Principles of Communications
通訊原理
Lecture 0: Introduction

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Time/Date/Instructor

- 9:10 – 10:00am (Tuesday) ED201;

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  Please make an appointment in advance (請儘可能事先預約時段)
- Class notes:
  - Adapted from Prof. Hsueh-Ming Hang's class notes
  - http://twins.ee.nctu.edu.tw

Textbook & Grading

- **Textbook:** R. E. Ziemer and W. H. Tranter, *Principles of Communications*, 6th ed., Wiley, 2010.
- **Recommended Readings**:

  1. S. Haykin and M. Moher, *Communication Systems*, 5th ed., Wiley, 2010.
  2. J. G. Proakis and M. Salehi, *Fundamentals of Communication Systems*, Prentice-Hall, 2004.
  3. A. B. Carlson and P. B. Crilly, *Communication Systems*, 5th ed, McGraw Hill, 2009.

- **Lectures and Homework Assigns: 20%**
- **Quiz: 10%**
- **Midterm Exam.: 35%**
- **Final Exam: 35%**

Course Contents

- The first course (of the series) mainly covers the analog communications system, but an introduction to the digital communications is also included.

- Prerequisites:
  - Signals and Systems, Probability, Linear algebra

"Chap 0"

- What is a "communication system"?
- Example: "mobile phone"
- Goal: Send "messages" to the other end (person)
  - What is "message" ("information")?
  - What is the media that can carry messages?
  - What are the problems? "Uncertainty"

Communication System?

- A communication system conveys information from a source to a destination.

