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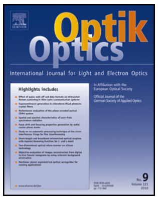

Performance analysis in multi-channels ellipsoid structure wireless optical communications

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ABSTRACT

Wireless optical is categorized as a last mile solution for the sake of complementing the Gigabits network solution. Recently, multi-channels wireless optical (WO) has been introduced to increase the coverage and the link range up to kilometers and reduce other possible losses. This paper proposed a multi-channels ellipsoid structure by analyzing a transmission distance by incorporating the number of aligned transceiver. The performance of conventional single channel and multi-channels WO are also compared and the analysis showed that the WO system with increment of number of transceiver pairs (number of channels) is performing better, having low geometrical path loss, higher received power and link margin.

1. Introduction

The growing demand toward higher data rate forces network operators to invest in new infrastructure and equipment in order to face the increased bandwidth requirement. The capacity gap between radio frequency (RF) wireless and optical fiber network speeds remains huge because of the limited availability of RF spectrum [1]. Though efforts for an all-optical internet will likely provide cost-effective solutions to the last mile problem within the wired context. To achieve high-speed wireless point-to-point communications, WO communication has received attention particularly for high-altitudes such as space communications [2] and building top metro-area communications [3,4]. Although, in areas where a large amount of ducts already exists, Fiber-to-the-Cabinet (FTTC) could provide a viable access solution in contrast to the Fiber-to-the-Home (FTTH) whose investment prospects are severely limited due to enormous fiber roll out. WO communication has the potential to bridge the capacity gap between backbone fiber links and end-users, especially in the last mile. Using key economic figure of merits, it was shown that in areas which duct availability is limited, WO can provide an interesting, economically viable broadband alternative to FTTH [5]. This is due to the fact that WO installation does not require any costly civil works, which are the main cost factor in FTTH cases. In addition Risk Analysis evaluation shows that investment in WO technology has less risk compared to the FTTH cases [5].

Today, most of the WO communication is developed for long distance point-to-point applications such as building-top installations. Although the equipment for this long distance transmission is expensive and highly sensitive, this kind of installation has overcome the issues of adverse weather condition which the main attenuation factor that affect the performance. However, extensive research has done to overcome these LOS requirements on quality of transmission. Because of their high throughput capacity, this WO deployment is typically a mesh network installation in which the backbone of network established by WO links. Besides, various techniques such as mechanical auto-tracking [6] or beam steering [7] have been developed for stationary deployments of WO to tolerate the attenuation factors such as scintillation [8]. By using multi-channels WO which fits multiple transceiver pairs in a single WO device helps in increasing link range and reducing and minimizing possible losses. Meanwhile, the performance that has been improved should be further investigated to show that it is worthwhile and cost effective.

Fig. 1 shows simple illustration of multi-channels ellipsoid structure omnidirectional of WO communication.

In this paper, the performance of single channel point-to-point and multi-channels multipoint-to-multipoint for 2-dimensional are analyzed and further perform comparison between them. The rest of the paper is organized as follows: Section 2 describes the

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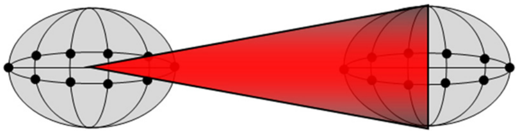

Fig. 1. Multi-channels ellipsoid structure omnidirectional wireless optical communications.

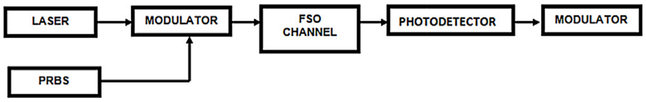

Fig. 2. Single channel free space optical communication system.

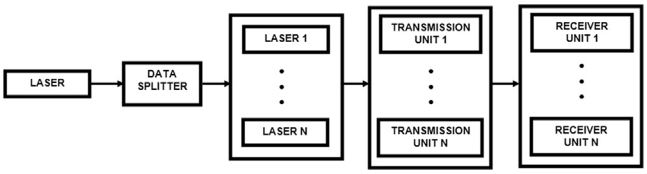

Fig. 3. Multi-channels free space optical communication system.

proposed system for point-to-point. Section 3 carries out the results and discussions and Section 4 concludes this paper.

2. Description of the system

Fig. 2 below simply illustrates that single channel WO is only for one to one wireless communication. At transmitter side, lasers are used as optical sources for emitting modulated data onto free space (air) toward the receiver. The distinct property of WO is that it can emit narrow beam light by having a small optical spectrum (line width), while having a high-output optical power which means that it is a photons-concentrated beam. Whereas at the receiver side, it consists of a photodetector which is used to decode, and interpret the optical signal received. The performance evaluation parameters for single channel WO are such as probability bit of error (BER), received signal power and link margin. Wireless communication often affected by the losses induced externally and internally which should be taken into consideration when evaluating the performance of WO system. Losses such as geometrical path loss, pointing loss, scattering, and so on are the main losses that affect the overall performance of WO system.

