Performance Analysis of 5G Millimeter Waves over Free Space Optics System

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Abstract. In recent year the free-space optical communication (FSO) has become more interesting as its alternative to radio frequency communication. The links of Free-space optical (FSO) communication very sensitive for a lot of variability which make a real challenge for efficient, robust system design. In free space optic the information sends through the optical fiber as pluses, so a large dynamic range will provide, from designed systems in most cases. The FSO is a line-of-sight (LOS) technology that transmits a modulated beam of visible or infrared light through the atmosphere for broadband communications. The focus of this work is to investigate the feasibility and design of free-space optical (FSO) with millimeter waves for 5th generation. Consequently, the conducted analysis done by using optisystem software. As a result, the analysis generated based on Eye diagram, transmitted power, Q factor and distance.

Keywords: Free space optic, Millimetres waves, 5G.

1. Introduction

The demand increased rapidly for high throughput and low latency applications for end users which make fundamental forcing changes to cellular network topologies. These days 4G is the public technology to share data and information where the growth of mobile users over the existing cellular 4G backhaul is expected to increase sevenfold by 2021 and the development of the idea of the Internet of Things may reach between 20 and 30 billion devices by 2020.[1] Fifth-generation (5G) technology it will give new services with ultra-high system capacity, massive device connectivity, low latency, strong security, ultra-low consumption of energy, and extremely high quality [2].

Microwave and optic fiber technologies have been considered as feasible solutions for next-generation backhaul networks. However, such technologies are not cost effective to deploy, particularly for the backhaul in rugged areas or high-density urban, such a place which surrounded by mountains and solid rocks. [3] Free-space optic (FSO) has many features as cost-effective and large wide-bandwidth solution as compared to traditional backhaul solutions. FSO communication has a good attention in interested research today, because its high rates of transmission and unlicensed bandwidths.[4] Line of-sight (LOS) technology uses optical bands (ultraviolet, visible light, and infrared) to establish a communication link for several kilometers at a data rate of up to 10 Gbps which
is considered the highest ever reported. Free-space optical (FSO) communication is away for
transmitting the information from one area to another by sending light as pulses.[5, 6]

The focus of this work is to investigate the design of free-space optical (FSO) with millimeter waves
for 5th generation. Consequently, the analysis displayed based on multi parameters by using optisystem
software. The analysis will determine the performance of FSO system based on Eye diagram, power
transmitted, frequencies, and distance.

2. Proposed System
For designing a wireless communication system, it's necessary to know firstly the status of the signal
when its travels through the mediums, this duty is usually achieved by make measurement or simulating
the channel impulse response. The huge bandwidth promised by FSO communications is available only
under clear sky conditions. [7,8] the great potentials of free space optical communications and
acceptable measures should be achieved in the designing of transmitter and receiver [9]. In this work,
free space optical with millimeter waves for 5th generation systems will be designed and studied the
effect of distance, eye diagram and data rate on the performance of the system under different conditions.
The basic elements that any free space optical system consist of are: transmitter (Tx), channel which is
FSO and reception (Rx). In The transmitter part many components included such as laser source
(1550nm), plus generator (Pseudo Random Bit Sequence), line coding as (Non-Return to Zero) and
modulator which mix the optical signal with electrical signal called MZM (Mach Zehnder Modulator).
Through the FSO channel the optical signal received at the receiver part, and directly detected by PIN
photodetector. Then the signal going through two type of visualizer's called optical power meter which
measure the strength of received power even in Watts or decibel (dB), and analyzer for checking the
BER, which automatically generate the BER value. In addition to the calculation of Q-factor and
displayed the eye diagram. Therefore, the designed system will have tested many parameters for
different frequencies for the 5G, the block diagram of proposed system shown in Figure 1.

Figure 1. Block Diagram of millimeter waves FSO System.

In designed system, the signal source used laser beam which send very high bandwidth data from
sender to the reception during the atmospheric channel of free space. So, the signal travel through the
transmitting antenna and subsequently received at the receiver antenna in the atmosphere. As mentioned
before the received signal is generated by photo detector which is always proportional to the
instantaneous (received) optical power that is generally weakly received [10,11].

