A

Seminar report

On

Free Space Optics

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Of ECE

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Preface

I have made this report file on the topic **Free Space Optics;** I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

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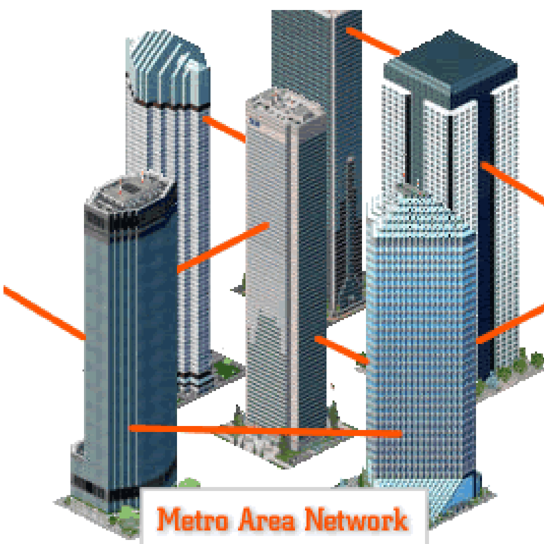
INTRODUCTION

Free Space Optics (FSO) communications, also called Free Space Photonics (FSP) or Optical Wireless, refers to the transmission of modulated visible or infrared (IR) beams through the atmosphere to obtain optical communications. Like fiber, Free Space Optics (FSO) uses lasers to transmit data, but instead of enclosing the data stream in a glass fiber, it is transmitted through the air. Free Space Optics (FSO) works on the same basic principle as Infrared television remote controls, wireless keyboards or wireless Palm devices.



HISTORY OF FREE SPACE OPTICS (FSO)

The engineering maturity of Free Space Optics (FSO) is often underestimated, due to a misunderstanding of how long Free Space Optics (FSO) systems have been under development. Historically, Free Space Optics (FSO) or optical wireless communications was first demonstrated by Alexander Graham Bell in the late nineteenth century (prior to his demonstration of the telephone!). Bell's Free Space Optics (FSO) experiment converted voice sounds into telephone signals and transmitted them between receivers through free air space along a beam of light for a distance of some 600 feet. Calling his experimental device the "photophone," Bell considered this optical technology – and not the telephone – his preeminent invention because it did not require wires for transmission.

Although Bell's photophone never became a commercial reality, it demonstrated the basic principle of optical communications. Essentially all of the engineering of today's Free Space Optics (FSO) or free space optical communications systems was done over the past 40 years or so, mostly for defense applications. By addressing the principal engineering challenges of Free Space Optics (FSO), this aerospace/defense activity established a strong foundation upon which today's commercial laser-based Free Space Optics (FSO) systems are based.

HOW FREE SPACE OPTICS WORKS

Free Space Optics (FSO) transmits invisible, eye-safe light beams from one "telescope" to another using low power infrared laser in the teraHertz spectrum. The beams of light in Free Space Optics (FSO) systems are transmitted by laser light focused on highly sensitive photon detector receivers. These receivers are telescopic lenses able to collect the photon stream and transmit digital data containing a mix of Internet messages, video images, radio signals or computer files. Commercially available systems offer capacities in the range of 100 Mbps to 2.5 Gbps, and demonstration systems report data rates as high as 160 Gbps.

Free Space Optics (FSO) systems can function over distances of several kilometers. As long as there is a clear line of sight between the source and the destination, and enough transmitter power, Free Space Optics (FSO) communication is possible.

FSO: WIRELESS, AT THE SPEED OF LIGHT

Unlike radio and microwave systems, Free Space Optics (FSO) is an optical technology and no spectrum licensing or frequency coordination with other users is required, interference from or to other systems or equipment is not a concern, and the point-to-point laser signal is extremely difficult to intercept, and therefore secure. Data rates comparable to optical fiber transmission can be carried by Free Space Optics (FSO) systems with very low error rates, while the extremely narrow laser beam widths ensure that there is almost no practical limit to the number of separate Free Space Optics (FSO) links that can be installed in a given location.

HOW FREE SPACE OPTICS (FSO) CAN HELP YOU

FSO's freedom from licensing and regulation translates into ease, speed and low cost of deployment. Since Free Space Optics (FSO) transceivers can transmit and receive through windows, it is possible to mount Free Space Optics (FSO) systems inside buildings, reducing the need to compete for roof space, simplifying wiring and cabling, and permitting Free Space Optics (FSO) equipment to operate in a very favorable environment. The only essential requirement for Free Space Optics (FSO) or optical wireless transmission is line of sight between the two ends of the link.

