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ABSTRACTS

In this graduation project, I briefly explain the Analysis Guided and Ungided Media for the Communication Systems. For the human life, Communication Systems is very interesting and important topic. Because it is very useful in our daily life to communicate with other peoples.

I specially thank to Prof. Dr. Fahrettin M. Sadıgoğlu for giving me an opportunity to work with him. I gain thank to everybody who help me in this project by the bottom of my heart.

PREFACE

During this graduation project, I try to explain the nature and theory of the Guided and Unguided Media, Communication channels for the Communication Systems.

In the nearly years, we saw merger of the fields of Guided and Unguided Media and Data Communication that profoundly changed the technology, products, and companies of the row combined computer communication industry. Although the consequences of this revolutionary merger are still being worked out, it is safe to say that the revolution occured and investigation of the field of Communication System must be made with in the new context. It is very huge field and in the coming years the topic will very improved.

In this project I covered the chapter about Guided and Guided Media with related topics about Communication Systems.

INTRODUCTION

Historical background

(Early work in Digital Communication)

Every day, ~~in our work and in our leisure time,~~ we ~~come in~~ contact ~~with~~ and we use a variety of modern communication systems and communication media the most common being the telephone, radio, television and internet service. Through these media we are able to communicate (nearly) instantaneously with people on different continents, transact our daily business and receive information about various developments and events of note that occur all around the world. Electronic mail and facsimile transmission have made it possible to rapidly communicate written messages across great distances.

Telegraphy and telephony. One of the earliest inventions of major significance to communications was the invention of the electric battery by Alessandro Volta in 1799. This invention made it possible for Samuel Morse to develop the electric telegraph, which he demonstrated in 1837. The first telegraph line linked Washington with Baltimore and became operational in May 1844. Morse devised the variable - length binary code given in Table 1.1, in which letters of the English alphabet are represented by a sequence of dots and dashes (code words). In this code, more frequently occuring letters are represented by longer code words.

The *Morse code* was the precursor to the variable - length source coding methods. It is remarkable that the earliest form of electrical communication that was developed by Morse, namely, *telegraphy,* was a binary digital communication system in which the letters of the English alphabet were

TABLE 1-1 MORSE CODE

(a) Letters		(b) Numbers
A . -	N -.	
B -...	O ---	
C -.-.	P .--.	
D -..	Q --.-	1 .----
E .	R .-.	2 ..---
F ..-.	S ...	3...—
G --.	T -	4 ....-
H	U ..-	5 .....
I ..	V ...-	6 -....
J .---	W .--	7 --...
K -.-	X -..-	8 ---..
L .-..	Y -.--	9 ----.
M --	Z --..	0 -----

efficiently encoded into corresponding variable - length code words having binary elements.

Nearly forty years later, in 1875, Emile Baudot developed a code for telegraphy in which each letter was encoded into fixed- length binary code words of length 5. In the ***Baudot code,*** the binary code elements were of equal length and designated as mark and space.

An important milestone in telegraphy was the installation of the first transatlantic cable in 1858 that linked the united States and Europe. This cable failed after about four weeks of operation. A second cable was laid a few a years later and became operational in July 1866.

Telephony came into being with the invention of the telephone in the 1870's. Alexander Graham Bell patented his invention of the telephone in 1876 and in 1877 established the Bell Telephone Company. Early versions of telephone communication systems were relatively simple and provided service over several hundred miles. Significant advances in the quality and range of service during the first two decades of this century resulted from the induction coil.

The invention of the troide amplifier by Lee DeForest in 1906 made it posible to introduce signal amplification in telephone communication systems and thus to allow for telephone signal transmission over great distances. For example, transcontinental telephone transmission become operational in 1915.

Two world wars and the Great Depression during the 1930's must have been a deterrent to the establishment of transatlantic telephone service. It was not until 1953, when the first transatlantic cable was laid, that telephone service became available between the United States and Europe.

Automatic switching was another important advance in the development of telephony. The first automatic switch, developed by Strowger in 1987, was an electromechanical. With the invention of the transistor, electronic (digital) switching became economically feasible. After several years of development at the Bell Telephone Laboratories, a digital switch was placed in service in Illinoise in June 1960.

Wirelles communications. The development of wirelles communications stems from the works of Oersted Faraday, Gauss, Maxvel and Hertz. In 1820, Oersted demonstrated that an electric current produces a magnetic field. On August 29, 1831, Michael Faraday showed that an induced current is produced by moving a magnet in the vicinity of a conductor. Thus, he demonstrated that a changing magnetic field produces an electric field. With this early work as background, James C. Maxwell in 1864 predicted the extince of electromagnetic radiation and formulated the basþs theory that has been in use for over a century. Maxwell's theory was vertified experimentally by Hertz in 1887.

In 1894, a sensitive device that could detect radio signals, called the coherer was used by its inventor Oliver Lodge to demonstrate wirelles communication. Marconi is credited with the development of wireless telegraphy. Marconi demonstrated the transmission of radio signals at a distance of approximately 2 kilometers in 1895. Two years later, in 1897, he patented a radio telegraphy system and established the Wireless Telegraph and Signal Company. On December 12, 1901, Marconi received a radio signal at Signal Hill in Newfoundland, which was transmitted from Cornwal, England - a distance of about 1700 miles.

The vacuum diode was invented by John Fleming in 1904 and the vacuum troide amplifier was invented by Lee DeForest in 1906, as previously indicated. The invention of the triode made radio broadcast possible in the early part of the twentieth century. AM (amplitude modulation) broadcast was initiated in 1920 when radio station KDKA, Pitsburgh, went on the air. From that date, AM radio brodcasting grew very rapidly across the country and around the world. The superheterodyne AM radio receiver, as we know it today, was invented by Edwin Armstrong during World War I. Another significant development in radio communications was the invewntion of FM (frequency modulation), also by

$A\ d_m = 20\log\left(\frac{2\pi d}{\lambda}\right)^2$

Armstrong. In 1993, armstrong built and demonstrated the first FM communication system. However, the use of FM was slow to develop compared with AM broadcast. It was not untill the end of World War II that FM broadcast gained in popularity and developed commercially.

The first television system was built in the United States by Vladimir Zworykin and demonstrated in 1929. Commercial television broadcasting began in London in 1936 by the British Broadcasting Corporation (BBC).

The past fifty years. The invention of the transistor in 1947 by Walter Brattain, John Bardeen, and William Shockley; the integrated circuit in 1958 by Jack Kilby and Robert Noyce; and the laster by Townes and Schawlow in 1958, have made possible the development of small-size, low-power, low weight, and high-sped electronic circuits which are used in the construction of satellite communication systems, wideband microwave radio systems, and lightwave communication nication systems using fiber optic cables. A satellite named Telstar I was launched in 1962 and used to relay TV signals between European and the United States. Commercial satellite communication services began in 1965 with the launching of the Early bird satellite.

Currently, most of the wireline communication systems are being replaced by fiber optic cables which provide extremely high bandwidth and make possible transmission of a wide variety of information sources, including voice, data, and video. Cellular radio has been developed to provide telephone service in people in automobiles. High-speed communication networks link computers and a varieoty of peripheral devices literally around the world.

Today we are witnessing a significant growth in the introduction and use of personal communications services, including voice, data, and video transmission. Satellite and fiber optic networks provide high-speed communication services around the world. Indeed, this is dawn of the modern telecommunications era.

CHAPTER I

Introduction to an Communication channels.

ELEMENTS of AN ELECTRICAL COMMUNICATION SYSTEM

1.1ELEMENTS of AN ELECTRICAL COMMUNICATION SYSTEM

Electrical communication systems are designed to send messages or information from a source ~~that generates the messages to one or more~~ to destinations. In general, a communication system can be represented by the functional block diagram shown in Figure 1.1.

The information generated by the source may be of the form of voice (speech source), a picture (image source), or plain text in some particular language, such as English, Japanese, German, French etc. An essential feature of any source that generates information is that its output is described in probabilistic terms; that is, the output of a source is not deterministic. ~~Otherwise,~~ there would be ~~no need to transmit the messages.~~

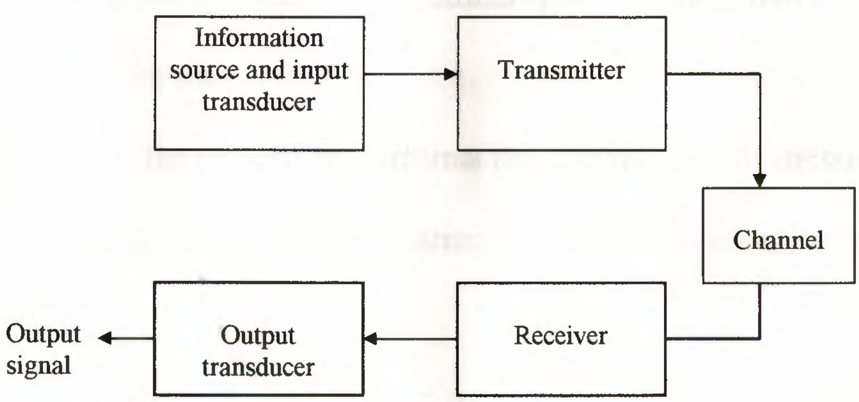


FIGURE 1.1 Functional block diagram of an communication system.

A transducer is usually required to convert the output of a source into an electrical signal that is suitable for transmission. For example, a microphone serves as the transducer that convers an acoustic speech signal into an electrical signal, and a video camera convers an image into an electrical signal. At the destination, a similar transducer is required to convert the electrical signals that are received into a form that is suitable for the user.

The transmitter. The transmitter convers the electrical signal into a form that is suitable for transmission through the physical channel or tranmission medium. ~~For example, in raido and TV broadcast, the Federal Communications Commission (FCC) specifies the frequency range for each transmittion station.~~ Hence, the tranmistter must translate the information signal to be transmitted into the appropriate frequency range that matches the frequency allocation assigned to the transmitter. Thus, signals transmitted by multiple radio stations do not interfere with one another. Similar functions are performed in telephone communication systems, where the electrical speech signals from many users are transmitted over the same wire.

In general, the transmitter performs the matching of the message signal to the channel by a process called modulation. Usually, modulation involves the use

of the information signal to systematically vary the amplitude, frequency, or phase of a sinusodial carrier. For example, in AM radio broadcast, the information signal that is transmitted is contained in the amplitude variations of the sinusoidal carrier, which is the center frequency in the frequency band allocated to the radio transmitting station. This is an example of ampitude modulation. In FM radio broadcast, the information signal that is transmitted is contained in the frequency variations of the sinusodial carrier. This is an example of frequency modulation. Phase modulation (PM) is yet a third method for impressing the information signal on a sinusoidal carrier.

