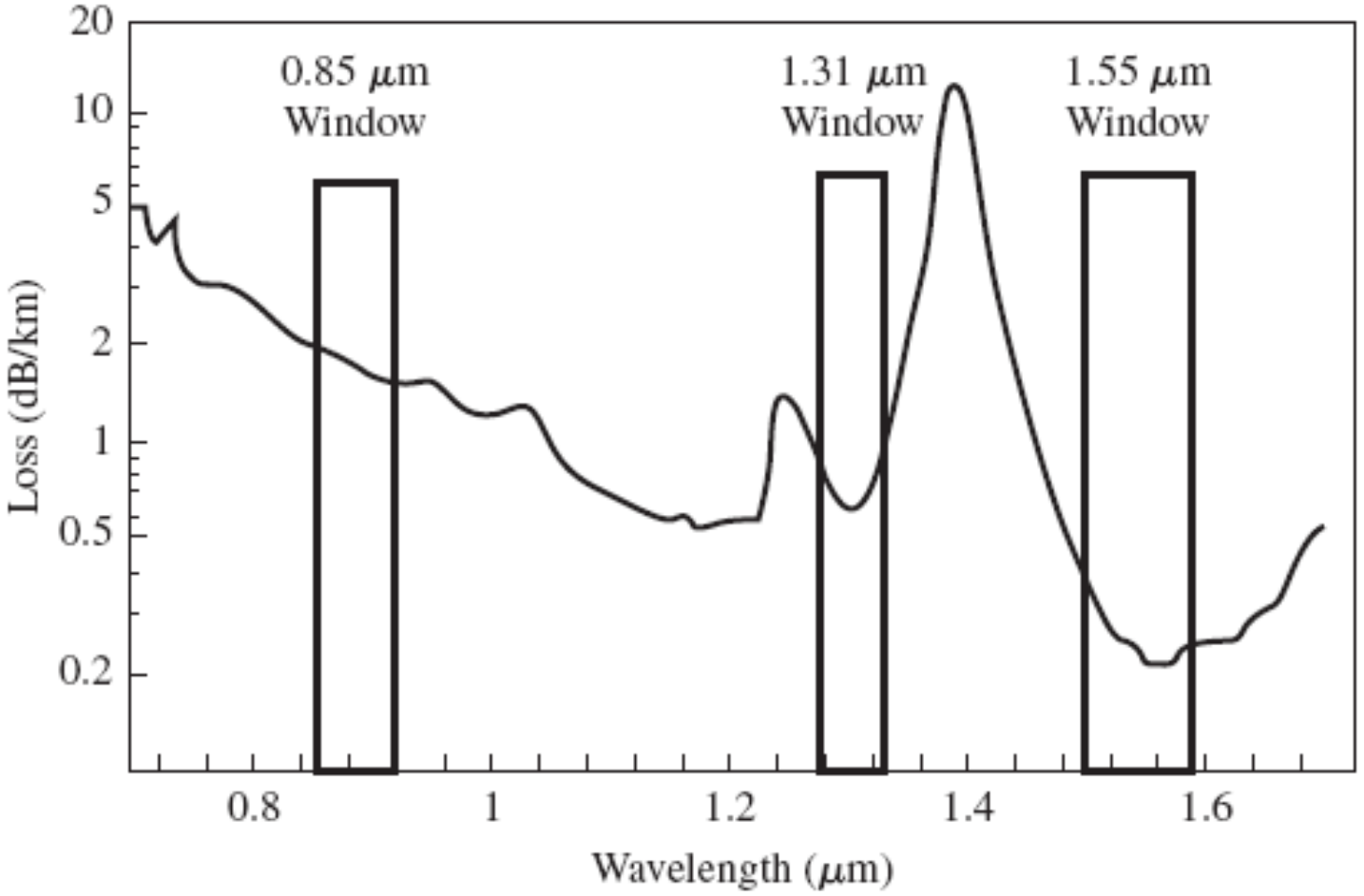
- Different rays ("modes") travel along paths of different lengths $\Rightarrow$ spreading of the pulse at the output.
- Step-index multimode fiber is used in LAN or campus network applications that require high bandwidth over relatively short distances.

Types of Fiber (contd)

- ***Graded Index multimode fiber*** offers a higher bandwidth than a step-index multimode fiber by creating a core whose index of refraction varies parabolically from the center towards the cladding.

- Optical fibers are medium of choice in so many applications because of
  - Lower attenuation การลดทอนต่ำ, as low as 0.2 dB/km at 1550 nm wavelength.
  - Optical bandwidth available in 3 transmission windows as shown in Figure.
  - Dielectric nature of transmission medium provides total electrical isolation and noise immunity.

