Communication Systems Principles

Introduction

History

1838 Samuel Morse transmits over a 16 km line. The First commercial service was started in 1844.

1864 James Clerk Maxwell formulated the electromagnetic theory of light and predicted radio waves.

1876 Heinrich Hertz verified Maxwell's theory experimentally. Trans-Atlantic communication was demonstrated by Marconi 1901.

1876 Alexander Graham Bell "perfects" the acoustic transducer.

1887 Step by step switching telephone exchange was invented by A. B. Strowger an undertaker from Kansas City, after a local switchboard operator became friendly with his competitor.

1906 Lee de Forest invents the triode Valve, allowing for amplification of electric signals.

1910 The first experimental AM broadcasts, leading to the First "regular" Broadcasting stations in 1920 (KDKA Pittsburg).

1923 Mechanical TV was demonstrated by Baird (UK) and Jenkins (USA), leading to the first broadcasts in the UK in 1927. The first all electronic TV was demonstrated in 1928 by Philo T. Farnsworth. Regular broadcasts started by the BBC in 1939.

1936 FM proposed by Edwin H Armstrong, who also developed the heterodyne AM receiver in 1918.

1937 Alec Reeves invented Pulse Code Modulation. This was used by the military during the war, but had to wait to the early 70's for commercial exploitation. Now PCM is used extensively in CD's and all new communication systems.

1938 Radar developed, used extensively during world war II.

1945 The first electronic computer ENIAC was built at University of Pennsylvania.

1945 Arthur C. Clark proposed geostationary satellites for communications.

1948 Claude Shannon published "A Mathematical Theory of Communication", relating channel capacity to signal to noise ratio and bandwidth.

1948 The Transistor was invented by Walter H. Brattain, John Bardeen and William Shockley at Bell Labs.

1958 The first silicon IC was produced by Robert Noyce.

1957 Sputnik I launched by the Soviet Union, leading to the first communication satellite Telstar I in 1962

1958 The laser was invented by A. L. Schawlow and C. H. Townes. The first working laser was produced in 1960 by Theodore H. Marman.

1965 Early Bird, the first commercial communication satellite is launched.

1966 K. C. Kao and G. A. Hockham publish the principles of Fibre Optic Communication

1969 ARPANET was created linking 4 American universities. In 1973, ARPANET went international linking to universities in England and Norway, thus the Internet was born.

1971 Intel produces the first single chip computer.

1973 The U.S. Defense Advanced Research Projects Agency (DARPA) initiated a research program to investigate techniques and technologies for interlinking packet networks of various kinds. This was called the Internetting project. Development of TCP/IP, Transmission Control Protocol (TCP) and Internet Protocol (IP).

1976 The first PC's become available.

1980 The Compact Disk is developed by Philips and Sony.

1981 The IBM XT is introduced

1987 USA establishes Advanced Television Service Committee (ATSC)

1987 Mobile Phone Network started in Australia.

1986 The U.S. National Science Foundation (NSF) initiated the NSFNET which, today, provides a major backbone communication service for the Internet.

1989 Pocket cellular telephone introduced by Motorola.

1991 The Internet includes more than 5,000 networks in more than 40 countries, serving over 700,000 host computers and used by over 4,000,000 people.

1991 European Launching Group (ELG) formed to discuss digital television. Renamed to Digital Video Broadcasting (DVB) project in 1993.

1993 Grand Alliance for ATSC digital TV formed

1994 Bluetooth development initiated

1995 The introduction of Digital Audio Broadcasting in the UK

1996 ATSC digital TV standard adopted by the FCC in the USA

1997 DVB standards adopted

1998 Bluetooth Standards adopted (IEEE802.15)

1998 ATSC transmission started, more than 50% of USA covered by end of 1999.

1998 DVB-T broadcasting started in the UK, Sweden, Spain and Finland

1999 IEEE802.11 a and g WLAN standards adopted.

2001 DVB2.0 standard adopted

2001 DVB-T broadcasting started in all capital cities in Australia.

2001 DVB-T broadcasting started in Singapore, MRT busses fitted with TV sets

2003 DVB-T broadcasting started in Netherlands, Germany

2003 ISDB-T Integrated Services Digital Broadcasting-Terrestrial started in Japan

2003 IEEE 802.11 g WLAN standard ratified.

2003 3rd Generation Mobile Phone Rollout started in Australia.