For Metro Area Network (MAN) providers the last mile or even feet can be the most daunting. Free Space Optics (FSO) networks can close this gap and allow new customer's access to high-speed MAN's. Providers also can take advantage of the reduced risk of installing a Free Space Optics (FSO) network which can later be redeployed.

WHY FSO?

The increasing demand for high bandwidth in metro networks is relentless, and service providers' pursuit of a range of applications, including metro network extension, enterprise LAN-to-LAN connectivity, wireless backhaul and LMDS supplement has created an imbalance. This imbalance is often referred to as the "last mile bottleneck." Service providers are faced with the need to turn up services quickly and cost-effectively at a time when capital expenditures are constrained. But the last mile bottleneck is only part of a larger problem. Similar issues exist in other parts of the metro networks. "Connectivity bottleneck" better addresses the core dilemma. As any network planner will tell you, the connectivity bottleneck is everywhere in metro networks.

From a technology standpoint, there are several options to address this "connectivity bottleneck," but most don't make economic sense.

The first, most obvious choice is fiber-optic cable. Without a doubt, fiber is the most reliable means of providing optical communications. But the digging, delays and associated costs to lay fiber often make it economically prohibitive. Moreover, once fiber is deployed, it becomes a "sunk" cost and cannot be re-deployed if a customer relocates or switches to a competing service provider, making it extremely difficult to recover the investment in a reasonable timeframe.

Another option is radio frequency (RF) technology. RF is a mature technology that offers longer ranges distances than FSO, but RF-based networks require immense capital investments to acquire spectrum license. Yet, RF technologies cannot scale to optical capacities of 2.5 gigabits. The current RF bandwidth ceiling is 622 megabits. When compared to FSO, RF does not make economic sense for service providers looking to extend optical networks.

The third alternative is wire- and copper-based technologies, (i.e. cable modem, T1s or DSL). Although copper infrastructure is available almost everywhere and the percentage of buildings connected to copper is much higher than fiber, it is still not a viable alternative for solving the connectivity bottleneck. The biggest hurdle is bandwidth scalability. Copper technologies may ease some short-term pain, but the bandwidth limitations of 2 megabits to 3 megabits make them a marginal solution, even on a good day.

The fourth-and often most viable-alternative is FSO. The technology is an optimal solution, given its optical base, bandwidth scalability, speed of deployment (hours versus weeks or months), re-deployment and portability, and cost-effectiveness (on average, one-fifth the cost of installing fiber-optic cable).

Only 5 percent of the buildings in the United States are connected to fiber-optic infrastructure (backbone), yet 75 percent are within one mile of fiber. As bandwidth demands increase and businesses turn to high-speed LANs, it becomes more frustrating to be connected to the outside world through lower-speed connections such as DSL, cable modems or T1s. Most of the recent trenching to lay fiber has been to improve the metro core (backbone), while the metro access and edge have completely been ignored. Studies show that disconnects occurs in the metro network core, primarily due to cost constraints and the deployment of such non-scalable, non-optical technologies such as LMDS. Metro optical networks have not yet delivered on their promise. High capacity at affordable prices still eludes the ultimate end-user.

FREE SPACE OPTICS (FSO) ISSUES

Free space optical communications is now established as a viable approach for addressing the emerging broadband access market and its “last mile” bottleneck. 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. Optical wireless systems offer many features, principal among them being low start-up and operational costs, rapid deployment, and high fiber-like bandwidths. These systems are compatible with a wide range of applications and markets, and they are sufficiently flexible as to be easily implemented using a variety of different architectures. Because of these features, market projections indicate healthy growth for optical wireless sales. Although simple to deploy, optical wireless transceivers are sophisticated devices.

The many sub-systems require a multi-faceted approach to system engineering that balances the variables to produce the optimum mix. A working knowledge of the issues faced by an optical wireless system engineer provides a foundation for understanding the differences between the various systems available. The different elements considered by the system engineer when designing the product are discussed below.

WHICH WAVELENGTH?

Currently available Free Space Optics (FSO) hardware can be classified into two categories depending on the operating wavelength – systems that operate near 800 nm and those that operate near 1550 nm. There are compelling reasons for selecting 1550 nm Free Space Optics (FSO) systems due to laser eye safety, reduced solar background radiation, and compatibility with existing technology infrastructure.

EYE-SAFETY

Laser beams with wavelengths in the range of 400 to 1400 nm emit light that passes through the cornea and lens and is focused onto a tiny spot on the retina while wavelengths above 1400 nm are absorbed by the cornea and lens, and do not focus onto the retina, as illustrated in Figure 1. It is possible to design eye-safe laser transmitters at both the 800 nm and 1550 nm wavelengths but the allowable safe laser power is about fifty times higher at 1550 nm. This factor of fifty is important as it provides up to 17 dB additional margin, allowing the system to propagate over longer distances, through heavier attenuation, and to support higher data rates.

