Section 1: Introduction

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1. Introduction

1.1 What is Communication?

Communication involves the transmission of information from one point to another.

Communication Theory is the study of communication systems and the signals associated with them.

Various aspects include:

- Signal representation in time & frequency
- Bandwidths required for various signals
- Modulation and demodulation methods
- Filtering of signals
- Random signals and noise
- Effects of noise on communication systems
- Errors in digital systems
- Coding and error correction
- Information theory

By necessity, the transmission of information from one point to another requires that the signals be random (unknown), since if they were deterministic (known), there would be no need to transmit them.

The basic message signal is called the ***baseband*** signal, and this is usually converted into another form suitable for the transmission medium. This conversion process is called ***modulation***, with the reverse process called ***demodulation***.
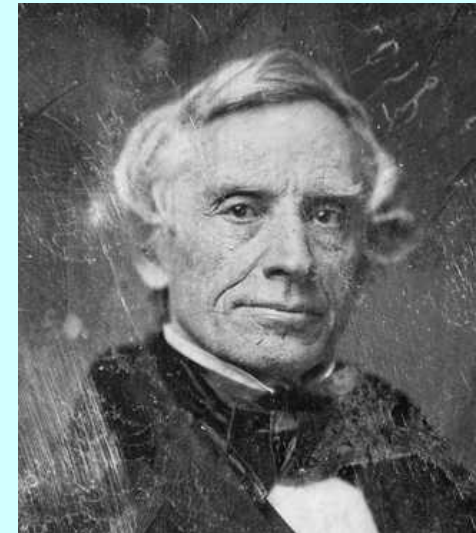
Accompanying most transmissions are random perturbations not related to the wanted signal. These perturbations are called *noise*, and may originate in the transmission medium or in the receiving apparatus.

Hence both the signal and noise in communication systems will be random, so probabilistic methods of describing the properties of such signals will be required.

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1.2 Telegraphy & Telephony

The first electric communication system was the *telegraph*. The first telegraph line linked Washington and Baltimore in 1844, and encoded letters of the alphabet, numerals and punctuation marks using a variable length binary code invented by Samuel Morse.

$$A = \bullet - \qquad J = \bullet - - -$$

$$E = \bullet \qquad\quad Q = - - \bullet -$$

$$T = - \qquad\quad Z = - - \bullet \bullet$$

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In 1875 Emile Baudot invented a code which encoded each letter with a fixed length binary code, the forerunner to the **ASCII code** we use today.
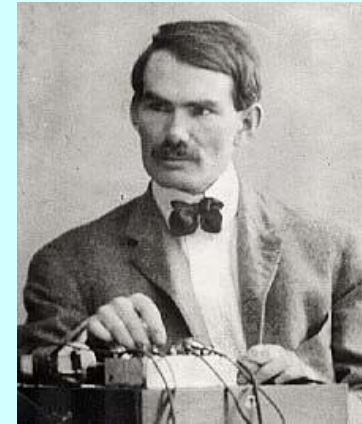
The first **transatlantic telegraph cable** was laid in 1858 but failed after 4 weeks. A second cable became operational in 1866.

The **telephone** was patented by Alexander Graham Bell in 1876, and in 1877 the Bell Telephone Company was formed.
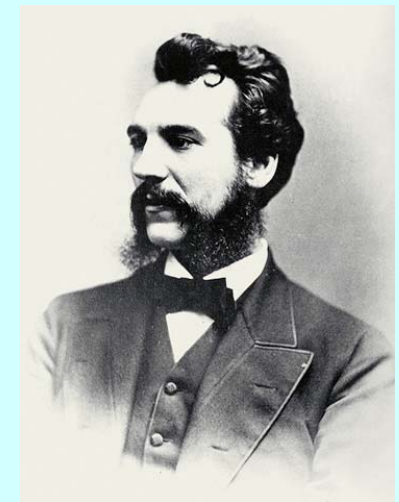
In 1906, Lee DeForest invented the **triode valve** which made it possible to amplify signals and allow telegraph and telephone communication over larger distances. Transcontinental telephone transmissions became operational in 1915.

The first **transatlantic telephone cable** was not laid until 1953.

Automatic switching of telephone calls was developed by Almon Strowger in 1897.

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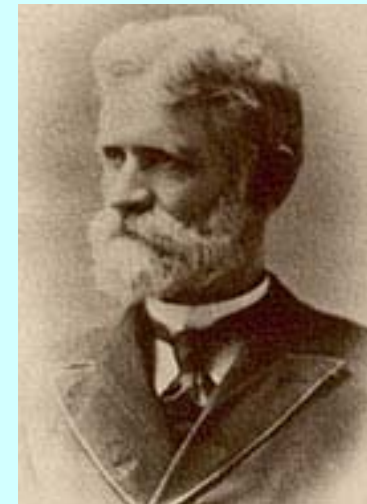
Electronic switching became economically feasible with the invention of the transistor, and the first digital switch was placed in service in Illinois in 1960.

