Review of Wireless Technology Via Satellite Communication

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Abstract - When assessing the need for wireless and making a determination of its use, a study of its markets, trends, future growth, policies, and regulations must be taken into consideration. Wireless technology via satellite communications can offer a great advantage of information exchange for mobility-deployed organizations requiring extensive geographical coverage such as peacekeeping operations. With the emergence of higher transmission rates and technological options (i.e. video conferencing, Wide Area Networking, internet accessibility, voice/fax/data transfer, etc.) for satellite communication, the examination of wireless technology and the options it presents becomes paramount. Peacekeeping efforts involve the coordination and collaboration of civilian/military organizations that depend exclusively on information exchange for rapid response and operational readiness. The use for wireless as a necessary communication requirement will aid in the achievement of these objectives.

Keywords- optical wireless communication, attenuation, range, pointing errors

INTRODUCTION

Inter-satellite Optical wireless communication (IsOWC) is a capable solution for very high data rate point to point communication. With the rising popularity of high definition television and video conferencing, the demand for both high speed wired and wireless access is continuously increasing in indoor and outdoor environments [1]. The microwave and RF frequencies are used to transfer the information but they suffer from serious drawbacks like radiations make a way into walls and less data rate transfer due to losses [2]. So the microwave and RF links are replaced by optical wireless technology. The IsOWC technology has a lot of reimbursements than the disadvantages. Its high data rate capability, license free operation, unregulated bandwidth, low power, high efficiency, lesser antenna sizes and low cost. All these features made the IsOWC technology came into survival [3]. The disadvantage includes the tracking problem and misalignment of transmitter and receiver apertures and the changes due to atmospheric conditions. The tracking problem causes various noise sources such as laser relative noise intensity, Johnson noise, dark current noise. Vibration noise is the most degrading factor in IsOWC communication system. These noises made the system more susceptible towards the pointing errors. The main focus is to reduce the power dissipation and to reduce the BER. This result in high transmitter power and lesser receiver noise to obtain desired signal [4].

IsOWC has provided a bottleneck solution for the connectivity and long Optical remote communication is considered appropriate for advanced indoor and outdoor broadband remote applications ranging from short-run remote communication systems to last-mile connection systems with access between end clients, existing fiber optic communications, and inter-space laser connections. Indoor optical remote communication is known as remote infrared communication whereas outdoor optical remote communication is known as wireless optical communication. One of the most significant applications of wireless optics is that of inter-satellite optical wireless communication (Is-OWC) system transmitted between satellite and space interchanges within a short span. In case of the applications of wireless infrared communication, non-directed links without any transmitter-receiver alignment are required. These links are categorized as line-of-sight (LOS) and diffuse links. LOS links require a specified path for hassle-free communication whereas diffuse links require multiple optical paths from surface reflections. Is-OWC requires directed LOS and point-to-point laser links between transmitter and receiver via the atmosphere. OWC technology provides potentials of broadband communication capacity with unlicensed optical wavelengths. But disparities in temperature and atmospheric pressure result in refractive index variations over the transmission path, which further leads to spatial and temporal variations in the optical intensity on the receiver resulting in fading.Further, the faded links can adversely affect system performance resulting in increased bit error rate (BER) and transmission delays.

The application of Is-OWC can be used for inter-satellite communication in similar or distinctive circles with the light wave transmission of 3 x 108 m/s through which information can be transmitted with larger data and less constriction. Higher quantity of information can be sent to a longer distance by using optical connection over radio frequency (RF) technology with fewer payloads. Moreover, OWC systems use RF wavelength which is more suitable than lasers in terms of beam-width, resulting in lower attenuation. Is-OWC systems are quickly deployable and provide secure communication frameworks which are compatible with any advanced sensor communication system.

another ground station located at a considerable distance away from the first. Another use of the satellite is when, as is the case with

SATELLITE BACKGROUND

In 1977, European space agency (ESA) placed research contract for the assessment of modulators for high data rate laser links in space. This is the first step towards long and sustained ESA involvement in space optical communications. ESA R&D developed a large number of study contracts and preparatory hardware developments. In mid 1980, ESA took an ambitious step by embarking on the semiconductor laser inter-satellite link experiment (SILEX) program, to demonstrate a preoperational optical communication link in space. In 2001, the world-first optical inter satellite communication link was established between the SPOT-4 and Advanced Relay and Technology Mission Satellite (ARTEMIS) satellites, proving that optical communication technologies can be reliably mastered in space. In 2006, the Japanese Space Agency (JAXA) demonstrated a bidirectional optical link between its Optical Inter-Orbit Communications Engineering Test Satellite and ARTEMIS, and in 2008, the German Space Agency (DLR) established an inter satellite link between the near-field infrared experiment and TerraSAR-X satellites already based on the second generation of laser communication technology. In March 2003, SILEX started routine operations on optical intersatellite link which has put ESA in a world leading position in optical intersatellite links. In 1993, the Japanese

