Scope of Potential in FSO Technology as Compared to RF Technology in the Next Generation Networks

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Abstract – This paper presents the scope of potential in free space optical communication as compared to the RF communication. In the present era of global technologies, the proper telecommunication infrastructure is one of the most important factors for integrating different platforms together and leads to success on time. In many ways the foundation of your routine functioning like business or any other day to day activity is nowadays linked directly or indirectly to your telecommunications facilities. This paper presents the comparative analysis of establishing a high speed point to point wireless link by radio frequency (RF) and free space optics (FSO) technologies respectively. Since from decades the use of RF in wireless communication has been implemented at a very broader volume and remains successful as well. Nowadays, due to certain limitations in the RF technology like scarcity of spectrum owing to very high demand of various wireless applications, there is a need of shifting from RF to optical wireless communication like FSO. After analyzing different parameters like budget, speed, latency and time to market, etc., the comparative report is presented between RF and FSO high speed links.

Index Terms – Radio frequency (RF), free space optics (FSO), spectrum, high speed link.

1. INTRODUCTION

The different technologies pertaining to various wireless communication systems have become an area of comprehensive research in the modern era of global communication. The ever increasing demand of channel capacity and bandwidth have led to need of very advanced wireless communication system with adequate reliability and flexibility to handle the varying traffic rates and different data patterns[1]. The future of different wireless communication technologies is based on the outcome of reliable and efficient transfer mechanism, such as file transfer, internet access, interactive data, voice, video and composite multimedia data. In terms of the availability of the system resources the huge bandwidth traffic is generally more restricted than small bandwidth traffic load and hence the system capacity is mainly determined by the large bandwidth traffic. Establishing a high speed point to point links are of paramount importance in the field of communication networks, which caters thousands of different services in the diverse sections of information technology. One of the finest wireless links used till date is RF link and no doubt it has served our purpose, but due to the exponential increase in the data traffic the need for high bandwidth cannot be sufficiently addressed by the RF technology. Therefore, we have to search for another option for addressing this problem.

To make use of optical wireless communication technology like free space optics (FSO) is one of the potential options before us to address the aforementioned need of high bandwidth and high capacity respectively. The free space optics are the emerging area of optical wireless communication with some inherent properties of high speed and large bandwidth[2]. Despite the fact that FSO suffers a lot in terms of its performance due to adverse weather conditions, optical wireless communication has proved a good alternative in terms of bandwidth requirements and system capacity[3]. With the recent advancement in optoelectronics, the FSO technology has become an alternative to the optical fiber links and also to the RF links. Keeping in view the major attributes of a particular communication link, the FSO link is better than an RF link in establishing a high speed point to point communication link. These links, mostly serve as backbone links as they have a large capacity and large bandwidth. After analyzing the advantages of both FSO and RF links, to harness them we have one more option of developing the hybrid FSO/RF links in certain cases and it has proved a better option in the present days and has also been successfully implemented[4]. The following section elaborates the detailed comparative analysis of FSO and RF links. Both RF and FSO links are used in practical fields [5].

2. COMPARATIVE ANALYSIS

The principal operation of free space optics technology is similar to the fiber optic communication, but without using an optic fiber cable and the data is transmitted over an optical carrier through atmosphere based on line of sight (LOS) propagation[6][7]. Optical link offers many advantages over the radio frequency link except the fact that optical wireless link is more adversely affected by the atmospheric conditions. The question is why then RF has been used till date compared to Optical wireless links. The answer is that RF is less affected by atmospheric conditions and the requirements in terms of bandwidth and capacity was met by RF till date, but due to the exponential increase in the present day data all over the globe the need of technology which possess high capacity and large bandwidth arise and this is not in RF technology. Therefore, we need to gradually shift to the optical domain from the RF domain and accordingly address the issues in the optical wireless system. The major difference between the RF and FSO systems is due to their large difference in wavelength. As per the weather statistics available, the visibility is almost more than 10 miles during the clear atmospheric conditions and this transmission window falls within the near infrared wavelength range between 0.7 μ m to 1.6 μ m. while the transmission window of RF communication lies between 30mm to 3m. So FSO wavelength is thousand times shorter than the RF systems or in other words the FSO frequency is thousand times larger than the RF systems and hence we can say that FSO systems have large bandwidth. Hence the overall capacity of FSO systems is much larger than RF systems.

Narrow beam divergence:

The beam divergence plays a very vital role in the wireless communication systems. The coverage area and the directivity of any waveform are the functions of beam divergence. The beam divergence is directly proportional to wavelength and inversely proportional to aperture diameter.