Today, fibre optic cables are rapidly replacing copper cables, and all telephone switching is carried out electronically.
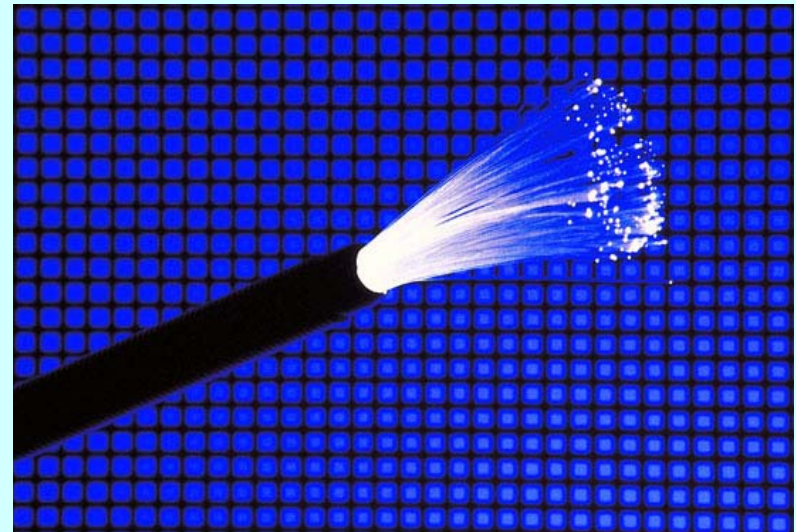
1.3 Wireless Communication Systems

Wireless communications stem from the work of Oersted, Faraday, Gauss, Maxwell and Hertz in the 19th century.

In 1831 Faraday showed that a moving magnet induced a voltage in a nearby conductor.

In 1864 Maxwell developed the basic theory of electromagnetic radiation.

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In 1887 Maxwell's theory was verified experimentally by Hertz.

In 1894 Oliver Lodge demonstrated wireless communication over a distance of 150 metres.

In 1897 Guglielmo Marconi transmitted radio signals over a distance of 2 km, and in 1901 a transatlantic communication of 2700 km was achieved - and this was before vacuum tubes.

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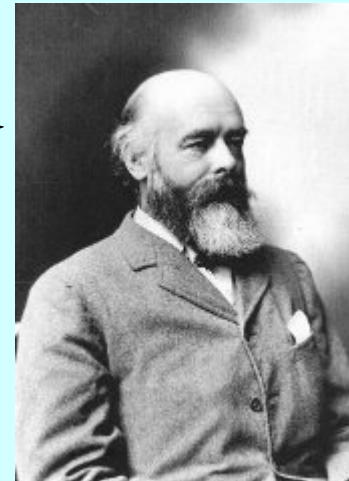
John Fleming invented the vacuum diode in 1904, followed by the triode invented by Lee DeForest in 1906.

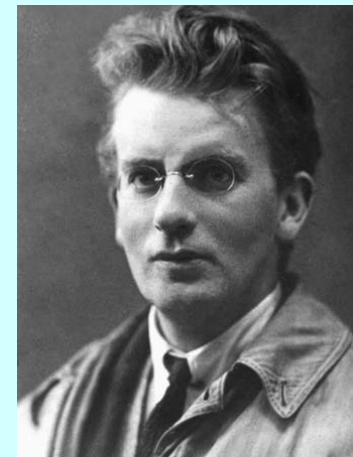The first *amplitude modulation* broadcast occurred in 1920 in Pittsburg.