The choice of the type of modulation is based on several factors, such as the amount of bandwidth allocated, the types of noise and interference that the signal encounters in transmission over the channel, and the electronic devices that are available for signal amplification prior to transmission.

The channel. The communications channel is the physical medium that is used to send the signal from the transmitter to the receiver. In wireless transmission, the channel is usually the atmosphere (free space). On the other hand, telephone channels is usually employ a variety of physical media, including wirelines, optical fiber cables, and wireless (microwave radio). Whatever the

physical medium for signal transmission, the esential feature is that the transmitted signal is corrupted in a random manner by a variety of possible mechanisms. The most common form of signal degradation comes in the form of additive noise, ~~which is generated at the front end of the receiver,~~ where signal amplification is performed. This noise is often called thermal noise. In wireless transmission, additional additive disturbances are man - made noise and electrical lighting discharges from thunderstorms is an example of atmospheric noise. Interference from other users of the channel is antoher from of additive noise that often arises in both wireless and wireline communication.

In some radio communication channels, ~~such as the ionospheric channel that is used for long- range, short- wave radio transmission, another form of~~ signal degradation is multipath propagation. Such signal distoriton is characterized as a nonadditive signal disturbance which manifests itself as time variations in the signal amplitude, usually called fading. or multiplicative noise.

Both additive and nonadditive signal distortions are usually characterized as random phenomena and described in statistical terms. The effect of these signal distortions must be taken into account in the design of the communication system.

Impulse noise

The receiver. The function of the receiver is to recover the message signal contained in the received signal. If the message signal is transmitted by carrier modulation, the receiver performs carrier demodulation to extract the message from the sinusodial carrier. ~~Since signal~~ demodulation is performed in the presence of additive noise and possibly other signal distortion, the demodulated message signal is generally degraded to some xtent by the presence of these distortions in the received signal. As we shall see, the fidelity of the received message signal is a function of the type of modulation, ~~the strength of~~

and signal to noise ratio in the channel,

~~the additive noise, the type and strength of~~ any other additive interference nd the type of any nonadditive interference.

Besides performing the primary function of signal demodulation, the receiver also performs a number of peripheral functions, including signal filtering and noise suppression.

1.2Digital Communication Systems

Early

Alternatively, an analog source output may be converted into a digital form and the messsage can be transmitted via digital modulation and demodulated as a digital signal at the receiver. There are some potential advantages to transmitting an analog signal by means of digital modulation. The most important reason is that signal fidelity is better controlled through digital transmission than analog transmission. Another reason for choosing digital transmission over analog is that the analog message signal may be highly redundant. With digital processing, redundancy may be removed prior to modulation, thus conversing channel bandwidth. Yet a third reason may be that digital communication systems are often cheaper to implement.

1.2.1 Early Work in Digital Communications

Although Morse is responsible for the development of the first electrical digital communication system (telegraphy), T the beginnings of the what ~~we now regard as~~ modern digital communications ys it related with stem ~~from~~ the work of Nyquist (1924), who investigated the ~~problem of determining the maximum signaling rate that can be used over a telegraph channel of a given bandwidth without intersymbol interference.~~ relationship with the bandwidth of chan maximum achieved signal transmission rate (T_r) achieved by a given channel bandwidth. He formulated a model of a telegraph system in which a transmitted signal has the general form

$$s(t) = \sum_{n} a_n g(t - nT)$$

where g(t) represents a basic pulse shape and (a_n) is the binary data sequence of

transmitted at a rate of 1/T bits Per second. Nyquist set out to determine the optimum pulse shape that was bandlimited to W Hz and maximised the bit rate 1/T under the constraint tht the pulse caused no intersymbol interference at the sampling times k/T, k=0 1 2...... His studies led him to conclude that the

cont
circuit

maximum pulse rate 1/T is 2W pulses Per second. This rate is now called the Nyquist rate. Moreover, this pulse rate can be achieved by using the pulses g(t)=(sin Wt)/2 Wt. This pulse shape allows the recovery of the data without intersmbol interference at the sampling instants. Nyquist's result is equivalent to a version of the sampling theorem for bandlimited signals, which was later stated precisely by Shannon (1948). The sampling theorem states that a signal of analog cont be recovered from its samples
samples Per second using the interpolation formula

$$s(t) = \sum_{n} s\left(\frac{n}{2W}\right) \frac{\sin 2\pi W(t - n/2W)}{2\pi W(t - n/2W)}$$

$f_s \geq 2f_m$

Another significant advance in the development of communications was the work of Wiener(1942) who considered the problem of estimating a desired signal waveform s(t) in the presence of additive noise n(t), based on observation of the received signal r(t)=s(t)+n(t). This problem arises in signal demodulation.
optimal filtering
Wiener determined the linear filter whose output is he best mean-square approximation to the desired signal s(t).The resulting filter is called the *optimum linear (Wiener)* filter.

Hartley's and Nyquist's on the maximum transmission rate of digital information were precursors to the work of Shannon(1948 a,b) who esttblished the mathematical foundations for information theory and derived the fundamental
that relates channel capacity (C)

limits for digital communication systems. In his pioneering work, Shannon formulated the basic problem of reliable transmission of information in statistical terms, using probabilistic models for information sources and communication channels. Based on such a statistical formulation, he adopted logarithmic measure for the information content of a source. He also demonstrated that the effect of a transmitter power constraint, a bandwidth constraint, and additive noise can be associated with the channel and incorporated into single parameter, called the *channel capacity*. For example, in the case of an additive white (spectrally flat) Gaussian noise interference, an ideal bandlimited channel of bandwidth W has a capacity Q given by

$$C = W \log_2 \left(1 + \frac{P}{W N_0} \right) \text{ bits/s}$$

where P is the average transmitted power and N is the power spectral density of the additive noise. The significance of the channel capacity is as follow: If the

information rate R from the source is less than C (R<C), then it is theoretically possible to achieve reliable (error-free) transmission through the channel by appropriate coding. On the other hand, if R>C, reliable transmission is not possible regardless of the amount of signal processing performed at the transmitter and receiver. Thus, Shannon established basic limits on communication of information and gave birth to a new field that is now called information theory.

Another important contribution to the field of digital communications is the work of Kotelnikov (1947) which provided a coherent analysis of the various digital communication systems based on a geometrical approach. ~~Kotelnikov's 1approach was later expanded by Wozencraft and Jocobs (1965).~~

The increase in the demand for date transmission during the last three decades, coupled with the development of more sophisticated integrated circuits, has led to the development of very efficient and more reliable digital communications systems. In the course of these development of very efficient and more reliable digital communications systems. In the course of these developments, Shannon's original results and the generalisation of his results on maximum transmission limits over a channel and on bounds on the performance

achieved have served as benchmarks for any given communications system design. The theoretical limits derived by Shannon and other researchers that contributed to the development of information theory serve as an ultimate goal in the continuing efforts to design and develop more efficient digital communications systems.

Following Shannon's publications came the classic work of Hamming (1950) on error detecting and error - correcting codes to combat the detrimental effects of channel noise. Hamming's work stimulated many researchers in the yeras that followed, and a variety of new powerful codes were discovered, many of which are used today in the implementation of modern communication systems.

1.3 COMMUNICATION CHANNELS AND THEIR CHARACTERISTICS

The physical channel may be a pair of wires that carry the electrical signals, or an optical fiber that carries the information on a modulated light beam, or an underwater ocean channel in which the information is transmitted acoustically, or free space over which the information - bearing signal is radiated by use of an antenna. One common problem in signal transmission is additive noise. This noise is generated internally by components such as resistor and solid state devices used to implement the comm. syst. This noise is some times is called thermal noise

Other sources of noise and interference may arise externally to the system, such as interference from other users of the channel. When such noise and interference occupy the same frequency band as the desired signal, its effect can be minimized by proper design of the transmitted signal and its demodulator at the receiver. Other types of signal degradations that may be encountered in transmission over the channel are signal attenuation, amplitude and phase distortion, and multipath distortion.

1.4 MATHEMATICAL MODELS FOR COMMUNICATION CHANNELS

In the design of communication systems ~~for transmitting information through~~ physical channels, we find it convenient to construct mathematical models that reflect the most important characteristics of the transmission medium. Then, the mathematical model for the channel is sed in the design of the channel encoder and modulator at the transmitter and the demodulator and channel decoder at the receiver. Below, we provide a brief description of the channel models that are frequently used ~~to characterize many of the physical channels that we encounter~~ in practice.

The additive noise channel. The simplest mathematical model for a communication channel is the additive noise channel, illustrade in Figure 1.2. In

Fig 1.2

this model, the transmitted signal *s(t)* is corrupted by an additive random noise process *n(t)*. Physically, the additive noise ~~process~~ may arise from electronic components and aplifiers at the receiver of the communication system, or from interfrence encountered in transmission as in the case of radio signal transmission.

If the noise is introduced primarily by electronic components and amplifiers at the receiver, it may be characterized as thermal noise. This type of noise is characterized statistically as a *Gaussian noise process.* Hence, the rsulting mathematical model for the channel is usually called the *additive Gaussian noise channel.* ~~Because this channel model applies to a broad class of physical communication channels and because of its mathematical tractability, this is the predominant channel model used in our communication system analysis and design.~~ Channel attenuation is easily incorporated into the model. When the signal undergoes

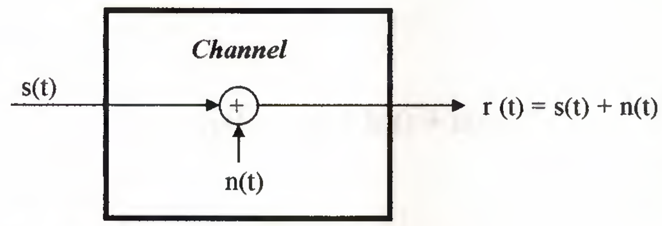


FIGURE 1.2 The additive noise channel.

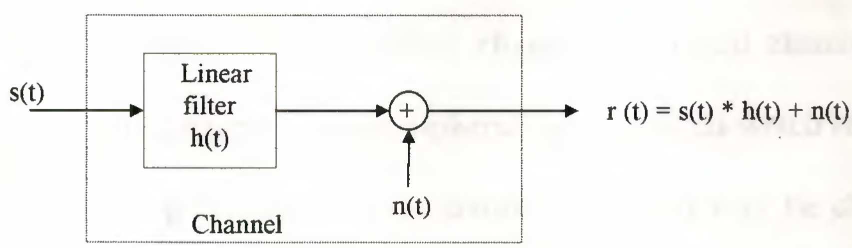
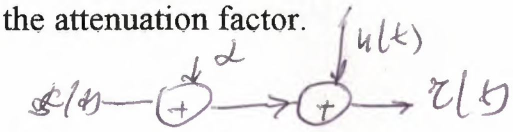


FIGURE 1.3 The linear filter channel with additive noise.

