Performance Assessment of 8 X 112 Gbps Coherent WDM OFDM based ROF system using SMF and ULAF cables for Long Reach

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Abstract: - Using higher order modulation formats along with coherent detection scheme at receiving end systems enable a new generation of high speed and spectrally efficient optical transport platforms. Here we established 8 x 112 Gbps (0.896 Tb/s) WDM ROF link employing 32 QAM-OFDM modulation schemes concept up to considerably long reach. Use of 32-QAM format and 112Gbps data rate per channel for suggested 3000Km channel span make our proposed research work different from other research works. The analysis carried out for proposed WDM ROF link systems with pre-optical amplifier inside link, one optical amplifier outside and one inside loop span and both optical inside designed recirculating loop channel span from 1000 km to 5000 kilometers. Here amplifiers were used in gain-controlled operation mode. Without using any specific dispersion or non-linearity mitigation scheme our simulation results shown that 3000 km is the best suitable transmission distance for our proposed system with specified parameters. Extensive simulations were carried out to analyze the performance of suggested system in terms of parametric values of Estimated Symbol Error, Error Vector Magnitude and Q-factor for link span from 1000 km to 5000 km.

Keywords*: Wavelength Division Multiplexing (WDM), Quadrature Amplitude Modulation (QAM), Orthogonal Frequency Division Multiplexing (OFDM), Estimated Symbol Error (ESE), Error Vector Magnitude (EVM), Quality Factor (Q-factor), Digital Signal Processing (DSP), Digital Back Propagation (DBP), Single Mode Fiber (SMF) cable, Ultra Large Aperture Fiber (ULAF) cable.

I. Introduction

To handle increasing traffic demand, information with massive data rate on each individual channel is always in demand for multi-channel WDM based ROF systems for catering bandwidth hungry applications. To increase the spectral density, transmission of data having two or more bits per symbol is recommended for required high speed transmission long reach distance WDM based systems [13]. Use of M-ary quadrature amplitude modulation methods like 8 QAM,16 QAM,32QAM or 64 QAM along with OFDM concept is better option to accomplish current and future need of data rate hungry applications [12], [14], [16]. Natural inherent characteristics like nonlinearity and various types of dispersion of optical fiber are performance degrading key challenges for designing long distance WDM optical communication systems. To enrich the working performance of such systems, suppression cum mitigation of such bottlenecking problems is always required. Use of coherent detection system with dispersion compensating (DCF) fibers, suitable digital back propagation techniques and pre-equalization techniques also can be done to minimize adverse effects due to dispersive and non-linear behavior of fibers [1], [3], [5], [14]. Use of optical amplifiers (OA) in different configurations with recirculating loop made channel span along with QAM-OFDM modulation format and coherent detection at the receiver side can be used for systems supporting high data rate with long reach distance. Literature survey shows use of DSP as offline process in such systems as an emerging technology [2], [4]. Usage of DSP has been suggested at receiver end to further enhance the performance of such systems [12], [14].

The remainder of the paper is organized as follow. Section II shows the proposed simulated system design, which includes Fig. (1) General block diagram of 8 channel WDM ROF system. Fig. (2) channel wise internal arrangement to generate OFDM signals. Fig. (3) Spectrum view of 8 WDM channel output. Fig. (4) System arrangement with both optical amplifiers inside channel span. Fig. (5) Receiver section side arrangement for coherent detection and Fig. (6) The structure of QAM OFDM receiver for single channel. Section III illustrates results and discussion and finally conclusion is given in section IV.

II. System Design

Keeping suggested research works in the mind we have simulated 8 channels WDM ROF system using 32 QAM-OFDM modulation formats. Each channel carrier was modulated at data rate 112 Gbps, so after multiplexing such signal having overall data rate 0.896

Tb/s was sent up to 5000 Km for system performance checking purpose.

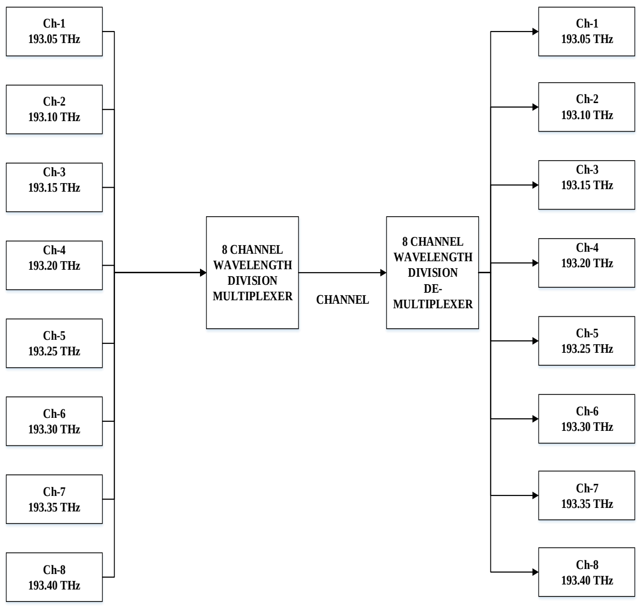

Figure :(1) Block diagram of 8 x 112Gbps (0.896Tb/s) channel WDM ROF system.