Attenuation Characteristics of Optical Fibers



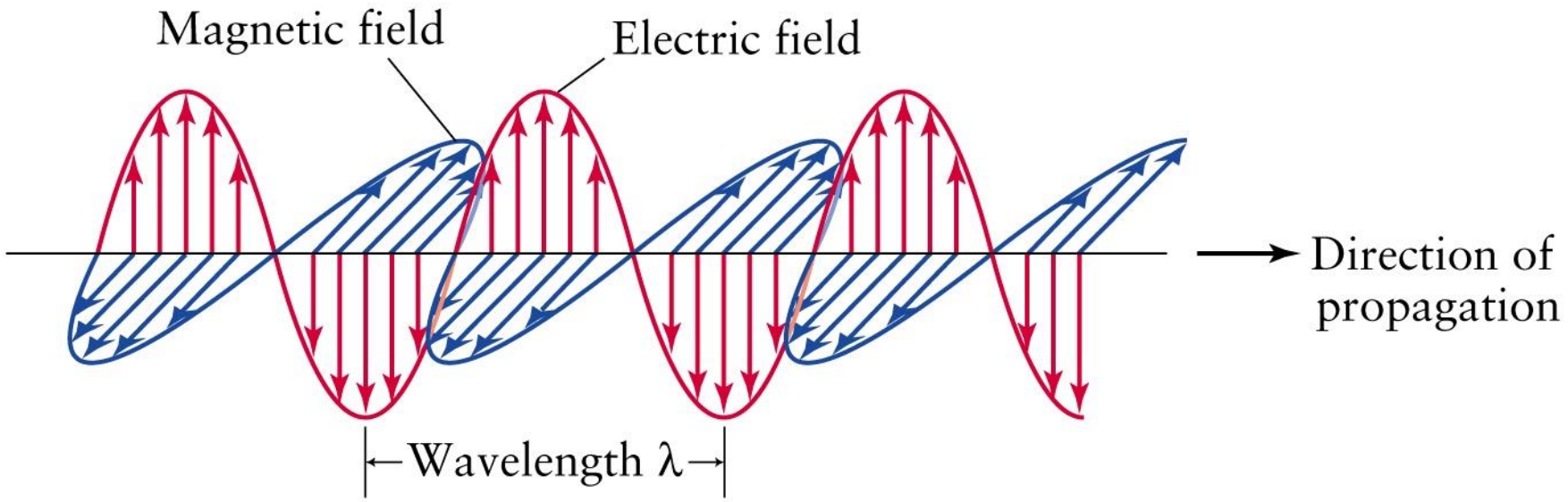
Wireless media : Radio Channels สื่อไร้สาย หรือ คลื่นวิทยุ

- An attractive option for communication is to use electromagnetic (EM) wave propagation through space, i.e., radio.
- Requires the use of frequency spectrum (สเปกตรัม)
- Excellent attenuation characteristics over long distances in specific frequency bands.
- The radio frequency (RF) spectrum is allocated on a worldwide basis by the International Telecommunication Union (ITU) (สหภาพโทรคมนาคมระหว่างประเทศ)
- In United States, the Federal Communications Commission (FCC) (คณะกรรมการกลางกำกับดูแลกิจการสื่อสาร)
- **คณะกรรมการกิจการกระจายเสียง กิจการโทรทัศน์ และกิจการโทรคมนาคมแห่งชาติ (กสทช.)**
- Table 1.1 summarizes the frequency bands in the RF spectrum.

RF Spectrum Allocation

Frequency Band	Frequency Range
Very Low Frequency (VLF)	3–30 kHz
Radio navigation	
Fixed maritime mobile communications	
Submarine communications	
Low Frequency (LF)	30–300 kHz
Fixed maritime mobile communications	
Radio navigation	
Medium Frequency (MF)	300–3000 kHz
AM radio broadcasting	530–1700 kHz
Traveler's information service	
High Frequency (HF)	3–30 MHz
Shortwave radio broadcasting	5.95–26.1 MHz
Very High Frequency (VHF)	30–300 MHz
TV channels 2–6	54–88 MHz
FM radio broadcast	88–108 MHz
TV channels 7–13	174–216 MHz
Ultra High Frequency (VHF)	300–3000 MHz
TV channels 14–83	420–890 MHz
Cellular telephony	824–894 MHz
Industrial, scientific, and medical (ISM): Wi-Fi	902–928 MHz
Global positioning system (GPS)	1227.6, 1575.4 MHz
Cellular telephony: Personal communications services (PCS)	1850–1990 MHz
ISM: Wi-Fi	2400–2483.5 MHz
Superhigh (Microwave) Frequencies (SHF)	3–30 GHz
G band: Geostationary satellite communications	4–6 GHz
J band: Geostationary satellite communications	10.7–14.5 GHz
Ka band: Satellite communications	26.5–40 GHz

- They travel as **vibrations in electrical and magnetic fields.**
  - Have some magnetic and some electrical properties to them.