2003 ADSL introduced in Australia

2003 Nov. Eureka digital radio trial on channel 9A (VHF TV band) ABC and SBS

2004 3rd Generation Mobile Phones available in Australia (Telstra/Hutchinson)

2004 DVB-H being introduced in many countries

2004 Bluetooth 2 specifications released (3MB/s)

2004 Dec ZigBee V1 standard published.

2005 3G network rollout started in Australia

2005 ADSL2 introduced in Australia

2006 NextG network introduced giving 3G capability to nearly all Australians

New systems are being introduced, for example: UWB Ultra wide band short distance transmissions (>500 MHz bandwidth 1- 10 GHz). Digital Radio

At Present

The rapid improvement in computer power, the miniaturisation of electronics, the development of digital communication techniques and the increasing availability of communication bandwidth, through the use of fibre optic cables is creating an explosive communication situation.

20 years after the mobile phone was introduced, most people in developed countries own a mobile phone and the third generation of mobile phones base-stations has been rolled out to most of Australia. At the moment there are more mobile phones in Australia than people. Mobile Phones can now used for voice, video and data communications. DVB-H will allow mobile phones to be used as a TV receiver. Many newer households only have a mobile phone and not a landline connection.

Most households now own a computer and many of them are now connecting to the Internet. Only a few years ago Internet connections were limited to Universities. The use of the Internet by companies to market their products has gone from a small percentage a few years ago to the majority at present. It is easier to download data sheets from a web site than to try and locate them in a probably out of date data book. The Internet traffic is growing at an exponential rate.

Digital Audio Broadcasting and Digital Television will allow the broadcaster to use the same frequency throughout the country, a great saving in spectral usage. In the UK by going digital the number of channels that can be used in the present TV band goes from 5 channels to 350 channels. In addition the quality of the digital signals is much better. Digital TV is being introduced in most countries and by 2010 analogue TV will no longer be used in many countries including Australia. High Definition TV is transmitted in the USA and Australia and is being considered in other countries. DAB is scheduled for introduction in Australia in 2009.

Portable communication services such as wireless LAN, Bluetooth and similar systems are developing rapidly.

Communication Problem

The first systems consisted of a dedicated cable between each user. One had a separate telephone for calling each person. This is still used for some simple systems like a computer being connected to a printer as illustrated in Figure 1. This is expensive and too complex.

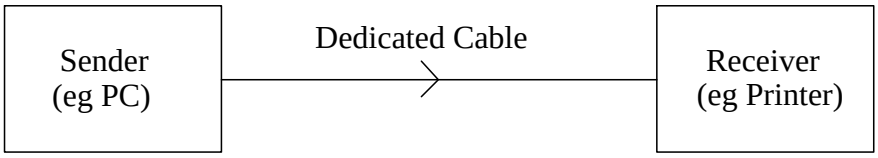

Figure 1: Simple Communication System

A common or shared medium is normally used. That means each user must be coded, or modulated so that they can all use the service. For example AM Radio, Shortwave radio, FM radio, Analogue and Digital TV, Wireless LAN, Mobile and Cordless Phones all use the same transmission medium.

The same techniques are used on cables. Roughly 32256 telephone messages of 64 kB/s each are carried on one optical fibre, the size of a human hair, operating at 2.48832 GB/s. Using different wavelengths allows typically 16 different 2Gbps data streams do be combined on the one fibre. The fibre optic cables typically have 50 or 100 fibres in them.

