Free Space Optics (FSO) for High Data Rates using Line of Sight (LOS) Communication

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Abstract - Free-space optical communication (FSO) is an optical communication technology that uses light propagating in free space to transmit data for telecommunication or computer networking. "Free space" means air, outer space, vacuum, or something similar. This contrasts with using solids such as optical fiber cable or an optical transmission line. The technology is useful where the physical connections are impractical due to high costs or other considerations. This line-of-sight technology approach uses invisible beams of light to provide optical bandwidth connections. It's capable of sending up to 1.25 Gbps of data, voice and video communications simultaneously through the air — enabling fiber-optic connectivity without requiring physical fiber-optic cable. It enables optical communications at the speed of light. This paper gives a comprehensive overview about general technology of FSO along with its Pros and Challenges.

***Keywords* -** FSO, LOS, WDM, Optical Fiber.

I. INTRODUCTION

FSO is a line-of-sight technology that uses invisible beams of light to provide optical bandwidth connections that can send and receive the voice, video, and data, information. Today, FSO technology has enabled the development of a new category of outdoor wireless products that can transmit voice, data, and video at bandwidths up to 1.25 Gbps but can be increased to 10 Gbps using WDM. In fiber optic communications, WDM (Wavelength-Division-Multiplexing) is a technology which multiplexes number of optical carrier signals onto a single optical fiber by using different wavelengths (colours) of laser light. Fig. 1 shows basic working of FSO. This optical connectivity doesn't require expensive fiber-optic cable or securing spectrum licenses for radio frequency (RF) solutions. FSO technology requires light. The use of light is a simple concept similar to optical transmissions using fiber-optic cables; the only difference is the medium. Light travels through air faster than it does through glass, so it is fair to classify FSO technology as optical communications at the speed of light. Fig. 1 show the system installed at CMI (Czech metrology institute).

Fig.1: FSO systems installed at CMI (Czech metrology institute)

II. WORKING

FSO technology is surprisingly simple. It's based on connectivity between FSO-based optical wireless units, each consisting of an optical transceiver with a transmitter and a receiver to provide full-duplex (bi-directional) capability. Each optical wireless unit uses an optical source, plus a lens or telescope that transmits light through the atmosphere to another lens receiving the information. At this point, the receiving lens or telescope connects to a high-sensitivity receiver via optical fiber. Fig. 2 shows the Internal Structure diagram of FSO.

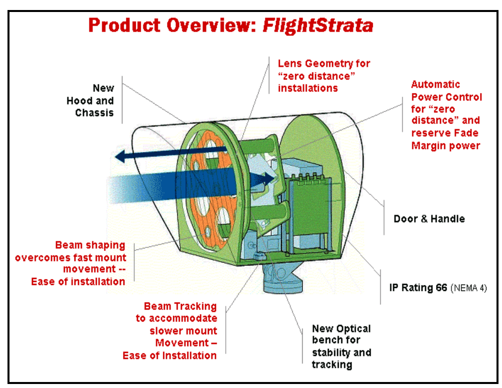

Fig. 2 : Internal structure diagram of an FSO

III. FSO VS WIRELESS

Optical wireless, based on FSO-technology, is an outdoor wireless product category that provides the speed of fiber, with the flexibility of wireless. It enables optical transmission at speeds of up to 1.25 Gbps and, in the future, is capable of speeds of 10 Gbps using WDM. This is not possible with any fixed wireless or RF technology. Optical wireless also eliminates the need to buy expensive spectrum (it requires no FCC or municipal license approvals worldwide), which further distinguishes it from fixed wireless technologies. Moreover, FSO technology's narrow beam transmission is typically two meters versus 20 meters and more for traditional, even newer radio-based technologies such as millimeter-wave radio. Optical wireless products' similarities with conventional wired optical solutions enable the seamless integration of access networks with optical core networks and help to realize the vision of an all-optical network.

IV. APPLICATIONS OF FSO

Typically scenarios for use are:

- LAN-to-LAN connections on campuses at Fast Ethernet or Gigabit Ethernet Speed.
- LAN-to-LAN connections in a city, a metropolitan area network.
- Speedy service delivery of high-bandwidth access to optical fiber networks.
- Converged Voice-Data-Connection.
- Temporary network installation (for events or other purposes).
- Re-establish high-speed connection quickly (disaster recovery).
- As an alternative or upgrade add-on to existing wireless technologies.
- As a safety add-on for important fiber connections (redundancy).
- For communications between spacecraft, including elements of a satellite constellation.
- For inter- and intra -chip communication.

