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A 4 channel WDM Based Hybrid Optical Fiber/FSO Communication System using DP QPSK Modulation for Bit Rate of 100/112 Gb/s

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***Abstract*—In this paper, a bit rate of total 400 Gbps and 448 Gbps using 4 channels WDM based hybrid optical communication system is proposed . The data transmission is efficiently possible by both fiber optics and FSO channels. The better performance is achieved using Dual Polarization QPSK modulation technique, and the optical coherent DP QPSK receiver is used for the detection of received signals. The system is successfully demonstrated, designed, simulated using Opti system software version 15 and its performance is also analyzed in terms of Bit Error Rate. It is found that FSO coverage area is up to 700m while 420 km by fiber optics for 100 Gbps per channel transmission and 450m by FSO while 360km by fiber for 112Gbps/channel data transmission.**

Keywords*— *Dp qpsk modulation; optical coherent detection; fso/ fiber hybrid system; wdm; ber

I. INTRODUCTION

The increasing demand in telecommunication network system requires transmission of high data rate (up to Tb/s) with efficient performance. For this the hybrid optical fiber/FSO communication systems are designed to handle high speed operations, multiple-channels, long distance data transmissions and so on. FSO is a line of sight wireless optical communication technique considered as best for short distance data transmission in both indoor and outdoor area [1]. It is highly famous due to its high bandwidth, unregulated spectrum, easily deploy able quality, low infrastructure cost, security, allowing higher data rate etc. They have wide range of applications such as MAN extension, LAN connectivity, fiber back-up, back haul for wireless cellular network, disaster recovery, HD TV and medical image/video transmission, video surveillance etc[1]-[3]. While at the same time, an Optical fibers are wired communications technique having advantage of transmitting data over long distances with less attenuation, less EMI (electromagnetic interference), transparent to wireless signal, greater information carrying capacity and multiple channel can be multiplexed with the help of WDM on it [4]. Signal propagation through an optical fiber experience a loss in quality and power due to the attenuating properties of fiber materials and dispersion . Due to huge demand on communications, installation of optical fiber at large scale can be bulky and cost effective [4]-[5]. With the integration of both Fiber and FSO, the hybrid system were designed which provides excellent performance in desirable coverage area and higher bit rates.FSO links are affected by atmospheric turbulence which induce fading and path loss causing limitations of link distances. To overcome these problems some advanced modulation technique (BPSK, DPSK, QPSK, QAM etc) are implemented at a transmitter and receiver section [6]-[8].These modulations allow the transmission system to carry data at a channel bit rate higher than 100 GB/s e.g. 112 GB/s,200 GB/s,400 GB/s to 1 TB/s or beyond.

The C-band(1530nm-1565nm) and L-band(1565nm-1625nm) transmission WDM technology in optical communication system now enhances system design and flexibility. A 64×10Gbps NRZ WDM with 100 GHz channel spaced is demonstrated using FRA. The WDM signals are propagated through SMF of 96 km, DCF of 16 km and RF of 10 km distance [10]. Hafiz et al. proposed a 100×40 Gbps, 0.2nm spaced DWDM system for long haul applications. This system combined with two hybrid amplifier (Er-Yb co doped wave guide amplifier and fiber optical parametric amplifier)which can achieve flat gain of 30.6 dB, ripple gain of 6.18 with low noise figure [11]. An optimized hybrid optical system was designed using modified duo binary RZ(MDRZ) modulation in fiber based DWDM system and QPSK modulation in FSO for bit rates of 160 Gb/channels,100 Gb/channels,40 Gb/channels [12]. This proposed system uses fiber optics for long haul, point to point communication and wireless optical diffused link for short haul, multi casting applications.It was also mentioned at strong atmospheric turbulence effect with 160 Gbps bit rate the optimized coverage distance obtained 419.53 km in fiber link and 129.34 m in wireless diffused link [12]. To obtain higher spectral efficiency and high bit rate transmission, DP-QPSK modulation is preferred which uses two orthogonal polarization (horizontal polarization and vertical polarization) of laser beam with same QPSK modulation signal on each polarization. For any given baud rate, it doubles the channel capacity. Kim et al. described with a practical implementation that DP-QPSK shows the best performance on optical noise tolerance and implementation complexity with the presence of AWGN in amplified spontaneous emission [13]. Their measurement result showed that DP-QPSK with one or two

