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Free Space Optics Communication - Trends and Challenges

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***Abstract* - In recent period of communication there is a necessity of systems with high capacity and bandwidth. This is achieved by the non-fiber optics based system recognized as free space optical communication system. These systems that are reliant upon optics in free space, does not require any license for its operation. Free space optical (FSO) wireless communication has emerged as a viable technology for bridging the gap in existing high date rate fiber network and as a temporary backbone for rapidly deployable mobile wireless communication infrastructure. Free space optical communication offers the potential to send large amount of data security over moderate distances without the expense of laying fiber optic cable. The technology is helpful where the physical connection of the transmitter and receiver locations is difficult. 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 system offers many features among them being the low-start up and operational cost, rapid development and high fiber-like bandwidth. In this paper first part introduces the FSO system, its advantages, and disadvantages its applications. Second part informs about the challenges which a FSO system faces while working. The challenges faced by FSO system is atmospheric attenuation. The atmospheric attenuation is caused by the fog, smog, rain, smoke, bird flap etc.**

***Keywords*- Free space optics (FSO), WDM, Atmospheric turbulences, Line of sight, Beam divergence**

I. INTRODUCTION

The growth of wireless communications be treated as one of the most noteworthy phenomena in the past of technology. Free space optical (FSO) communication is a major area to research and researcher give emphasis on this technology due to numerous advantages. This type of wireless optical communication technology uses highly narrow beam to transmit data from one point to the other one. This LOS (line of sight) technology offers benefits to both telecommunication users and providers. It provides a high data rates up to several Gbps, has immunity to radio frequency interferences, requires no licensing, gives a highly secured communication link due to the usage of a very narrow beam angle, and offers an inexpensive, fast and easy deployment when compared to the fiber optic installation.[1]. Wireless devices and technologies have become pervasive much more rapidly than anyone could have imagined thirty years ago and they will continue to be a key element of modern society for the foreseeable future.

Optical communication systems provide the highest available carrier frequencies and thus the fastest data rates possible today [2]. FSO is designed to be a lower cost alternative to conventional fiber-optic cable-based communication links. The most mature technology used in FSO equipment relies on low cost semiconductor lasers or LED's operating in the near infrared at wavelengths of 785 nm or 850 nm. In the past few years, systems operating at 1550 nm have also been developed. At first the vendors of these systems claimed that the 1550 nm wavelength had better propagation characteristics in severe weather than the 785 nm wavelengths [3]. With further analysis and research, those claims were withdrawn. Now there are claims that even longer wavelengths near 10 microns will solve the FSO link availability issues associated with severe weather. Hype about such magic wavelengths for FSO is both a disservice to the investors who will lose the money they are investing based on exaggerated claims, and to the rest of the FSO industry which should be creating realistic expectations for the capability of its equipment [4]. In the weather conditions which normally cause the highest attenuation for FSO systems, namely coastal fog and low clouds, 10 microns offers no propagation advantage over shorter wavelengths [5].

II. DEVELOPMENT OF FSO TECHNOLOGY

Optical communication in various forms, have been used for thousands of years. The ancient Greeks used a coded alphabetic system of signalling with torches .In the modern era, wireless solar telegraphs called heliographs were developed, using coded signals to communicate with their recipients. On June 3, 1880, Bell conducted the world's first wireless telephone transmission between two buildings, some 213 meters (700 feet) apart. The invention of lasers in the 1960s revolutionized free space optics. Military organizations were particularly interested and boosted their development. In 2008, MRV Communications introduced a free-space optics (FSO)-based system with a data rate of 10GB/s initially claiming a distance of 2 km at high availability. This equipment is no longer available; before end-of-life, the product's useful distance was changed down to 350m. In 2013, the company MOSTCOM started to serially produce a new wireless communication system that also had a data rate of 10GB/s as well as an improved range of up to 2.5 km, Recent advances in FSO technology have opened up mainstream communications uses, from short-term solutions for short distance network bridges to an attractive and viable alternative for service providers to deliver the promise of all-optical networks. As an optical technology, FSO is a natural extension of the metro optical network core, bringing cost-effective, reliable and fast optical capacity to the network's edge.