ATMOSPHERIC ATTENUATION

Carrier-class Free Space Optics (FSO) systems must be designed to accommodate heavy atmospheric attenuation, particularly by fog. Although longer wavelengths are favored in haze and light fog, under conditions of very low visibility this long-wavelength advantage does not apply. However, the fact that 1550 nm-based systems are allowed to transmit up to 50 times more eye-safe power will translate into superior penetration of fog or any other atmospheric attenuator.

NETWORK PROTOCOL – TRANSPARENT OR MANAGED?

For carriers today the issue of interoperability of systems within their multi-faceted networks made up of both legacy and next generation networks is crucial. Most Free Space Optics (FSO) systems currently available are physical layer devices that act the same way as fiber optic cables and receivers and are therefore able to work with all protocols while not being limited to any of them. There are systems on the market that incorporate ATM into the device but most designers of Free Space Optics (FSO) systems have opted for a protocol 'transparent' approach for both deployment flexibility and cost-reduction. Should a carrier wish to add such switching functionality to networks incorporating physical layer products there are many switches available on the market, all of which will interoperate with a physical layer device.

PERFORMANCE - TRANSMIT POWER & RECEIVER SENSITIVITY

Free Space Optics (FSO) products performance can be characterized by four main parameters (for a given data rate):

- Total transmitted power
- Transmitting beamwidth
- Receiving optics collecting area
- Receiver sensitivity

A figure of merit (FOM) can be used to compare competing systems, based on the basic physics of this equation:

Figure of Merit =
(Power*Diameter2)/ (Divergence2*Sensitivity);

Where

Power = Laser power in milliwatts

Diameter = effective diameter in cm (excluding any obscuration losses)

Divergence = beam divergence in milliard

Sensitivity = receiver sensitivity in nanowatts

High transmitted power may be achieved by using erbium doped fiber amplifiers, or by non-coherently combining multiple lower cost semiconductor lasers. Narrow transmitting beam width (a.k.a. high antenna gain) can be achieved on a limited basis for fixed-pointed units, with the minimum beam width large enough to accommodate building sway and wind loading. Much narrower beams can be achieved with an actively pointed system, which includes an angle tracker and fast steering mirror (or gimbals). Ideally the angle tracker operates on the communication beam, so no separate tracking beacon is required. Larger receiving optics captures a larger fraction of the total transmitted power, up to terminal cost, volume and weight limitations. And high receiver sensitivity can be achieved by using small, low-capacitance photo detectors, circuitry which compensates for detector capacitance, or using detectors with internal gain mechanisms, such as APDs. APD receivers can provide 5-10 dB improvement over PIN detectors, albeit with increased parts cost and a more complex high voltage bias circuit. These four parameters allow links to travel over longer distance, penetrate lower visibility fog, or both.

In addition, Free Space Optics (FSO) receivers must be designed to be tolerant to scintillation, i.e. have rapid response to changing signal levels and high dynamic range in the front end, so that the fluctuations can be removed in the later stage limiting amplifier or AGC. Poorly designed Free Space Optics (FSO) receivers may have a constant background error rate due to scintillation, rather than perfect zero error performance.

FREE SPACE OPTICS (FSO) ADVANTAGES

Free space optical (FSO) systems offer a flexible networking solution that delivers on the promise of broadband. Only free space optics or Free Space Optics (FSO) provides the essential combination of qualities required to bring the traffic to the optical fiber backbone – virtually unlimited bandwidth, low cost, ease and speed of deployment. Freedom from licensing and regulation translates into ease, speed and low cost of deployment. Since Free Space Optics (FSO) optical wireless transceivers can transmit and receive through windows, it is possible to mount Free Space Optics (FSO) systems inside buildings, reducing the need to compete for roof space, simplifying wiring and cabling, and permitting the equipment to operate in a very favorable environment. The only essential for Free Space Optics (FSO) is line of sight between the two ends of the link.

FREE SPACE OPTICS (FSO) CHALLENGES

The advantages of free space optical wireless or Free Space Optics (FSO) do not come without some cost. When light is transmitted through optical fiber, transmission integrity is quite predictable – barring unforeseen events such as backhoes or animal interference. When light is transmitted through the air, as with Free Space Optics (FSO) optical wireless systems, it must contend with a complex and not always quantifiable subject - the atmosphere .

