Performance of RoFSO OFDM System under Malaysia Climatic Condition for Wireless Communication

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Abstract. Radio over Free Space Optics (RoFSO) is believed to be the most reliable technology in future communication as it provides high speed, high bandwidth and low consumption energy for data transmission. However, some turbulence weather factor such as fog, haze and rain may cause data attenuation in the FSO network. This project presents the effect of haze attenuation on RoFSO transmission system for Orthogonal Frequency Division Multiplexing (OFDM) modulation technique with Quadrature Amplitude Multiplexing (QAM) scheme. The data obtained was referring to the Air Pollution Index (API) from the region of Sepang, one of the town in Malaysia. The system is modelled and simulated using a software called OptiSystem. The result performance of RoFSO system when being modulated by OFDM is compared in terms of the BER value, received optical power and constellation diagram.
Keyword: Free Space Optic (FSO), Radio over Free Space Optic (RoFSO), Orthogonal Frequency Division Multiplexing (OFDM), Air Pollution Index (API), constellation diagram.

Introduction

Communication is the sharing of information, opinions, ideas or feelings between two or more individuals who share a mutual interest [1]. Nowadays, there are two mediums available for data transmission which are fiber cables and wireless system. Fiber cable or optical fiber cable are built up of glass fiber strands inside an insulated casing that is used in telecommunication, which provides high speed data transmission between two points. The wireless system offers communication with no physical connection between two or more devices. Wireless signals are transmitted and interpreted by suitable antennas through the air.

Today, with growing demand for broadband service technology, high bandwidth, high data transmission speed and high data transmission performance, wireless communication technology is the most appropriate solution that can meet all the demands [1]. One of the most reliable wireless technology is Radio over Free Space Optic (RoFSO). The RoFSO system is based on the concept between RoF system and FSO system. The radio frequency signal and the optical signal need to experience a modulation process at a transmitter before the modulated signal can be transmitted to a receiver [2].

In this research, the RoFSO system is modulated with Orthogonal Frequency Division Multiplexing (OFDM) as the modulation technique. To verify whether or not this system is good to be deployed in Malaysia based on its weather condition, OptiSystem software is chosen to simulate the RoFSO system since the cost of experimental is quite expensive. OFDM is a technique that has been applied widely in wireless communication which divides the spectrum of a signal into an equal spaced sub-channels while carries a portion of user's information on each of the sub-channel [7].

OFDM is a technique of multicarrier modulation, where the sub carriers are mutually orthogonal to each other. The main OFDM theory requires the conversion of a serial data stream into a series of longer-term parallel data streams [8]. There are basically two OFDM system classifications, which are direct detection and coherent detection system. Direct detection system uses only a single photodiode. The photodiode is a semiconductor device that transforms light into an electrical signal. Direct detection system consists of a simpler transmitter side and receiver side compared to consistent detection, which makes it cost-effective. Coherent detection system uses local oscillator and optical hybrid to utilize the principle of optical mixing. Direct detection system consists of a simpler transmitter side and receiver side compared to consistent detection, which makes it cost-effective.

Coherent detection OFDM system or CO-OFDM is a better choice for long haul networks as it combines the advantages of coherent detection system as well as that of OFDM. The CO-OFDM system has the ability to overcome many optical fiber restrictions such as Chromatic Dispersion (CD) and Polarization Mode Dispersion (PMD) besides the system is also resistant to inter-symbol interference (ISI) because of the cyclic prefix code [3]. This shows that both types of OFDM modulation technique has their own characteristics and specialty for specific purpose.

Material and methods

The schematic of the system created in OptiSystem are designed based on the basic block diagram of a RoFSO system is shown in Figure 1. The basic part of a communication system consists of transmitter, channel that was built up from optical fiber and free space, and receiver.

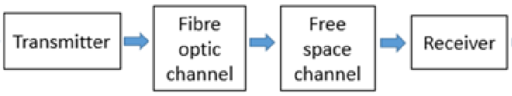

Figure 2: **Basic block diagram of RoFSO system**

Transmitter

The design of the transmitter part is shown in Figure 2. There were a few important components such as QAM generator and OFDM modulator that were used in transmitter side in order to carry out several functions before forwarding an optical signal through the transmission channel. All of the components used must be in high quality, have less error and is always available to make the system operate smoothly. The reference wavelength was set at 1550nm as it provides lesser attenuation compare to the other wavelength [9]. The system was built up by setting the bit rate to 15Gbps with CW laser power of 15dBm. The OFDM modulator parameters were set with 1024 number of subcarriers, 2048 FFT points and number of prefix points 10.