The *superheterodyne receiver* was invented by Edwin Armstrong during World War I, and in 1933 Armstrong demonstrated the first *frequency modulation* system.
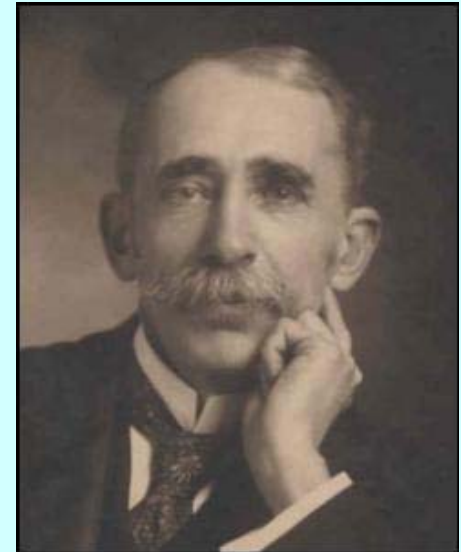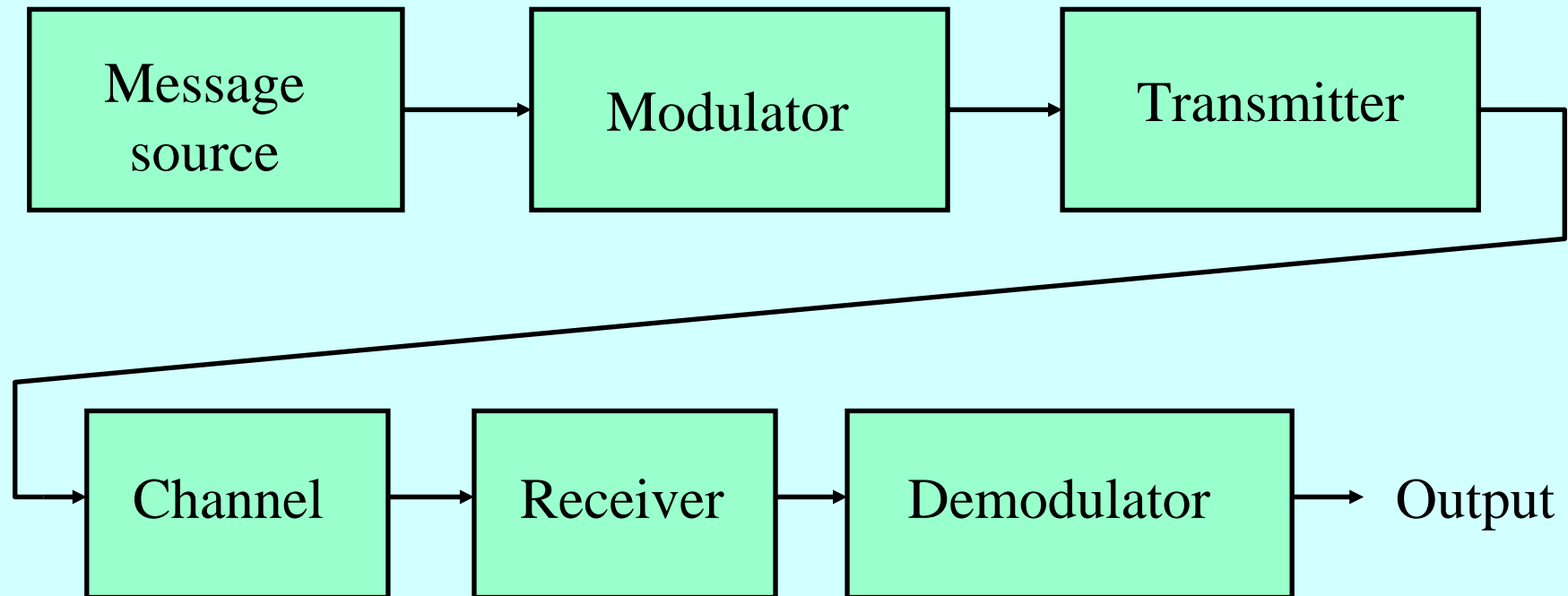
The first television system using electronic scanning was built by Vladimir Zworykin in 1929, although there were many earlier attempts using mechanical scanning by people such as John Logie Baird.

Commercial television broadcasting began in London in 1936 and 5 years later in the United States of America.

1.4 Communication Systems

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┌─────────────┐      ┌─────────────┐      ┌─────────────┐
│   Message   │ ───► │  Modulator  │ ───► │ Transmitter │
│   source    │      │             │      │             │
└─────────────┘      └─────────────┘      └─────────────┘
                                                 │
    ┌────────────────────────────────────────────┘
    │
    ▼
┌─────────────┐      ┌─────────────┐      ┌─────────────┐
│   Channel   │ ───► │  Receiver   │ ───► │ Demodulator │ ───► Output
└─────────────┘      └─────────────┘      └─────────────┘
```

In what follows we will usually assume an additive noise channel. The simplest of these is the *additive white Gaussian noise* (AWGN) channel, where the noise has a uniform power spectral density and is added to the wanted signal.

We can also have multiplicative noise, the most common of which is fading, a very important feature of mobile and high frequency communication channels.

1.5 Decibels

Many quantities in communication theory, and in particular signal to noise ratios, are expressed in decibels.

$$\text{SNR(dB)} = 10\log_{10}(\text{SNR})$$

Where SNR is the actual **power ratio**. In all of the various formulae used in this course, the actual power ratio must be used. **Values in decibels must never be used.**