Advanced Communication Systems

ELEN90051 (Lecturer: Margreta Kuijper)

Introduction and subject outline

1st Semester 2018

Subject Information

Lecture times and venues

- Tuesdays 5:15 – 6:15pm Theatre 3 (FBE Business and Economics Building, 2nd floor)
- Wednesdays 2:15 – 3:15pm Theatre C (124, Old Arts Building)
- Thursdays 9:00 – 10:00am Theatre C (124, Old Arts Building)

Some of these lectures are dedicated to interactive student-led tutorial sessions.

Consultation times

- Tuesdays 1-2pm, Rm 216, Main EE Building.

Workshop times and venues: see LMS, please enrol in 1 workshop slot per week; Workshops start in week 3.

Subject Information

Assessment

- Final written exam (60%) – Hurdle requirement
- Workshops (30%) – Starting from Week 3
- Progress test (10%) – to be held on **Tuesday 24 April 5:15pm at Union Hall** (in week 8)

Textbook

- J.G. Proakis and M. Salehi, *"Digital Communications"*, 5th ed, McGraw Hill 2008

Other good reference books

- see LMS "Subject information"

Prerequisites

- ELEN90057 Communication Systems

Course Outline

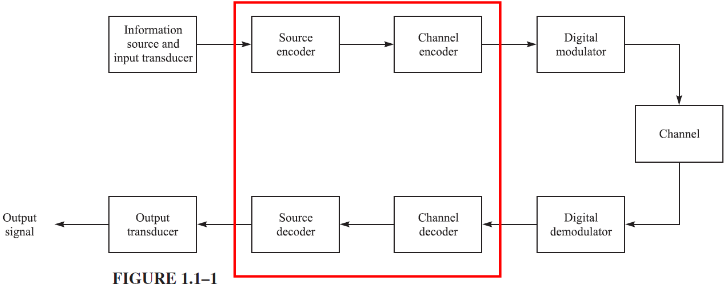


FIGURE 1.1–1
Basic elements of a digital communication system.

Part 1 – Source Coding

- Entropy,
- Huffman coding, Lempel-Ziv coding, arithmetic coding
- Image compression.

Course Outline

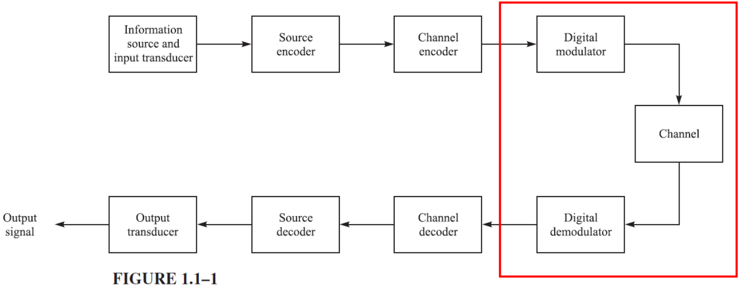


FIGURE 1.1–1
Basic elements of a digital communication system.

Part 2 – Digital Modulation and Demodulation

- Digital modulation for AWGN channels
- Optimum receivers for AWGN channels
- Probability of error analysis
- Digital communication through band-limited channels

Course Outline

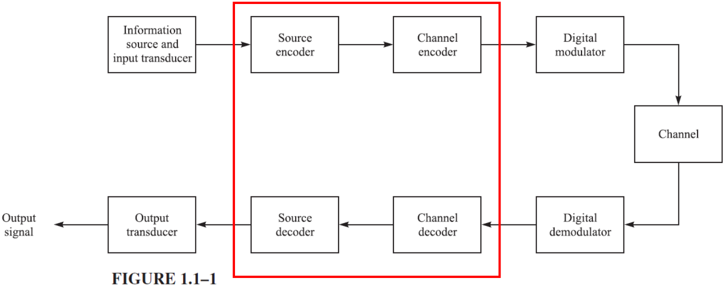


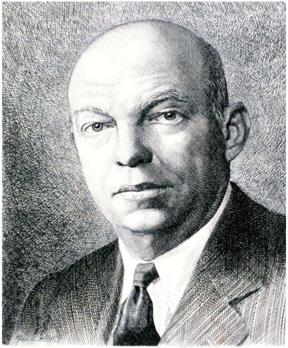
FIGURE 1.1–1
Basic elements of a digital communication system.