Allocation of Frequency Spectrum การจัดสรรสเปกตรัมความถี่

Electromagnetic Waves are characterized by:

ความยาวคลื่น **Wavelength, λ [m, cm, mm, μm, etc]**

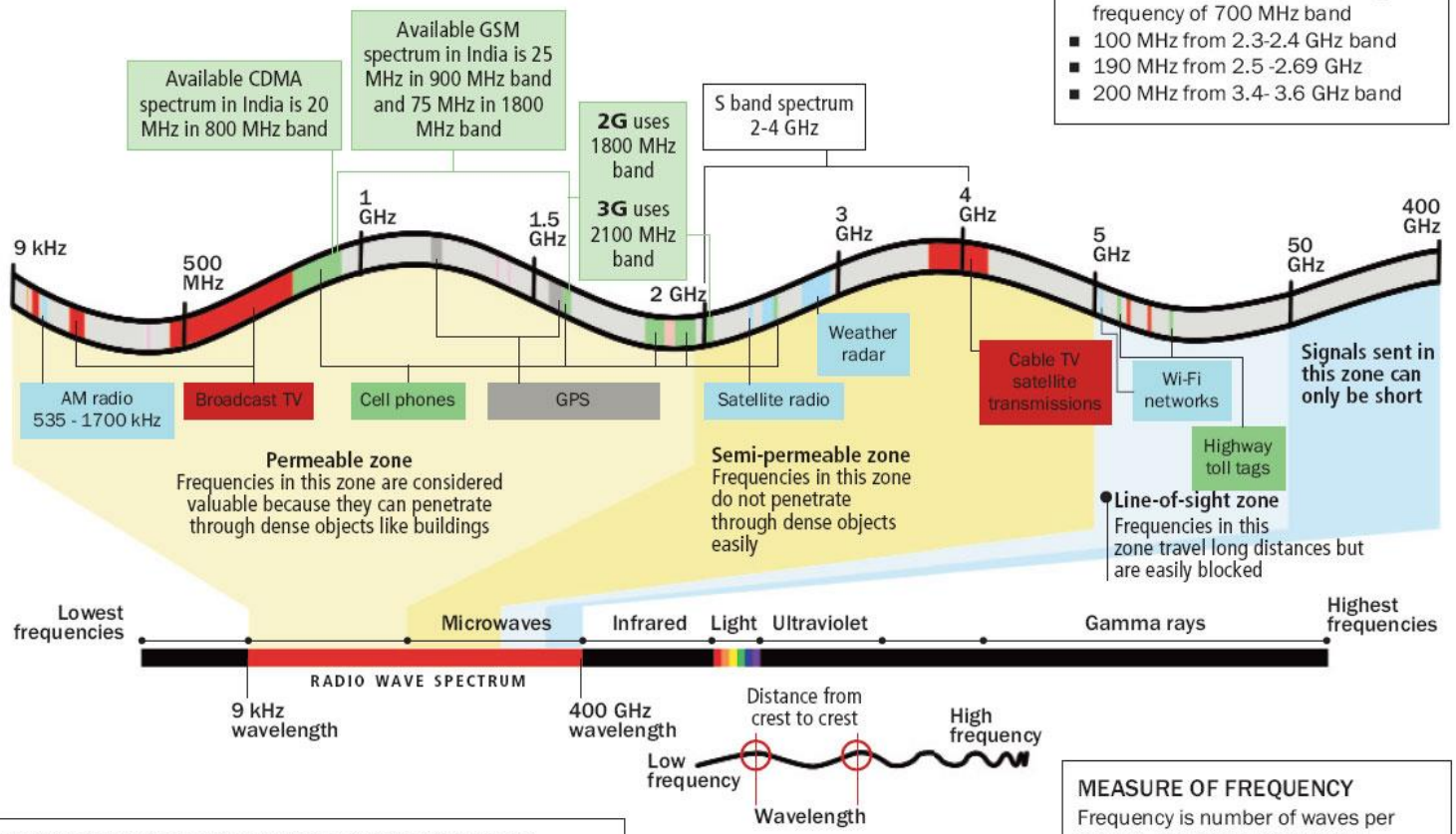
ความถี่ **Frequency, f [s^{-1}, hertz (Hz), megahertz (MHz), gigahertz (GHz), etc]**

where: $c = \lambda f$

c is velocity of radio waves in air

The speed of any electromagnetic waves in free space is the speed of light c = $3x10^8$ m/s

RADIO SPECTRUM



WAYS TO FULFILL DEMAND

Telecom industry is looking towards new sources, including:

- 108 MHz from the broadcasting frequency of 700 MHz band
- 100 MHz from 2.3-2.4 GHz band
- 190 MHz from 2.5 -2.69 GHz
- 200 MHz from 3.4- 3.6 GHz band

EVOLVING MOBILE TECHNOLOGY

- 1G: Short for first generation wireless telephone technology. Mobile phone was first launched in the 1980s in this technology. Radio signals on 1G networks were analog, where information is transmitted by modulating a continuous signal, like sound waves. Used frequency band 824-894 MHz
- 2G: Short for second generation wireless telephone technology. Mobile phone in India was launched based on this technology. Radio signals on 2G networks are digital. It allows data services for mobile phones, including text messages and downloading of ringtones. Uses 1800 MHz band
- 3G: Short for third-generation wireless telephone technology. It supports services like mobile TV and high-resolution video. Uses 2.1 GHz band

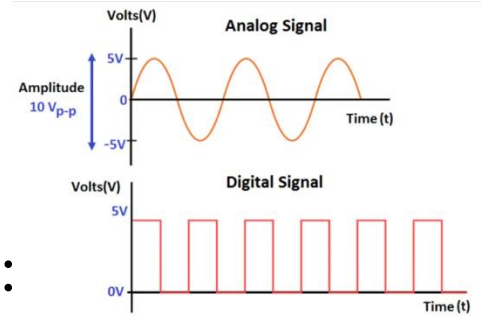
BANDS AVAILABLE FOR MOBILE PHONE SERVICES

800 band = 824-844/869-889 MHz
900 band = 890-915 MHz/935-960 MHz
1800 band = 1710-1785/1805-1880 MHz
2100 band (2.1 GHz) = 1920-1980 MHz/2110-2170 MHz

MEASURE OF FREQUENCY

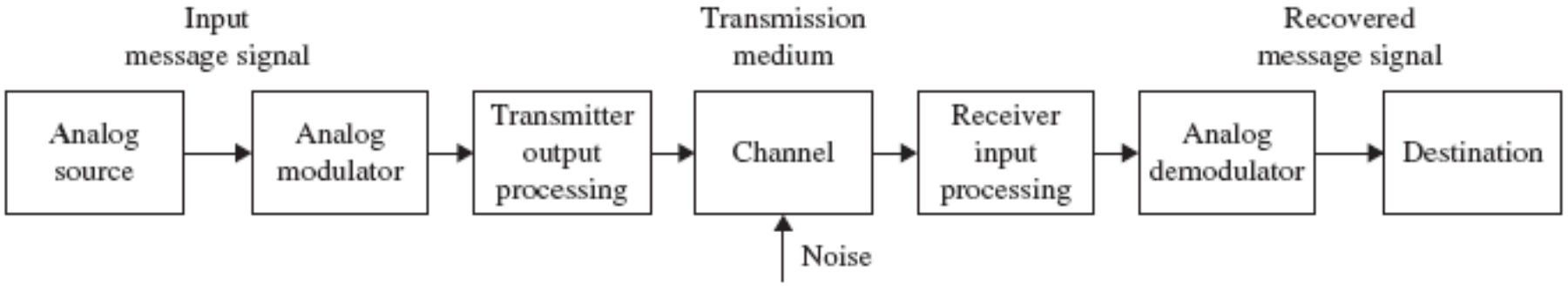
Frequency is number of waves per second. It is measured in hertz.
1 hertz = waves per second
1 kilohertz (kHz) = 1000 hertz
1 megahertz (MHz) = 1000 kHz
1 gigahertz (GHz) = 1000 MHz

Communication Systems ระบบสื่อสาร



- There are two types of Communication Systems :
  - Analog Communication Systems ระบบสื่อสารแอนะล็อก
  - Digital Communication Systems ระบบสื่อสารดิจิทัล

- Analog Communication Systems : Convert analog message signals into waveforms suitable for transmission over a communication channel.

