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Spectrum Sliced WDM using Array Waveguide Grating in Free Space Optical Communication

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Abstract—*In this paper array waveguide grating (AWG) component is used for spectrum slicing wavelength division multiplexing (SS-WDM) in FSO communication system. The system is evaluated at a data rate of 1.56 Gbps up to 3km of link distance on a wavelength of 1550nm. The spectrum sliced WDM FSO system has been carried out using a single continuous wave laser source with SS (spectrum sliced) technique for 4 channels with different modulation formats such as NRZ, RZ and CSRZ. The results after simulation spectacle that using spectrum sliced WDM technique we can transmit data rate of 1.56 Gbps over the link distance of 3 km with BER of* $2.35e^{-10}$*and power of 0 dBm.*

Keywords*: Spectrum Slicing (SS), Free Space Optical Communication (FSO), Wavelength Division Multiplexing (WDM), Array Waveguide Grating (AWG), Bit error rate (BER), Quality-factor (Q- factor).*

1. INTRODUCTION

Free Space Optical communication (FSO) has been widely studied topic because of its beneficial characteristics and properties as compare to wired optical communication [1]. To transmit data wirelessly or through free space for telecommunication, FSO communication technology is used in which light travels through free space [2]. Many researches have been conducted in the past for data transmission of high speed and cost efficient system. FSO occupies various advantages such as high speed data transfer, large bandwidth, large capacity, licensed free spectrum, work on low power, easy and fast installation and no cost for trenching and permits as in wired optical communication [3-5].There are various weather conditions which degrades the performance of FSO system such as rain, fog, haze etc. [6]. To alleviate the effect of atmospheric disturbances various research work has been introduced and investigated for free space optical communication system such as advance modulation OFDM (orthogonal frequency division multiplexing) [7], aperture averaging[8], signal amplification and diversity[9].Lots of wavelength division multiplexing systems has been proposed for the enhancement of capacity of the FSO system with constricts channel spacing and high data rate [10]. WDM is like an abutment for many users on which various access networks depends and are plinth on slices of available spectrum. WDM support wide coverage over atmospheric fickleness in FSO communication because of bidirectional data transmission and increase of capacity. Spectrum slicing gives affirmation on allocation of multiple wavelengths light to number of users [11]. Spectrum slicing technique is less complicated when comparing with WDM, as it uses various sources operates at different wavelengths.

WDM needs to work as a wavelength selective for each channel at a fixed wavelength. This necessity of WDM will be subdue by our proposed scheme, which is spectrum slicing WDM. Spectrum slicing WDM exhibits similar qualities as wavelength division multiplexing such as installation cost is also very low, less convoluted and power effective for wireless networks [12]. For our proposed scheme we will consider heavy rain as a weather condition. . The AWG based spectrum sliced WDM-FSO communication system is evaluated at 1.56 Gbps of data rate up to 3 Km distance under heavy rain weather. For transmitting different multiple subcarriers on a single channel WDM is used for multiplexed them.

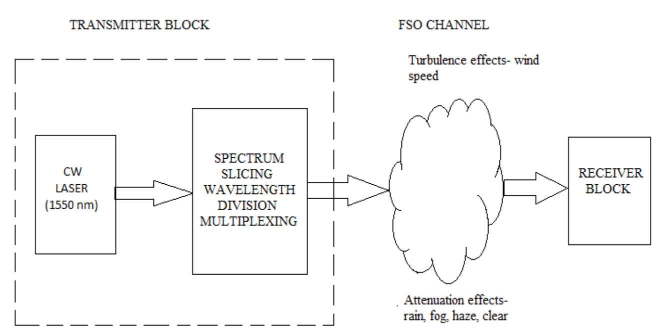

Figure 1: Block diagram of SS-WDM-FSO communication system.

The performance of SS-WDM FSO systems is investigated. WDM- demux is used to distribute power of the transmitted signal.

2. SS-WDM TECHNIQUE PRINCIPLE

As wavelength division multiplexing applications uses multiple lasers which increase the cost of a system. Spectrum slicing is an alternate of this as it offers low cost system. Wide waveforms are sliced into many slices of lower speed with the help of spectrum slicing technique and each slice is transmitted in parallel. Spectrum slicing also improves the dispersion tolerance of optical system. Different modulation formats such as pulse amplitude modulation etc. are used to increase the data rates. In this paper, NRZ, RZ and CSRZ modulation formats are used along with spectrum slicing. The propound spectrum sliced WDM is shown in figure1. The transmitter side consist of single CW laser operates at 1550nm wavelength and SS-WDM block which slicing the whole spectrum into small low power slices. SS-WDM divides the signal into 4 channels each operating at different frequency with particular channel spacing.