Space Agency National Space Development Agency (NASDA) and ESA agreed on cooperation to perform optical inter satellite communication experiments, and in 2006, communication links were established. A second generation of terminals was developed, which are now operational in orbit, since 2008. They will form the backbone of the new European Data Relay Satellite (EDRS) system to be deployed in 2013.

television broadcasts, the ground station's uplink is then down linked over a wide region, so that it may be received by many

2.1 OVERVIEW OF SATELLITE

A satellite is an object that orbits or revolves around another object in space. The satellite itself is also known as the space segment, and is composed of the three separate units, namely the fuel system, the satellite and telemetry controls, and the transponder. The transponder includes the receiving antenna to pick-up signals from the ground station, a broad band receiver, an input multiplexer, and a frequency converter which is used to reroute the received signals through a high powered amplifier for downlink. In the case of a telecom satellite, the primary task is to receive signals from a ground station and send them down to customers possessing compatible equipments. The Moon is a satellite to Earth and the Earth is a satellite to the Sun. There are generally two kinds of satellites: (a) Natural satellites (b) Manmade satellites. A natural satellite is a natural object that goes around orbits of a planet. Moon is the earth's natural satellite. Some other planets have many more natural satellites. On the other hand the satellites which are sent in free space by humans are called man made satellites. There are two types of satellites one is active satellite and other one is passive satellite. In the passive satellite system beams power at the reflector, the receiving ground system receives a fraction of the power that has been intercepted by the reflector and reradiated. In active satellites, the satellites receive a fraction of the energy beamed toward it by the ground transmitting system and the received power is amplified by active electronics means, usually in conjunction with frequency shifting.

2.2 OPTICAL ORBITS FOR COMMUNICATION SATELLITES

The path a Satellite or a planet follows around a planet or a star is defined as an orbit. In general the shape of an orbit of a satellite is an ellipse with the planet located at one of the two foci of the ellipse. Satellite orbits are also classified in terms of the orbital height. These are:

- Low Earth Orbit (LEO)
- Medium Earth Orbit (MEO) / Intermediate Circular Orbit (ICO)
- Geosynchronous Earth Orbit (GEO)

Satellite orbits with orbital height of approximately 1000 km or less are known as Low Earth Orbit (LEO). LEOs tend to be in generally circular in shape. Satellite orbits with orbital heights of typically in the range of 5000 km to about 25,000 km are known as Medium Earth Orbit (MEO) / Intermediate Circular orbit (ICO). MEO and ICO are often used synonymously, but MEO classification is not restricted to circular orbits. Satellites in Highly Elliptical Orbit (HEO) are suitable for communications in the higher latitudes.

2.3 LITERATURE REVIEW

In the present course of time, the application has witnessed remarkable technical advancement particularly in optical wireless communication as implemented widely by government authorities, corporate, and higher academics. The use of precision pointing and tracking control subsystems in optical inter-satellite communication was proposed in 1990 [5]. Moreover, the study identified disturbance effects and developed appropriate models to resolve them.. In order to minimize FWM-induced crosstalk, a technique was developed for channel frequency allocation [6]. The study found that when the system bandwidth is expanded, unequal channel separations are available without any imposition of four-wave mixing product on the channels. The study also performed simulation in a system of 10-channel with 10 Gbps per channel in order to probe the effectiveness of the technique. An additional study discussed the probability of high speed optical satellite network construction as a part of integrated space terrestrial network [7]. The study described the utility of optical wireless inter-satellite links for global networking with the creation of local area networks and wide area networks across the globe. Inter-satellite links can also be used for connecting remote sensing satellites, submarines and ships, airplanes, and space-crafts. Quantum cryptography can also be employed in inter-satellite links [8]. Another study used laser as a beacon and a transmitter in a pointing control system for inter-satellite laser communication and ranging link [9]. Optical inter-satellite network can also be developed using wavelength division multiplexing (WDM) technology consisting of a fixed node, high altitude platform (HAP) of 30 Km from the earth's surface, and a mobile node on a LEO orbit communicating between HAP and eight LEO micro satellites [10]. A further study examined error performance of heterodyne differential phase-shift keying (DPSK) OWC system under intensity-fluctuated conditions such as turbulence-induced fading and path loss [11]. Laser satellite communication can be used for inter-satellite and satellite-to-ground communications [12]. While examining the outage behavior of optical inter-satellite communication links, a study found that long wavelength provides better performance than shorter wavelength [13]. Another study proposed the design of an ultra-high bit-rate (400 Gbps) inter-satellite optical wireless communication (IsOWC) system which was a non-diffused link used for quadrature phase-shift keying (QPSK) modulation [14] [15]. Another reported work found that inter-satellite link (ISL) can be implemented between satellites distanced by 1000 Km at a data rate of 2.5 Gbps with or without square root module (SM) [16]. SM module can be used for achieving BER with improved SNR ratio while transmitting less power for 2.5 Gbps data over ISL link of 1000 Km at 1550 nm wavelength [17]. Another study designed an inter-satellite OWC system for establishing ISL of 1000 Km length between satellites at 2.5 Gbps data