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subcarrier transmits 46 Gbps or 112 Gbps using symbol rate of 11.5,14,28 Gbaud and DP-16QAM can transmit 224 Gbps. This article also mentioned the tolerance of coherent detection to transients and propagation conditions due to which it can enable transmission of 200,400,1000 Gbps per wavelength. Li etal. described for above 100 Gb/s data transmission through FSO,dual-polarization QPSK modulation techniques with coherent detection using DSP techniquesgivesthe best result as in improving line efficiency and maximizing spectral efficiency in DWDM system[14]. A hybrid optical 16-channel DWDM system proposed with DP-QPSK modulation technique which can transmits data rate of 400 Gbps/channel. To transmit this ultra high bit rate FSO covers 340m whereas Fiber covers 1000km [15]. The coherent receivers integrated with complicated DSP circuits to suppress and compensate the phase and polarization fluctuations occurred between reference light and signal light.In this paper a 4-channels WDM technique based optical hybrid FSO/FIBER is designed, simulated and performance is analyzed and compared. The data transmission of 400 Gbps (100 Gbps/channel) and 448 Gbps (112 Gbps/channel) is possible using DP-QPSK modulation. The 100 Gbps data rate can be transmitted up to 420km by fiber and 700m by FSO with bit error rate of 0.00012. similarly 112 Gbps data transmission possible up to 360km by fiber and 450m by FSO with BER of 0.00552.

II. PROPOSED TECHNIQUES

A. DP QPSK modulation

The dual polarization quadrature phase shift keying (DP-QPSK) is one of the most useful modulation techniques for the 100 GB/s or higher bit rate transmission among all the multilevel modulation techniques. It uses two orthogonal state of polarization (horizontal and vertical) of laser beam with IQ modulator (QPSK) signal for digital modulation and encodes 4 bits/symbol rate. DP-QPSK is widely used in optical communication to represent laser output into symbols for reducing the BW of the transmission of information. The system information is encoded in both polarizations and phase. The symbol rate of 25 Gsymbol/s is set for 100 Gb/s and 28 Gsymbol/s is set for 112 Gb/s due to DP-QPSK modulation as it contains 4bits/symbols in its constellation.

B. Coherent Detection

The optical coherent receiver is required to recover the modulated DP-QPSK signal. The receiver section involves polarization beam splitter, a local oscillator or CW laser, 90-degree hybrid, balanced photo detectors, electrical subtractors, electrical amplifiers, threshold detector, PSK decoder, serial to parallel converter. All these combinedly recover the amplitude and phase of the transmitted signal. Then amplified signal passed to DSP which equalizes the linear transmission impairments such as GVD and PMD of optical fiber. DSP performs the impairment compensations to recover the incoming transmission signals after coherent detection. The threshold detector/decision components process the I and Q electrical signal channels received from DSP stage, normalizes the electrical amplitudes of each I and Q channels to respective M-ARY grids to perform decision for each received symbols into threshold levels. Then it is passed to PSK sequence decoder to decode into binary signals. The resultant is given to parallel to serial converter to produce DP-QPSK signal at output for further transmission.

III. PROPOSED HYBRID FSO/FIBER WDM SYSTEM USING OPTISYSTEM SOFTWARE

The proposed 4-channel WDM based hybrid FSO/Fiber system is designed ,simulated using opti system version 15, optical communication system design software.The results are analyzed and tested using BER test set. The wavelength of FSO subsystems (T_{ch1}, T_{ch2}, T_{ch3}, T_{ch4}) were set to 1560.60nm, 1552.52nm, 1544.52nm, 1536.60nm respectively. Channel spacing is set to 1 THz. . Then the optical information signals are received and demodulated by using optical coherent DP-QPSK receivers with equal wavelengths. The demodulated signal is further processed and passed to DP-QPSK transmitters which has power penalty of 3dbm. A 4:1 WDM MUX carry all these wavelengths, multiplexed and the single output is fed to optical fibers. Two optical fibers used e.g. SMF (single mode fiber) and DCF (dispersion compensating fiber). The 4-channel multiplexed wavelengths were carried by two 25km SMF and one 10km DCF using 7 loop controls for 100 Gb/s while 6 loops controls for 112 Gb/s.The transmitted optical signals were amplified by using erbium doped fiber amplifier (EDFA) with gain of 5db. To compensate fiber losses an EDFA is used to boost the WDM signals. A 1:4 WDM DEMUX is used to demultiplex the 4 channel wavelengths with BW of 75 Ghz. Again, 4 optical subsystems used to detect the received signals from DEMUX output efficiently. An optical coherent receiver using DP-QPSK demodulation techniques demodulate the information signals for further processing at receiver section. The power of 5dbm is set to each channel receiver. Finally, at receiver section which consists of 4 FSO subsystems performs similar operations as per transmitter section. All turbulence effect such as scintillation, absorption, scattering, rain, fog by which FSO system may be affected is set around 25db/km. The DSP of coherent receiver compensated the losses occurred during reception. The complex amplitudes of both horizontal and vertical polarization are simultaneously measured and processed via DSP at receiver section. The BER test set is used to compare the bit error rate obtained from input sequence to output sequence. It was observed 400Gb/s and 448 Gb/s data is transmitted successfully using 4-channel WDM fiber/FSO hybrid optical systems.