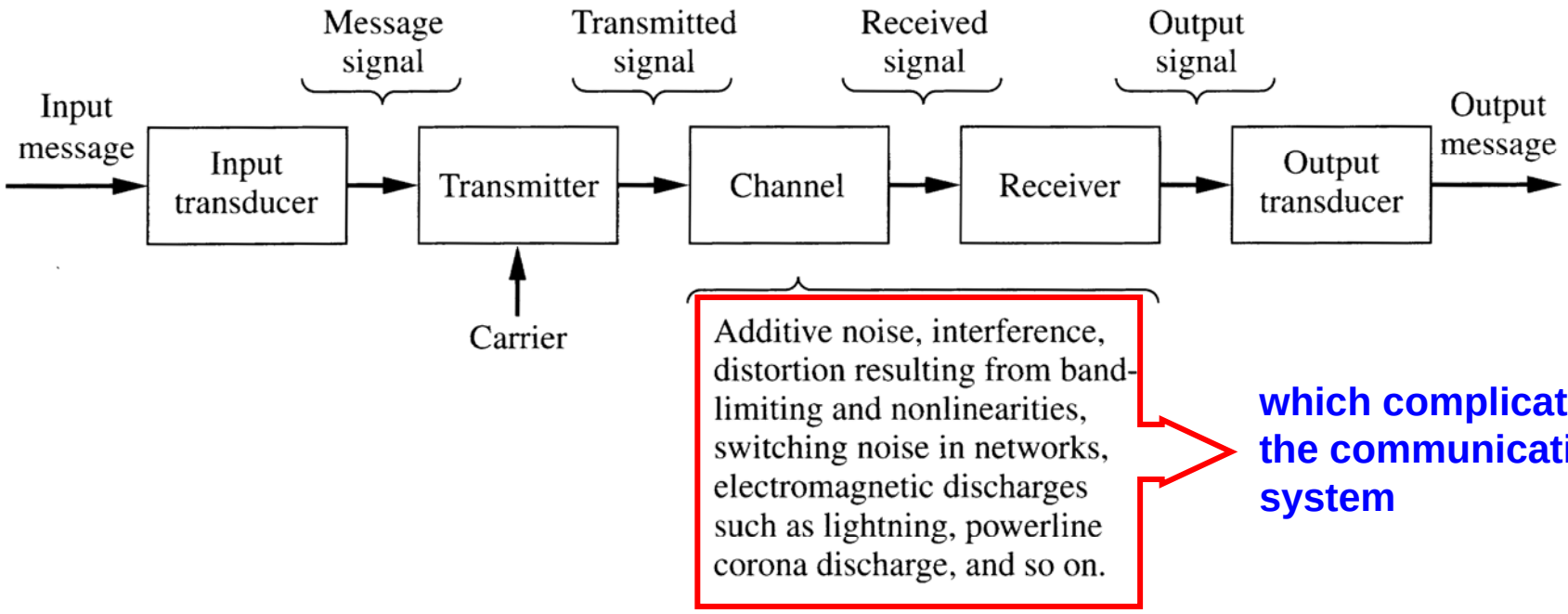


Figure 1.1
The Block Diagram of a Communication System.

Communication Channels Example

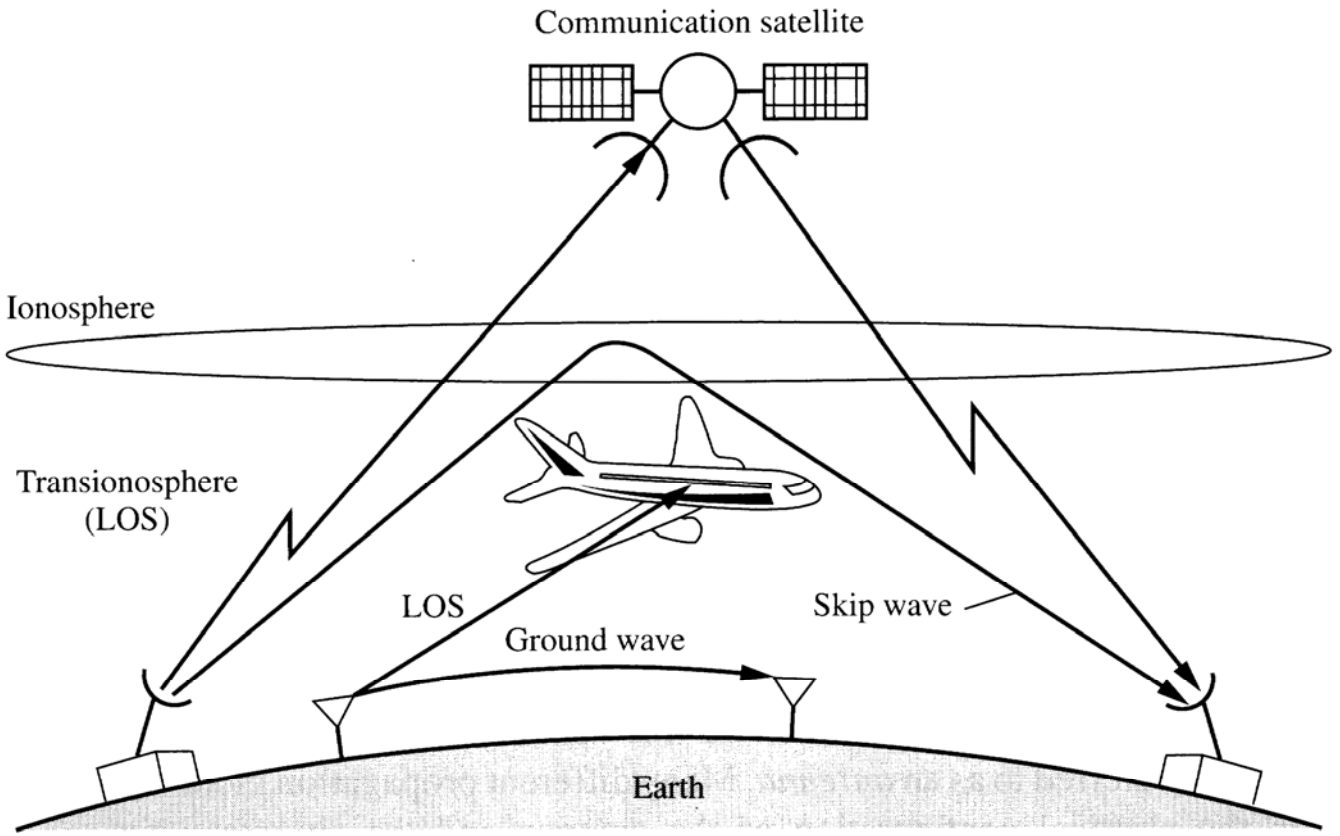


Figure 1.2
The various propagation modes for electromagnetic waves.

