CHAPTER 1

1.0 INTRODUCTION

Transfer of information from one point to another point is called communication. When the information is to be transmitted over a distance a communication system is usually required. Communication is frequently achieved by superimposing information on to an electromagnetic wave, which acts as a carrier for the information signal. This carrier with information is then transmitted to the required destination where it is received and the original signal is separated from the carrier electromagnetic wave.

Many techniques have been developed for this process using electromagnetic carrier waves operating at radio frequency as well as microwave and millimeter wave frequencies. Communication can also be achieved by using an electromagnetic wave, which is selected from the optical range of frequencies. This type of communication is called optical communication. Limited use of light wave for communication has been common for a long time. Simple communication like fire, reflecting mirror or signaling lamps have provided successfully but limited information transfer. As early as 1880 Alexander Graham Bell reported the transmission of speech using a light beam [1]. In early stages optical communication used was limited due to a lack of suitable light sources and the restriction of light communication to the line of sight which is severely affected by disturbances like sun, rain, snow, dust and atmospheric turbulence. It is found that lower frequencies electromagnetic waves like radio and microwave provide better carriers for information transfer in the a free-mentioned atmospheric conditions.

Information carrying capacity is directly related to the bandwidth or frequency extent of the carrier electromagnetic wave, which is generally limited to a fraction of the carrier frequency. In other words, the greater the carrier frequency the larger the available transmission bandwidth and thus greater the information carrying capacity of the communication system. For this reason radio communication was developed to higher frequencies, such as VHF and UHF, leading to the introduction of even higher microwave and millimeter wave transmission. Communication at the optical frequencies offers an increase in the potential usable bandwidth by a factor of 10^4 over the high frequency microwave transmission. Laser was invented in early 1960s. This device provided a powerful coherent light source together with the possibility of modulation at high frequency. Because laser light has lower divergence, it made free space medium distance optical communication possible. In 1966 optical communication via a dielectric wave-guide was proposed to avoid digression of the optical signal by the atmosphere [2]. Initially the optical fibers fabricated from glass exhibited very high attenuation such as 1000dB km^{-1} and were not comparable with the coaxial cable which has attenuation around 5 to 10dB km^{-1}. But within the space of ten years optical fiber losses were reduced to 5dB km^{-1} and suitable low loss joining techniques were developed. It is found that there are wavelengths where signal loss in silica based glass shows very small loss. The 0.8μm to 0.9μm in the near infra-red termed the first optical window. At these wavelengths it is easy and cheap to fabricate powerful lasers. The second region of wavelengths where optical fiber shows low attenuation is around 1.3μm, but producing lasers at this wavelength is relatively more difficult and expensive than producing at 0.8μm to 0.9μm. This region is called the second window. The third window, which extends between 1.5μm to 1.6μm is superior and widely used. But producing light sources at this wavelength is most difficult and expensive. At these wavelengths single mode optical fibers with attenuation below 0.2dB km^{-1} is commercially available. At 1.5μm, material dispersion and the wave-guide dispersion prove to be the lower ceiling for maximum achievable bandwidth. To obtain both low loss and low dispersion at the operating wavelength, new advanced single mode fibers have been realized; namely, dispersion shifted, dispersion flattened fibers, polarization maintaining fibers (PMF) etc. In our experiment free space or PMF is required and this will be discussed later. All the development mentioned made optical fiber communication cheaper and reliable.

1.1 General System

Most of the optical fiber communication systems are similar in nature. A block diagram of general communication is given below.

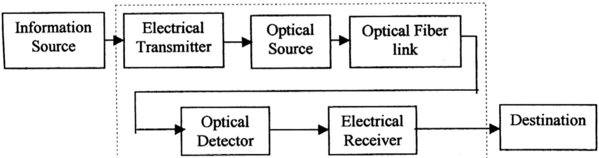

Fig. 1.1 Optical fiber communication system

The communication system consists of an electrical transmitter, which is linked to the information source. It changes the information into an electrical signal then this electrical signal is superimposed on the optical carrier, which is provided by the optical source.

1.2 Advantages Of Optical Fiber Communication

Fiber optic communication has a number of extremely attractive features. Here we will discuss the merits and special features offered by fiber optic communication over electrical communication.

1.2.1 Bandwidth

The optical carrier wavelength is around 1.5μm, which is in the near infrared region, which translates into 200 THz. It yields a far greater potential transmission bandwidth than any metal cable system or millimeter wave radio system of which the bandwidth is around 500MHz and 700 MHz respectively. At present a data rate more than 20GHz without intervening electronic regenerator over hundered of km has been tested. In case of wide–band coaxial cable, high loss restricts the transmission distance less than a hundred kilometers at bandwidth of over one hundred megahertz. Bandwidth can be increased by transmitting several optical signals, each at a slightly different wavelength, in a single fiber. Presently tested system use 32 to 64 channels with more in the planning. This is achieved by using wavelength division multiplexers (WDM) [3], which separate different wavelengths from single fiber.