Part 3 – Channel Coding

- Channel capacity
- Linear block codes, Hamming codes, Reed-Solomon (RS) codes
- Codes on graphs, convolutional codes, turbo codes, Low Density Parity Check (LDPC) codes.

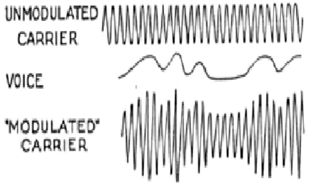
Analog Radio

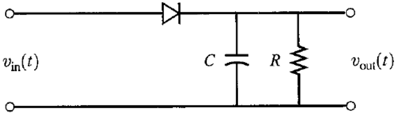
- In 1896, Guglielmo Marconi demonstrated first long distance wireless radio transmission.
- In 1920, first commercial AM radio station established in USA.
- In 1933, Edwin H. Armstrong invented FM system.



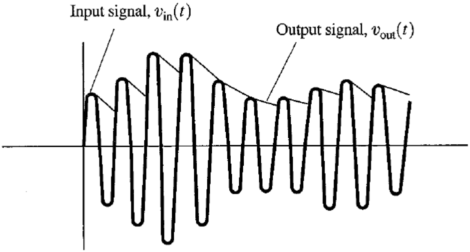
EDWIN H. ARMSTRONG
1890 - 1954

Amplitude Modulation

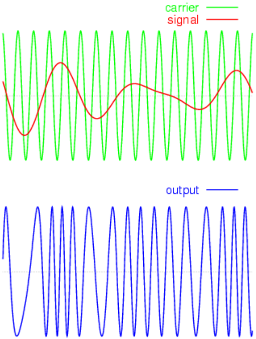


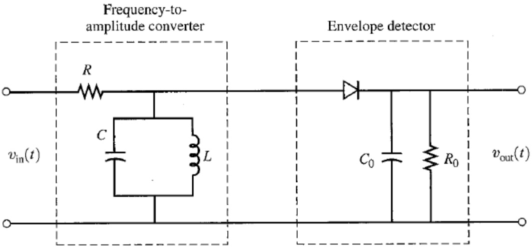


A Diode Envelope Detector



Frequency Modulation





Analog Television

- In 1956, first televised news bulletin in Australia presented by ABC TV.
- By the mid-1960s, colour TV broadcasting was widely used in the industry.

Analog Mobile

- In 1979, the world's first cellular system was implemented by Nippon Telegraph and Telephone (NTT) in Japan using 600 FM duplex channels.
- In 1983, US deployed its own cellular system known as Advanced Mobile Phone System (AMPS) developed by Bell Labs.

Digital Television

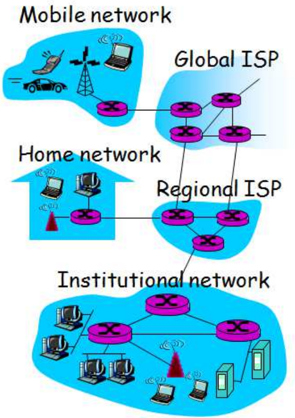
- In Australia, digital TV broadcast began in 2001: Supports high resolution video image, improved sound quality, and additional services such as electronic program guides (EPG).
- Also supports encryption (—> more control by the broadcaster)
- Analog TV signals permanently switched off on 10 December 2013. Resulted in reallocation of TV bands to clear up 694-820 MHz for mobile communications ⇒ Digital dividend