Millimeter waves are a high frequency used in wireless communication systems that enabled
technology for multi Gbit/s data transmission. It is considered the wavelengths from 1 to 10 mm, which
is identical to the frequencies range in 30-300 GHZ especially from 24-86 as recommended by ITU-
WRC 19, [12]. During this rang there are some frequencies specified for study among of them 28, 38,
72 GHz. Tire FSO and the technologies used to support multi Gbit/s transmission over distance for few
kilometers, with millimeter Wave [13]. In this research the frequencies used to test designed system are
28 GHz, and 38 GHz, which is mostly a band used in the research of 5G, based on WCR. [14,15].
3. Results and Discussion

In this part, the results of FSO simulations that have been carried out with wavelengths of 1550 and distances of 1 km, 1.5 km, 2 km, 2.5 km, and 3 km. It produces the amount of Q Factor and bit rate error. As a Quality Factor, Q is an important indicator to determine the optical performance which is used to characterize the BER. The performance of the system can be measured by opening of eye diagram. So, a good performance when the eye diagram opened wide and it becomes poor when the eye narrower.

The results from the simulations are displayed and discussed. Clear and wide eye diagrams show a successful transmission of 5 Gbps data with acceptable error for a distance of 1 km, 2 km and 2.5 km. Figure 2, display the eye diagram at distance 3 km which considered the longest distance and received acceptable signal of power transmitted 150 mw, while the performance at same distance become worse with transmitted power 50 mw and 100 mw.

![Eye Diagrams](image)

**Figure 2.** Display eye diagram with transmit power 50, 100, 150 and 300 mw respectively for distance 3 km.

Figures 3, 4, illustrate the relation between the distance and BER with changing in the power transmitted at 28 and 38 GHz. It can be observed that the BER increase with increase the distance and reduce the power transmitted. At low power transmit (50 mw), the performance of the system still acceptable until 1.5 km, after that its become worse. While for high power transmitted (300 mw) the quality of the received signal still a good at 3 km distance. Also, it’s clear from the Figures, there are slightly difference in a BER between 28 and 38 GHz, which indicated that the 28 GHz is a little better in performance than 38 GHz.
Figure 3. Show the BER vs. distance with range of power transmit.

Figure 4. Show the BER vs. distance with range of power transmit at 38 GHz

Figure 5, 6 shows how the quality factor decreases as the distance increased from 0.5 km to 3 km with fixed data rate (5 Gbps). As the signal travel for long distance, the quality factor become worse and gradually decays. Thus, the signal data is better received at 1 km distance with low distortion while the information is large corrupted at 3 km, due to the bit error received at reception part. It can be observed that the maximum Q factor system increase when the power transmitted increased. In other words, it shows that the error in the received signal decreases when the transmitted powers increase too. Besides that, it can be seen that the BER has slightly improvement at 28 GHz as a compared with 38 GHz. In addition to the improvement happed when the power transmitted increased.
Figure 5. Show the Q factor vs. distance with range of power transmit at 28 GHz.

Figure 6. Show the Q factor vs. distance with range of power transmit at 38 GHz.

The comparison between the selected frequencies in this research made in Figure 7, as it mentioned before and clear from the values in the Figure, there is a bit improvement when the 28 GHz frequency is used compared to 38 GHz.

Figure 7. Show the BER vs. distance at 28, 38 GHz.
4. Conclusion
Free space optical become famous nowadays because it gathers the optical technique with wireless generation based on different frequencies for each generation. In this research, the performance of millimeter waves tested over free space optical system. 28 GHz and 38 GHz frequencies are used. The system analysis made based on eye diagram, Q factor, distance and range of transmitted power. The free space optical channel can provide the best results, at 0.5 km, 1 km, 1.5 km, 2 km and 2.5, by calculating the minimum bit error value and increasing the value of the quality Factor. While the quality of FSO is getting lower at distance 3 km, because the Free Space Optic channel is susceptible to atmospheric interference and the distance between the transmitter and receiver. From all of the above, it can be concluded that, the farther the distance travelled by FSO the lower the Quality of the signal. And as a frequencies comparison, the channel can provide slightly better results at 28 GHz compared to 38 GHz.

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