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Free Space Optical Communication

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ABSTRACT

With the worldwide demand for larger bandwidth & greater mobility there is a rapid advancement in the area of broadband wireless communications. The high capacity & low loss of optical fibre has seen its exploding growth in the last few decades in the WAN's and LAN's. But, there is a disadvantage in optical fibre cable communication is that optical fibre gets damaged in a long distance installation. So, the Free Space Optical (FSO) wireless communication has emerged as a viable technology for bridging the gap in existing high data rate fibre network and as a temporary backbone for rapidly deployable mobile wireless communication infrastructure.

In the recent past, free-space optical communication (FSO) proved to be an important replacement to radio frequency communication. In this paper, a brief description about free space optical (FSO) communication and its connectivity with central cellular network is explained. This paper also provides the information about the role of free space optics in the central cellular network which contains a RF network, which has connections within the Radio Access Network (RAN) & the Central Network (CN) for connecting the mobile user subscriber to the Public Switched Telephone Networks (PSTN) and Internet. Moreover, free space optical communication paves the way for a high bandwidth requiring applications, high transmission security, full duplex transmission and protocol transparency will give a broader view to free space optical communication.

KEYWORDS: *Optical Communication, FSO, FSO technology, FSO applications.*

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I. INTRODUCTION

In any communication system, signal is transmitted from one end via a transmitter and received at other end by a matched receiver through a low loss medium. Similarly, the data and various information from different users are transmitted from one end of the transmitter and received at the other end using low loss medium as shown in figure 1.

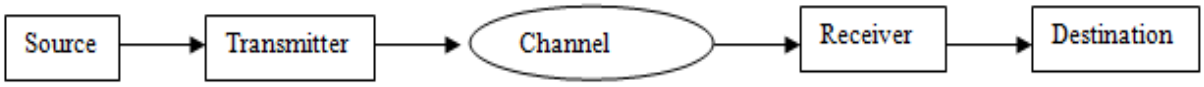

Fig. 1

Telephone signals are transmitted through copper wire at frequencies up to 4 KHz. Higher frequencies are transmitted through atmosphere from ground to satellite and then back to ground. Broadband communication at super high frequencies (10^{14} Hz) is done over optical fibre cables which are satisfactory working at 1300 nm, 1550 nm and in future it will go to higher wavelengths around 2550 nm.

II. OPTICAL FIBRE

Optical fibre carries much more information than conventional copper wire and in general it is an electromagnetic interference and needed in retransmission of signals [1]. Most telephone company long-distance lines are now made of optical fibre. In the electromagnetic spectrum infrared region (0.7–100mm) lies between microwave frequency and visible spectrum, (0.32 – 0.7mm). First generation optical fibre communication was designed at 820 nm but after 1980, the optical fibre communication is done at 1300 nm and 1550 nm. The 1550 nm range provides the minimum attenuation of light signals over long distances but this wavelength has much larger dispersion. At present, most of the systems, which are operational in the world, are based on 1550 nm laser wavelength in the near infrared region. This wavelength, 1550 nm is selected after studying the fibre attenuation with respect to wavelength from 300 nm to 2000 nm. It is found that fibre attenuation is 0.5 dB/km for 1300 nm and it is around 0.2 dB/km for 1550 nm wavelength. So, optical fibre transmitter, optical receiver and fibre cable suitable for 1300nm and 1550 nm are successfully developed and are now operating worldwide. Further low attenuation losses are seen in fibres around 2.55 mm. research works is going on so that attenuation losses of the order of 0.001 dB/km may be achieved on longer wavelengths of optical fibre cables.

III. EVOLUTION OF FSO

Free-space optical communication offers the potential to send large amounts of data securely over moderate distances without the expense of laying fibre-optic cable. The technology is useful where the physical connection of the transmitter and receiver locations as shown below figure is difficult. FSO systems represent one of the most promising approaches for addressing the emerging broadband access market [10]. These robust systems, which establish communication links by transmitting laser beams directly through the atmosphere, have matured to the point that mass-produced models are now available. FSO systems offer many features, principal among them being low start-up and operational costs, rapid deployment, and high fibre-like bandwidths. FSO systems offer capacities in the range of 100Mbps to 2.5 Gbps, and demonstration systems report data rates as high as 160 Gbps. Free space optics (FSO) is a line-of-sight technology that currently enables optical transmission up to 2.5 Gbps of data, voice, and video communications through the air, allowing optical connectivity without deploying fibre optic cables or securing spectrum licenses. FSO system can carry full duplex data at giga bits per second rates over Metropolitan distances of a few city blocks of few kms. FSO, also known as optical wireless, overcomes this last-mile access bottleneck by sending high bit rate signals through the air using laser transmission. Even though FSOs offer high security as its laser beams cannot be determined with the devices like spectrum analyzers or RF meters there are some challenges in the implementation of it.

Free space optics is an optical communication technology that uses light propagating in free space to transfer data. FSO uses LED or laser as a light source and the bandwidth required is up to 2.5Gbps. Free Space Optics communications, also called Free Space photonics (FSP) or Optical Wireless, refers to the transmission of visible and infrared (IR) beams through the atmosphere to obtain optical communications. Like fibre, Free Space Optics uses asers and LED to transmit data, but instead of enclosing the data stream in a glass fibre, it is transmitted through the air. FSO communication is an effective means of communication at high bit rates over short distances. FSO is a line-of-sight technology that uses lasers to provide optical bandwidth connections or FSO is an optical communication technique that propagate the light in free space means air, outer space, vacuum, or something similar to wirelessly transmit data for telecommunication and computer networking. Currently, FSO is capable of up to 2.5 Gbps [1] of data, voice and video communications through the air, allowing optical connectivity without requiring fibre optic cable and operate between the 780 – 1600 nm wavelengths bands and use O/E and E/O converters.