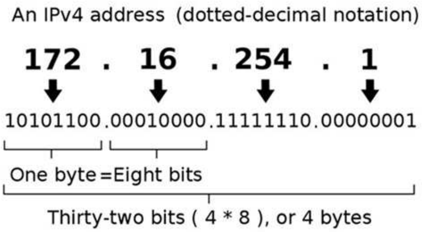
Digital Mobile

- In 1990s, 2G digital cellular networks were deployed in Europe (GSM) and US (CDMA).
- 2G introduced text messaging (SMS) and other data services.
- 3G developed to support high-speed data transmission.
- 4G supports theoretical peak download speeds of 100 Mbps for high mobility and 1 Gbps for low mobility. Operates on all-Internet Protocol (IP) core network using **packet switching** for both voice and data traffic. This enables the Internet of Things.

Digital Internet

Data grouped into **packets** which are essentially a series of bits (ELEN90061 Communication Networks).





Digital Communications

Advances in electronic circuits and communications theory as well as data compression enable low-cost, long-range, and high-speed digital communications.

- Transistor (1948), integrated circuit (1958), fibre optic cables (1966), etc.
- Nyquist theorem (1924), optimum linear filter (1942), Shannon capacity (1948), geometric signal representation (1947), Hamming codes (1950), Reed-Solomon codes (1960), Viterbi algorithm (1967), Trellis Coded Modulation (1982) etc.
- Shannon Source Coding Theorem (1948), Huffman coding (1951), Lempel Ziv coding (1977), arithmetic coding (IBM, 1976)

Current impact of Digital Communications

For example recent trends are:

- video-on-demand (catch up TV, Netflix etc)
- Internet of Things, for example
  - vehicle tracking
  - smart metering
  - smart recycling bins (from IEEE Spectrum, January 2018)

  - smart streetlights (from IEEE Spectrum, January 2018)

PREDICTING FUTURE DIRECTIONS IN THE PAST

This prototype player, which will be put on the market later, will display 'information for the listener' such as title, composer, 'track number' and playing time of the piece of music. The different sections of the music on the disc can also be played in the order selected by the user — the numbers on the far right.

FIGURE: from "Philips Technical Review, Vol. 40, 1982

PREDICTING FUTURE DIRECTIONS IN THE PAST

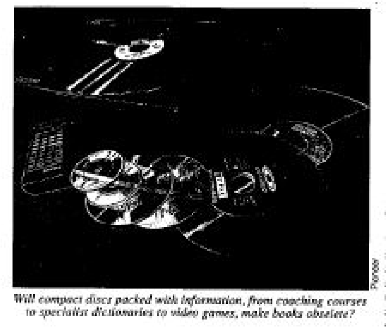


FIGURE: from "Multimedia in a muddle" by Barry Fox, New Scientist 1991

PREDICTING FUTURE DIRECTIONS IN THE PAST

Photographers will soon be able to store their work on a compact disc and play back the images through a television screen

FIGURE: from "Multimedia in a muddle" by Barry Fox, New Scientist 1991

DIGITAL COMMUNICATIONS: FUTURE DIRECTIONS

- 5G in approximately 2019, leading to improvements in speed, throughput etc.
- driver-less cars use digital communication
- The Internet of Things is only just starting, it will expand creating
    - Smart Homes
    - Smart Cities
    - Intelligent Transport
    - E-health,

  just to name a few.

DIGITAL COMMUNICATIONS SYSTEM

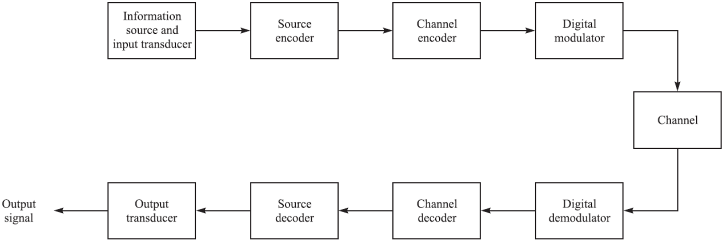
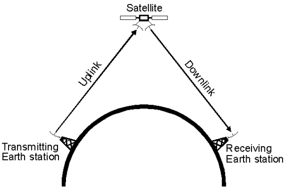


FIGURE 1.1–1
Basic elements of a digital communication system.