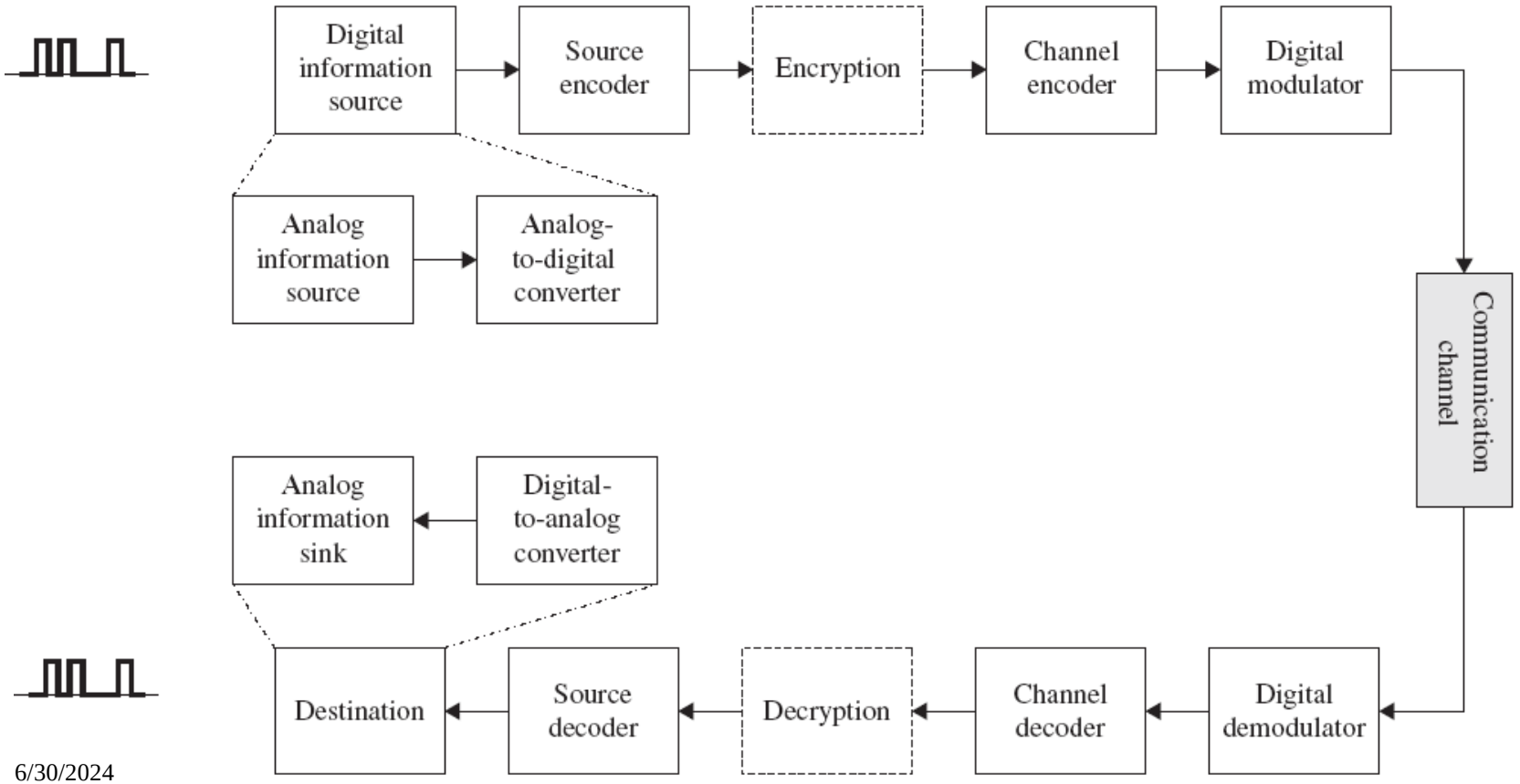


Analog Communication System

- Modulation การมอดูเลต, i.e., vary the amplitude, phase, or frequency of a high-frequency sinusoidal waveform (called a **carrier**) in accordance with the analog message signal.
- At the other end of the channel, the **demodulation** การดีมอดูเลต process recovers the original analog message signal.
- For example, AM and FM broadcasting.
- Performance degraded by noise and other channel impairments.
  - In terms of SNR (signal to noise ratio)

Digital Communication System

- The block diagram of a typical digital communication system is shown in Figure.



Digital Communication System (contd)

- **Digital modulator** – serves as the interface to the communication channel
  - Maps a block of channel encoder output bits into a continuous-time waveform suitable for transmission through the channel. For example, ASK, FSK PSK.
- **Digital demodulator** – processes the channel-distorted and noisy received waveform and generates an estimate of the channel encoder output sequence.
- **Encryption** is optionally used to assure the security of message transmission, that is, only the intended receiver can understand the message and only the authorized sender can transmit it.
- Performance in terms of BER (Bit Error Rate)