Attenuation in transmission through the channel, the received signal is

$$r(t) = \alpha s(t) + n(t)$$

where α represents the attenuation factor.



The linear filter channel. In some physical channels such as wireline telephone channels, filters are used to ensure that the transmitted signals do not exceed specified bandwidth limitations and thus do not interfere with one another. (Fig. 3) The channel output is the signal

$$r(t) = s(t) * h(t) + n(t)$$

$$= \int_{-\infty}^{+\infty} h(\tau)s(t-\tau)\,d\tau + n(t)$$

where h(t) is the impulse response of the linear filter and * denotes convolution.

The linear time - variant filter channel. Physical channels such as underwater acoustic channels and ionospheric radio channels which result in time - variant multipath propagation of the transmitted signal may be characterized mathematically as time - variant linear filters. Such linear filters are characterized by a time - variant channel impulse response h (;t) is the response of the channel at time t due to an impulse applied at time t - . For an input signal s(t), the channel output signal is

$$r(t) = s(t) *h(\; ; t) +n(t)$$

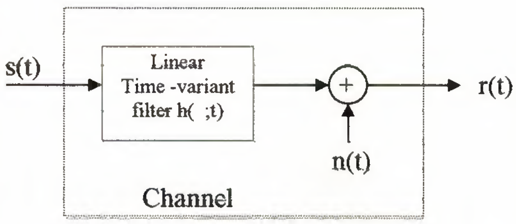


FIGURE 1.4 Linear time - variant filter channel with additive noise.

1.5 TRANSMISSION IMPAIRMENTS

With any communications system, it must be recognized that the signal that is received will differ from the signal that is transmitted due to various transmission impairments. For analog signals, these impairments introduce various random modifications that degrade the signal quality. For digital signals, bit errors are introduced: A binary 1 is transformed into a binary 0 and vice versa.

In this section, we examine the various impairments and comment on their effect on the information - carrying capacity of a communication link; the next chapter looks at measures that can be taken to compensate for these impairments.

The most significant impairments are:

- ~~Attenuation and~~ A attenuation and distortion.
- Delay distortion
- Noise

1.5.1 Attenuation

The magnitude ~~strength~~ of a signal falls off with distance over any transmission medium. For guided media, this reduction (different types of cables) is ~~in~~ strength, or attenuation, is generally logarithmic and thus is typically expressed as a constant number of decibels Per unit distance.

$$A[dB] = 2\log \frac{P_2}{P_1} = 20 \log \frac{U_2}{U_1}$$

For unguided media, attenuation is a more complex function of distance and the makeup of the atmosphere. Attenuation introduces three consideration for the transmission engineer. 1) ~~First,~~ A received signal must have sufficient magnitude strength so that the electronic circuitry in the receiver can detect and interpret the signal. 2) A ~~Second, the~~ signal must maintain a level sufficiently higher than noise to be received without error. 3) ~~Third,~~ attenuation is an increasing function of frequency.

The third ~~first~~ problem is particularly noticeable for analog signals. Because the attenuation varies as a function of frequency, the received signal is distorted, reducing intelligibility. To overcome this problem, techniques are available for equalizng attenuation across a band of frequencies. This is commonly done for voice - grade telephone lines by using loading coils that change the electrical properties of the line; the result is to smooth out attenuation effects. Another approach is to use amplifiers that amplify high frequencies more than lower frequencies.

An example is shown in Figure 1.5. which shows attenuation as a function of frequency for a typical leased line. In he figure, attenuation is measured relative to the attenuation at 1000 Hz. ~~Positive values on the y axis represent attenuation greater than that at 1000 Hz. A 1000 - Hz tone of a given power level is applied to the input, and the power,~~ P_{1000} ~~is measured at the output.~~ For any other frequency f, ~~the procedure is repeated and~~ the relative attenuation in decibels is

$$N_f = 10 \log_{10} P_f / P_{1000} \quad = 20 \log_{10} \frac{P_2}{P_1}$$

The solid line in Figure shows attenuation without equalization. ~~As can be seen, frequency components at the upper end of the voice band are attenuated much more than those at lower frequencies. It should be clear tht this will result in a distortion of the received speech signal~~. The dashed line shows the effects of equalization.

1.5.2 Delay Distortion

~~Delay distortion is a phenomenon peculiar to quided transmission media.~~

The delay distortion is caused by the fact that the velocity of propagation of a signal through a quided medium varies with frequency. ~~and fall off toward the two edges of~~

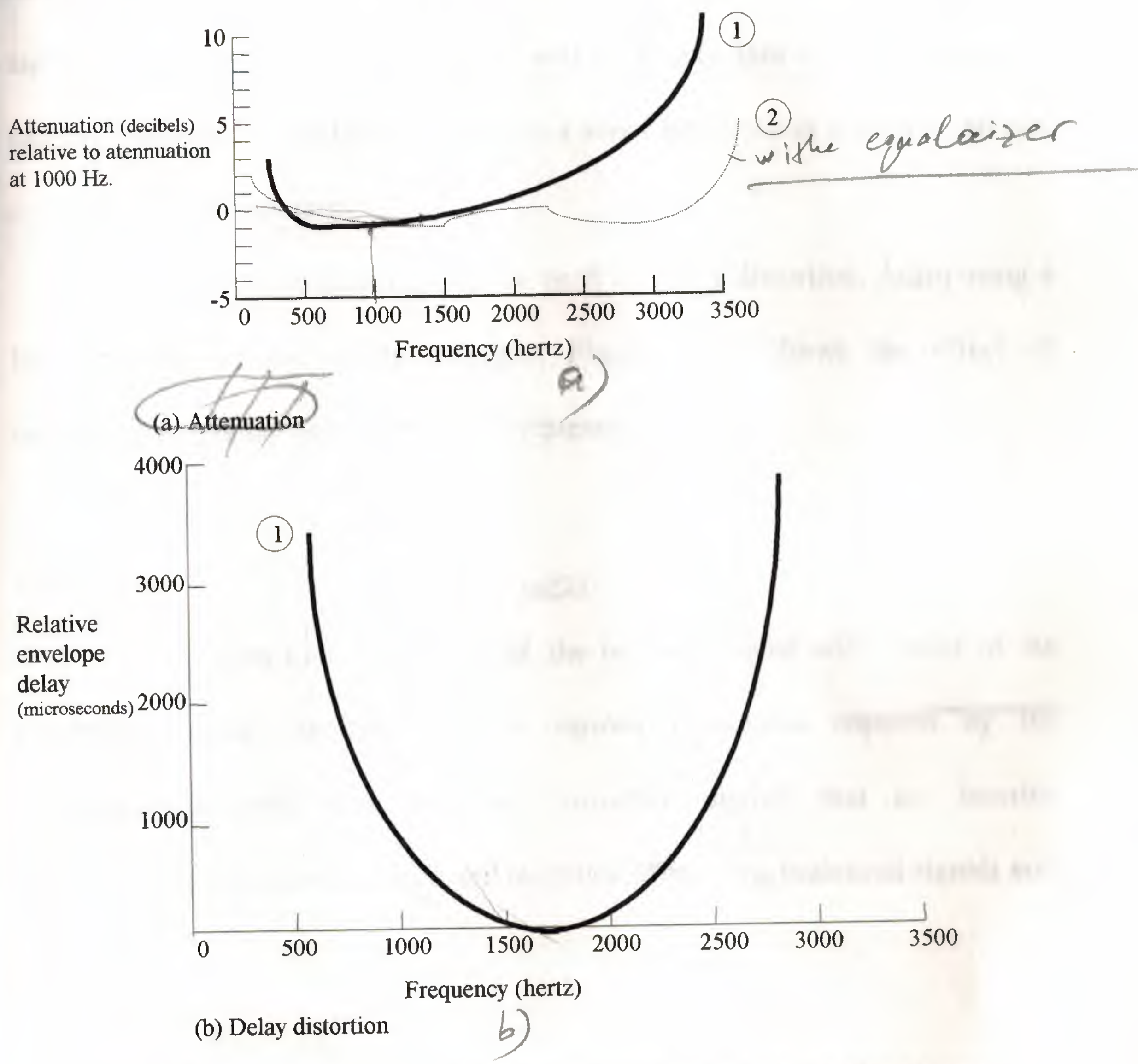


FIGURE 1.5 Attenuation and delay distortion curves for a voice channel.

In result

the band. ~~Thus~~ various frequency components of a signal will arrive at the receiver at different times.

This effect is referred to as delay distortion, since the received signal is distorted due to variable delay in its compopnents. Delay distortion is particularly critical for digital data. ~~Consider that a sequence of bits is being transmitted, using either analog or digital signals~~. Because of delay distortion, some of the signal components of one bit position will spill over into other bit positions, causing intersymbol interference, which is a major limitation to maximum bit rate over a transmission control.

Equalizing techniques can also be used for delay distortion. Again using a leased telephone line as an example, Figure 2-14b shows the effect of equalization on delay as a function of frequency.

1.5.3 Noise

system

For any ~~data~~ transmission ~~event~~, the recieved signal will consist of the transmitted signal, modified by the various distortions ~~imposed by the transmission system~~, plus additional unwanted signals that are inserted somewhere between transmission and reception. This ~~The latter~~, undesired signals are referred to as noise. ~~It is noise that is the mahor limiting factor in communications system performance.~~

Noise may be divided into four categories [FREE81]

- Thermal noise
- Intermodulation noise
- Crosstalk
- Impulse noise.

Thermal noise is due to thermal agitation of electrons in a conductor. It is present in all electronic devices and transmission media and is a function of temperature. Thermal noise is uniformly distrubuted across the frequency spectrum and hence is often reffered to as white noise. ~~Thermal noise cannot be eliminated and therefore places an upper bound on communications system performance~~. The amount of thermal noise to be found in a bandwidth of 1 Hz in any device or conductor is

$$No = kT$$

where

No = noise power density, watts/ hertz

k = Boltzmann's constant = 1.3803×10^{-23} $J/^{0}K$

T = temperature, degrees Kelvin

The noise is assumed to be independent of frequency. Thus the thermal noise in watts present in a bandwidth of W hertz can be expressed as

$$N = kTW$$

or, in decibel - watts:

$$N = 10 \log k + 10 \log T + 10 \log W$$

$$N = -228.6 \text{ dbW} + 10 \log T + 10 \log W$$

When signals at different frequencies share the same transmission medium, the result may be intermodulation noise. The effect of intermodulation noise is to produce signals at a frequency which is the sum or difference of the two original frequencies or multiples of those frequencies. For example, the mixing of signals at frequencies f_1 and f_2 might produce energy at the frequency $f_1 + f_2$. This derived signal could interfere with an intended signal at the frequency $f_1 + f_2$.