3. SIMULATION SET-UP OF SS-WDM SYSTEM

A cost effective arrayed waveguide grating based spectrum sliced wavelength division multiplexing FSO communication system is implemented. The AWG SS-WDM-FSO system is analyzed at 1.56 Gbps data rate up to the distance of 3km. Because of its non-ideal nature, AWG broadened the spectrum for spectrum slicing. Four WDM channels with channel spacing of 100 GHz are investigated for spectrum sliced system. Comparison of spectrum slicing using different modulation formats are realized for FSO system under heavy rain weather condition. The software named Optiwave Optisystem is used for the simulation of spectrum sliced FSO system. As WDM requires N number of coherent light sources for the generation of N number of frequencies, this increases the total cost of the system. So in that case instead of using WDM, spectrum slicing is used as an alternate. Therefore the main aim of our work was to generate broad spectrum for slicing with the use of non- ideal nature of AWG. For the broadening of the spectrum AWG is fed by CW laser having operating power of 0 dBm and frequency 193.1 THz as shown in figure 2. AWG generates the broad spectrum at its end. 4 frequency signals 193.1 THz, 193.2 THz, 193.3 THz and 193.4 THz are sliced at 100 GHz of channel spacing to save the available bandwidth. These spectrums are modulated with the non-return to zero (NRZ), return-to-zero (RZ) and compressed spectrum- return-to-zero (CSRZ) line coding and binary data is generated at 1.56 Gbps with PRBS generator. After modulation using NRZ, RZ and CSRZ these signals are multiplexed and transmitted FSO channel.

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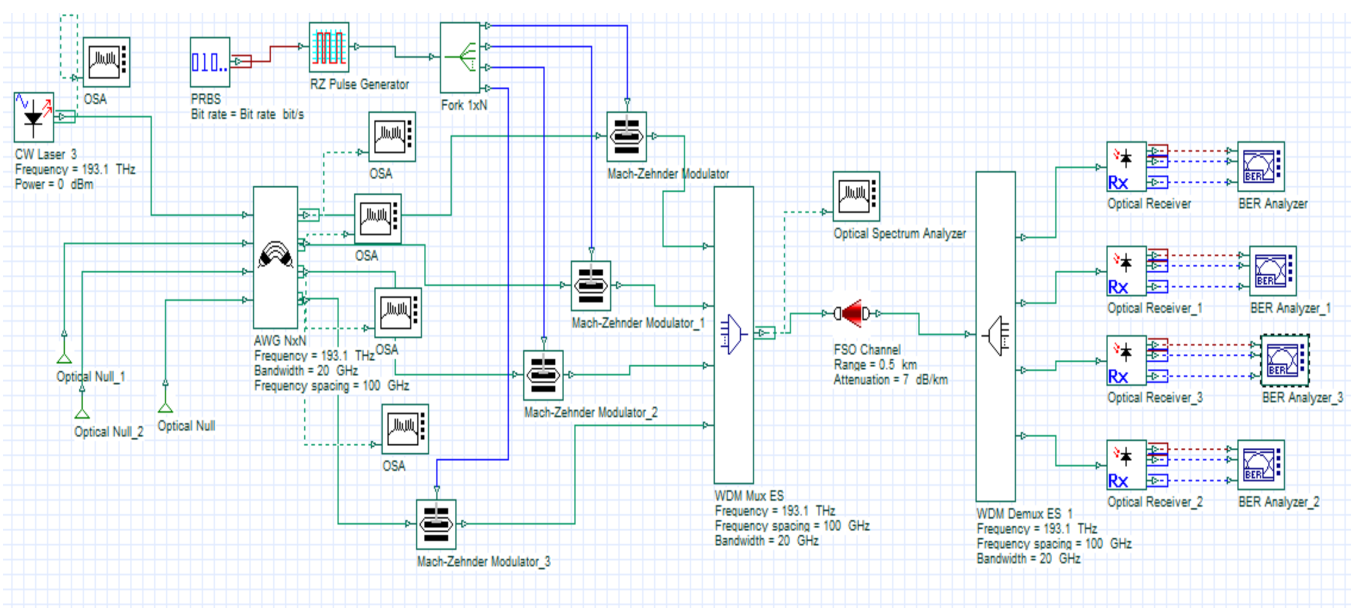
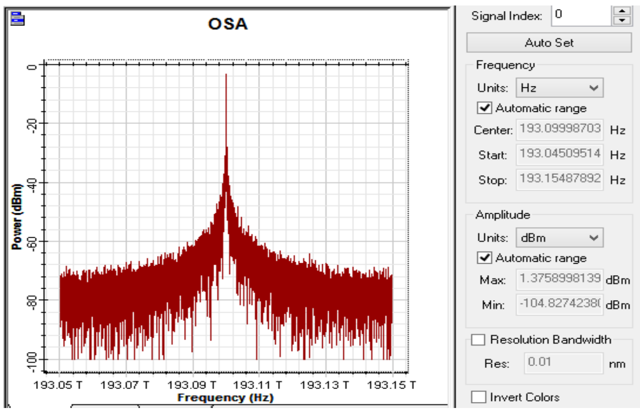