1.2.2 Small Size And Weight

Optical fibers have a very small diameter. Even when these fibers are covered with a protective coating they are far smaller and much lighter than equivalent copper cables. This is a big advantage in congested cities. Light weight and small size is also ideally suited for expansion of signal transmission within automobiles, aircraft, satellites etc.

1.2.3 Electrical Insulator

Optical fibers are made from glass or plastic polymer. These materials are good electrical insulators. This makes it ideal for communication in electrically hazardous environments. Fibers do not create sparks or short circuits.

1.2.4 Security Of Signal

Signal from optical fiber does not emit significant radiation thus providing a higher degree of security. This feature is attractive for banking, general data transmission and especially for military applications.

1.2.5 Less Interference

Optical signals pass through a dielectric wave-guide and are immune to electromagnetic interference, such as radio frequency interference and even spiking transient electromagnetic pulses such as caused by lightning. It is very easy to ensure that there is no interference between fibers, even when many fibers are cabled together. Since the light-wave is guided in the fiber.

1.2.6 Low Transmission Loss

Commercial fiber with losses as low as 0.2dB km^{-1} is available at a very low price. This feature has become a major advantage of optical communication.

1.2.7 Toughness And Flexibility

Optical fibers can be manufactured to process very high tensile strength and at the same time can also be bent to quite small radii and these optical fibers are also easy to store and transport.

1.2.8 Reliability And Maintenance

Reliability of the optical components is no longer a problem with a predicted lifetime of 20 to 30 years. Since optical fibers have low loss and are rugged that makes it easy to maintain and costs less over period of time [4,5].

1.2.9 Low Cost

Presently commercially available optical fiber costs only few cents a meter, which is quite comparable to copper cable. Cost of semiconductor lasers and detectors are also coming down. All these factors make optical fiber communication cheaper, more reliable and long lasting. In fact it is a matter of time when most of the copper cable for communication will be replaced by optical fiber for high-density information transmission [6 to 8].

1.3 Aim Of Thesis

Most of the deployed optical communication systems utilize intensity modulation / direct detection (IM/DD) in which intensity of the light wave is modulated and this intensity variation can be directly detected. There are other types of communication systems like frequency modulation and phase modulation [9,10]. These techniques are difficult and are more expensive to implement relative to IM/DD. Among all of these techniques phase modulation technique, also called phase shift keying (PSK), is one of the most efficient as far as energy and high-density information are concerned. But at the same time it is also very difficult to implement because it needs polarization-maintaining fiber (PMF), polarizations maintaining couplers, and narrow band light sources. Recent development in PMF, polarization-maintaining couplers, high power stable narrow band light sources have inspired us to explore PSK communication system. In most of multi-channel communication systems including PSK more than one light sources are used. In this thesis three things are explored. These are

- communication by using single light source
- to increase number of communication channels in a PSK communication system
- to explore the ways to reduce the effect of phase fluctuation and polarization fluctuation in PSK communication system.

1.4 References

[1] A.G. Bell, "Selenium and the photophone", The Electrician, pp 214, 215, 220, 221, 1980.

[2] K. C. Kao and G. A. Hockham, "Dielectric fiber surface waveguides for optical frequencies", Proc. IEE, 113(7), pp. 1151-1158, 1966.

[3] J. M. Senior, "Wavelength division in optical fiber networks", Communications Internat., 15(4), pp. 52-54,59, 1988.

[4] E. Desurvir, " Erbium-Doped fiber Amplifier for New Generation of Optical Communication System", Optics & Photonics News, vol. 2, No. 1 pp. 6-11, 1991

[5] Nakagawa and S. Shimand, "Optical Amplifiers in Future Optical Communication Systems", IEEE Lightwave Communication System Magazine, vol. 1, No. 1 pp. 57-62, 1990

[6] H. F. Wolf (Ed.), Handbook of Fiber Optics Theory and Applications, Granada, 1981

[7] F. A. Jenkins and H. E. White, "Fundamentals of Optics (4th Edn), McGraw-Hill, 1976.

[8] G. R. Fowles, Introduction to Modern Optics (2nd edn), Holt, Rinehart & Winston, 1975.

[9] R. A. Linke and A. H. Gnauck, " High-capacity Coherent Lightwave Systems",Journal of Lightwave Tech. Vol. 6, pp. 1750-1769, 1998.

[10] W. J. Tomlinson and C. A Brackett, Telecommunications Applications of Integrated Optics and Opto-electronics, Proceeding of the IEEE, vol. 75, pp. 1512-1523, 1987.