Intermodulation noise is produced when there is some nonlinearity in the transmitter, receiver, or interviewing transmission system. Normally, these components behave as linear systems; that is, the output is equal to the input times a constant.

Crosstalk has been experienced by anyone who, while usðng the telephone, has been able to hear another conversation: it is an unwanted coupling between signal paths. It can occur by electrical coupling between nearby twisted pair or rarely, coax cable lines carrying multiple signals. Crosstalk can also occur when unwanted signals are picked up by microwave antennas: although highly directional, microwave energy does spread during propagation. Typically, crosstalk is of the same order of magnitude as, or less than, thermal noise.

All of these types of noise discussed so far have reasonable predictable and reasonably constant magnitudes. Thus it is possible to engineer a transmission system to cope with them. Impulse noise, however, is noncontinuous, consisting of irregular pulses or noise spikes of short duration and of relatively high akplitude. It is generated from a variety of causes, including external electromagnetic disturbances, such as lightning, and faults and flaws in the communications system.

Impulse noise is generally only a minor annoyance for analog data. Fro example, voice transmission may be corruted by short clicks and crackles with no loss of intelligibility. ~~However,~~ impulse noise is the primary source of error in digital data communication. For example, a sharp spike of energy of 0.01 s duration would not destroy any voice data, but would wash out about 50 bits of data being transminted at 4800 bps. Figure 2 -15 is an example of the effect on a digital signal. Here the noise consists of a relatively modest level of the thermal noise plus occasional spikes of impulse noise. The digitla data are recovered from the signal by sampling the received waveform once Per bit time. As can be seen, the noise is occassionally sufficient to change a 1 to a 0 or a 0 to 1.

1.5.4 Channel Capacity

We have seen that there are a variety of impairments that distort or corrupt a signal. ~~For digital data, the question that then arises is to what extent these impairments limit the data rate that can be achieved.~~ The rate at which data can be transmitted over a given comunication path, or channel, under given conditions, is reffered to as *the channel capacity*.

There are four concepts here that we are trying to relate to one another.

- Data rate: This is the rate, in bits Per second (BPS), at which data can be communicated.
- *Bandwidth: This is the bandwidth of the transmitted signal* as constraines by the transmitter and the nature of the transmission medium, expressed in cycles Per second, or Hertz.

[illegible]

- Noise: The averge level of noise over the communications path.

- Error rate: The rate at which errors occur, where an error is the reception of a

is given 10^{-5} means

1 when a 0 was transmitted or the reception of a 0 when a 1 was transmitted.

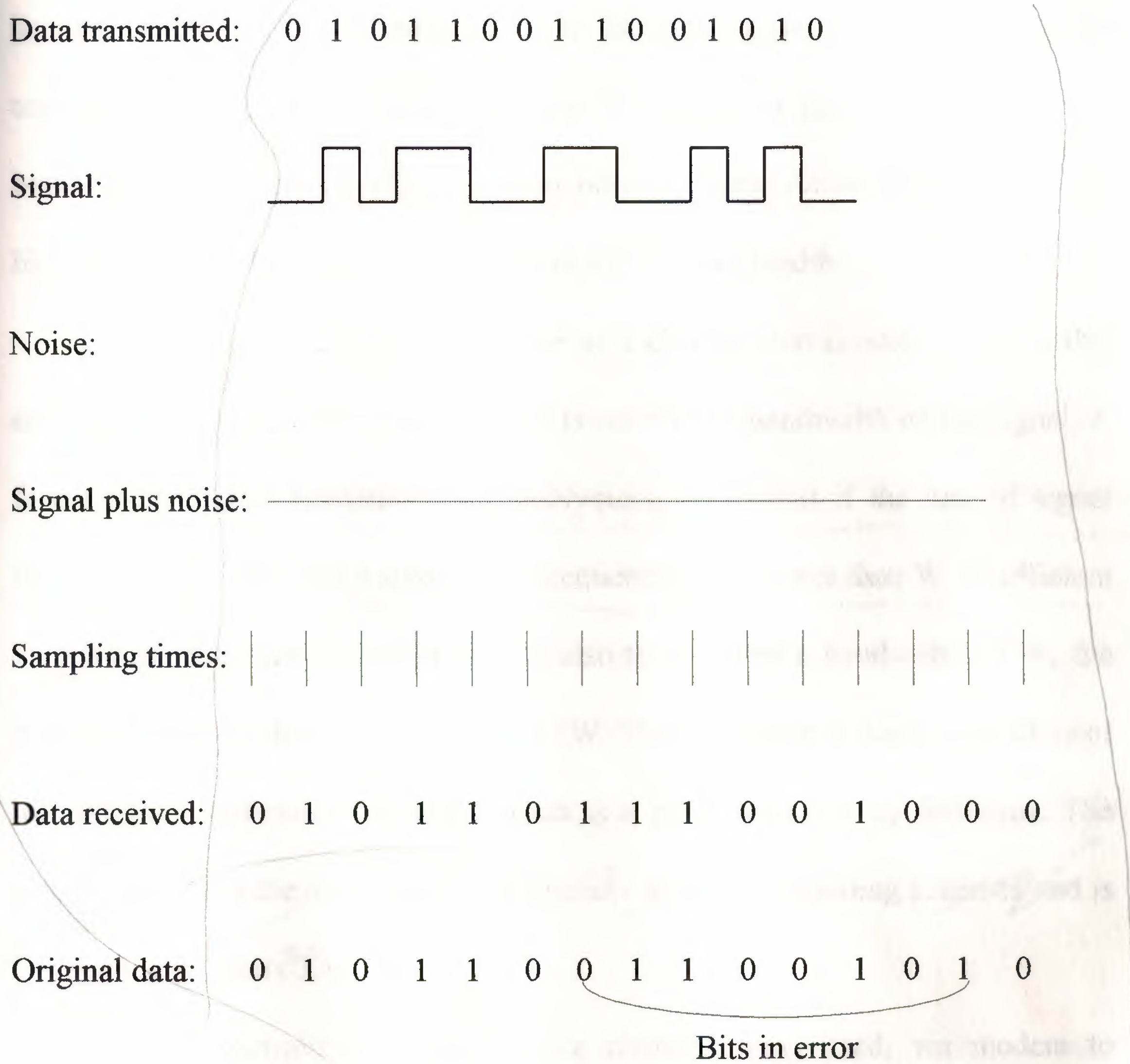


FIGURE 1.6 Effect of noise on a digital signal

The problem we are addressing is this: Communications facilities are expensive and, in general, the greater the bandwith of a facility the greater the cost. Furthermore, all transmission channels of any practical interest are of limited bandwidth. The limitations arise from the physical properties of the transmission medium or from deliberate limitations at the transmitter on the bandwidth to prevent interference from other sources. Accordingly, we would like to make as efficient use as possible of a given bandwidth.

To being, let us consider the case of a channel that is noise- free. In this environment, the limitation on data rate is simply the bandwidth of the signal. A formulation of this limitation, due to Nyquist, states that if the rate of signal transmission is 2W, then a signal with frequencies no greater than W is sufficient to carry the data rate. The conserve is also true: Given a bandwidth of W, the highest signal rate that can be carried is 2W. This limitation is due to the effect of intersymbol interference (FREE80), such as is produced by delay distortion. The result is useful in the development of digital - to analog encoding schemes and is derived in Appendix 3A.

As an example, consider a voice channel being used, via modem to transmit digital data. Assume a bandwidth of 3100 Hz. Then the capacity, C of the channel is 2W= 6200 bps. However, as we shall see in chapter 3, signals with more than two levels can be used; that is each signal element can represent more than one bit. For example; if four possible voltage levels are used as signal then each signal element can represent two bits. With multilevel signaling, the Nyquist formulation becomes.

$$C = 2W \log_2 M$$

where M is the number of discrete signal or voltage levels. Thus, for M = 8, a value used with some modems. C becomes 18,600 bps.

So, far a given bandwidth, the data rate can be increased by increasing the number of different signals. However, this palces an increased burden on the receiver. Instead of distinguishing one of two possible signals during each signal time, it must distinguish one of M possible signals. Noise and other impairments on the transmission line will limit the practical value of M.

Thus, all other things being equal, doubling the bandwidth doubles the data rate. This can be explained intuitively by again considering Figure 1.6. For convenience this ratio is often reported in decibels:

$$(S/N)_{dB} = 10 \log \frac{\text{Signal power}}{\text{Noise power}}$$

This expresses the amount, in decibles, that the intended signal exceeds the noise level. A high S/N will mean a high - quality signal and a low number of required intermediate repeaters.

The signal - to noise ratio is important in the transmission of digital data because it sets the upper bound on the achievable data rate. Shammon's result is that the maximum channel capacity, in bits Per second, obeys the equation.

$$C = W \log_2 (1+ S/N)$$

where C is the capacity of the channel in bits Per second and W is the bandwith of the channel in Herta. As an example, consider a voice channel being used, via modem, to transmit digital data. Assume a bandwidth of 3100 Hz. A typical value of S/N for a voice - grade lines is 30 dB, or a ratio of 100:1. Thus

$$C = 3100 \log_2 (1 + 1000)$$

$$= 30.894 \text{ bps}$$

This represents the theoretical maximum that can be achieved. In practice, however, only much lower rates are achieved. One reason for this that the formula assumes white noise (thermal noise). Impulse noise is not accounted for, nor are attenuation or delay distortion.

The capacity indicated in the preceding equation is referred to a the error - free capacity. Shannon proved that if the actual information rate on a channel is less than the error - free capacity. Then it is theoretically possible to use a suitable signal code to achieve error - free transmission through the channel.

Shannon's theorem unfortunately does not suggest a means for finding such codes, but it is does provide a yardstick by which the performance of practical communication schemes may be measured.

Physical Description: A twisted pair consist of two insulated copper wires arranged in a regular spiral pattern. A wire pair acts as a single communication link. Typically, a number of those pairs are bundled together into a cable by wrapping them in a tough protective sheath. Over longer distances, cables, may contain hundreds of pairs. The twisting of the individual pairs minimises electromagnetic interference between the pairs. The wires in a pair have thicknesses of from 0.016 to 0.036 in.

~~**Uses:**~~ By far the most common transmission medium for both analog and digital data is twisted pair. It is the backbone of the telephone system as well as the workhorse for intrabuilding communications.