Figure 2: System setup having 4 channels AWG-SS-WDM free space optic communication

4. RESULTS AND DISCUSSION



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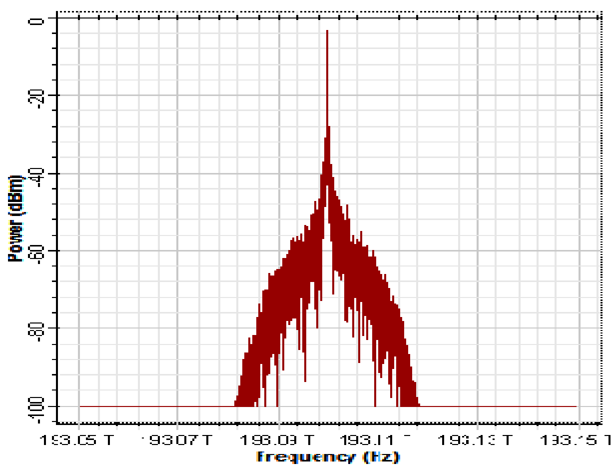

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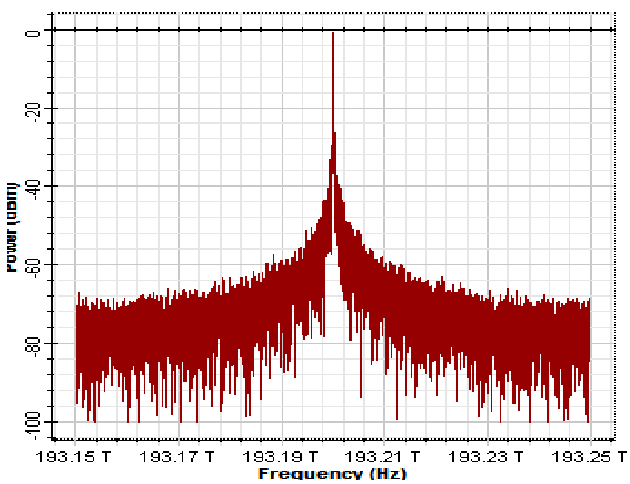

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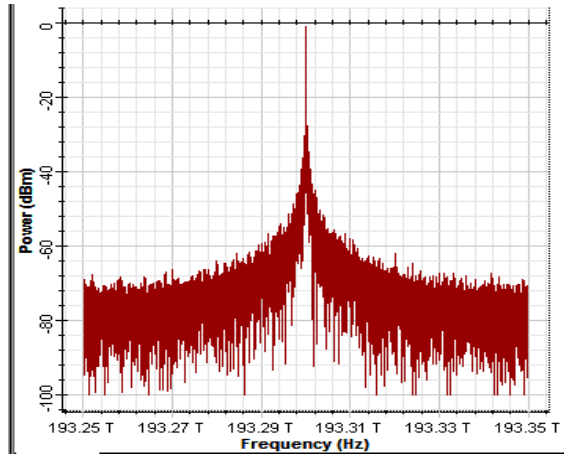

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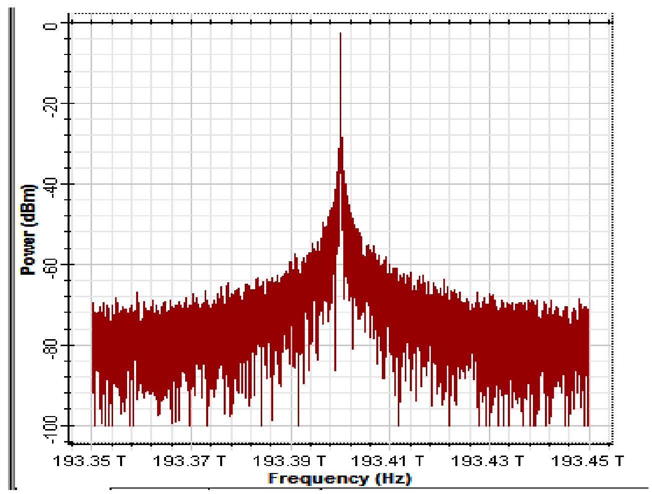