2.4 ADVANTAGES OF ISOWC LINK

Unlicensed spectrum: Unlike radio and microwave systems, optical inter-satellite communication technology needs 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.

1. **Reducing antenna size:** In optical wireless system the antenna size gets reduced, as its carrier frequency is very large hence reducing the weight of the satellite minimizes the power used for the communication system.
2. **Huge modulation bandwidth:** In any communication system, the amount of data transported is directly related to the bandwidth of the modulated carrier. Using an optical carrier of high frequencies, bandwidth up to 2000 THz can be used. Optical inter satellite communication therefore guarantees an increased information capacity compared to radio frequency based communication systems. This is simply because on the electromagnetic spectrum, the optical carrier frequency, which includes infrared, visible and ultra violet frequencies, is far greater than the radio frequency. The usable frequency bandwidth in RF range is comparatively very lower.
3. **Narrow beam size** – The optical radiation is known for its extremely narrow beam, a typical laser beam has a diffraction limited divergence of between 0.01 – 0.1μrad. This implies that the transmitted power is only concentrated within a very narrow area, thus providing

an optical inter-satellite link with adequate spatial isolation from its potential interferers.

4. **High data rates –** We can develop high speed inter-satellite links using light as a carrier frequency. Data rates up to several Gbps can be easily achieved in inter-satellite communicati0on.

1.1 INTER-SATELLITE OPTICAL LINK APPLICATIONS

There are many applications of IsOWC, where satellites need to communicate with each other.

1.2 Data Relay for Inter Orbit Satellites

Unlike GEO satellites, LEO and MEO satellites orbit are not stationary with respect to Earth. This means that the satellite is not constantly in earth station's view. By using inter-satellite link, data can be sent between a LEO and MEO satellite at any time by using a GEO satellite as relay. Data can also be relayed from one LEO satellite to another if they have line of sight. This concept is shown in figure 1. The conventional way of relaying data is as shown in figure 2 (a) while figure 2 (b) shows relaying data by using inter-satellite links. Transmitting data from Earth to satellite has high time delay; therefore by using IsOWC, the time delay can be reduced.

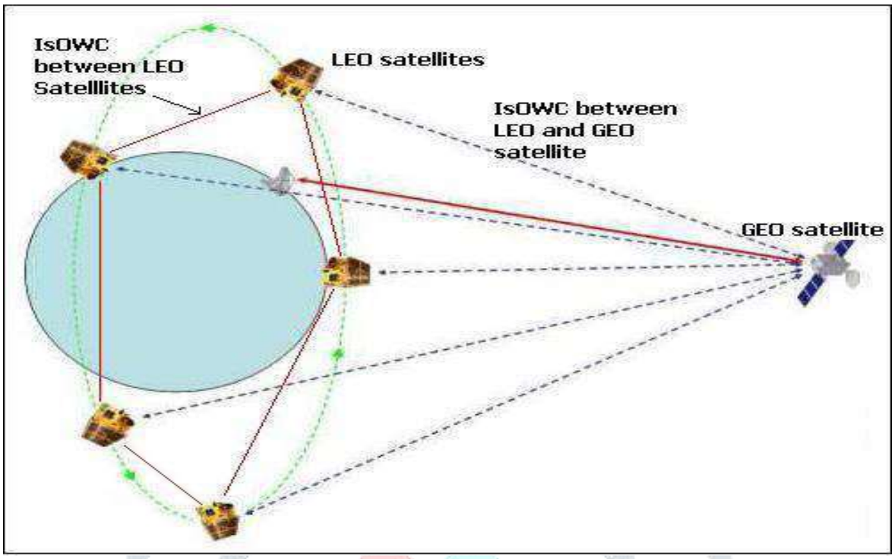
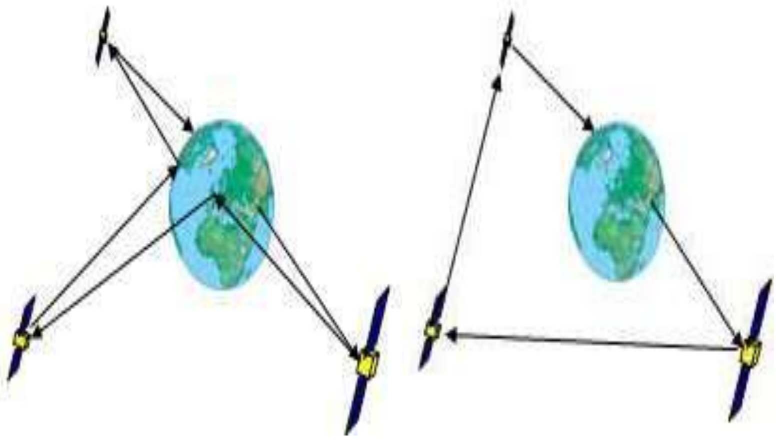