In the telephone system, individual telephone sets are connected to the local telephone exchange or "end office" by twisted - pair wire. These are referred to as "local loops". Within an office building, telephone service is often provided by means of a private branch exchange (PBX). ~~The PBX will be discussed in detail~~. Essentially, it as an on- prentise telephone exchange system that service a number of telephones within a building. It provides for intrabuilding calls via extension numbers and outside calls by trunk connection to the local end office. Within the building, the telephones are connected to the BPX via twisted pair. ~~For both of the systems just described, twisted pair has primarily been a office. Digital data traffic can also be carried over moderate distances. For modern digital PBX systems, data rates of about 64 kbps are~~

Bandwidth of telephone channel is B = 4 KHz achievable using digital signaling. Local loop connections typically require a modem, with a maximum data rate of 9600 bps. However, twisted pair is used for long - distance trunking applications and data rates of 4 Mbps or more may be achieved.

Twisted pair is also the medium of choice for a low - cost microcomputer local network within a building. This application is discussed in Chapter 11.

Transmission Characteristics: Wire pairs may be used to transmit both analog and digital signals. For analog signals, amplifiers are required about every 5 to 6 km. For digital signals, repeaters are used every 2 or 3 km.

Compared to other transmission media, twisted pair is limited in distance, bandwidth and data rate. Attenuation for twisted pair is a very strong function of frequency (FREE85a). Other impairments are also severe for twisted pair. The medium is quite susceptible to interference and noise because of its easy coupling with electromagnetic fields. For example, a wire run parallel to an ac power line will pick up 60 - Hz energy. Impulse noise also easily intrudes into twisted pair.

For point- to- point analog signaling, a bandwidth of up to about 250 kHz is possible. For voice transmission such as the local loop, the attention is about 1dB/km over the voice frequency range. A commn standard for telephone lines is a maximum loss of 6dB; hence a t km section of line represents an upper limit on the distance that can be covered.

2.2. Coaxial Cable

Physical Description: Coaxial cable, like twisted pair, consists of two conductor, but is constrcuted differently to permit it to operate over a wider range of frequencies (Figure 2-20). It consists of a bollow outer cylindrical conductor.

Coaxial cable has been perhaps the most versatile tranmission medium and is enjoying increasing utilizing in a wide variety of applications. The most important of these are:

- Long-distance telephone and television transmission
- Television distribution
- Local area networks
- Short-run system links

Coaxial cable has been an important part of the long-distance telephone network, although it is being rapidly supplanted by optical fiber, microwave, and satelite. Using frequency-division multiplying a coaxial cable can carry over 10.000 voice channels simultaneously. Cable is also used for long distance television transmission.

Coaxial cable is also spreading rapidly as a means of distributing TV signals to individual homes-cable TV.

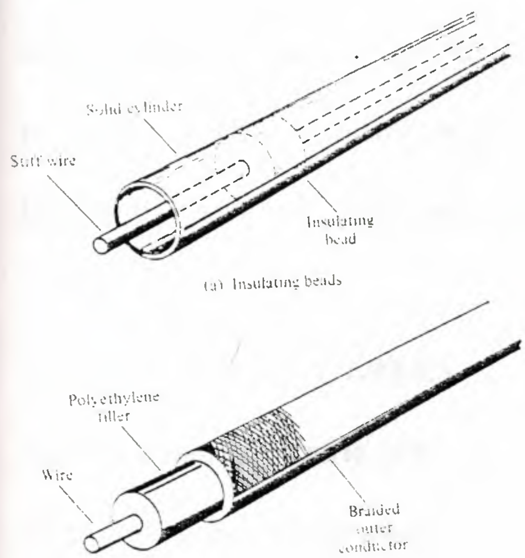


Figure 2.1 Coaxial Cable Construction.

An equally explosive growth area for a coaxial cable is local area networks. It is the medium of choice for many local network systems. Coaxial cable can support a large number of devices with a variety of data an traffic types, over distance that encompass a single building or a complex of buildings.

Finally, coaxial cable is commonly used for short-range connections between devices. Using analog signaling, coaxial cable is used to transmit radio or TV signals. With digital signaling, coaxial cable can be used to provide high-speed I/O channels on computer system.

Transmission Characters Coaxial cable is used to transmit both analog and digital signals. Long-distance systems may be either analog or digital. CATV is analog, ~~and digital techniques have been used for local networks~~ The principal constraints on performance are attention, thermal noise, and intermodulation noise. The latter is present only when several channels (FDM) or frequency bandwiths are in use on the cable.

2.3. **FIBER-OPTIC CABLES**

Just as standard electric cables come in a variety of sizes, shapes, and types, fibre-optic cables are available in different configurations. The simplest cables is just a single strand of fiber,, whereas complex cable are made up of multiple fibers with different layers and other elements.

The portion of a fibre optic cable that carries the light is made from either glass or plastic. Another name for glass is silica. Types of fiber optic cables and the configuration are given in ch 4.

Glass has superior optical characteristics over plastic. However, glass is far more expensive and more fragile than plastic. Although the plastic is less expensive and more flexible, its attenuation of light is greater. For very logn distance transmission, glass is certainly preferred. For shorter distance, plastic is much more practical.

A Fiber-optic cable is rarely used alone. The fiber, which is called the core, is usually surrounded by a protective cladding as illustrated in Fig. 2.2. The cladding is also made of glass or plastic but has a lower index of refraction. Some fiber-optic cables have a glass core with a glass cladding. Others have a plastic core with a plastic cladding. Another common arrangement is a glass core with a plastic cladding. It is called plastic-clad silica (PCS) cable.

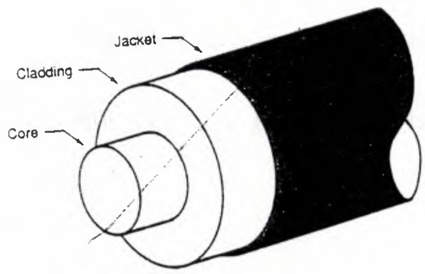


Fig. 2.2. Basic construction of a fiber-optic cable.

In observing a fiber-optic cable, you typically cannot tell the division betweent eh core and the cladding. Since the two are usually made of the same types of material of the naked eye it is not possible to see the difference. A plastic jacket similar to the outer insulation on an electric cable is usually put over the cladding.

There are two basic ways of classifying fiber-optic cables. The second way of classification is by mode. Mode refers to the various paths that the light rays can take in passing through the fiber.

There are two basic ways of defining the index of refraction variation across a cable. These are step index and graded index. The other type of cable has a graded index. In this type of cable, the index of refraction of the core is not constant. Instead, theindex of refraction of the core is not constant. Instead, the index of refraction varies smoothly and continuously over the diameter of the core as shown in Fig. 2.4. As ou get closer to the center of the core, the index of refraction gradually increases, reaching a peak at the center and then declining as the other outer edge of the core is reached. The index of refraction of the cladding is constant.

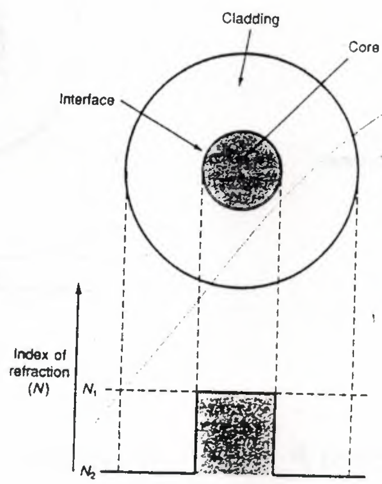
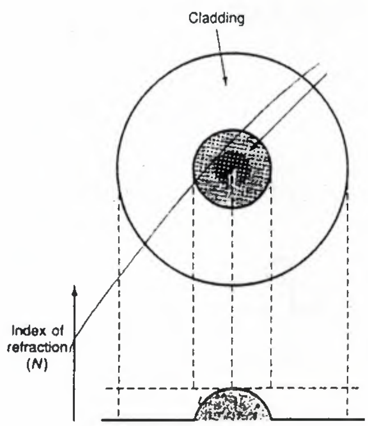
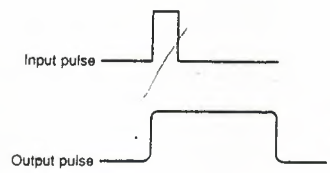


Fig. 2.3. A step-index cable cross section.

Mode refers to the number of paths for the light rays in the cable. There are two classifications: single mode and multimode. In single mode, light follows a sngle path through the core. In multilode the light takes many paths through the core. In practice, there are three commonly multimode step index, single-mode step index and multimode gradded index. Let's take a look at each of these types in more detail.

The muldimode step-index fiber cable is probably the most common and widely used type.





2.4 Graded index table cross section. 2.5 A multimode step- indexcable.

The main advantage of a multimode step index fiber is the large size. Typical core diameters are in the 50-to 1000 range. The light takes many hundreds or even thousands of paths through the core before exiting. The problem with this is that it stretches the ligh pulses.

For example, in fig. 2.5. a short light pulse is applied to the end of the cable by the soruce. Light rays from the source will travel in multiple paths. Other rays begin to reach the end of the cable later in time until light ray the longest path finally reaches the end, concluding the pulse. In fig. 2.5. ray A reaches the end first, then B, then C. The stretching of the pulse is referred to as modal dispersion.

Because the pulse has been stretched, input pulses cannot occur at a rate faster than the output pulse duration permits. Otherwise the pulses will essentially merge together as shown in fig. 2.6. At the output, one long pulse will occur and will be indistinguishable from the three separate pulses originally transmitted.

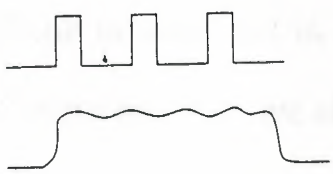


Fig. 2.6. The effect of modal dispersion on pulses occuring too rapidly in a multimode step-index cable

In a single-mode, or mono-code, or mono-mode, step-index fiber cable the core is so small that the total number of mode or paths through the core are minized and modal dispersion is essentially eliminated. Fig. 2.7. With minimum refraction, no pulse stretching occurs.

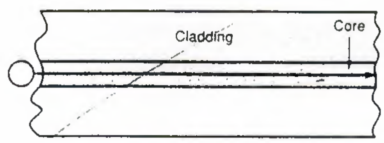


Fig. 2.7. Single-mode step-index cable

The single-mode step-index fibers are by far the best since the pulse repetition rate can be high and the maximum amount of information can be carried.

The main problem with this type of cable is that because of its extremely small size, it is difficult to make and is, therefore very expensive. Handling, splicing and making interconnections are also more difficult. Finally, for proper operation an expensive superintense light source such as a laster must be used. For long distances, however, this is the type of cable preferred.