III. OPERATION PRINCIPLE

FSO-links are majorly influenced by weather conditions. For that reason, some significant characteristics of the atmosphere have to be elaborated prior to describing the optical wireless systems in more detail. The lowest part of the atmosphere up to 10 km above the Earth's surface is called the troposphere or the weather sphere. It has a varying refraction index, which is dependent on the height above the Earth's surface. Normally the refraction index decrease with the height, but at weather inversion situations there is a different relationship. Atmospheric conditions degrade laser communications through the atmosphere in two ways. First, the atmosphere acts as a variable attenuator between the transmitting and receiving terminals. Second, a free space laser link is subjected to scintillations. Attenuation is more in the foggy days and less at the time of thin fog. Moreover the haze also effects the transmission as the medium is air. Rain does not affect the signal at much extent as the drop size are not comparable to laser wavelength.

IV. FSO ARCHITECTURES

FSO technology has proven itself in other applications, particularly those requiring a tactical, point-to-point link. FSO's greatest success so far has come from the LAN/campus connectivity market. Such applications could include a link between a newsroom and a broadcasting station, or a dedicated link between two high-traffic nodes in a large building complex. Thus, to maintain quality of service for a particular customer, the distance from that customer's location to the nearest hub may have to be shortened.

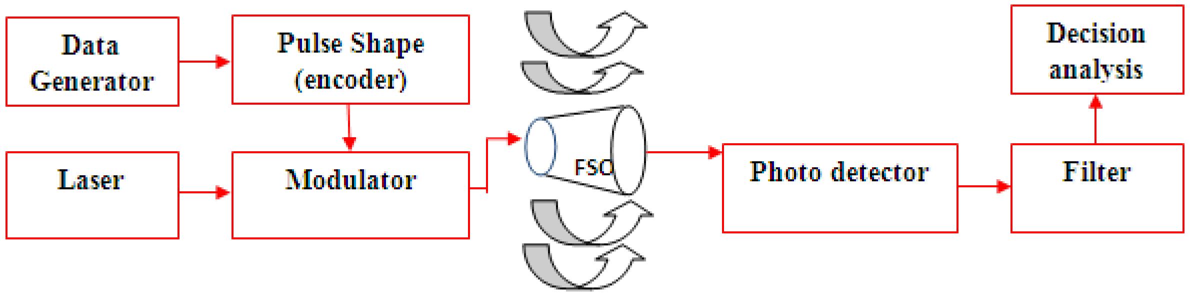

Figure 1 Block diagram of FSO based Communication System [5]

Three main FSO architectures have been used so far [4].

- Point to point architecture is a dedicated connection that offers higher bandwidth but is less scalable.
- Mesh architecture may offer redundancy and hig reliability with easy node addition but restrict distances more than the other options.
- Point to multipoint architecture offers cheaper connections and facilitates node addition but at the expanse of lower bandwidth than the point to point option.

V. ATMOSPHERIC EFFECTS ON FSO LINK

The actual transmission rates are weather dependent as the atmospheric attenuation is variable and hard to predict. The link may not work well in locations where the atmosphere is affected by conditions such as fog, storm, scintillation etc.

FSO and Fog: Fog substantially attenuates visible radiation and it has a similar effect on the near infrared wavelengths that are employed in the FSO system (1550nm). Note that the effect of fog on the free space optical wireless radiation is entirely analogous to the attenuation and fades suffered by the RF wireless system due to rain fall. Similar to the case of rain attenuation with RF wireless fog attenuation is not a 'showstopper' for FSO (signals block out on the television during heavy rain) because the optical link can be engineered such that for a large fraction of time an acceptable power is received even in presence of heavy fog. FSO optical wireless based communication system can be enhanced to yield even greater availabilities [6].

