

# LIFI SPATIAL MODULATION FOR INTERSATELLITE COMMUNICATION AND TO IDENTIFY SPACIAL OBJECTS

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**Abstract**—Usage of Light as a medium to transmit Data is used in LiFi Technology. LiFi is a wireless communication system in which light is used as a carrier signal instead of traditional radio frequency as in WIFI. The paper make use of European Data Relay System(EDRS) technique to have Intersatellite laser light communication and use microwave medium to enable communication between satellite and ground station. This paper also discusses about interference of satellites and between satellite and ground station in addition it explains how interconnection of satellites helps in identifying space objects entering Earth's orbit .

**Keywords**—Lifi, EDRS, Geo and Leo satellites, Laser light

## I. INTRODUCTION

The wireless technology has bloomed to a greater extent. Various wireless communication schemes such as Wi-Fi make use of radio or micro wave frequencies of required bandwidth to transmit and receive data. Radio frequencies are finite due to constrained bandwidth. Data can be transmitted by making use of illumination; this technology is the Lifi technology. The advantage of using Light as medium to transmit data is that the transmission takes place at a speed of light, so large amount of data can be transmitted quickly with no time delay other advantages are high bandwidth, small optical antenna, narrow beam and more power efficient. In this paper we make use of EDRS principle for intersatellite communication and use microwave or radio wave as a medium to transmit data from satellite to ground station. It also gives brief explanation about Geo and Leo Satellites. Using the technique of intersatellite communication the paper proposes to use the Laser light medium to identify space objects entering Earth orbits.

## II. EUROPEAN DATA RELAY SYSTEM

European Data Relay System is a joint venture program designed to provide data transmission services based on optical and Intersatellite links (ISL). EDRS make use of Laser light to transmit and receive data, it consists of two terminals one is the laser terminals manufactured by TESAT Spacecom (Germany) and the other is the microwave terminal. Both the terminals are bi-directional and are used to transmit and receive data continuously. The farm of laser terminals in EDRS consists of 4 laser terminals providing data rate up to 3.6Gbps.The main objective of EDRS is to have a SpaceDataHighway so all the data and information in space systems are transferred by using Laser light as medium.

## III. LASER LIGHT IN SPATIAL COMMUNICATION

Various satellites are present around the Earth; these satellites are controlled and coordinated by ground station on Earth. The ground stations communicate with the satellites by making use of Radio waves. The data collected by the satellites are in range of terabytes. The Radio waves whose frequency varies from 3 kHz to 300GHz, So transferring such huge data simultaneously is not possible and time lag takes place. This can be overcome by making use of Laser light as a medium to transmit data; the frequency of laser light varies from 400THz to 700THz so transmission of data takes place continuously with no time delay.



Fig. 1: Two solar powered satellites communicating via laser light

## IV.LASER TERMINALS SYSTEM

The angle between the line of sight and laser beam which forms a communication medium must be as small as a few  $\mu$  rad. To have proper alignment between the terminals of satellite, Optical beacons and servo loops are incorporated at both terminals. The servo loops is mechanical controller depending on the feedback and optical beacons are used to attract optical signal and render information to control loops. The terminals used in laser light communication are bidirectional in nature, they consists of both transmitter and receiver that share the laser light medium with an optical antenna. The transmitter block shown in

figure 2, with laser light source S operating in transverse mode to have highest antenna gain. The laser operates either continuously or in pulse mode with periodic pulse train. M is the modulator used to convert data signal to high beam. The high intense modulated beam enters an optical duplexer (DUP) and FPA (fine pointing assembly) before it enters the telescope which act as transmitting antenna (ANT). The telescope is used to increase the diameter of beam and reduces divergence. Coarse pointing antenna (CPA) is provided for steering. The received beam passes through antenna and FPA and is then moved to the receiving part of the terminal with the support of duplexer. A beam splitter (BS) is used for demodulation of received signal which directs one part of the received signal to the data detector (DD) further signal is processed in data electronics unit (DE), the other part of the received signal is used for control of pointing mechanism with acquisition and tracking detector (ATD) always pointing central. This is the basic concept used for the designing of terminals for optical communication between satellites.