Multimode graded-index fiber cables have several modes or paths of transmission through the cable, but they are much more orderly and predictable. Figure 2.8. shows the typical paths of the light beams. Because of the continously varying index of refraction across the core, the light rays are bent smoothly and converge repeatedly at points along the cable.

Fig. 2.8. A multimode graded-index cable

There are many different types of cable configurations. Many have several layers of protective jackets. Some cables incorporate a flexible strength or tension elements which helps minimize damage to the fiber-optic elements when the cable is being pulled or when it must support its own weight.

The amount of attention, of course, varies with the type of cable and its size. But more importantly, the attenuation is directly proportional tot he length of the cable. It is obvious that the longer the distance the light has to travel, the greater the loss due to absorptioni scatteing and dispersion.

The attenuation of a fiber-optic cable is expressed in decibles Per unit of length. The standard is decibes Per kilometer. The standard decible formula used is

$$dB = 10 \log \frac{P_o}{P_i}$$

where Po is the power out and Pi is the power in.

Figure 2.9. is a table shows the percentage of output power for various decibel losses. The higher the decibel figure, the greater the attenuation and loss. A 30dB loss means that only one thousand of the input power appears at the end.

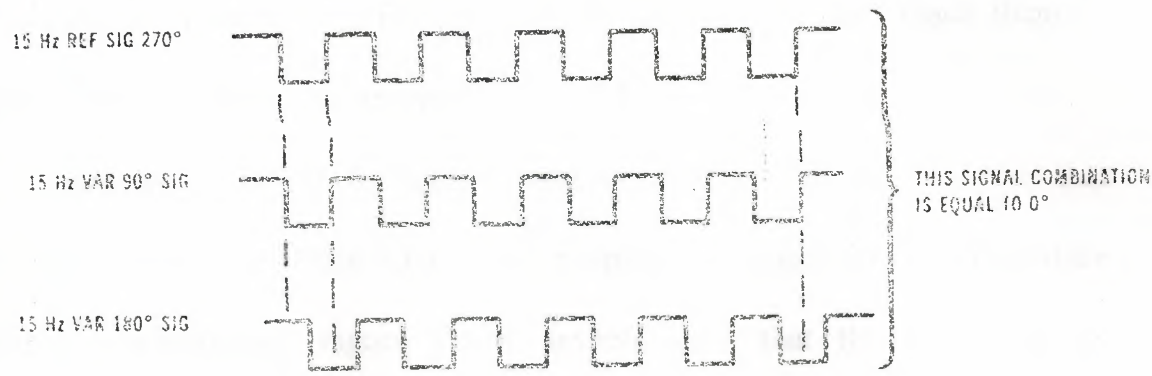


Figure 2.9.

The attenuation rating of fiber-optic cables vary over a considerable range. Typically, those fibers with an attenuation of less than 10 dB/km are called low-loss fibers, while those with an attenuation of between 10 and 100 dB/km are called low-loss fibers. High-loss fibers are those with over 100dB/km ratings. Naturally, the smaller the decibel number, the less the attenuation and the better the cable.

You can easily determine the total amount of attenuation for a particular cable if you know the attenuation rating. If two cables are spliced together and one has an attenuation of 17 dB and the other 24 dB, the total attenuation is simply the sum, or 17 + 24 = 41 dB.

When long fiber-optic cables are needed, two or more cables may be spliced together. The ends of the cable are perfectly aligned and then glued together with a special, clear, low loss epoxy. Connectors are also used. A variety of connectors provide a convenient way to splice cables and attach them to transmitters, receivers, and repeaters.

The two ends of the cables must be aligned with precision so that excessive light is not lost. Otherwise, a splice or connection will introduce excessive attenuation. Figure shows several ways that the cores can be misaligned. A connector corrects these problems.

CHAPTER 3

WAVE PROPAGATION

3.1 ELECTRICAL TO ELECTROMAGNETIC CONVERSION

Early radios were often reffered to as the "wireless". This new machine could speak without being "wired" to the source as the telegraph and telephone are.

The transmitting antenna converts its input electromagnetic energy. The antenna can thus be thought of as a transducer – a device that converts from one from of energy into another. In that respect, a light bulb is very similar to an antenna. The light bulb also converts electrical energy into electromagnetic energy – light. The only difference between light and the radio waves we shall be concerned with is their frequency. Light is an electromagnetic wave at about 5 x 10^4while the usable radio wave extend from about 1.5 x 10^4 Hz up to 10^{11} Hz. The human eye is responsive (able to perceive) to the very narrow range of light frequencies, and consequently we are blind to the radio waves.

The receiving antenna intercepts the transmitted wave and converts it back into electrical energy. An analogous transducer for it is the photovoltaic cell that also converts a wave (light) into electrical energy. Since a basic knowledge of waves is necessary to your understanding of antennas and radio communications, the following section is presented prior to your further study of wave propagation.

3.2 Wafefronts

If an electromagnetic wave were radiated equally in all directions from a point source in free space, a spherical wavefront would result. Such a source is terned an isotropic point source. A wavefront may be defined as a plane joining all points of equal phase. Two wavefronts are shown in Fig. 3.1 isotropic source raidates equally in all directions. The wave travels at the speed of light so that at some point in time the energy will have reached the area indicated by wavefront 1 in Fig 3.1. The power density *P* (in watts per square meter) at wavefront 1 is inversely proportional to the square of its distance from its source, r (in meters), with respect to the originally transmittes power, Pt. Stated mathematically,

$$P = P_t / 4\pi r^2$$

If wavefront 2 in Fig 3.1 is twice the distance of wavefront 1 from the source, then its power density in watts, per unit area is just one- fourth that of wavefront 1. Any section of a wavefront is curved in shape. However, at appreciable distances from the source, small sections are nearly flat.

Wavefront 2

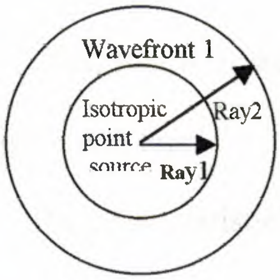


Figure 3.1 Antenna wavefronts

Characteristic Impedance of Free Space

The strength of the electric field, E (in volts per meter), at a distance r from a point source is given by

$$E = \sqrt{30Pt} / r$$

Where P_t is the originally transmitted power in watts. That is one of Maxwell's equations, which were finalized in 1873 and allowed mathematical analysis of electromagnetic wave phenomena.

Power density P and the electric field E are realted to impedance in the same way that power and voltage relate in an electric circuit. Thus,

$$P = \ /$$

Where is the characteristic impedance of the medium conduction the wave.

Thus, it is seen that free space has a characteristic impedance just as does a transmission line.

The characteristic impedance of any electromagnetic wave – conducting medium is provided by.

$$Z = \sqrt{\frac{\mu}{\varepsilon}}$$

Where is the medium's permiability and is the medium's permittivity. For free space. $= 1.26 \times 10^{-6}$ H/m and $= 8.85 \times 10\text{-}12$ F/m. Substitting in

3.3 WAVES NOT IN FREE SPACE

Reflection

Just as light waves are reflected by a mirror, radio waves ~~are reflected by~~ any conductive medium such as metal surfaces, or the earth's surface. The angle

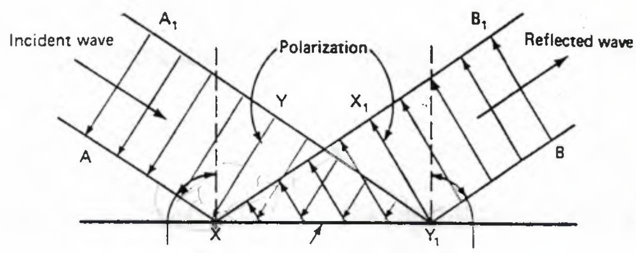


Figure 3.2 Reflection of a wavefront.

of incidence is equal to the angle of reflection, as shown in Fig 3.2. Note that there is a change in phase of the incident and reflected wave, as seen by the difference in the direction of polarization. The incident and reflected waves are 180^0 out of phase.

Complete reflection occurs only for a theoretically perfect conductor and when the electric fields is perpendicular to the reflecting element. For it the coefficient of reflection p is 1 and is defined as the ratio of the reflected electric field intensity divided by the incident intensity. It is less than 1 in practical situations due to due to the absorption of energy by the nonperfect conductor and also because some of the energy will actually propagate right through it.

Refraction

Refraction of electromagnetic radio waves occurs in a manner akin to the refraction of light. Refraction occurs when waves pass from one density medium to another.

An example, of refraction is the apparent bending of a spoon when it is immersed in water. The bending seems to take place at the water's surface, or exactly at the point where there is a change of density. Obviously, the spoon does not bend from the pressure of the water. The light forming the image of the spoon is bent as it passes from the water, a medium of high density, to the air, a medium of comparatively low density.

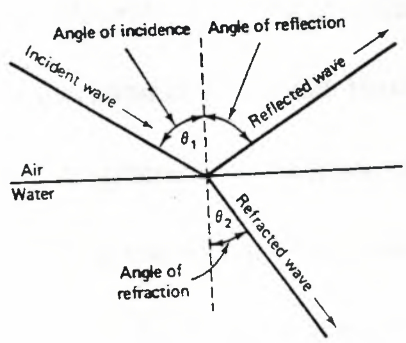


Figure 3.3 Wave refraction and reflection.

The bending (refraction) of an electromagnetic wave (light or radio wave) is shown in Fig 3.3. Also shown is the reflected wave. Obviously, the coefficient of reflection is less than 1 here since a fair amount of the incident wave's energy is propagated through the water – after refraction has occurred.

The angle of incidence, Q_1, and the angle of refraction, Q_2, are related by the following expression, which is Snell's law:

where n_1 is the refractive index of the incident medium and n_2 is the refractive index of the refractive medium.

Recall that the refractive index for a vacuum is exactly 1 and approximately 1 for the atmosphere, while glass is about 1.5 and water is 1.33.

Diffraction

Diffraction is the phenomennon whereby waves travelling in straight paths
изгиб, сгиб, поворачивать
bend around an obstacle. This effect is the result of Huygens' principle, advanced by the Dutch astronomer Christian Huygens in 1960. The principle states that each point on a spherical wavefront may be considered as the source of a secondary spherical wavefront. This concept is important to us since it explains radio reception behind a mountaine or tall

building. Figure 3.4 shows the diffraction process allowing reception beyond a mountain in all but a small area, which is called the shadow zone. The figure shows that electromagnetic waves are diffracted over the top and around the sides of an obstruction. The direct wave fronts that just get by the obstruction become new sources of wave fronts that start filling in the void, making the shadow zone a finite entity.