(e)

Figure 3: A continuous wave laser spectrum (a) and (b) after AWG for 1st CH (c) after AWG for 2nd CH (d) after AWG for 3rd CH (e) after AWG for 4th CH

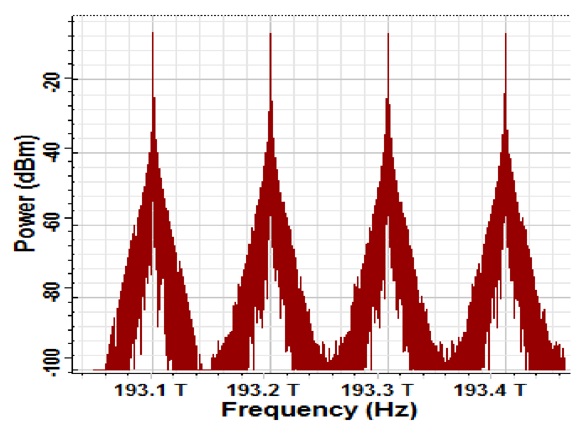


Figure 4: Four multiplexed spectrum sliced channels at optical spectrum analyzer

The system's performance is estimated by using BER analyzers. In this implementation, spectrum slicing is realized with NRZ, RZ and CSRZ modulation format. Optical spectrum analyzer is used for carrier representation after laser and Figure 3 (a) depicts the spectrum of the laser before AWG. It is noted that there is divergence of the spectrum to different frequencies other than desired frequency, which is called laser linewidth. The carrier signal is divided into 4 channels, each with different frequency with 100 GHz channel spacing as shown in figure 4. The frequency of these four optical carriers is 193.1 THz, 193.2 THz, 193.3 THz and 193.4 THz. The wavelengths of the four optical carriers are 1552.5 nm, 1551.7 nm, 1550.9 nm and 1550.1 nm, respectively.

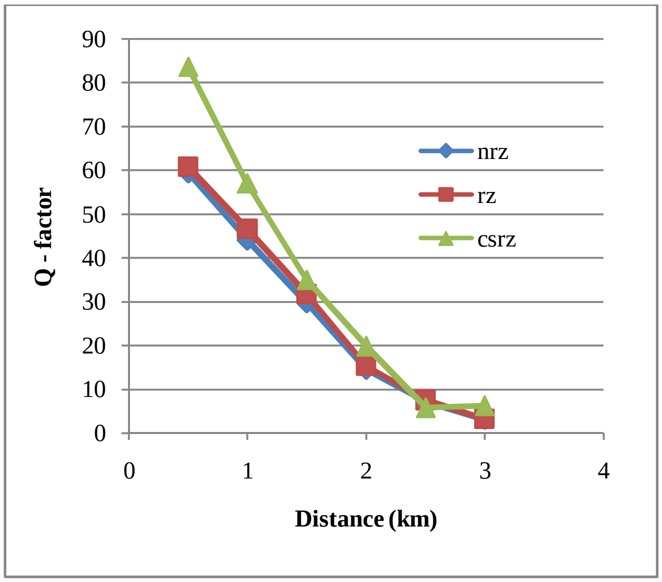


Figure 5: Comparison of Q-factor v/s Distance(km) in case of NRZ, RZ and CSRZ modulation formats