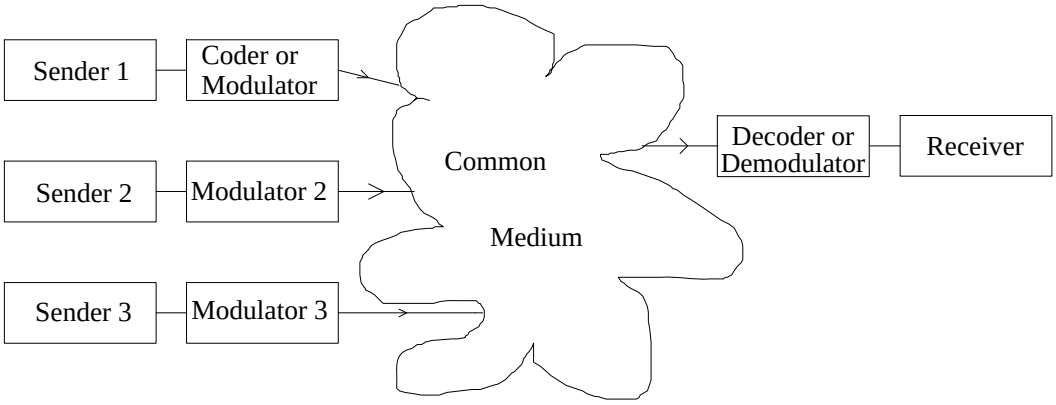

Figure 2 : Communication system where different senders share common channel.

To receive the wanted signal one must decode or demodulate that signal in order to separate the wanted signal from all the others carried by the transmission medium.

Basically there are only 2 ways of separating the signals sent on a common channel.

Time Division Multiplexing (TDM) :

This is where each sender is given complete use of the common channel in a prescribed time slot. The combination of 32256 telephone messages onto one optical fibre uses TDM.

Frequency Division Multiplexing (FDM) :

Each sender transmits signals in a different frequency slot and the receiver filters out the required signal. Using different Wavelengths (Frequencies) to combine different 2GBps data-streams onto the one fibre optic cable uses FDM.

Advanced Coding Schemes

Some communication systems multiply the signals from different users with different coding signal and transmit all these signals using the same frequency band. To separate the signals from each user the coding signal is again used. This is called **Code Division Multiplexing** or **Code Division Multiple Access (CDMA).**

Fundamental Limitations

The signals diminish in power (attenuate) as they travel and noise is added during transmission. In order to be able to detect the signal, it must be sufficiently large compared with the noise.

Power

We can achieve a better SNR by increasing the signal power, however there are limitations:

1 Limitations in the transmission medium: electric breakdown, sparks, melting.

2 Limitations on equipment and power supplies.

3 Cost of providing higher power equipment and providing the power to run it.

4 Biological: The transmitted power must not exceed safe radiation levels.

Bandwidth

We can increase the received SNR by increasing the bandwidth. Spectrum is however a scarce and expensive resource. We must allow other users to transmit their signals as well. Alternately by using a smaller bandwidth, we can pack more users in an allocated bandwidth and make more profit.

Noise

Thermal and man-made noise will be present is all communications systems.

Summary

The basic design requirement for communication systems is thus:

How can we transmit and correctly detect our message with the smallest transmitted power and using the smallest available bandwidth.

Radio Spectrum Classification

Name	Frequency	Properties	Usage
VLF **Very Low Frequency**	3-30 kHz	Ground wave, World wide	**Long range navigation, submarine communications**
LF **Low Frequency**	30-300 kHz	Ground wave, Shorter range in daytime	**Radio Beacons, Maritime Communications**
MF **Medium Frequency**	0.3-3 MHz	Ground and Sky wave	**AM radio**
HF **High Frequency**	3-30 MHz	Ionospheric reflection	**Short Wave radio**
VHF, Very High Frequency	30-300 MHz	Near line of sight	**VHF TV, FM radio, Mobile Phones**
UHF, **Ultra High Frequency**	.3-3 GHz	Line of sight	**UHF TV, mobile phones, radar, microwave radio links, satellite communication, WLAN, Microwave Ovens, Bluetooth**
L	1-2 GHz		
S	2-4 GHz		
SHF, Super High Frequency	3-30 GHz	Rain attenuation above 10 GHz, Water absorption at 22.2 GHz	**Satellite Communication, radar, microwave links., WLAN**
C	4-8 GHz		
X	8-12 GHz		
Ku	12-18 GHz		
K	18-27 GHz		
Ka	27-40 GHz		
R	26.5-40 GHz		
EHF, Extremely High Frequency	30-300 GHz	High absorption of water at 183 GHz, and Oxygen at 60 and 119 GHz	**Radar, Satellite, Experimental**
Q	33-50 GHz		
V	40-75 GHz		
W	75-300 GHz		
mm	110-300 GHz		
Optical	3-300 THz	IR, Visible, UV	**Optical Communication**
Visible	**0.4-0.7 μm**		