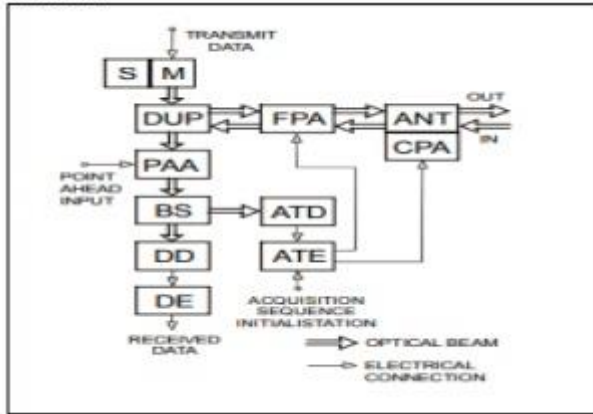


Fig. 2: Block Diagram of Optical transmitter and receiver for inter space communication (S-laser source, M-modulator, DUP-optical duplexer, FPA-fine pointing assembly, ANT-antenna, CPA-coarse pointing assembly, PAA-point head assembly, BS-beam splitter, DD-data detector, DE-data electronics, ATD-acquisition and tracking detector, ATE-acquisition and tracking electronics)



Fig. 3: Laser communication system module

## V. GEO AND LEO SATELLITES

LEO stands for Low Earth Orbit, satellites which are launched to these orbits are called LEO satellites. The LEO satellites are at a distance of 400 to 1000 miles above earth's surface and are used mainly for telecommunication network use. They are used for data communication which includes email, messages, video conferencing etc. The advantages of using LEO satellites are they consume less power and power amplifier rating required for transmission is also less and high speed communication. Geostationary satellites are launched at a distance 22300 miles above earth's surface and these satellites are Earth satellites as they revolve in the same direction of Earth. A single geostationary satellite is enough to cover almost 40% of total earth's surface; three such satellites placed at an angle of 120 degree can nearly cover almost the total surface of the earth. The two types of satellites are mainly used for getting data in and around the earth.

## VI. COMMUNICATION

The main purpose of satellites around the earth is to view and collect data of the earth atmosphere and send the collected data to the required ground station. The satellites are controlled by the commands given to them by the ground station. As we discussed the data collected by LEO satellites are more accurate compared to that of the higher orbit satellites. As we make use of EDRS technique data should be transmitted and communicated by Laser light. The ground station gives commands to the higher order satellite, these satellites consisting of laser terminals in them produce a high intense laser beam of light. The satellites of which data has to be collected consist of same laser terminals, the high intense laser beam from the higher orbit satellite must get in contact, once the laser connection is formed between them the laser light between them acts as a medium to transfer data. Proper measure has to be taken before starting to transfer data the laser link formed between the satellites is strong enough and the two satellites should maintain the link for sufficient amount of time, if connection between them is lost in middle then large amount of data would be lost so, proper precaution has to be taken before transferring the data. Once the data is received by the satellite it will transfer the data to the ground station. The data collected by the satellite has to be sent to the ground station. We can not use laser light as a medium to transfer data from the satellite to ground station. The environmental factors are not suitable for laser light communication between satellite and ground station, the amount of clouds, rain disturbs the laser light communication, apart

from this we cannot use such intense light inside atmosphere as it might damage and kill birds and other living organisms as result we can't use laser light as a communication medium instead microwaves are used for communication between satellites and ground station. The frequency of microwaves varies between 300MHz to 300GHz compared to radio waves usage of microwaves are more advantageous. Using microwave as medium the data collected are transferred to the required ground station. But use of microwave is harmful, so depending on the environmental factors, the life or living organisms in and around ground station are checked. If there is no problem with using microwaves then only microwaves are used in communication. Otherwise normal radio waves are used for communication between satellite and ground station. The other advantage over Laser light is that it does not require line of sight so we make use of either radio or microwaves as medium of communication. Therefore for the intersatellite communication we make use of Laser light as communication medium and for communication between ground station and satellite we use microwave or radio wave as communication. By using this, the data collected from the satellite is obtained by the ground station. Thus by making use of this we can have Spacedatahighway using only light as medium to communication and to transfer data from satellite to satellite and for communication with ground station.