Higher spacing between sub carriers can improve performance by reduction in Q penalty at the expense of spectral-efficiency. [8].

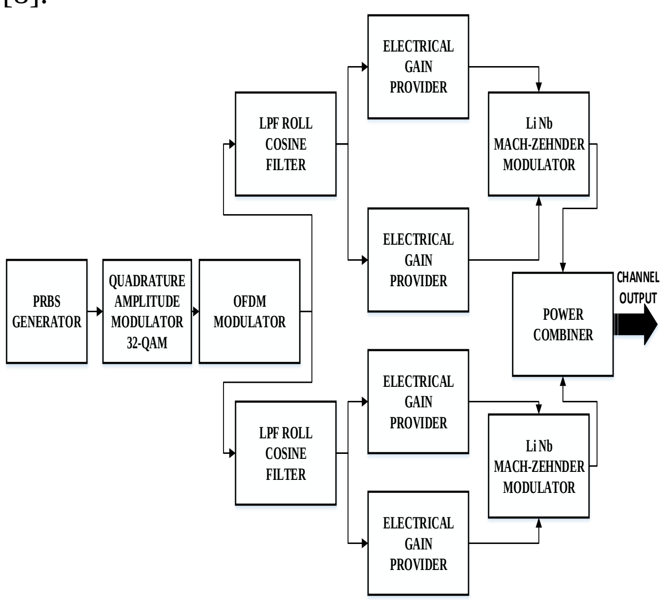

Figure :(2) Channel wise internal arrangement to generate OFDM signals.

It has been noticed that using digital back propagation (DBP) and pilot-aided methods with coherent optical communication systems using QAM-OFDM format such dispersion managed links given reliable results up to 4000 km transmission with 112 Gb/s per channel data rate [9].WDM optical system with PM-DQPSK signals containing single mode fiber (SMF), DCF and EDFAs for 100 Gb/s data rate at the transmission distance of 2700 km is reported [10]. Dual carrier differential quadrature phase shift keying (DC-DQPSK) / Dual polarization quadrature phase shift keying (DP- QPSK) signal is transmitted up to 1000 km at a data rate of 112 Gb/s with co-propagating 10.7 Gb/s OOK signals in long distance WDM optical systems [11]. Here in our paper we have estimated the performance of 8 channel WDM ROF systems with 896 Gb/s transmission rate employing QAM-OFDM modulation format.

Simulative performance of such WDM system using one pre - optical amplifier in link, one optical amplifier (OA)outside and one amplifier (OA) inside channel span and two optical amplifiers (OA) inside recirculated loop channel span observed and compared in terms of system performance judging parameter values like Q factor, Estimated Symbol Error Rate and Error Vector Magnitude. Iterative loop channel concept is used in our design to establish long distance up to 5000 km. Proposed system and Fiber cables specifications are shown in Tables 1 and 2.

Parameter	Value of Parameter
Types of fiber used	SMF, ULAF
Fiber attenuation loss (SMF)	0.2 [dB/Km]
Fiber attenuation loss (ULAF)	0.185[dB/Km]
Dispersion amount (SMF)	16.75 [ps/nm/km]
Dispersion amount (ULAF)	19.9 [ps/nm/km]
Dispersion slop	0.075 [ps/nm^2 /k]
Effective area of cable (SMF)	80 [µm2]
Effective area of cable (ULAF)	120 [µm2]
Nonlinearity coefficient	1.31 [W-1 m-1]

Tables 1 Fiber cable Specifications.

Parameter	Value of Parameter
Data rate	112 Gbps per channel
Reference wavelength	1550 [nm]
Input signal power level	0 dBm
Sequence length	32768 bits
Modulation type	32 QAM-OFDM
Number of WDM channels	8
Channel spacing	50 GHz
Channel span length	Up to 5000 [Km]

Tables 2 System Specifications.