Fundamental Limitations

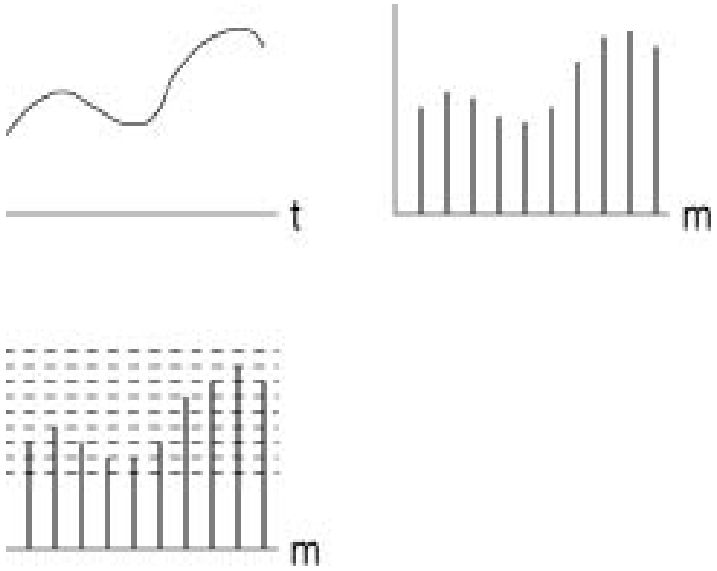
- Goal of communication:

  Reliable transmission (reproduce source messages at the destination)
- Fundamental limitations of communication systems

  -- limited by imperfect channel:
  - **bandwidth** and **noise**
  - **Shannon Theorems**

Signals (Waveforms)

	Time/ Space	Amp.
Analog Signals x(t)	Conti.	Conti.
Discrete-time (discrete-space) (sampled-data) signal x(m)	Discrete	Conti.
Digital signals x(m)	Discrete	Discrete



Communication System Types

- Analog communication system:
  - Messages are analog signals
- Digital communication system:
  - Messages are digital signals
- Techniques used in communication systems
  - Analog commun.: Modulation (demodulation) *Modem*
  - Digital commun.: Modulation
    Channel coding
    Source coding (compression)