FSO requires light, which can be focused by using either light emitting diodes (LEDs) or lasers (light amplification by stimulated emission of radiation). The use of lasers is a simple concept similar to optical transmissions using fibre optic cables; the only difference is the transmission media. Light travels through air faster than it does through glass, so it is fair to classify FSO as optical communications at the speed of the light as shown below figure 3. FSO communication is considered as an alternative to radio relay link line-of sight (LOS) communication systems. This chapter is

concentrate on ground-to-ground free-space laser communications. FSO components are containing three stages: transmitter to send of optical radiation through the atmosphere obeys the Beer-Lamberts' law, free space transmission channel where the turbulent exist eddies (cloud, rain, smoke, gases, temperature variations, fog and aerosol) and receiver to process the received signal. Typical links are between 300 m and 5 km, although longer distances can be deployed such as 8–11 km are possible depending on the speed and required availability.

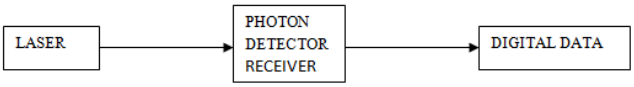

Fig.2

IV. FSO TECHNOLOGY

Fig a-FSO Transmitter

Fib b-FSO Receiver

Optical wireless, based on FSO- technology, is an outdoor wireless product category that combines the speed of fibre with the flexibility of wireless [4]. It enables optical transmission at speeds of up to 1.25 Gbps and, in the future, is capable of speeds of 10 Gbps and beyond using WDM technology. This is not possible with any standard microwave spectrum based, fixed wireless or RF technology. Optical wireless also eliminates the need to buy expensive spectrum licensing (it requires no FCC or municipal license approvals worldwide), which further distinguishes it from fixed wireless technologies [11].

A. Leveraging FSO Technology

Lasers operate in the infrared, visible and ultraviolet regions of the electromagnetic spectrum, from one millimetres down to 100 nanometres in wavelength. Typically, lasers are described by their wavelength as contrasted with radar systems that are characterized by frequency, because the laser's frequency is 10,000 to 1,000,000 times higher than typical microwave radars. Both microns (mm or 10-6 meters) or nanometres (nm or 10-9 meters) will be used in this study to characterize lasers. In contrast, radar systems usually have wavelengths on the order of millimetres to centimetres. This chapter explores the inherent benefits of using lasers for communication.

V. FSO APPLICATIONS

- Telecommunication and computer networking
- Point-to-point LOS links
- Temporary network installation for events or other purpose as disaster recovery
- For communications between spacecraft, including elements of satellite constellation
- Security applications
- Military application: (its potential for low electromagnetic emanation when transferring
- sensitive data for air forces)
- Metro network extensions: carriers can deploy FSO to extend existing metropolitan area
- Fibre rings, to connect new networks, and, in their core infrastructure, to complete SONET.
- Enterprise connectivity: the ease with which FSO links can be installed makes them a natural for interconnecting local area network segments that are housed in buildings separated by public streets or other right-of-way property.
- Fibre backup: FSO may also be deployed in redundant links to backup fiber in place of a second fibre link.
- Backhaul: FSO can be used to carry cellular telephone traffic from antenna towers back to facilities wired into the public switched telephone network.
- Service acceleration: FSO can be also used to provide instant service to fiber-optic customers while their fibre infrastructure is being laid.
- Last-Mile access: In today's cities, more than 95% of the buildings do not have access to the fibre optic infrastructure due to the development of communication systems after the metropolitan areas. FSO technology seems a promising solution to the connection of endusers to the service providers or to other existing networks. Moreover, FSO provides high speed connection up to Gbps, which is far more beyond the alternative systems.

VI. FSO ADVANTAGES AND DISADVANTAGES

A. Advantages

- Long distance up to 8 km.
- High bit rates speed rates: the high bandwidth capability of the fibre optic of 2.5 Gbps to 10 Gbps achieved with wavelength division multiplexing (WDM). Modern systems can handle up to 160 signals and can thus expand a basic 10 Gbit/s system over a signal fibre pair to over 1.6 Tbit/s.
- Immunity from electromagnetic interference: secure cannot be detected with RF meter or spectrum analyzer, very narrow and directional beams
- Invisible and eye safe, no health hazards so even a butterfly can fly unscathed through a beam
- Low bit error rates (BER)
- Absence of side lobes
- Deployment of FSO systems quickly and easily
- No Fresnel zone necessary
- Low maintenance (Practical)
- Lower costs as compared to fibre networks (FSO costs are as low as 1/5 of fiber network costs).
- License-free long-range operation (in contrast with radio communication)

B. Disadvantages

For terrestrial applications, the principal limiting factors are: Beam dispersion, atmospheric absorption, rain, fog, snow, interference from background light sources (including the sun), shadowing, pointing stability in wind, and pollution.

C. Comparison between FSO vs. fibre optics vs. other technologies

In the future fibre optics replaced by FSO for the following reasons:

• Optics is the study of the behaviour and properties of light

• Optical fibres can carry a laser beam for long distances

• Most of the recent large effort of digging up the ground and laying down new fibre has been directed towards extending the fibre optic backbone to new central offices, and not laying fibre directly to the customer

• Like fibre, FSO uses lasers to transmit data, but instead of enclosing the data stream in a glass fibre, it is transmitted through the air.

VII. CONCLUSION

FSO networks can be rapidly deployed to provide immediate service to the customers. Some believe that it may be unlimited bandwidth solution for the metro urban core of downtown buildings-to-buildings communication, as well as the optimal technology for home-to-home and office-to-office connectivity. FSO adds the wireless feature to the OFC and thus provides the high bandwidth requirements.

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