A. TRANSMITTER SECTION DESIGN

Block diagram of our proposed 8 x 112Gbps (0.896Tb/s) channel WDM ROF system is shown in Fig. (1).8 CW lasers are used with optical carrier frequency centered from 193.05 THz to 193.40 THz respectively.50 GHz channel spacing was implemented to increase channel capacity. It has been also observed that decreased channel spacing results with Q factor penalty. Spectrum of 8 multiplexed carriers is shown in Fig: (3).

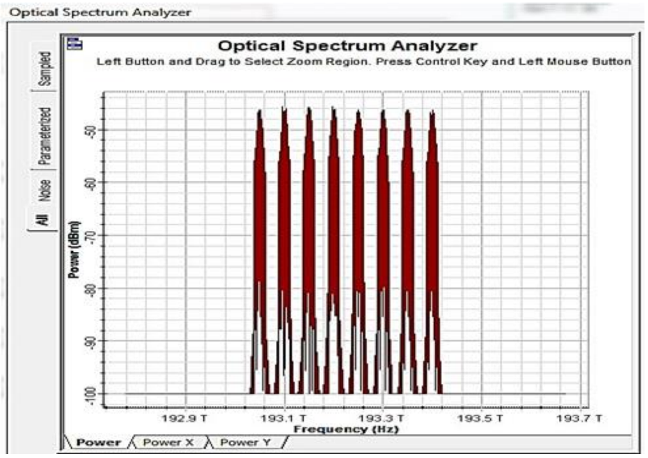

Figure :(3) Spectrum view of 8 WDM channel output.

B. *CHANNEL SPAN SECTION DESIGN*

To simulate our proposed system, we have made following suggested channel span configurations:

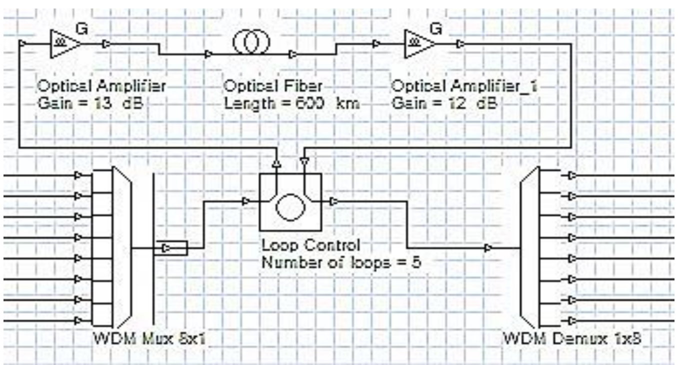

Figure :(4) With both optical amplifiers inside channel span.

To compensate loss occurring along with channel span with insertion of single optical amplifier (OA) simulation was carried out up to 5000 km transmission distance.

Addition of a greater number of optical amplifiers in optical channel will result with OSNR penalty because being an active device and with residual nonlinearity of cable each successive amplifier will contribute adversely in terms of added noise.

Without using any specific dispersion compensation technique, we have checked performance of system arrangement as shown in Fig.4. We noticed best possible results at 3000 km as transmission distance within overall simulated channel span. Signal loss compensation was taken care through used two optical amplifiers in gain control operation mode having gain values 12dB and 13dB respectively.

C. RECEIVER SECTION DESIGN:

System arrangement for coherent detection purpose is shown in fig. 5. Fig. 6 shows the structure of single channel QAM-OFDM receiver [12, 13].

Variation of Q Factor values Vs. channel span, Variation of Error Vector Magnitude values Vs. channel span, Variation of Estimated Symbol Error Rate values Vs. channel span is plotted in Figures (8), (9), (10). Due to different amount of performance impact experienced by different wavelength-based channels, non-uniformity observed in results so average values of 8 channel were considered for required comparison purpose. To decide the optimum input power level per channel further we have investigated system performance for input signal power level ranges from -3 dBm to +3 dBm.

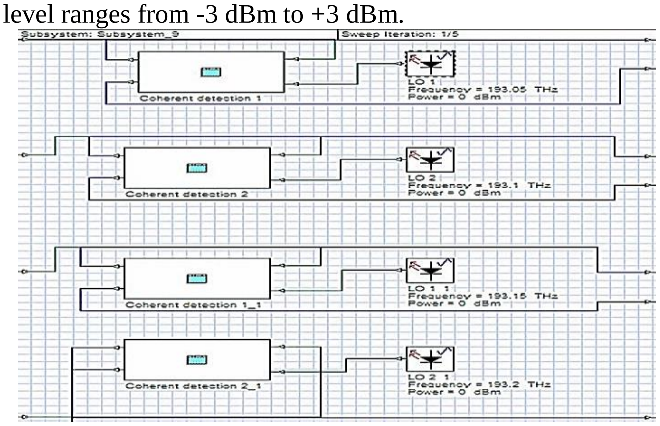

Figure: (5) Inside view of receiver for coherent detection purpose.