Digital Communication System

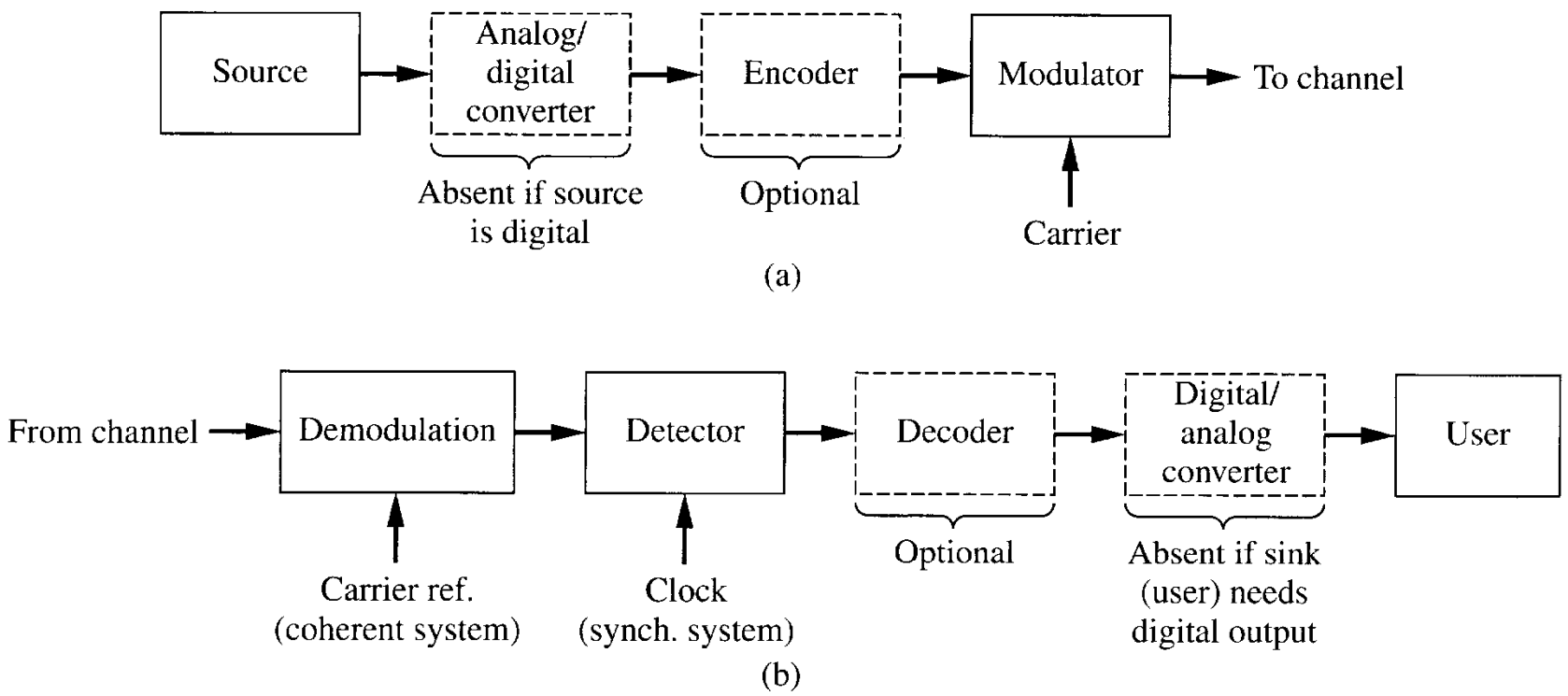


Figure 8.1
Block diagram of a digital data transmission system.(a) Transmitter. (b) Receiver.

Some Terminologies (1)

- **Input Transducer**

  Messages: analog or digital

  Message conversion: e.g. speech → voltage variations
- **Transmitter**

  Purpose: couple the message to the channel

  Primary functions: modulation, filtering, amplification, and coupling.
- **Modulation:**

  (1) for ease of radiation

  (2) to reduce noise and interference

  (3) for channel assignment

  (4) for multiplexing or transmission of several messages over a single channel

  (5) to overcome equipment limitations.

Some Terminologies (2)

- **Channel:** Signal degradation.
- **Receiver:** Primary functions are demodulation and amplification.
- **Output Transducer:** Loudspeaker, tape recorders, personal computers, LCD screens, etc.
- **Noises (Three major sources listed below)**

  Internal noise: Noise generated by components within a communication system, such as resistors and solid-state active devices. (Thermal noise, shot noise, etc.)

  External noise: Atmospheric noise; Man-made noise (Ignition noise; Switching noise; Radio-frequency interference (RFI), etc.)