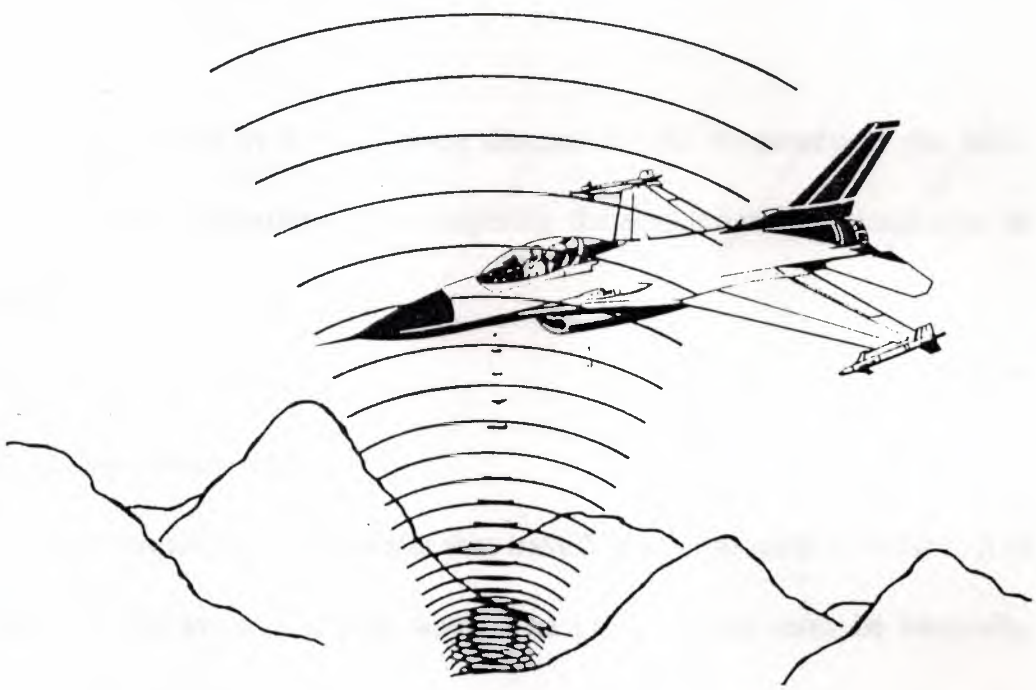


Figure 3.4 Diffraction around an object.

3.4 GROUND AND SPACE – WAVE PROPAGATION

There are four basic modes of getting a radio wave from the transmitting to receiving antenna:

1. Ground wave
2. Space wave (line-of sight)
3. Sky wave
4. Satellite communications

As will be seen in the following discussion, the frequency of the radio wave is of primary importance in considering the performance of each type of propagation.

0.3 – 3 MHz

Ground – Wave Propagation

A ground wave is a radio wave that travels along the earth's surface. It is sometimes reffered to as a surface wave. The ground wave must be vertically polarized (electric field vertical) since the earth would short out the electrical field if horizontally polarized. Changes in terrain have a strong effect on ground waves. Attenuation of ground waves is directly related to the surface impedence of the earth. This impedance is a function of conductivity and frequency. If the earth's surface is highly conductivite, the absorption of wave energy, and thus its attenuation, will be reduced. Ground – wave propagationis much better over water (especially salt water) than say a very dry (poor conductivity) desert terrain.

The ground losses increase rapidly with increasing frequency. For this reason ground waves are not very effective at frequencies above 2 MHz. Ground waves are, however, a very reliable communications link. Reception is not affected by daily or seasonal changes such as with sky- wave propagation.

Ground- wave propagation is the only way to communicate into the ocean with submarines. To minimize the attenuation of seawater, extremely low frequency (ELF) propogation is utilized. ELF waves encompass the range 30 to 300 Hz. At a typically used frequency of 100 Hz, the attenuation is about 0.3 dB/m. This attenuation increases steadily with frequency such that at 1 GHz a 1000 – dB/m loss is sutained!

SPACE – WAVE PROPAGATION

The two types of space waves are shown in Fig 3.5. They are the direct wave and ground reflected wave. Do not confuse these with the ground wave just discussed. The direct wave is by far the most widely used mode of antenna communications. The propagated wave is direct from transmitting to receiving antenna and does not travel along the ground. The earth's surface, therefore, does not attenuation it.

The direct space wave does have one severe limitation – it is basically limited to so – called line – of – sight transmission distances. Thus, the antenna height and the curvature of the earth are the limiting factors. The actual radio horizon is about 1/3 greater then the geometric line of sight due to diffraction effects and is emprically predicted by the following approximation:

$$d = \sqrt{2h_t} + \sqrt{2h_r}$$

$d = 2\sqrt{h}$ if $h_r = h_t = h$. feet = 30 cm mile = 1,6 km.

Where d= radio horizon (mi)

h_t = transmitting antenna height (ft)

h_r = receiving antenna height (ft)

The diffraction effects cause the slight wave curvature as shown in Fig. 3.6. If the trandmatting antenna is 20 ft high, a radio horizon of about 50 mi result. This explains the coverage that typical broadcast FM and TV stations provide since they are utilizing direct space- wave propagation.

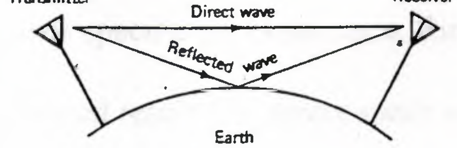
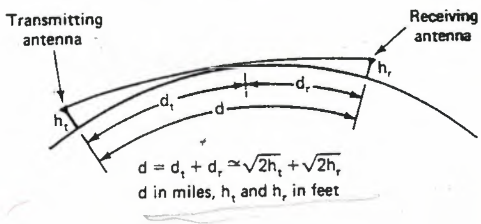


Figure 3.5 Direct and ground reflected space waves,



1 feet =
1 miles =

3.6 Radio horizon for direct space waves.

The reflected wave in Fig. 3.5 can cause reception problems. If the phase of these two received compenents is not the same, some degree of signal fading and/or distortion will occur. This can also result when both a direct and ground wave are received or when any two or more signal paths exist. A special case involving TV reception is precented next.

TE7H6-ghost

Ghosting in TV reception. Any tall or massive objects obstruct space waves. This result in diffraction (and subsequent shadow zones) and reflections. Reflections pose a specific problem since, for exampe, reception of a TV signal may be the combined result of a direct space wave and a reflected space wave, as shown in Fig 3.7. This condition results in ghosting, which manifests itself in the form of a double – image distortion. This is due to the two signals arriving at the receiver at two different times – the reflected signal has a farther distance to travel. The reflected signal is weaker that the direct signal because of the inverse square – law relationship of signal strength to distance (Eq. (12-1)) and because of losses incurred during reflection.

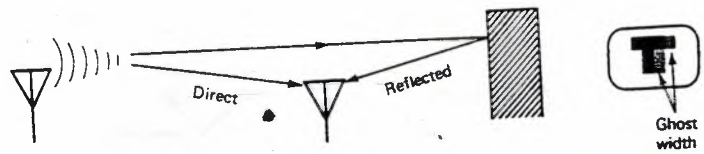


Figure 3.7. Ghost interference

A possible solution to the ghosting problem is to detune the receiving antenna orientation so that the reflected wave is too weak to be displayed. Of course, the direct wave must exceed the receiver's sensitivity limit as it will also be reduced in level when the antenna is detuned. It should be noted that ghosting can also be caused by transmission line reflections between antenna and set.

3.5 SKY WAVE PROPAGATION

One of the most frequently used methods of long distance transmission 's by the use of the sky wave Sky waves are those waves rediated from the transmitting antenna in a direction that produces a large angle with reference to the earth. The sky wave has the ability to strike the ionosphere, be refracted from t to the ground., strike the ground, be reflected back toward the ionosphere, and so on. An illustration of this skipping effect is shown in Fig 3.8.

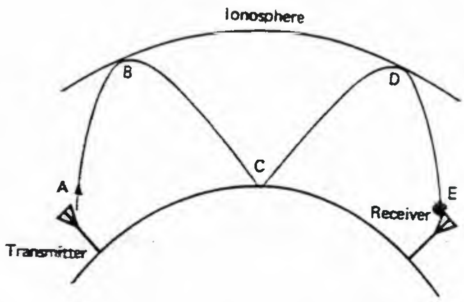


FIGURE 3.8 Sky- wave Propagation.

CHAPTER 4

UNGUIDED MEDIA

For unguided media, the spectrum of frequency band of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics. As we have already mentioned the higher the center frequency of a signal the greater the potential bandwith and hence date rate. Another property of signals transmitted by antenna is directionality. In general, at lower frequencies signals are omnidirectional; that is, the signal propagates in all directons from the antenna. At higher frequencies, it is possible to focus the signal into a directional beam.

Two general ranges of frequencies are of interest in discussion. Microwave frequencies cover a range of about 2 to 40 ~~Hz~~ GHz. At these frequencies, highly directional beams are possible, and microwave is quite suitable for point-to- point transmission. We will refer to signals in the range 30 MHz to 1 GHz as radio frequencies waves. Omnidirectional transmission is used and signals at these frequncies are suitable for broadcast applications.

The ~~reader should also be aware of a finer~~ subdivision of the electromagnetic spectrum defined by the International Telecommunications Union and shown in Table 4.1.