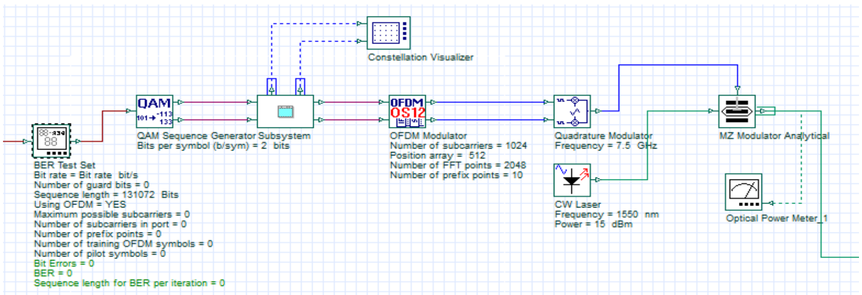

Figure 3: Transmitter part of RoFSO system.

Channel

The components used to design the channel part are shown in Figure 3. Channel of a RoFSO system consists of optical fiber and FSO channel. Both channels have its own advantages and disadvantages on how to transmit data from receiver to the destination. For example, fiber cable is more stable to radio frequency interference, low attenuation loss, large bandwidth and easy to install [4]. Free space optic system channel offers a high security, large bandwidth, robust towards radio frequency interference, high data speed, cost effective, easy installation and many more. Transmission in FSO has high security because the transmitter and receiver were installed on a very high building [5]. In this RoFSO system, the optical signal will pass through both type of channel medium which also means will it sum up the attenuation from both fiber optic and free space. However, for free space transmission, its performance can be infected by bad weather condition, atmospheric disturbance, scintillation and alignment [6].

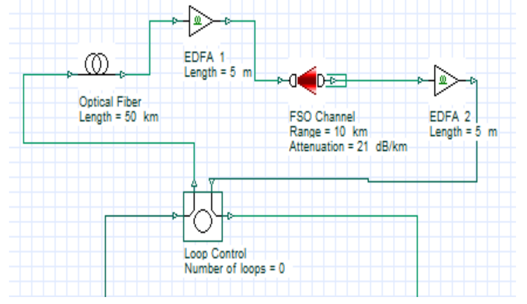

Figure 4(a) **Channel part.**

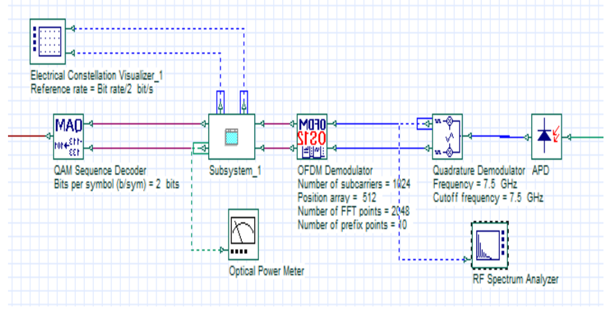

Figure 5(b) **Receiver part.**

The parameter settings for FSO channels were set as 5 cm transmitter aperture diameter, 2 mrad beam divergence, 20 cm receiver aperture diameter and 0 dB loss for transmitter and receiver were used. The attenuation value inserted were based on the real haze attenuation obtained from Malaysia Meteorological Department.

Receiver

The last section was the receiver part of the RoFSO system. This part will conduct the process of converting optical signal back to electrical signal. The design of the receiver part is shown as in Figure 3 (b). From the displayed Figure 3(b), the receiver part consists of QAM decoder, OFDM demodulator, and a photodetector. Photodetector is responsible to convert optical signal into an electrical signal.

Results and discussions

In this section, the graph of simulation results for the proposed model for the RoFSO system using OFDM technique with QAM modulation were presented in terms of constellation diagram, bit error rate (BER) and received power.