- Source encoder: Converts source data into bits and minimize redundancy, e.g. zip, jpeg.
- Channel encoder: Introduces controlled redundancy in bit sequence to overcome errors due to noise and interference in channel.
- Digital modulator: Maps bit sequence to signal waveforms that can be transmitted over the channel.

Digital Communications System

Transmission: From place A to place B, e.g., telephone, satellite, GPS, radio and TV broadcast, computer networks, Internet, etc.



Storage: From time A to time B, e.g., optical discs (CD, DVD, Blu-ray), magnetic disks (HDD), electronic disks (USB, SSD), etc.

Communication Channels

Examples of physical channels:

- Deep space, earth atmosphere, underwater acoustic channels, copper cables, fibre optic cables, optical discs

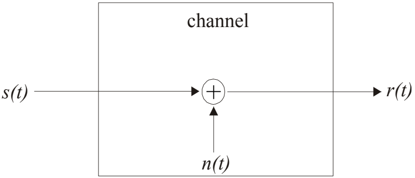
Examples of random channel impairments:

- Noise, e.g., thermal noise due to heat in hardware, atmospheric noise, man-made noise
- Interference, e.g., co-channel signals from other users
- Physical impairments, e.g., fingerprints/scratches
- Fading due to the presence of objects in path (ELEN90007 Wireless Communication Systems)

Communication Channels

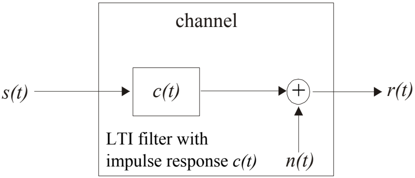
Additive White Gaussian Noise (AWGN) Channel Model:

$r(t) = s(t) + n(t)$ where $s(t)$ is transmitted signal and $n(t)$ is noise



Linear Filter Channel Model (Band-Limited Channel):

$$r(t) = s(t) * c(t) + n(t)$$
$$= \int_{-\infty}^{\infty} c(\tau)s(t-\tau)d\tau + n(t)$$



- Digital demodulator: Processes the received signal waveforms into bit estimates to be decoded by channel decoder. Designed to minimize error in estimates based on knowledge of the channel.

How to Assess Performance?

- Demodulator-decoder combination measured by average bit error rate (BER) and average symbol error rate (SER).
- BER/SER are functions of:
  - Code characteristics
  - Types of modulation waveforms
  - Transmitter power
  - Channel characteristics
  - Method of demodulation and decoding
- Other aspects:
  - Transmission speed
  - Energy efficiency
  - Bandwidth utilization

Digital vs Analog

Recall: Nyquist-Shannon Sampling Theorem

If signal is bandlimited to W, then it is sufficient to sample with sampling rate

$$f_s > 2W$$

in order to construct signal exactly. 2W = Nyquist sampling rate

Example—a naive view:

- Transmit voice signal with 3 kHz bandwidth
- Use sampling rate of 8 kHz
- Quantize each sample with 8 bits $\Rightarrow$ 64kbps
- Binary modulation $\Rightarrow$ about 64 kHz needed

It seems that going digital requires a big bandwidth expansion. But, in reality digital TV uses *much less bandwidth* than analog TV. How can this be? You will find out in this subject.

Advantages of Digital over Analog

- Enables compression
- Higher resistance to noise and channel corruption
- Flexibility in bandwidth and power trade-off
- Easy to incorporate secure digital cryptographic techniques
- Efficient design and implementation process due to modular system
- Utilizes cost-effective hardware, e.g., transistors, semiconductor-based integrated circuits, fibre optic cables