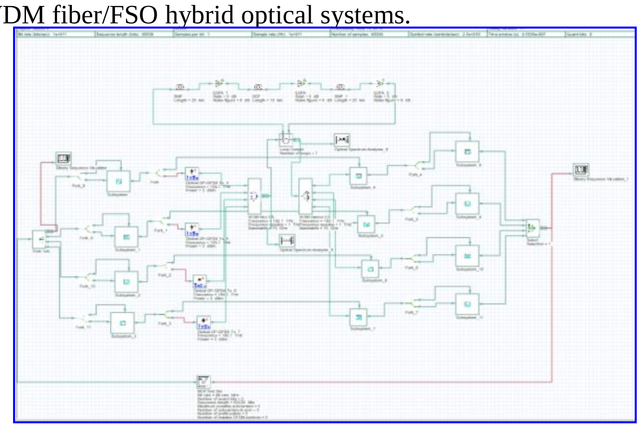

Fig.1: Proposed system designed using optisystem software

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IV. SIMULATED RESULT & DISCUSSION

The designed system is successfuly simulated and the results are analyzed given below.The details simulation parameters are given in tables.The input/output data of designed system is analyzed using optical spectrum analyzer,binary sequence visualizer, electrical constellation visualizer and tested by BER test set. The input and output bit sequences are shown at binary sequence visualizer. The simulation parameters are

TABLE I. WDM PARAMETERS

PARAMETERS	VALUES	
Bit rate per channel	100 Gb/s	112 Gb/s
Sequence Length	65536	65536
Samples per bit	1	1
Number of Channels	4	4
Frequency Spacing	1 THz	1 Thz
Reference Wavelength	1550nm	1550nm
Symbol rate	25 Gb/s	28 Gb/s
Sensitivity	-100dbm	-100dbm
Resolution	0.1nm	0.1nm
WDM BW	75 Ghz	75 Ghz

TABLE II. OPTTICAL FIBER & FSO PARAMETERS

PARAMETERS	**SMF**	**DCF**	**FSO**
Length	25km	10km	< 1km
Attenuations	0.2db/km	0.5db/km	25 dB/km
Dispersion	17ps/nm/km	-85ps/nm/km	NIL
Dispersion slope	0.075	-0.3	NIL
Differential group delay	0.2ps/km	0.2ps/km	NIL
Effective area	70 um^2	22um^2	NIL
EDFA gain	5db	5db	NIL
EDFA noise figure	6db	6db	NIL
Distance for 100 Gb/s	60km × 7 span=420 km		700 meter
Distance for 112 Gb/s	60km × 6 span=360 km		450 meter

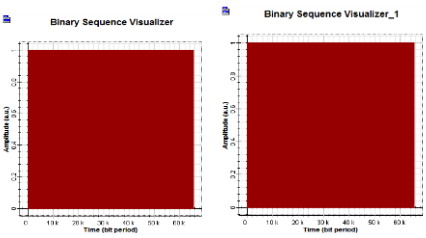

Fig .2: Input & Output bit sequence of for both 100 Gb/s and 112 Gb/s

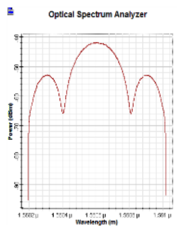

Fig .3: FSO output analyzer

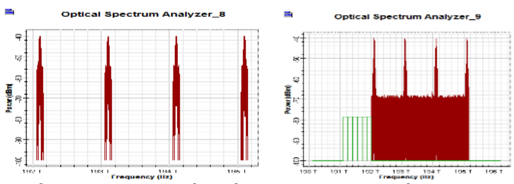

Fig .4: Optical spectrum view at 4-channel WDM MUX output and WDM DEMUX input for 100 Gb/s bit rate transmission