FOG AND FREE SPACE OPTICS (FSO)

Fog substantially attenuates visible radiation, and it has a similar affect on the near-infrared wavelengths that are employed in Free Space Optics (FSO) systems. Note that the effect of fog on Free Space Optics (FSO) optical wireless radiation is entirely analogous to the attenuation – and fades – suffered by RF wireless systems due to rainfall. Similar to the case of rain attenuation with RF wireless, fog attenuation is not a "show-stopper" for Free Space Optics (FSO) optical wireless, because the optical link can be engineered such that, for a large fraction of the time, an acceptable power will be received even in the presence of heavy fog. Free Space Optics (FSO) optical wireless-based communication systems can be enhanced to yield even greater availabilities.

PHYSICAL OBSTRUCTIONS AND FREE SPACE OPTICS (FSO)

Free Space Optics (FSO) products which have widely spaced redundant transmitters and large receive optics will all but eliminate interference concerns from objects such as birds. On a typical day, an object covering 98% of the receive aperture and all but 1 transmitter; will not cause an Free Space Optics (FSO) link to drop out. Thus birds are unlikely to have any impact on Free Space Optics (FSO) transmission.

FREE SPACE OPTICS (FSO) POINTING STABILITY – BUILDING SWAY, TOWER MOVEMENT

Fixed pointed Free Space Optics (FSO) systems are designed to be capable of handling the vast majority of movement found in deployments on buildings. The combination of effective beam divergence and a well matched receive Field-of-View (FOV) provide for an extremely robust fixed pointed Free Space Optics (FSO) system suitable for most deployments. Fixed-pointed Free Space Optics (FSO) systems are generally preferred over actively-tracked Free Space Optics (FSO) systems due to their lower cost.

SCINTILLATION AND FREE SPACE OPTICS (FSO)

Performance of many Free Space Optics (FSO) optical wireless systems is adversely affected by scintillation on bright sunny days; the effects of which are typically reflected in BER statistics. Some optical wireless products have a unique combination of large aperture receiver, widely spaced transmitters, finely tuned receive filtering, and automatic gain control characteristics. In addition, certain optical wireless systems also apply a clock recovery phase-lock-loop time constant that all but eliminate the affects of atmospheric scintillation and jitter transference.

SOLAR INTERFERENCE AND FREE SPACE OPTICS (FSO)

Solar interference in Free Space Optics (FSO) free space optical systems operating at 1550 nm can be combated in two ways. The first is a long-pass optical filter window used to block all optical wavelengths below 850 nm from entering the system; the second is an optical narrowband filter proceeding the receive detector used to filter all but the wavelength actually used for intersystem communications.

FREE SPACE OPTICS (FSO) SECURITY

- FSO is far more secure than RF or other wireless-based transmission technologies for several reasons:

- Laser beams cannot be detected with spectrum analyzers or RF meters.
- Laser transmissions travel along a line of sight path that cannot be intercepted easily. It requires a matching transceiver carefully aligned to complete the transmission. Interception is very difficult and extremely unlikely.
- The laser beams are narrow and invisible, making them harder to find and even harder to intercept and crack.
- Data can be transmitted over an encrypted connection adding to the degree of security available in FSO network transmissions.

FREE SPACE OPTICS (FSO) RELIABILITY.

Employing an adaptive laser power (Adaptive Power Control or APC) scheme to dynamically adjust the laser power in response to weather conditions will improve the reliability of Free Space Optics (FSO) optical wireless systems. In clear weather the transmit power is greatly reduced, enhancing the laser lifetime by operating the laser at very low-stress conditions. In severe weather, the laser power is increased as needed to maintain the optical link - then decreased again as the weather clears. A TEC controller that maintains the temperature of the laser transmitter diodes in the optimum region will maximize reliability and lifetime, consistent with power output allowing the FSO optical wireless system to operate more efficiently and reliably at higher power levels.

CONCLUSION

Free space optics (FSO) provides a low cost, rapidly deployable method of gaining access to the fiber optic backbone. FSO technology not only delivers fiber-quality connections, it provides the lowest cost transmission capacity in the broadband industry.

As a truly protocol-independent broadband conduit, FSO systems complement legacy network investments and work in harmony with any protocol, saving substantial up-front capital investments.

A FSO link can be procured and installed for as little as one-tenth of the cost of laying fiber cable, and about half as much as comparable microwave/RF wireless systems. By transmitting data through the atmosphere, FSO systems dispense with the substantial costs of digging up sidewalks to install a fiber link. Unlike RF wireless technologies, FSO eliminates the need to obtain costly spectrum licenses or meet further regulatory requirements.

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