RF Spectrum Analyser

The RF spectrum analyser was placed at both transmitter and receiver part of the system design. This analyser was used to calculate and display the electrical signal transmitted along the network system. Signal launched into the system will undergo signal degradation due to losses, noise and distribution. RF spectrum analyser depicted in Figure 4(a) was placed at the transmitter side of the system. It shown that the maximum amplitude of signal was approximately 12dBm and the RF spectrum analyser which was located at the receiver part depicted in Figure 4(b) was approximately -26dBm. This condition indicated the power loss happened when the signal was transmitted from transmitter to receiver due to the loss of an optical fiber, insertion loss, FSO range and attenuation.

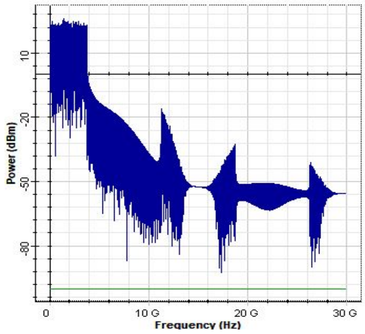

Figure 4(a) RF spectrum analyser at the transmitter

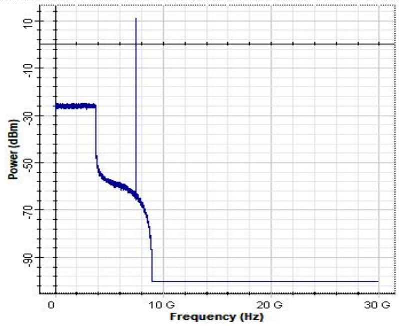

Figure 4(a) RF spectrum analyser at the receiver.

Constellation Diagram

The constellation diagram was used to explain the effect of interference on a signal. 4 QAM modulation eventually produces four points on constellation diagram, according to the modulation scheme. In Figure 5 (a) where the constellation visualizer was placed at the transmitted part, it can be seen that the four points are seen as four small blue dots since there was no signal impairments that can degrade the signal quality at transmitter.

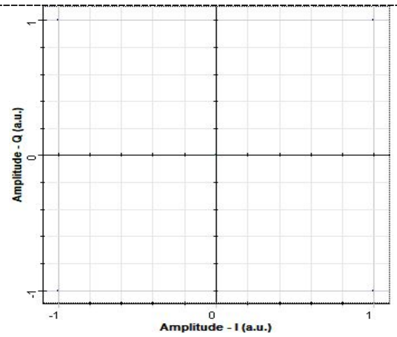

Figure 5(a) **Constellation diagram at the transmitter.**

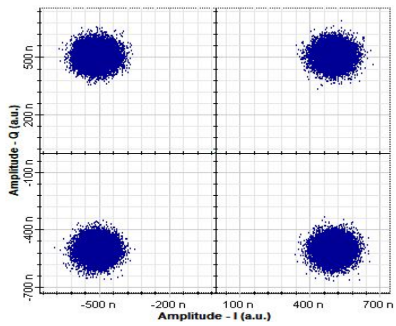

Figure 5(b) **Constellation diagram at 5.65 dB/km.**

Figure 5 (b) and Figure 6 show the constellation diagram which was located at the receiver part of the system with two different attenuations and haze conditions. The constellation diagram for 5.65dB/km.

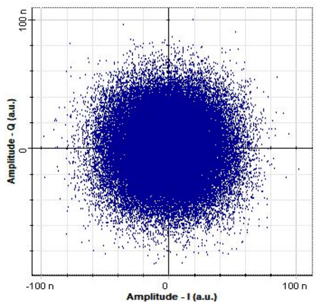

Figure 6 **Constellation diagram at receiver of 21dB/km.**

Figure 6 shows the constellation points are separated far from each other compared to the constellation points for 21dB/km attenuation. The cloud of all constellation points increases until they are overlapped and merged onto each other when the attenuation was increased. Like an eye diagram, constellation diagram represents real time visual. It can easily show changes of system performance when the system changes, or when new distortions are added. It offers a strong indication to the nature of any problems of the demodulation and decoding process of signals and the symbol of digital communication systems [10].

Conclusions

This research studied and analyzed the system performance of RoFSO network by the process of simulation and verification the design model using real data of haze attenuation in Malaysia to investigate the validation of the system designed before deploying it into a real RoFSO communication system. To conclude the simulation result, as the range and attenuation is increased, the received power at transmitter decreased, the distance between four points of constellation diagram decreased. Based on the performance result obtained, the integration of RoFSO system is reliable to be implemented as future communication system development to provide good performance of data transmission.

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