TABLE 2-4 Characteristics of Unguided Communications Bands

Frequency Band	Name	Analog Data Modulation	Analog Data Bandwidth	Digital Data Modulation	Digital Data Data Rate	Principal Applications
30–300 kHz	LF (low frequency)	Generally not practical		ASK, FSK, MSK	0.1–100 bps	Navigation
300–3000 kHz	MF (medium frequency)	AM	To 4 kHz	ASK, FSK, MSK	10–1000 bps	Commercial AM radio
3–30 MHz	HF (high frequency)	AM, SSB	To 4 kHz	ASK, FSK, MSK	10–3000 bps	Shortwave radio CB radio
30–300 MHz	VHF (very high frequency)	AM, SSB; FM	5 kHz to 5 MHz	FSK, PSK	To 100 kbps	VHF television FM radio
300–3000 MHz	UHF (ultra high frequency)	FM, SSB	To 20 MHz	PSK	To 10 Mbps	UHF Television Terrestrial Microwave
3–30 GHz	SHF (super high frequency)	FM	To 500 MHz	PSK	To 100 Mbps	Terrestrial microwave Satellite microwave
30–300 GHz	EHF (extremely high frequency)	FM	To 1 GHz	PSK	To 750 Mbps	Experimental short point-to-point

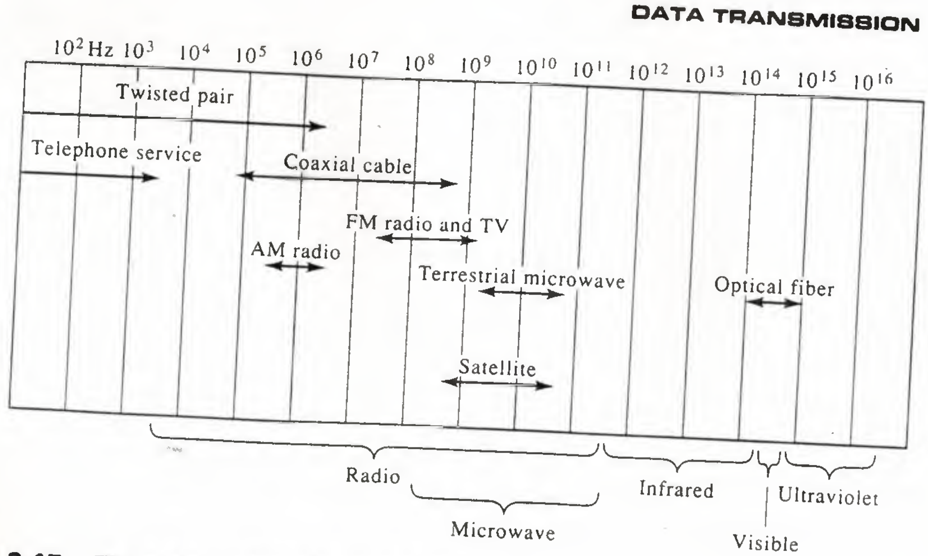


FIGURE 2-17. The electromagnetic spectrum.

Frequency Band	Name	Modulation
30–300 kHz	LF (low frequency)	
300–3000 kHz	MF (medium frequency)	AM
3–30 MHz	HF (high frequency)	AM, SSB
30–300 MHz	VHF (very high frequency)	AM, SSB; FM
300–3000 MHz	UHF (ultra high frequency)	FM, SSB
3–30 GHz	SHF (super high frequency)	FM
30–300 GHz	EHF (extremely high frequency)	FM

TABLE 4.1 Characteristic of Uniguided Communications Bands

4.1 Terrestrial Microwave

Physical Description: The most common type of microwave antenna is the parabolic "dish". A typical size is about 10 ft diameter. ~~The antenna is fixed rigidly and focuses a narrow beam to achieve line- of- sight transmission to the receiving antenna. Microwave antennas are usually located at substantial heights above ground level in order to to extend the range between antennas and to be able to transmit over intervening obstales.~~ With no intervening obstacles the maximum distance between antennas conforms to:

$$d = 7.14\sqrt{Kh}$$

where d is the distance between antennas in km; h is the antenna height in m; $K = \frac{4}{3}$ is ~~coefficient~~ is ~~adjacent~~ adjustment factor.

TRANSMISSION MEDIA

Bent of refracted with the curvature of the earth and will hence propagate farther than the optical line of the sight. ~~A good rule of thumb is K= 4/3. So~~

Example,

~~for example, two microwave antennas at a height of 100m may be as far as~~

Height of microwave antennas is 80 km.
Find ~~distance~~ maximal distance between them

d = 7.14 x $\sqrt{133}$ = 82 km apart. To achieve long distance transmission, a series of microwave relay towers is used, and point to point microwave links are strung together over the desired distance.

~~Uses:~~ The ~~primary use for~~ terrestrial microwave systems is ~~in~~ used for long- haul telecommunications service, as an alternative to coaxial cable for transmitting television and voice. Like coaxial cable, microwave can support high data rates over long distances. The microwave facility requires far fewer amplifiers or repeaters than coaxial cable for the same distance , but requires line- of sight transmission.

Another increasingly common use of microwave is for short point- to point links between buildings. This can be used for closed- circuit TV or as a data link between local networks.

Finally, a potential use for terrestrial microwave is for providing digital data transmission in small regions (radius < 10 km). this concept has been termed "local data distribution" and would provide an alternative to phone lines for digital networking.

Transmission Characteristics: As a table 4.1 indicates, microwave transmission covers a substantial portion of the spectrum. Common frequencies used for transmission are in the range range 2 to 40 GHz. The higher the requency used, the higher the potential bandwidth and therefore the higher the otential data rate.

As with any transmission system, a main source of loss for microwave is ttenuation. For microwave (and radio frequency), the loss (attenuation) can be expressed as

$$L = 10 \log \left(\frac{4\pi d}{\lambda}\right)^2 \text{ dB}$$

Vhere d is the distance and λ is the wavelength in the same units. Thus loss varies as the square of the distance. This is in contrast to twisted pair and coaxial cable where the loss varies logarithmically wih distance (linear in decibels). Thus repeaters or amplifiers may be placed farther apart for microwave systems – 10 to 100 km is typical. Attenuation is increased with rainfall. The effects become noticeable above 10 GHz.

Another source of impariment for microwave is interference. With the growing popularity of wicrowave, transmission areas overlap and interference is always a danger. Thus the assignmetn of frequency bands is strictly regulated. The most common bands for common carrier long- haul communications are the 4- GHz bands. With increasing congestion at these frequencies, the 11 GHz band is now coming into use. The 12 GHz band is used as a component to local CATV installations; the signals are then distrubed to individual subscribers via coaxil cable.

.2 Satellite Microwave

Physical Description: a communication satellite is, in effect, a microwave elay station. It is used to link two or more ground based microwave transmitter eceivers. The sattelite receives transmission on one frequency band (uplink), amplifies (analog transmission) or repeats (digital transmission) the signal and transmits it on another frequency (downlink). A single orbiting satellite will operate on a number of frequency bands, called transponder channels, or simply transponders.

Figure 4.1 depicts in a general way two common uses of communications sattelites. In the first, the satellite is being used to provide a point to point link communicaiton between one ground based transmitter and a number of ground basedreceivers. In fact, these depictions are only suggestive of the ways in which sattellites are used a subject. To remain stationary the satellite must have a period of rotation equal to the earth's period of rotation. This match occurs at a height of 35,784 km.

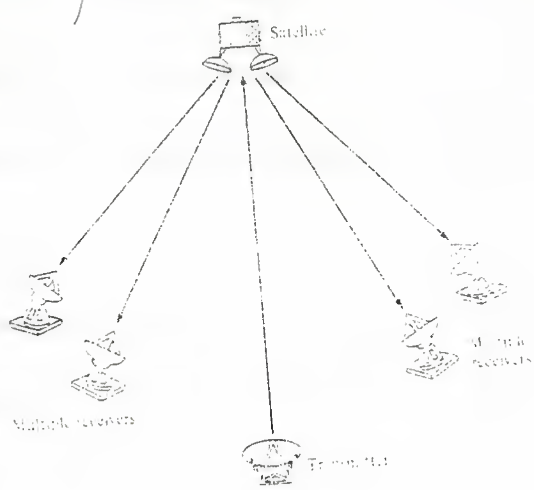


FİGURE 4.1

Uses: The communication sattellite is a technological revolution as important as fiber optics. Among the most important applications for satellites are:

Finally there are a number of business data applications for satellite. The satellite chanels to individual business users. A user equipped with the antennas at a number of sites can use a satellite chanel for a private network. Traditionally, such applications have been quite expensive and limited to larger organizations terminal (VSAT) system which provides a low- cost alternative. Figure 4.2 depicts a typical VSAT configuration. A number of subscriber stations are equipped with low cost VSAT antennas (about $400 per month per VSAT). Using some discipline these share a satellite transmission capacity for transmission to a hub station. The hub station can exchange messages with each of the subscribers and can relay messages between subscribers.

4.3 Radio Channel

Physical Description. The principal difference between radio and microwave is that radio is omnidirectional and microwave is focused. Thus radio does not require dish- shaped antennas, and the antennas need not be rigidly mounted a precise alignment.

Uses: Radio is a general term sometimes used to encompass all frequency bands of Table 4.1. This range covers FM radio and UHF and VHF television. In addition to these traditional uses, new applications have grown up in this band, and we mention several of these briefly.

A well known use of radio for digital data communications is packet radio, which is discussed in Chapter 10. A packet radio system uses ground- based antennas to link multiple sites in a data transmission network.

Transmission Characteristics. The range 30 MHz to 1 GHz is a very effective one for broadcast communications. Unlike the case for lower- frequency electromagnetic waves, the jonosphere is transparent to raido waves above 30 MHz. Thus with each other due to reflection fron the atmosphere. Unlike the higher frequencies of the microwave region, radio waves are less sensitive to attenuation from rainfall. For digital data communications the primary drawback of this frequency range is that lower data rates are achievable. Simply to distance obeys namely dB. Because of the longer wavelength radio waves suffer relatively less attenuation.

The transmission characteristics of radio used for broadcast communications are straightforward. The first such system was the ALOHA system in Hawaii. Two frequency bands were used, one at 407.35 MHz for transmission in the opposite direction. Transmission is in the form of short bursts of data called packets. The point range is about 500 km; repeaters were used to extend the system to a radius of about 500 km. A similar system is in operation in

Montreal using frequencies in the 220- MHz range. A system with mobile stations has been developed by the Printer Terminal Corp. using frequencies between 450 and 510 MHz.

CONCLUSION

I ‘m very gladful for working a topic like that. In this graduation project I covered Data Transmission, Electrical Communication Systems, Electronic Communication topics with related Guided and unguided media.

We are now in what is called the “Information age”. Information has became a commodity not only to the business community, but to all of society. There are technics on how best to handle physical commodities, so there are technics on how best to manage information, and how to transmit it in a timely fashion to where it is needed. Everyday in our work and spare time, we come in contact with and we use a variety of modern communication systems and communication media, the most common being telephone, radio, television, and internet services. These media we are able to communicate with people on different continents and receive information about various development and events of note that occur all around the world. Electronic mail and facsmile transmission have made it possible to quickly communicate written messages from the great distances.

Electronic communications systems are designed to send message or information from a sorce that generates the message to one or more destinations.

The succesfull transmission of data depends principally on two factors: the quality of the signal being transmitted and the characteristics off the transmission medium. The datas either analog or digital data may be transmitted using either analog or digital signals. It is common for intermediate processing to be performed between source and destination and, this processing has either on analog or digital chracter.

Because of I want to graduate on the topic of communication, this project very useful for me. While I search the topic, I learnt a lot of things about the communication. The last thing I want to say that, communication is very huge and interesting topic. I thank to my professor to help and to give me chance like that.

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