FSO and Scintillation: Atmospheric scintillation can be thought of as changing light intensities in time and space at the plane of a receiver detecting the signal from a transmitter at a distance. When the beam is scintillated, photons of light are temporally steered by pockets of air in random direction. This is the same atmospheric effect what causes stars to appear to twinkle at night. The received signal level at the detector fluctuates due to thermally induced changes in the index of refraction of the air along the transmit path. The index changes cause the atmosphere to act like a collection of small prisms and lenses that deflect the light beam into and out of the transmit path. The time scale of these fluctuations is about the time it takes a volume of air the size of the beam to move across the path and therefore is related to wind speed. For the case of free-space optics, which implies horizontal path propagation and therefore stronger scintillation, the distribution tends to be more exponential. One parameter that is often used as a measure of the scintillation strength is the atmospheric structure parameter. This parameter, which is directly related to wind speed, roughly measures how turbulent the atmosphere is [8]. To overcome the scintillation effects automatic gain control mechanism is used and also clock recovery phase lock loop time constant eliminates the effects of scintillation and jitter transference.

VI. APPLICATIONS

Education institutions connectivity: Today's l/university campuses are experiencing a triple play traffic (i.e., voice, data, fax, multimedia traffic) that is overwhelming the typical connections. FSO systems can bridge multiple buildings in corporate and campus networks supporting ultra-high speeds without the cost of dedicated fiber optic connections.

Support or back end for cellular systems: The growing number of bandwidth-intensive mobile phone services now requires the deployment of technologies such as FSO which allow much higher throughput act as back end.

Security: Today's cryptosystems are able to offer only computational security within the limitations of conventional computing power and the realization of quantum computers would, for example, make electronic money instantly worthless. Based on the firm laws of physics, quantum cryptography provides a radically different solution for encryption and promises unconditional security. Quantum cryptography systems are typically considered in conjunction with fiber optic infrastructure. FSO links provide a versatile alternative in cases where the fiber optic deployment is costly and/or infeasible.

Broadcasting: In broadcasting of live events such as sports and ceremonies or television reporting from remote areas and war zones, signals from the camera (or a number of cameras) need to be sent to the broadcasting vehicle which is connected to a central office via satellite uplink. The required high-quality transmission between the cameras and the vehicle can be provided by a FSO link. FSO links are capable of satisfying even the most.

VII. CHALLENGES AND FUTURE OF FSO

Free Space Optics (FSO) has become a viable, high-bandwidth wireless alternative to fiber optic cabling. The primary advantages of FSO over fiber are its rapid deployment time and significant cost savings. The disadvantage of FSO over fiber is that laser power attenuation through the atmosphere is variable and difficult to predict, since it is weather airports, the link availability as a function of distance can be predicted for any FSO system. These availability curves provide a good indication of the reasonable link distances for FSO systems in a particular geographical area. The carriers and ISPs are another potential large user of FSO systems, especially for last-mile metro access applications. If FSO systems are to be used in telecommunication applications, they will need to meet much higher availability requirements. Carrier-class availability is generally considered to be 99.999% . An analysis of link budgets and visibility-limiting weather conditions indicates that to meet carrier-class availability, FSO links should normally be less than 140m (there are cities like Phoenix and Las Vegas where this 99.999% distance limitation increases significantly). This calculation is based on a 53 dB link budget. This concept is extended to the best possible FSO system, which would have a 10 W transmitter and a photo counting detector with a sensitivity of 1 nW. This FSO system would have a 100 dB link margin, which would only increase the 99.999% link distance to 286 m. A more practical solution to extending the high availability range would be to back up the FSO link with a lower data rate radio frequency (RF) link. This hybrid FSO/RF system would extend the 99.999% link range to longer distances and open up a much larger metro/access market to the carriers. It is important to realize that as the link range increases, there will be a slight decrease in overall bandwidth. To show the geographical dependence of FSO performance, the first map of FSO availabilities contoured over area is need to be presented. This map is the first step to developing an attenuation map for predicting FSO performance, which could be used in similar fashion to the International Telecommunication Union (ITU)/Crane maps for predicting microwave performance.

CONCLUSIONS

In our survey, we observed that most of the applications of FSO are for short range communication. The FSO communication system using NRZ line code with 1550 nm rather than that of 850 nm operating wavelength utilizing APD receiver in different weather conditions achieves a remarkable performance in order to keep an acceptable received signal power and BER levels. In the rain environment the normal FSO communication system distorts the signal. However with effective reduction in atmospheric turbulences using different modulation techniques the distance may be extended up to a larger extent.

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