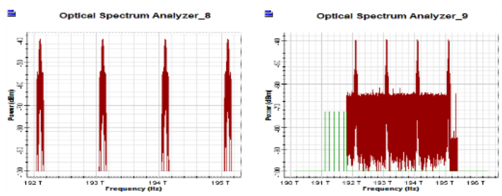

Fig.5: Optical spectrum view at 4-channel WDM MUX output and WDM DEMUX input for 112 Gb/s bit rate transmission

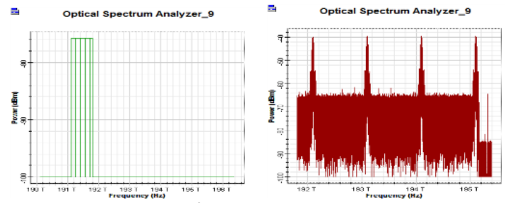

Fig.6: Optical spectrum view of received noise and 4-channel transmitted signals

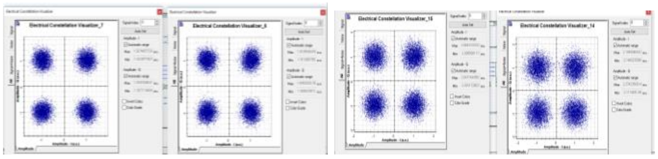

Fig.7: Constellation diagram of 192.1 Thz channel FSO subsystems at a distance of 450m with X-pol^{n} and Y-pol^{n} for 112 gb/s transmission

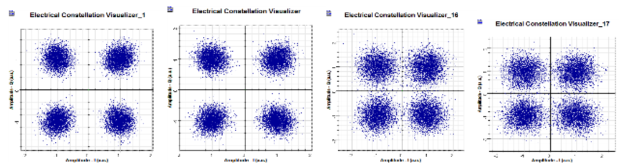

Fig 8: Constellation diagram of 192.1Thz channel FSO subsystems at a distance of 700m with X-pol^{n} and Y-pol^{n} for 100 gb/s transmission

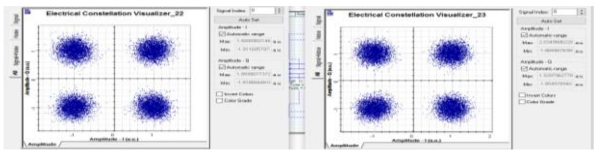

Fig 9: Signal constellation diagram of 192.1 Thz channel optical fiber at a distance of 360 km with X-pol^{n} and Y-pol^{n} for 112 gb/s transmission

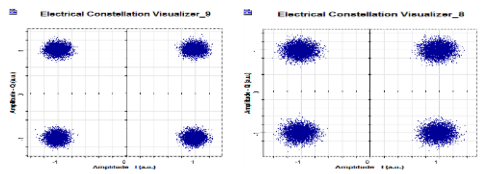

Fig. 10: Signal constellation diagram of 192.1Thz channel optical fiber at a distance of 420 km with X-pol^{n} and Y-pol^{n} for 100 gb/s transmision

CONCLUSION

The presented 4-channel WDM based optical hybrid system, which consists of two FSO link and Fiber link set up. The system is designed, simulated and performance is analysed for bit rate of 400 Gb/s (4×100 Gb/s) and 448 Gb/s (4×112 Gb/s) using DP-QPSK modulation technique. The BER rate for different FSO and fiber distances obtained and compared. The BER for transmitting 100Gb/s per channel obtained 0.00012, Log of ber= -3.913. For transmitting 112Gb/s per channel BER obtained 0.00552 and log of ber= -2.257. The constellation results showed both polarizations (X and Y) at receiver section. It is observed that DP-QPSK modulation performs better for data rate of 100Gb/s,112 Gb/s or more transmission per channels. The total coverage distance obtained for transmission of 100Gb/s is 700m on FSO link and 420km on optical fiber link while for transmission of 112 Gb/s is 450m on FSO and 360km on

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optical fiber. The above system is useful in future generation telecommunication mobile services, broadband services and so on due to high bit rate data transmitting capacity. The link range can also be extended further by applying more modified advanced modulations like M-ary QAM, OFDM etc.

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