Figure Error! No text of specified style in document. **Concept of data relay for inter orbit IsOWC [3]**



(a) **(b)**

Figure 2 Data relay methods (a) conventional (b) using inter-satellite data relay

Some missions and applications require more than one satellite such as the global tracking system (GPS) satellites and Iridium satellites. Figure 3 shows constellation of satellites orbiting Earth.

Figure 3 Constellations of satellite orbiting Earth

2.5 PROBLEMS AND CHALLENGES

Figure 4 shows the broad categorization of optical communication systems. There are two major categories: fiber communication and optical wireless communication. Fiber communication uses fiber as medium or channel whereas optical wireless communication transmits information without using fiber. Optical wireless communication is further divided into two categories: Is-OWC and free space optics (FSO). Is-OWC is used for communication between satellites and FSO for ground or terrestrial communication.

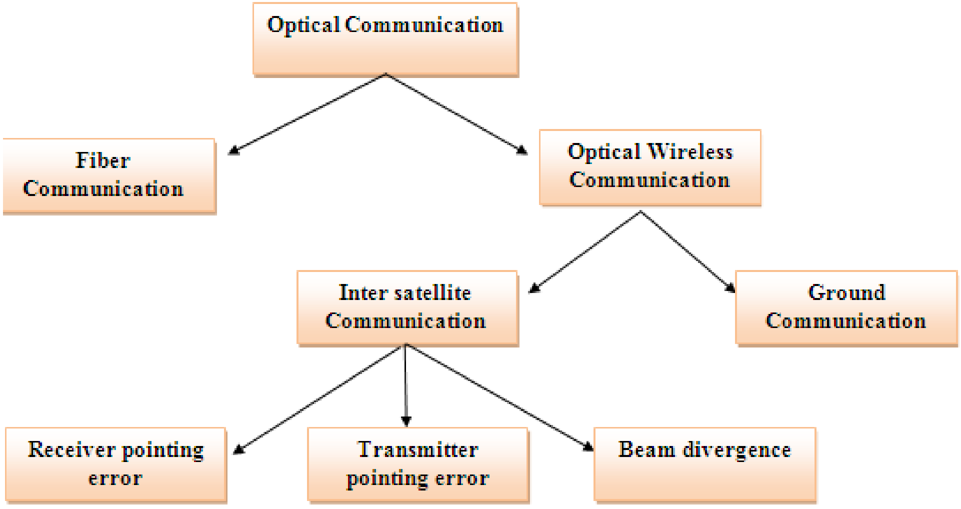


Figure 4 Categorization of optical communication [5]

Previous studies on Is-OWC have reported certain challenges such as beam divergence, and receiving and transmitting pointing errors which further limit transmission distance and capacity. When the transmitter and the receiver are not aligned, it leads to power reduction at the receiver side. These further results in pointing losses as shown by the equation below:

$L_{pointing}$=**4.3229(ϕ/Ω0)2**

In the above equation, ϕe refers to the boundary angle of diffraction which is the limited beam of the transmitter. Beam divergence refers to spreading of beam during its propagation from transmitter to receiver. These challenges must be considered by researchers during the design of inter-satellite communication system.

CONCLUSION

Is-OWC is the revolutionary technique which can establish the communication link between satellites through lasers. No doubt, Is-OWC communication has lot of rigorous advantages, but there are some challenges also which causes poor performance of its link. Turbulences such as transmitting pointing errors, receiving pointing errors, beam divergences etc. results in increase of attenuation which causes shut down of inter-satellite communication link. These turbulences must be taken under consideration while designing Is-OWC transmission system.

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