  Extraterrestrial noise: Solar & cosmic noise
- **Signal degradation:** Fading

Modulation

- Our focus in Commun. Principles:
  - **Modulation** techniques in analog (and digital) commun. systems
- Why modulation?
  - Efficient transmission – shift frequency

    -- Overcome hardware limitation
  - Reduce noise and interference
  - Frequency assignment

    -- Multiplexing

Wireless Channels

- Physical RF Bands

Table 1.2 Frequency Bands with Designations

Frequency band	Name	Microwave band (GHz)	Letter designation	
			Old	Current
3–30 kHz	Very low frequency (VLF)	0.5–1.0		C
30–300 kHz	Low frequency (LF)	1.0–2.0	L	D
300–3000 kHz	Medium frequency (MF)	2.0–3.0	S	E
3–30 MHz	High frequency (HF)	3.0–4.0	S	F
30–300 MHz	Very high frequency (VHF)	4.0–6.0	C	G
0.3–3 GHz	Ultrahigh frequency (UHF)	6.0–8.0	C	H
3–30 GHz	Superhigh frequency (SHF)	8.0–10.0	X	I
30–300 GHz	Extremely high frequency (EHF)	10.0–12.4	X	J
43–430 THz	Infrared (0.7–7 μm)	12.4–18.0	Ku	J
430–750 THz	Visible light (0.4–0.7 μm)	18.0–20.0	K	J
750–3000 THz	Ultraviolet (0.1–0.4 μm)	20.0–26.5	K	K
		26.5–40.0	Ka	K

Note: kHz = kilohertz = hertz $\times 10^3$; MHz = megahertz = hertz $\times 10^6$; GHz = gigahertz = hertz $\times 10^9$; THz = terahertz = hertz $\times 10^{12}$; μm = micrometers = $\times 10^{-6}$ meters.

RF Commun. Bands

Table 1.3 Selected Frequency Bands for Public Use and Military Communications

Use		Frequency
Omega navigation		10–14 kHz
Worldwide submarine communication		30 kHz
Loran C navigation		100 kHz
Standard (AM) broadcast		540–1600 kHz
ISM band	Industrial heaters; welders	40.66–40.7 MHz
Television:	Channels 2–4	54–72 MHz
	Channels 5–6	76–88 MHz
FM broadcast		88–108 MHz
Television	Channels 7–13	174–216 MHz
	Channels 14–83 (In the United States, channels 2–36 and 38–51 will be used for digital TV broadcast; others will be reallocated.)	420–890 MHz
Cellular mobile radio (plus other bands in the vacinity of 900 MHz)	Mobile to base station	824–849 MHz
	Base station to mobile	869–894 MHz
ISM band	Microwave ovens; medical	902–928 MHz
Global Positioning System		1227.6, 1575.4 MHz
Point-to-point microwave		2.11–2.13 GHz
Personal communication services	CDMA cellular in North America	1.8–2.0 GHz
Point-to-point microwave	Interconnecting base stations	2.16–2.18 GHz
ISM band	Microwave ovens; unlicensed spread spectrum; medical	2.4–2.4835 GHz
		23.6–24 GHz
		122–123 GHz
		244–246 GHz

台灣數位電視頻道分配

5 Broadcasters: TTV, CTV, CTS, FTV, PTV

NTSC:

-- n(north)

-- m(mid-Taiwan)

-- s(south)

DTTV: 2 channels for full-coverage use

Ch. No.	category	user		Ch. No.	category	user
5	VHF NTSC TV (8)	FTV		36	UHF Broadcast Reception Improve-Ment (12)	CTS-DTV
6		FTV		37		–
7		TTV(n)		38		–
8		CTS(m)		39		–
9		CTV(n)		40		–
10		CTV(m)		41		–
11		CTS(n)		42		–
12		TTV(m)		43		–
13	VCR	VCR-TV		44		–
24	Open (not Used) (6) UHF	CTV-DTV		45		–
25		CTV-DTV		46		–
28		FTV-DTV		47		–
29		FTV-DTV		48		–
31		TTV-DTV		49		Police
32		TTV-DTV		50	UHF broadcast (4)	PTV-DTV
33	UHF CTS Edu (4)	Edu(m)		51		PTV(s)
34		CTS-DTV		52		PTV-DTV
35		Edu(n)		53		PTV(m)

History (1)

Table 1.1 Major Events and Inventions in the Development of Electrical Communications