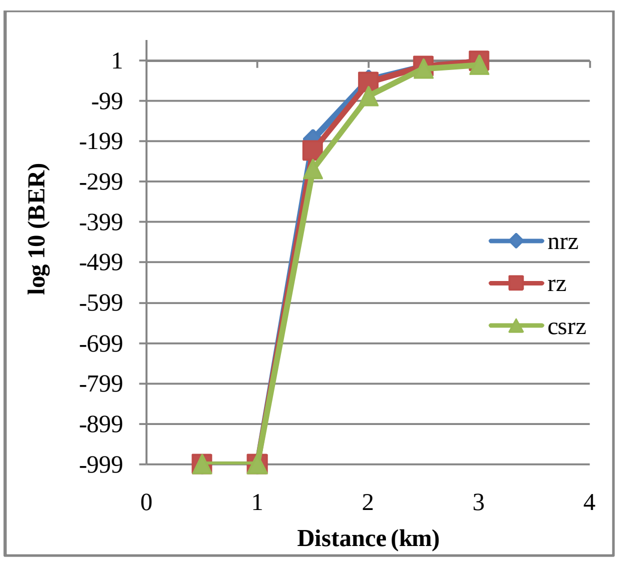
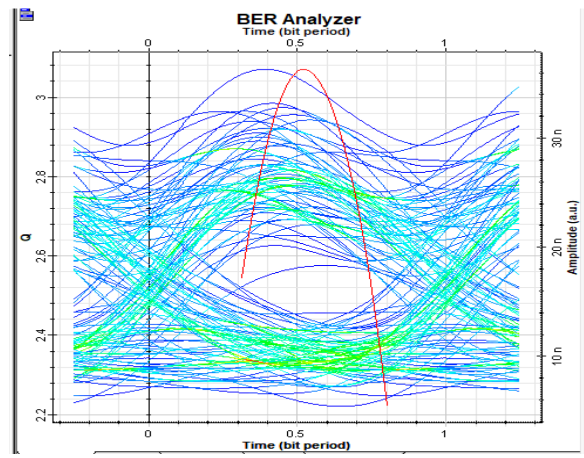
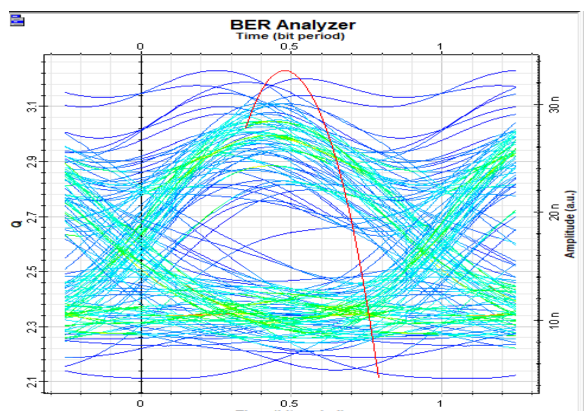


Figure 6: Comparison of log10 (BER) v/s Distance in case of NRZ, RZ and CSRZ modulation format

Length of the system is varied from 0.5 km to 3 km for calculating the Q-factor at attenuation of 7 dBm. Figure 5 illustrate the performance of spectrum sliced FSO in terms of Quality factor received at different distances. From figure 5 it is noted that Q-factor of SS-WDM FSO with CSRZ modulation format is 6.2088 at 3km distance whereas with NRZ modulation format the Q-factor is 3.2303 at 3km distance. This shows that good quality of reception is achieved when 1.56 Gbps data rate is transmitted over the link distance of 3km using CSRZ modulation format in FSO communication. This is because of the efficient slices of spectrum generated through arrayed waveguide grating. Figure 6 depicts the comparison of log10 (BER) v/s Distance (km) in case of NRZ, RZ and CSRZ in SS-WDM FSO system. It is seen that BER is more in case of NRZ when compared to CSRZ spectrum slicing WDM FSO communication system.



(a)



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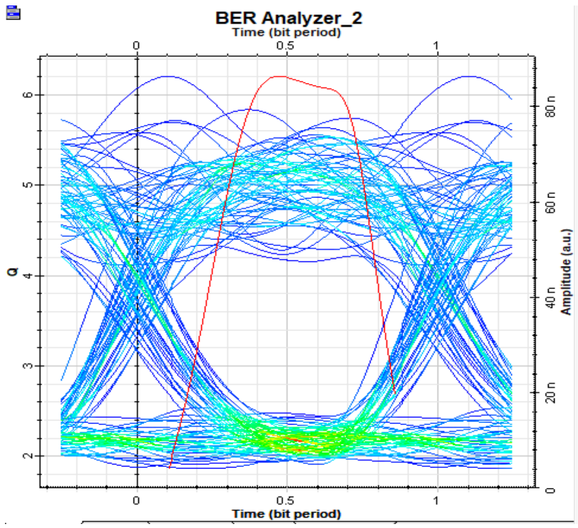

(c)

Figure 7: Eye diagram of NRZ, RZ and CSRZ of AWG-SS-FSO at a distance of 3 km

5. CONCLUSION

In the paper, the spectrum slicing wavelength division multiplexing (SS-WDM) was examined as flexible and extensible system for Free Space Optical communication in heavy rain weather. From figure 7(c) it is noticed that the eye opening in AWG-SS-FSO system with CSRZ modulation format is much better than the AWG-SS FSO communication system with NRZ and RZ modulation format. The simulation results shows that when using the spectrum sliced WDM techniques in FSO system, the data rate of 1.56 Gbps could be transmitted over 3km of transmission distance with operating power of 0 dB and BER of $2.35\times e^{-10}$.

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