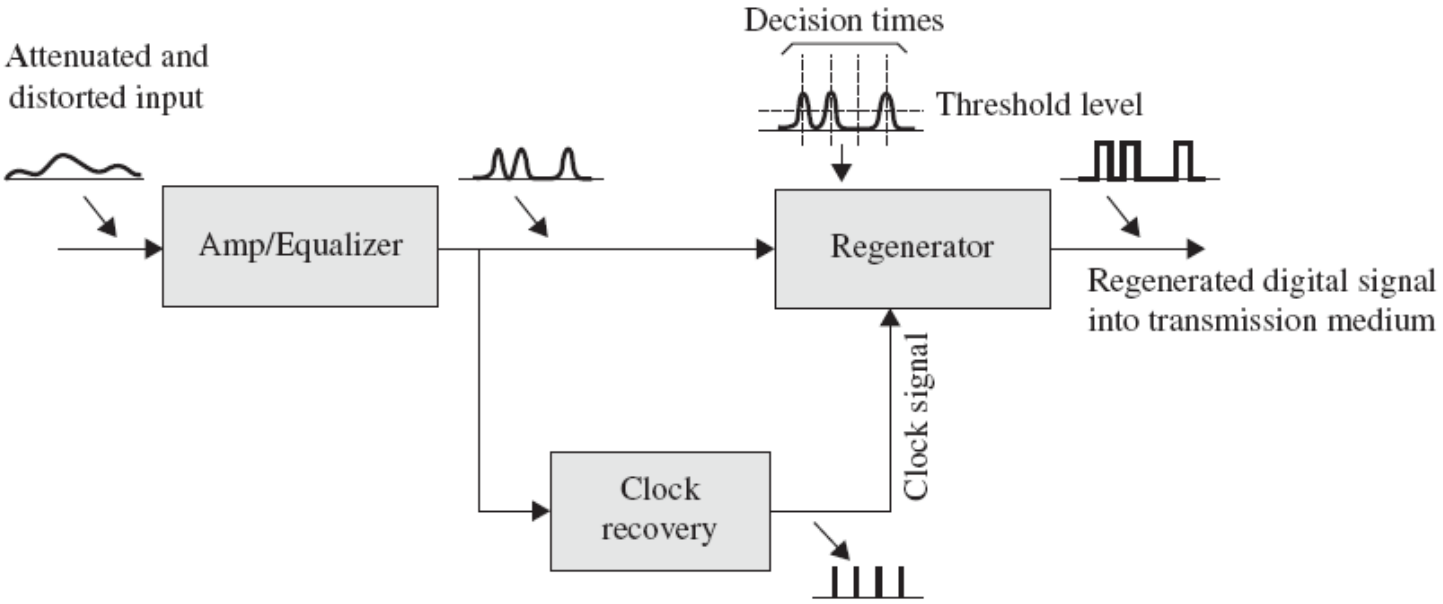
Why Digital Transmission? การสื่อสารดิจิทัล (ทำไม?)

- Digital transmission uses **regeneration**, i.e.,
  - Regeneration การสร้างสัญญาณใหม่⇒ the **rejuvenated** signal สัญญาณที่ได้ใหม่ is like the first time!.
- The **regenerator** produces a **clean** pulse whenever the magnitude of the sample is above the threshold value in the case of binary signaling ⇒ **no** accumulation of noise.

- Error occurs when noise สัญญาณรบกวน and interference สัญญาณแทรกสอด large enough that the received signal sample value crosses the threshold at the sampling point when no pulse is transmitted ⇒ the original symbol can be recovered error free virtually every time.

Why Digital Transmission? (contd)

- Note that the job of **regenerative repeater** is simple; it does not need to restore the original shape of the transmitted signal as in the case of an analog transmission



Advantages of Digital Transmission ข้อดีของการสื่อสารดิจิทัล

- Digital transmission has following advantages

  - **One network for all services** : Digital transmission systems can carry all types of information, whether inherently analog or digital, in one network.

  - **Lower transmitted power** : Digital transmission systems require several orders of magnitude less received power than analog systems for the same user experience or performance (voice or picture quality).

Advantages of Digital Transmission (contd)

- **Enhanced capabilities :** Digital transmission enables easier implementation of multiplexing, error control coding, and compression techniques
  - These capabilities have made feasible the availability of multimedia services and applications on a global scale.

- **Security :** Encrypting digital data is easier, more secure, and more cost effective. With the tremendous growth of mobile communications and electronic financial transactions, protection of information has become very important.