Year	Event
1791	Alessandro Volta invents the galvanic cell, or battery.
1826	Georg Simon Ohm establishes a law on the voltage–current relationship in resistors.
1838	Samuel F. B. Morse demonstrates the telegraph.
1864	James C. Maxwell predicts electromagnetic radiation.
1876	Alexander Graham Bell patents the telephone.
1887	Heinrich Hertz verifies Maxwell's theory.
1897	Guglielmo Marconi patents a complete wireless telegraph system.
1904	John Fleming patents the thermionic diode.
1905	Reginald Fessenden transmits speech signals via radio.
1906	Lee De Forest invents the triode amplifier.
1915	The Bell System completes a U.S. transcontinental telephone line.
1918	B. H. Armstrong perfects the superheterodyne radio receiver.
1920	J. R. Carson applies sampling to communications.

History (2)

1925–1927	First television broadcasts in England and the United States.
1931	Teletypwriter service is initialized.
1933	Edwin Armstrong invents frequency modulation.
1936	Regular television broadcasting begun by the British Broadcasting Corporation.
1937	Alec Reeves conceives pulse-code modulation (PCM).
WWII	Radar and microwave systems are developed. Statistical methods are applied to signal extraction problems.
1944	Computers put into public service (government owned).
1948	The transister is invented by W. Brattain, J. Bardeen, and W. Shockley.
1948	Claude Shannon's *A Mathematical Theory of Communications* is published.
1950	Time-division multiplexing is applied to telephoney.
1956	First successful transoceanic telephone cable.
1959	Jack Kilby patents the "Solid Circuit"—precurser to the integrated circuit.
1960	First working laser demonstrated by T. H. Maiman of Hughes Research Labs. (Patent awarded to G. Gould after a 20 year dispute with Bell Labs.)
1962	First communications satellite, Telstar I, launched.
1966	First successful facsimile (FAX) machine.
1967	U.S. Supreme Court Carterfone decision opens the door for modem development.
1969	Live television coverage of the manned moon exploration (Apollo 11).

History (3)

1969	First Internet started—ARPANET.
1970	Low-loss optic fiber developed.
1971	Microprocessor invented.
1975	Ethernet patent filed.
1976	Apple I home computer invented.
1977	Live telephone traffic carried by a fiber-optic cable system.
1977	Interplanetary grand tour launched: Jupiter, Saturn, Uranus, and Neptune.
1979	First cellular telephone network started in Japan.
1981	IBM personal computer developed and sold to public.
1981	Hayes Smartmodem marketed (automatic dial-up allowing computer control).
1982	Compact disc (CD) audio based on 16-bit PCM developed.
1983	First 16-bit programmable digital signal processors sold.
1984	Divestiture of AT&T's local operations into seven Regional Bell Operating Companies.
1985	Desktop publishing programs first sold. Ethernet developed.
1988	First commercially available flash memory (later applied in cellular phones, etc.).

History (4)

1988	Asymmetric digital subscriber lines (ADSL) developed.
1990s	Very small aperture satellites (VSATs) become popular.
1991	Application of echo cancellation results in low-cost 14,400-bps modems.
1993	Invention of turbo coding allows approach to Shannon limit.
mid-1990s	Second generation (2G) cellular systems fielded.
1995	Global Positioning System (GPS) reaches full operational capability.
1996	All-digital phone systems result in modems with 56 kbps download speeds.
late 1990s	Widespread personal and commercial applications of the Internet.
	High definition TV becomes mainstream.
2001	Apple iPoD first sold (October); 100 million sold by April 2007.
	Fielding of 3G cellular telephone systems begins. WiFi and WiMAX allow wireless access to the Internet and electronic devices wherever mobility is desired.
2000s	Wireless sensor networks, originally conceived for military applications, find civilian applications such as environment monitoring, healthcare applications, home automation, and traffic control as well.

Course Outline

- Introduction
- Review of signals and systems
- Analog signal transmission and reception
- Introduction to digital communications
- Review of probability
- Random processes
- Effect of noise on analog communication systems