Fig. 3 below shows that architecture of multi-channels WO communication. At transmitter side, the multi-channels here is made up of an array which each small aperture denotes an optical source for emitting modulated data toward the receiver at the other terminal. Since there are multiple receivers used for each device, the received power at the receiver is higher as compared to single channel. Received power is heavily based on the number of receivers (number of channels) used. From this figure, multi-channels are produced in a way that the signal is spatially diverse but not dividing the signal's bandwidth equally to produce multiple beams. As shown in the figure, a data splitter is used to provide redundant signals rather than dividing the signal and hence there are multiple beams produced in a single device.

The reason of using multi-channels is to overcome problems that normally faced by single channel such as laser redundancy in the case of laser failure, support longer link distance, combats short term path interruptions (bird flies and blocks line of sight), and minimize the impact of signal power fluctuations due to scintillation. The parameters which affect multi-channels WO performance that will be used for performance evaluation are such as beam divergence, number of channels, optical loss, alignment and atmospheric attenuation.

Table 1
Parameters used in the simulation.

Parameters	Signal/Noise model
Transmitted power	5 mW/beam
Receiver sensitivity	−30 dBm
Beam divergence	2 mrad
Data rate	1.25 Gbps
Wavelength	850 nm
Transmitter aperture diameter	2.5 cm
Receiver aperture diameter	8 cm

Algorithm used for Geometrical Path Loss of Single Channel WO [9]:

$$L_{GEO} = 10\ \log_{10}\left[\frac{d_{RX}}{d_{TX}+\theta\ell}\right]^2 \tag{1}$$

Geometrical Path Loss for Multi-Channels WO [10]:

$$L_{GEO} = 10\ \log_{10}\left[\frac{A_{RX}N_{RX}}{\pi(\ell\theta)^2}\right] \tag{2}$$

where d_{RX} is receiver aperture diameter (m), d_{TX} is transmitter aperture diameter (m), θ is beam divergence (miliradian), ℓ is link range (km), A_{RX} is receiver aperture area (m^2), and N_{RX} is number of receivers.

Algorithm used for Received Power of Single Channel WO [10]

$$P_r = P_t * \left[\frac{d_{RX}}{d_{TX}+\theta\ell}\right]^2 * 10^{(-\alpha * l/10)} \tag{3}$$

Received Power for Multi-Channels WO [11]:

$$P_r = P_t(linear) * L_{GEO} * 10^{(-\alpha * l/10)} \tag{4}$$

where, $P_T(linear) = \left((1*10^{-3})(10)^{\frac{P_A}{10}}\right)$, $P_A = P_t[dBm] + 10\ \log 10(N_{TX})$, N_{TX} is number of transmitters and α is atmospheric attenuation factor (dB/km).

Algorithm Used for Link Margin Comparison:

Single & Multi-Channels Algorithm [11]:

$$LM = P_A - RS - L_{GEO} - L_{SYS} - L_{ATM} \tag{5}$$

where P_A is total power transmitted (dBm), RS is receiver's sensitivity (dBm), L_{GEO} is geometrical path loss (dB), L_{SYS} is system loss (optical loss + pointing loss (dB)) and L_{ATM} is atmospheric attenuation (dB).

For simulation purposes, the following specifications will be used as provided by [12] (Table 1).

3. Results and discussion

Figures below show the overall performance comparison between single and multi-channels. By using Eqs. (1) and (2), the calculated values are plotted in Fig. 4. Based on Fig. 4, the geometric loss of single channel is apparently higher than multi-channels system. Take for instant, at 1.5 km, single channel suffers roughly 32 dB loss, 2-channels suffer about 28 dB, and as number of channels increases, the geometrical path loss decreases accordingly. For 10-channels, only 21 dB of loss is calculated.

It is easier to summarize them using the relationship below, where loss decreases when receiver aperture diameter increases, this means that area of the aperture also increases, and hence the light that will be impinging on the aperture is more concentrated (loss decreases) as compared to smaller receiver aperture. Another reason the number of channels used has the effect on the received power, as more power transmitted at the same time, and more receivers are used, then more power is received (loss decreases) as compared to only 1 pair of transmitter and receiver used.

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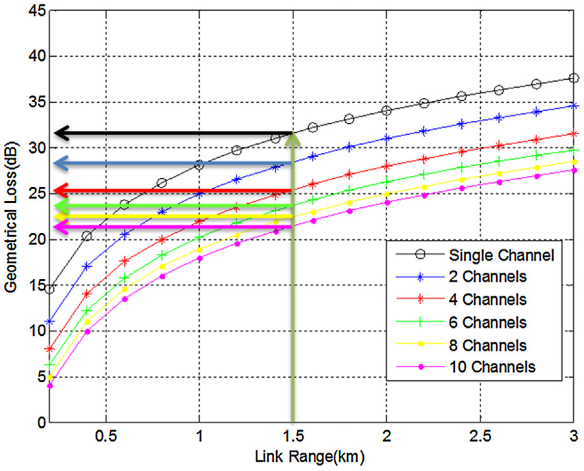

Fig. 4. Geometrical loss versus link range comparison.