Important Milestones in History of Communications

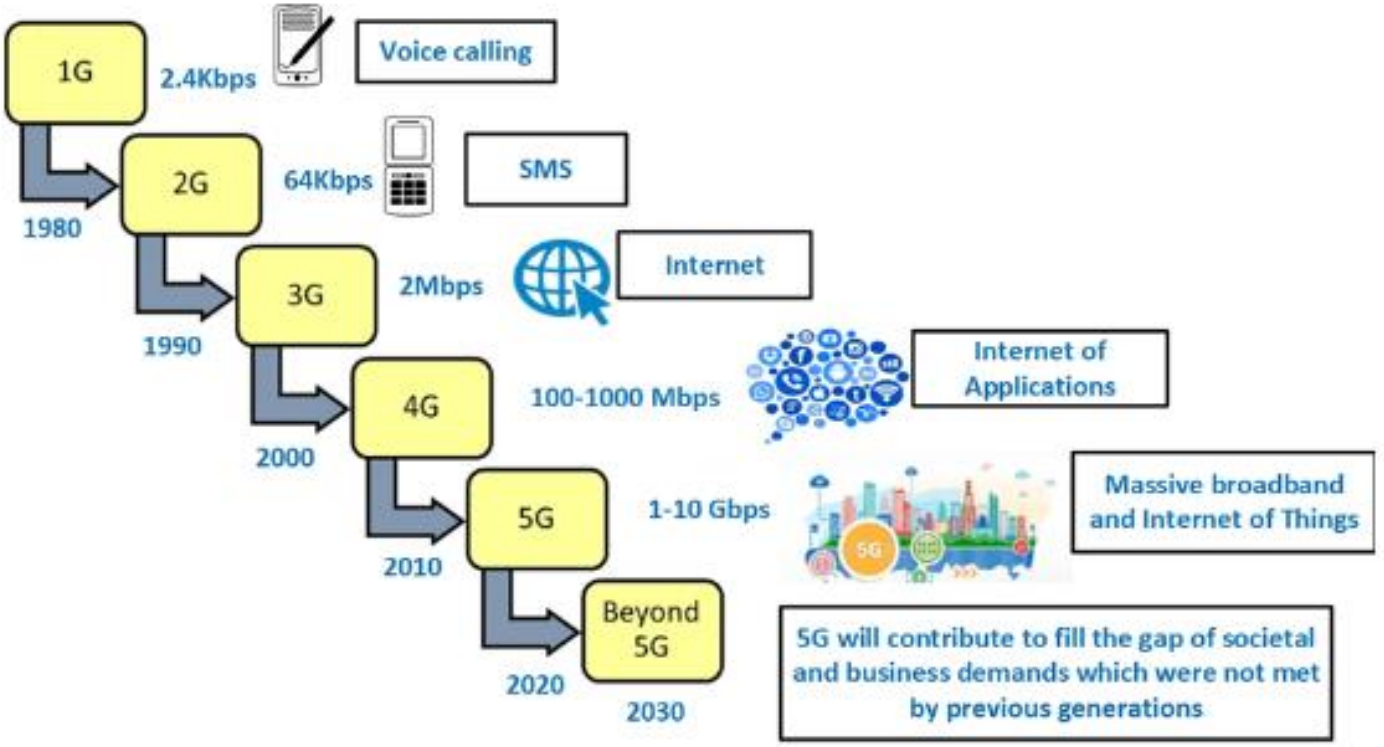
Year	Event
1820	Oersted shows electric currents create magnetic fields
1830–1840	Henry discovers induction; Faraday and others show changing magnetic fields produce electric fields
1838	Samuel Morse demonstrates telegraph
1844	First commercial telegraph link from Baltimore to Washington
1864	James C. Maxwell predicts electromagnetic radiation
1866	Transatlantic telegraph
1876	Alexander Graham Bell files patent application for the invention of telephone
1878	Alexander Graham Bell installs first telephone exchange in New Haven, Connecticut
1887	Hertz experimentally verifies Maxwell theory
1895	Radio, or "wireless," born when Guglielmo Marconi experiments with wireless telegraphy
1901	First transatlantic radio message by Marconi, United Kingdom to Canada
1904–1906	Fleming announces diode tube; DeForest announces triode
1906	AM radio broadcasting
1918	Edwin Armstrong devises superheterodyne receiver
1920	First modern radio broadcast by KDKA, Pittsburgh, Pennsylvania
1924–1928	Mechanical TV system demonstrations by John Baird, London
1928	Gaussian thermal noise papers of Johnson and Nyquist First all-electronic television system demonstrated by Philo Farnsworth, and also independently by Vladimir Zworkin in 1929
1933	Edwin Armstrong invents FM
1936	Commercial TV broadcasting by British Broadcasting Corporation, London

Important Milestones in History of Communications

1937	Alec Reeves patents pulse-code modulation (PCM) in England
1943	D. O. North introduces matched filter for radar detection application
1947	Kotelnikov in Russia introduces signal space concepts to develop theory of optimal reception of digital signals in the presence of noise
1948	Brattain, Bardeen, and Shockley demonstrate transistor in the United States; Claude Shannon publishes *A Mathematical Theory of Communication*
1949	Shannon publishes sampling theorem in the context of communication; Kotelnikov arrived at similar results in 1933 independently
1950–1955	Beginnings of computer software; beginnings of microwave long-haul transmission
1956	First transatlantic telephone cable
1959	Jack Kilby patents integrated circuit
1960s	Error-correcting codes begin rapid development
1960	Theodore Maiman introduces the first working laser in the United States
1962	AT&T introduces T1 digital carrier system, the transmission of voice in digital format First communication satellite, Telstar I, launched
1967	Viterbi proposes algorithm for efficient decoding of convolutional codes
1970	Low-loss optical fibers demonstrated
1971	Microprocessor invented
1975	Robert Metcalfe and others file a patent for Ethernet at Xerox PARC
1976	Apple I home computer invented
1979	First commercial citywide cellular network is launched in Japan by NTT
1981	IBM launches its personal computer (PC)
1983	FT3C (90 Mb/s) digital optical fiber system linking Washington D.C. to New York installed
1983	16-bit DSP chips commercially available
1985–1990	Cellular mobile telephones become widespread in Europe