**VII. INTERFERENCE**

As we make use of laser light as a medium for intersatellite communication and microwave for communication between ground station and satellite, interference may occur as we make use electromagnetic waves which results in loss of data. The communication between Geo and LEO satellites may have interference. To study this we have two scenario models:

1. Interference between Earth LEO station and Geo satellite which is Uplink connection.
2. Interference between Geo Earth station and LEO satellites which is Downlink connection.

The two scenarios are shown below:

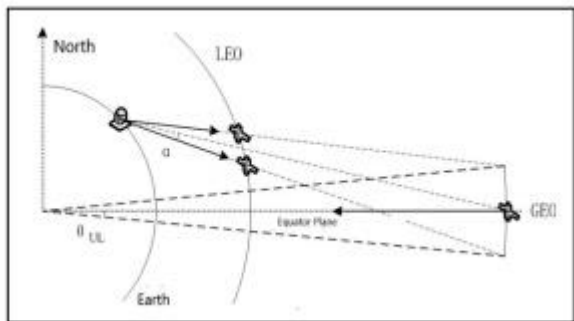


Fig. 4: Uplink communication

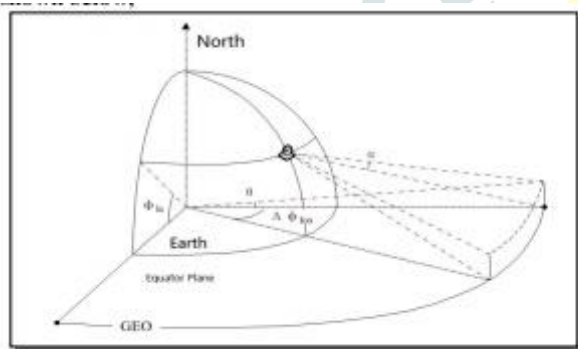


Fig. 5: Downlink communication

From above two figures figure 4 and figure 5, the coexistence interference varies with the LEO satellite moving in orbit, thus there should be an angle called Discrimination angle  $\alpha$  between satellite and Earth station to keep the interference to a minimum level. The geocentric angles  $\theta_{UL}$  and  $\theta_{DL}$  are segmented by  $\alpha$  on Geo celestial sphere respectively in both Uplink and Downlink scenarios. To analyze this we use EPDT to evaluate interference level in LEO-Geo communication. EPDT is defined as

**Geo communication. EPDT is defined as**

$$EPFD = 10 \log_{10} \left[ \sum_{i=1}^N 10^{\frac{P_i}{10}} \frac{G_t(\theta_i) G_r(\phi_i)}{4\pi d_i^2 G_{rmax}} \right]$$

Where N is the total number of transmitting nodes,  $P_i$  is transmitting power,  $d_i$  is transmitting distance,  $G_t$  and  $G_r$  are antenna gain of transmitting and receiving respectively.

The discrimination angle  $\alpha$ , if becomes smaller the communication between the ground station and satellites are turned off. Considering both Uplink and Downlink scenarios the value of  $\alpha$  is given by,  $\alpha = \max(\alpha_{UL}, \alpha_{DL})$ .  $\alpha_{UL}$  and  $\alpha_{DL}$  are the discrimination angle in Uplink and Downlink respectively. The relationship between  $\alpha$  and geocentric angle  $\theta$  are shown below,

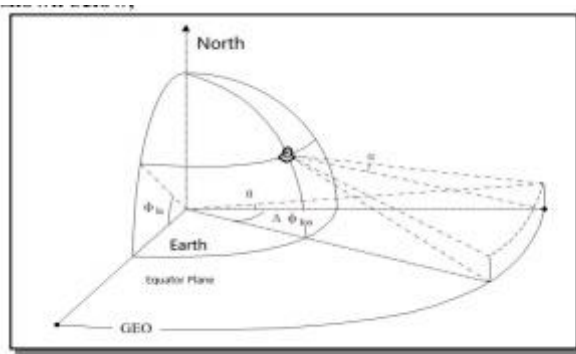


Fig. 6: Relationship between  $\alpha$  and  $\Theta$ ,  $\Delta \Phi_{lon}$  is the longitudinal difference between earth station and satellite  $\Phi_{la}$  latitude of Earth station.