By using Eqs. (3) and (4), the calculated values are plotted in Fig. 5. At link range of 4 km, received power for single channel is −95 dBm, 2-channels is −35 dBm, 8-channels is −22 dBm and for 10-channels is about −20 dBm. Again, the most number of transceiver pairs received the most power from the source as shown in Fig. 5.

With Eqs. (3) and (4) again, the received power in dBm is calculated. From the relationship shown in [7], for typical haze condition, the received power is not affected much if the link range is short, as link range increases, the received power decreases rapidly for single channel. 8-channels perform better in the way that it could support up to 5.7 km before the signal cannot be fully recovered as shown by blue arrow in Fig. 6.

Using Eq. (5), Fig. 7 is plotted with the calculated values. Generally, link margin with higher value is the most desirable as it can be used to cater unexpected losses such as weather changes into extreme condition, and severe pointing error which will collapse the system. As the system is designed for normal case because of cost efficiency, higher link margin can cope with these unexpected losses better. Multi-channels show the best result over the others as its link margin is still acceptable even the link is extended to 6 km. Also, 10-channels can have link margin of 24 dB even at 4 km, but for single channel, it can only have link margin of 29 dB at 0.2 km which is prone to collapse due to unexpected losses.

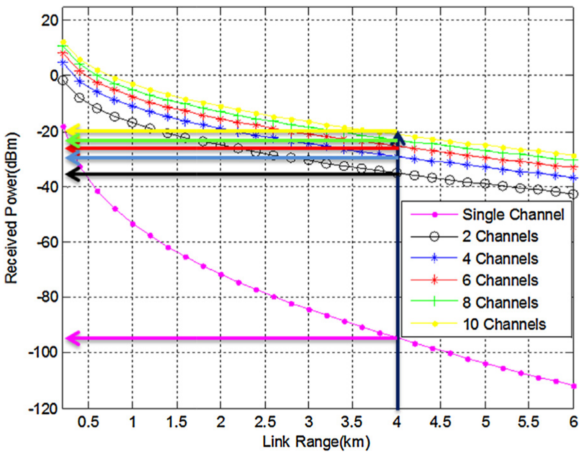

Fig. 5. Received power versus link range comparison.

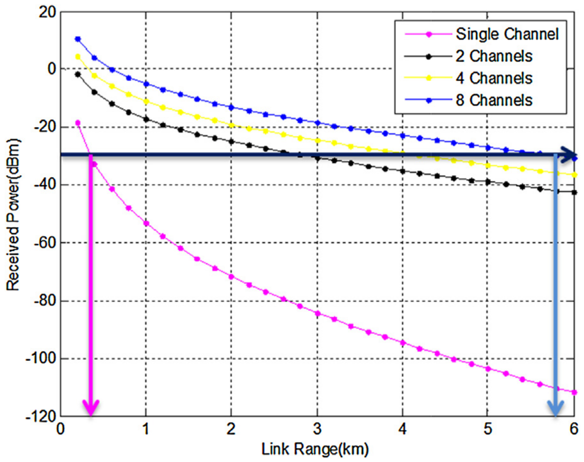

Fig. 6. Received power versus link range comparison under haze condition.

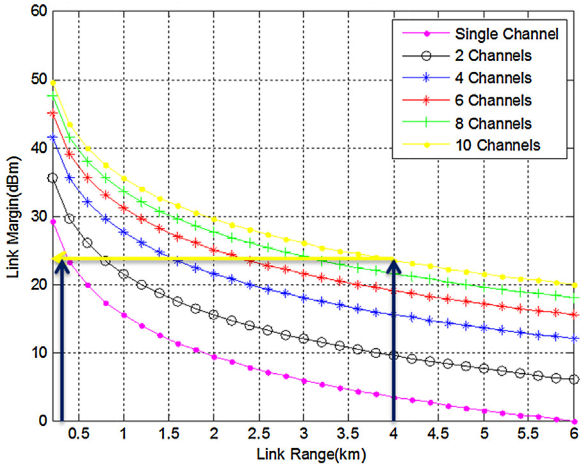

Fig. 7. Link margin versus link range comparison.

4. Conclusion

In this paper the performance of single channel and multi-channels is demonstrated. By implementing multi-channels in WO, it is possible to increase the link range up to kilometers before the signal cannot be fully recovered. Multi-channels WO perform in the way that it has overall major improvement that better than single channel. But, the size of the array that allocates these channels will increase also. Therefore, in conclusion, the number of channels should be determined according to the requirement and cost justified by the users. Performance, number of channels and cost will be compromised in order to design and deploy the best system for the users.

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