Important Milestones in History of Communications

1987	EDFA optical amplifier invented, a key enabling technology for wavelength-division multiplexing (WDM) systems
1988	Flash memory commercially available (key technology for PDAs, laptop computers, MP3 players, digital cameras, and cellular phones)
1991	Second-generation (digital) cellular system, GSM, begins operation in Europe
1993	Turbo coding invented by C. Berrou and others, approaches Shannon limit
1996	Demonstration of Tbit/sec rate transmission on single-mode fibers using WDM
Late-1990s	Internet proliferates
2001	First commercial launch of third-generation (3G) cellular network in Japan by NTT DoCoMo using WCDMA technology



Key Themes And Drivers

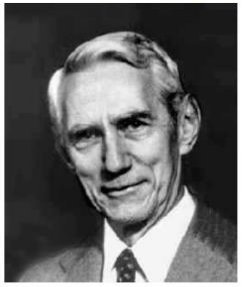
Harry Nyquist (1928)

"Certain topics in telegraph transmission theory", Trans. AIEE, vol. 47, pp. 617–644, Apr. 1928

Sampling Theorem

Continuous-time ⇨ Discrete-time

Claude Shannon (1948)



"A Mathematical Theory of Communication", *Bell System Technical Journal*. 1948

Information Theory

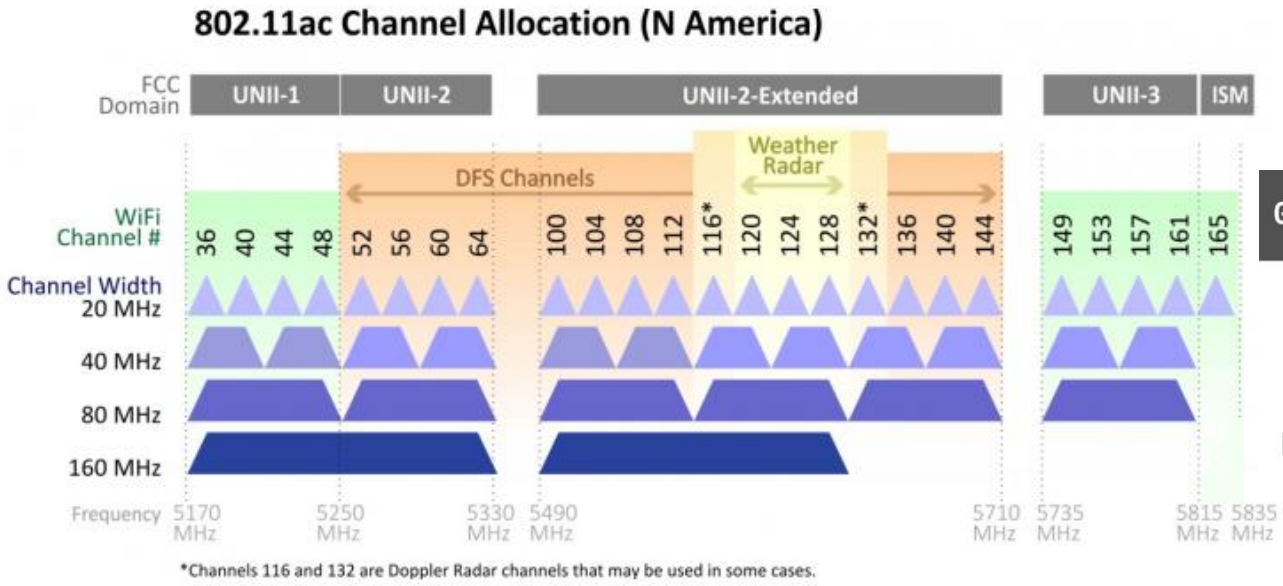
Fundamental limits of source compression rate and channel transmission rate

Analog communication ⇨ Digital communication

Bandwidth แบนด์วิดท์

- Bandwidth (BW) is that portion of the electromagnetic spectrum occupied by a signal.

- Channel bandwidth refers to the range of frequencies required to transmit the desired information.



Generation Wi-Fi	ชื่อเรียกใหม่	สัญลักษณ์
IEEE 802.11ax	Wi-Fi 6	
IEEE 802.11ac	Wi-Fi 5	
IEEE 802.11n	Wi-Fi 4	