The value of  $\Phi_{la}$  and angle  $\alpha$  remains constant, the value of  $\Theta$  increases with growth in  $\Delta \Phi_{lon}$ , under fixed condition of  $\Phi_{la}$  and  $\alpha$  the antenna elevation limits, the maximum value of  $\Theta$  can reach at boundary of Earth surface is given by,  $\Theta = f(\max(\Delta \Phi_{lon}), \Phi_{la}, \alpha)$ . The value of  $\Theta$  is so selected for a particular latitude and longitude so as to meet with required EPFD. So by doing this the interference can be minimized with no data lost during communication between satellites and ground station.

### VIII. CONCEPT OF SECURITY

As we discussed Low Earth satellites are closer to Earth and have high bandwidth and will be able to view and collect data of Earth atmosphere in an accurate way compared to that higher orbit satellites. Higher orbit satellites in this technique are mainly used for interconnection networks between higher orbital satellites and to transfer the data obtained to the ground stations. We know that by making use of only three geo stationary satellites the entire globe can be covered and the data can be easily sent to the required space ground station. There are large number of Leo satellites if both Leo and Geo satellites are positioned properly the data collected by the Leo satellites are transferred to the Geo satellites by establishing a laser link between the two satellites, as four laser terminals can be produced by a single Geo satellite by EDRS technique we should have continuous ongoing link with the Higher orbital Geo satellites this one high intense link between the three Geo satellites acts as a boundary, a border around the Earth as shown in figure 4. The other laser beams can be controlled and operated depending on the required satellite information. The one main thing that is to be taken care is that the laser link between the three Geo satellites should be continuous as Laser light has to be monitored continuously. When a space object tries to enter or pass near earth orbit the continuous ongoing link between the Geo satellites gets interrupted as a result the interconnection between the satellite is lost. Once the ongoing link is interrupted the operator can easily know that a space object or system moved near or entered earth orbital. In this way we use the inter Laser link as a medium to identify the space objects entering Earth orbit. We can even have emergency alarms to alarm whenever the signal between the satellites is lost. We can make use of distance relay to identify at what distance from the satellite the interruption has occurred so identification of space objects becomes more accurate. This technique cannot be used for particular protection, the areas which are mostly affected by special objects are identified and depending on that area satellites are positioned and having interlinks protection is given to that particular location. As we make use of only laser light as medium to act as border, its just a thin beam of light providing protection throughout the globe is difficult and the number of satellites for providing protection would be more and will not be economic.

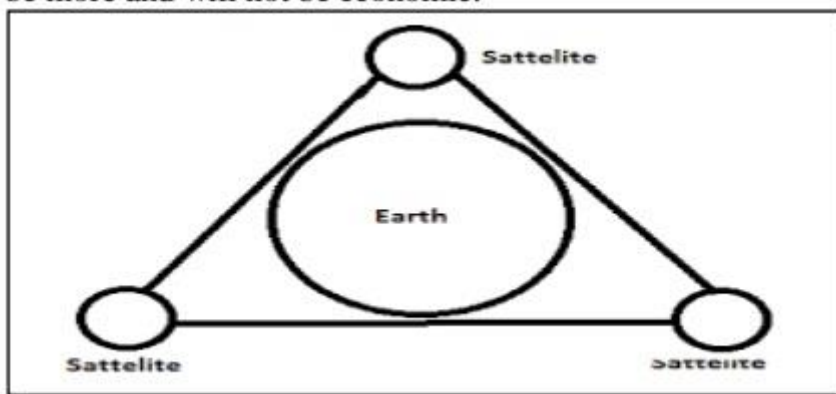


Fig. 7: Laser link between three geo satellites acting as frame work around earth

Advantages of this method are:

1. Ensure continuous Data Transmission.
2. Continuous link helps in transferring data to ground station with no time delay.
3. Interconnection of satellites helps in storing data in all the three satellites, data lost is not possible.
4. Helps in identifying the entry of space object or system into the Earth in a particular area.

Disadvantages of this method are:

1. Continuous Laser link between the Satellites.
2. Power consumed is more for continuous Laser link.
3. Cost required very high to have the required EDRS systems in all three satellites.
4. Cannot give Protection for the entire Globe.

## IX.CONCLUSION

High speed communication between satellites, data is transmitted with speed of light which increases communication efficiency between satellites and improves VLD (Very Long Distance) communication. Using laser light as medium to transmit data the transmission speed is very high and the interconnection between the satellites help in providing security and ensure safety of Earth surface in a particular area from space objects.

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