V. ADVANTAGES OF FSO

- Ease of deployment.
- License-free long-range operation (in contrast with radio communication).
- High bit rates.
- Low bit error rates.
- Immunity to electromagnetic interference.
- Full duplex operation.
- Protocol transparency.
- Very secure due to the high directionality and narrowness of the beam(s).
- No Fresnel zone necessary.

VI. CHALLENGES

While fiber-optic cable and FSO technology share many of the same attributes, they face different challenges due to the way they transmit information. While fiber is subject to outside disturbances from wayward construction backhoes, gnawing rodents, and even sharks when deployed under sea, FSO technology is subject to its own potential outside disturbances. The transmission performance of a free-space optical (FSO) link could be severely degraded due to atmospheric turbulence, which causes the temporal and spatial fluctuation of light intensity [1]. Optical wireless networks based on FSO technology must be designed to combat changes in the atmosphere, which can affect FSO system performance capacity. And because FSO is a line-of-sight technology, the interconnecting points must be free from physical obstruction and able to "see" each other.

All potential disturbances can be addressed through thorough and appropriate network design and planning. Among the issues to be considered when deploying FSO-based optical wireless systems:

1. Fog: The primary challenge to FSO based communications is dense fog. Rain and snow have little effect on FSO technology, but fog is different. Fog is vapor composed of water droplets, which are only a few hundred microns in diameter but can modify light characteristics or completely hinder the passage of light through a combination of absorption, scattering, and reflection. The primary answer to counter fog when deploying FSO-based optical wireless products is through a network design that shortens FSO link distances and adds network redundancies [5]. FSO installations in extremely foggy cities such as San Francisco have successfully achieved carrier-class reliability. Fig. 3 shows the effect of moderate and dense fog.

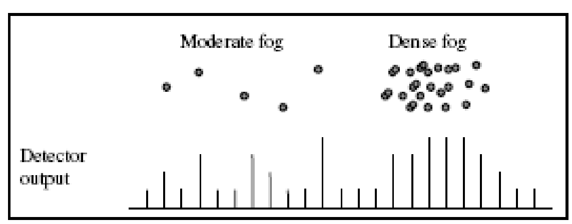

Fig. 3: Moderate Fog v/s Dense Fog

2. Absorption: Absorption occurs when suspended water molecules in the terrestrial atmosphere extinguish photons. This causes a decrease in the power density (attenuation) of the FSO beam and directly affects the availability of a system. Absorption occurs more readily at some wavelengths than others. However, the use of appropriate power, based on atmospheric conditions, and use of spatial diversity (multiple beams within an FSO-based unit) helps maintain the required level of network availability.

3. Scattering: Scattering is caused when the wavelength collides with the scatterer. The physical size of the scatterer determines the type of scattering. When the scatterer is smaller than the wavelength, this is known as Rayleigh scattering. When the scatterer is of comparable size to the wavelength, this is known as Mie scattering [2]. When the scatterer is much larger than the wavelength, this is known as non-selective scattering. In scattering, unlike absorption, there is no loss of energy, only a directional redistribution of energy that may have significant reduction in beam intensity for longer distances.

4. Physical obstructions: Flying birds or construction cranes can temporarily block a single-beam FSO system, but this tends to cause only short interruptions, and transmissions are easily and automatically resumed. Some optical wireless products use multi-beam systems (spatial diversity) to address temporary obstructions, as well as other atmospheric conditions, to provide for greater availability.

5. Scintillation: Heated air rising from the earth or man-made devices such as heating ducts creates temperature variations among different air pockets. This can cause fluctuations in signal amplitude which leads to "image dancing" at the FSO-based receiver end [4, 7]. Modern unique multi-beam system is designed to address the effects of this scintillation called "Refractive turbulence," this causes two primary effect on optical beams.

6. Beam Wander: Beam wander is caused by turbulent eddies that are larger than the beam.

7. Beam Spreading: Beam spreading (long-term and short-term) is the spread of an optical beam as it propagates through the atmosphere.

8. Safety: To those unfamiliar with FSO technology, safety can be a concern because the technology uses lasers for transmission. The proper use and safety of lasers have been discussed since FSO devices first appeared in laboratories more than three decades ago. The two major concerns involve eye exposure to light beams and high voltages within the light systems and their power supplies. Strict international standards have been set for safety and performance, and many optical wireless systems comply with these standards.

VII. CONCLUSION

Free Space Optics is an excellent wireless communication technology, especially as last mile access and nomadic use technology. The installation process is very easy and quick, the high data rates available are definitive a great advantage. In any case FSO systems should not be seen in competition with WLAN or other radio technologies it should rather be seen as a widening to the wireless world. Future work should concentrate on increasing the availability and reliability of FSO links [3].

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