Beam divergence = λ/D_R ……. (1)

Where $\lambda \rightarrow$ carrier wavelength and

$D_R \rightarrow$ aperture diameter

Though we are using the beams of very small wavelengths and hence use very low divergent beams. Therefore the optical carrier shows the narrower beam spread and the RF carrier spreads more. This leads to better directivity and also increase in the intensity of signal at the receiving end for a given transmitted power. The relative comparison of beam divergence of optical and radio signals coming back from Mars to Earth is shown in Fig. 2[8]. In point to point communication the preferred requirement in narrow divergence and in point to multipoint communication like in cellular communication the large divergence of beam is taken into consideration to provide the suitable coverage. Therefore in point to point communication FSO is suitable and in point to multipoint communication RF is better.

Huge bandwidth:

It is a fundamental fact that information carrying capacity is directly proportional to the increase in the carrier frequency. The acceptable bandwidth in radio waves is up to 20% of the carrier signal frequency. Unlike RF even if we take only 1% of the carrier frequency ($\approx 10^{16}$ Hz) in optical communication, the achievable bandwidth is 100THz. Hence it evolves from this fact that the practical bandwidth is in the order of THz in optical communication and it is approximately 10^5 times greater than the RF[9]. Since the capacity is directly proportional to the bandwidth [C = BW (1+SNR)], therefore optical wireless channels offer huge capacity as compared to RF channels due to huge modulation bandwidth.

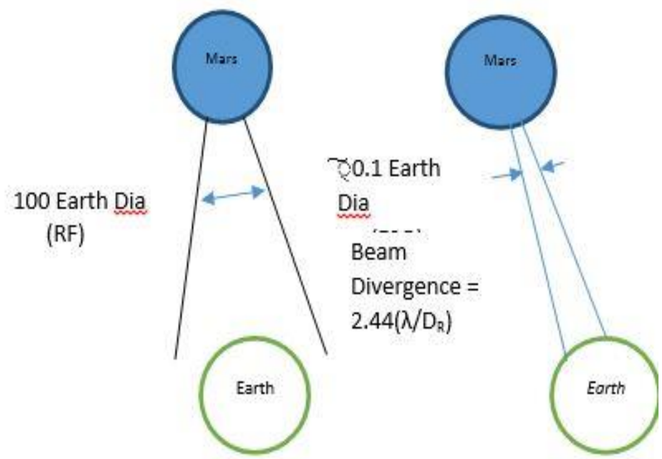

Figure 2. Comparison of RF and Optical beam divergence from Mars to words Earth.

Throughput:

It is a well-established fact that optical fiber communication is a matured technology in terms of speed and throughput and is used in abundance all over the globe to provide the connectivity mostly on the core of communication networks. But there is a bottle neck between the core and edge and to open this we need to have some compatible medium or technology like fiber to home (FTH) or FSO. Fiber to home is a wired connectivity and has its inherent problems of laying, digging, cost and maintenance and is not a viable technology especially in the urban and congested areas. Therefore FSO is the most viable solution to this problem and hence provides broadband access to the high speed core. FSO is very much similar in terms of throughput or speed with the fiber optics[10]. Whereas radio communication is the key source of connectivity with regard to last or first mile connectivity in the present times and is in place at large volume, but due to its low capacity and bandwidth in comparison to optic technology the need of the market cannot be addressed by it. The RF systems are spitted into different categories depending on the usage and data rate[11].

Throughput of FSO communication is determined by the weather conditions and in clear weather the throughput of FSO is better than RF communication.

Less power and smaller mass:

Due to the narrow beam divergence in optical wave the optical intensity is more at the receiver for a given transmitter power level. Also the smaller wavelength of the optical carrier helps into the design FSO system with smaller antenna size, while in case of RF system the antenna size is too large to achieve the same gain ($G_{antenna}$ is proportional to $1/\lambda^2$) .The optical system has typical size of 0.3 m vs 1.5 m for the spacecraft antenna[12]. Therefore it is evident from the above fact that the power consumption in FSO links is less as compared to the power consumption in RF links for achieving the same gain. The size of corresponding antenna is comparatively smaller in FSO system than RF systems; therefore the overall size of FSO is smaller than RF systems. RF system is based on radio transmitters consisting of huge equipment installed[13]. In table 1 , the power and mass comparison between the RF and FSO systems using 50 W and 10 W for RF (Ka Band) and optical systems respectively at 2.5 Gbps.

Link	Parameter	Optical (FSO)	RF
GEO-LEO	Antenna Diameter	10 cm	2.1 m
	Power	93 W	214 W
	Mass	65 kg	153 kg
LEO-LEO	Antenna Diameter	3.5 cm	0.8 m
	Power	33 W	78 W
	Mass	23 kg	56 kg
GEO-GEO	Antenna Diameter	14 cm	2 m
	Power	124 W	205 W
	Mass	87 kg	146 kg

Table 1. Power and mass comparison between the RF and FSO

High Directivity:

The size of antenna is proportional to the wavelength and therefore in FSO communication the size of antenna is very small as the wave length used is very small. The directivity of an antenna also depends on the gain of antenna. But the gain itself is inversely proportional to the beam divergence, so optical gain is always greater than RF gain.

The upper hand of optical carrier over RF carrier is depicted by ratio of antenna directivity as given below

$$\frac{FSOgain}{RFgain} = \frac{4\pi/\text{Sq.of optical Divergence}}{4\pi/\text{Sq.of RF Divergence}} \ldots\ldots (2)$$

From the above equation it is clear that optical beam is having higher directivity as compared to the RF beam. Therefore FSO links are more suited in point to point links.

Unlicensed spectrum:

The optical spectrum is absolutely free till date and no requirement of any licensing, whereas the RF spectrum is not free except some portion like ISM band and few others. To utilize RF bandwidth, we have to pay a lot and there are political and beurocratic interferences and mostly hinder the smooth functioning of regulations. The limited spectrum of RF leads to spectral overcrowding and maximum congestion. These certainly have number of performance issues of different types of interferences. Where the optical spectrum is virtually unlimited and there is no question of congestion in the present scenarios. This also reduces the initial cost set up and is cost effective[14].

Security:

The spectrum analyzers are not capable to detect the optical beam as optical beams used in FSO communication are narrow and highly directional due to their narrow divergence. The interception of any kind is very difficult and if intercepted by any means will lead to disruption of signal, this can be immediately known by the communicating parties and the identity of the attacker or hacker can be easily established. Unlike RF signal, optical signal cannot be passed through walls and no eavesdropping is possible[15].

Limitations:

The main limitations of FSO links are line of sight, adverse weather conditions, sway of buildings. The visibility plays a major role in the performance of FSO communication and visibility is in turn a function of atmosphere conditions like fog, snow, rain and mist etc[16][17][18][19]. Whereas RF technology is the prominent wireless communication technology used all over the world. RF bandwidth is regulated than optic bandwidth and hence costly technology. RF requires huge space for installation and weather conditions also impact on the performance of RF communication. To cover the large distance and high data rare RF communication requires more power and space as well[20].

Secondary benefits of FSO over RF:

1. Light weight and compact.
2. Large flexibility and hence reduces the size of network segments
3. It can be used where the optic fiber cable is difficult to use.

4. Maximum re-configurability and reusability.
5. Fast installation and hence less time to market.
6. Leads to all optic system, which is the need of modern communication technologies.
7. Electrical isolation.

3. CONCLUSION

The tremendous growth and recent advancement in the information and communication technologies has led to a concern to look for a medium which provides the large bandwidth and huge capacity to cater the existing and future needs. One of the best viable options before us is the optical wireless communication in addition to the existing RF technologies; therefore the very rich area of research is the optical wireless communication like free space communication (FSO) and the researchers and scholars have a very wide and open field in dealing with issues and challenges of FSO especially the dominant challenge is the impact of harsh weather on optical wireless communication. FSO link possesses a number of advantages over the RF channel in terms of cost, capacity, security and speed, etc. one of the major disadvantage the FSO technology is having over RF technology is the adverse effect of weather on FSO channel and if gets properly mitigated the FSO will certainly dominate the RF technology in future. Another disadvantage of FSO over RF system is that FSO requires tight acquisition, tracking and pointing (ATP) due to narrow beam divergence and the relative position of the Sun of the laser beams.

Presently the RF systems are heavily in place, but they could not cater to the current and future high demand of bandwidth capacity, and therefore the choice before us is to shift over optical wireless provided the ill effects of atmosphere on optical wireless communication are properly mitigated. After a deep understanding of the optical wireless communication, it is imperative that the light has tremendous potential in terms of signal carrying capacity and if properly harnessed can prove the very efficient medium in the next generation networks and solves the problem of large bandwidth requirements. Both RF and FSO are the wireless communication technologies and has their own advantages and disadvantages, but to cater the demand of high data rate FSO is the feasible choice. Although the FSO is new to the world, but growing at a faster rate for higher data rate and secure communication as is the need of the market.

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