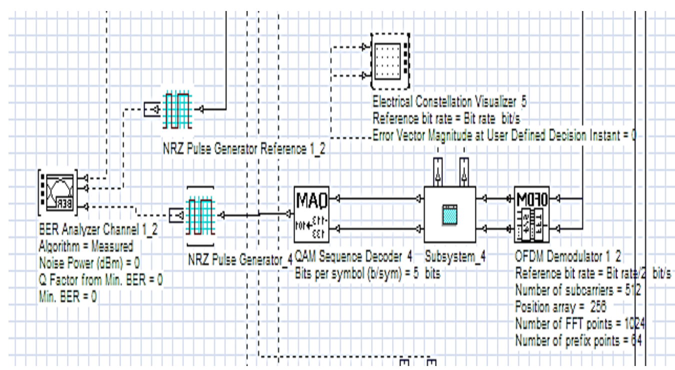

Figure: (6) The structure of single channel QAM-OFDM receiver.

The variation of Q factor with such input power levels was carried out for channel span 1000 km for same purpose. Plotted results in Fig. (7) Justify the selection of 0 dBm as signal power level.

III. RESULTS AND DISCUSSION

Extensive simulations were carried out to do the performance investigation of the proposed 8 x112Gbps (0.896Tb/s) WDM ROF system for mentioned different scenarios. Due to higher effective area, nonlinearity influence noticed low in case of system with ULAF fiber up to approximately 2500 km, but it has been observed at 3000 km distance SMF cable is performing better than ULAF cable. Then up to measured 5000 km transmission distance performance of both cables found nearly equal. Which can be seen from obtained and potted simulated results in tables 3, 4, 5 and figures (8), (9) and (10).

Q Factor from Estimated Symbol Error at User Defined Decision Instant	1000Km	2000Km	3000Km	4000Km	5000Km
ULAF CABLE	4.4107857	4.2618893	4.2910212	4.2910212	4.2910212
SMF CABLE	4.3082846	4.2327574	4.5834192	4.2910212	4.2910212

Table 3: Q Factor from Estimated Symbol Error at User Defined Decision Instant

Error Vector Magnitude at User Defined Decision Instant									
	1	2	3	4	5	6	7	8	Avg.values
1000KM	0.5012816	0.5039406	0.5299492	0.4486448	0.42169	0.4964506	0.5635257	0.4946094	0.4950115
2000KM	0.4402623	0.5179349	0.52519	0.4852615	0.47071	0.5678566	0.4768103	0.3945147	0.4848175
3000KM	0.4532613	0.5139903	0.4948979	0.478699	0.4595901	0.5503143	0.4844707	0.3954108	0.4788293
4000KM	0.4531719	0.5141808	0.4948495	0.4788266	0.4596447	0.5506103	0.4844631	0.3953705	0.4788897
5000KM	0.4531656	0.5141807	0.4948477	0.4788266	0.4596485	0.550612	0.4844627	0.3953749	0.4788899

Table 4: Error Vector Magnitude at User Defined Decision Instant

Estimated Symbol Error at User Defined Decision Instant	1	2	3	4	5	6	7	8	Avg. Values
1000 km	4.5395E-05	1.6354E-05	6.6741E-05	8.1791E-08	7.0343E-07	1.2656E-05	8.2E-05	1.5479E-05	2.99852E-05
2000 km	2.88584E-05	6.7437E-05	9.5235E-05	1.0968E-06	3.5604E-05	2.231E-05	2.2E-05	5.082E-06	3.46575E-05
3000 km	3.61104E-05	3.4871E-05	8.7211E-05	1.0972E-06	3.4918E-05	1.3327E-05	2.5E-05	4.5183E-06	2.95914E-05
4000 km	3.60823E-05	3.4906E-05	8.7197E-05	1.0991E-06	3.4935E-05	1.3342E-05	2.5E-05	4.508E-06	2.95974E-05
5000 km	3.60791E-05	3.4905E-05	8.7196E-05	1.0991E-06	3.4937E-05	1.3342E-05	2.5E-05	4.5082E-06	2.9597E-05

Table 5: Estimated Symbol Error at User Defined Decision Instant

We suggest on the base of obtained simulative results that improvement of Q factor is observed between 1000 km to 2500 km transmission distances using ULAF fiber in system. Corresponding lower values of EVM also obtained for system with ULAF fiber between 1000 km to 2500 km. Such system with ULAF fiber outperforms in comparison with system with SMF fiber up to 2500 km. At 3000 km performance of system with SMF cable dominates. It has been observed that up to 5000 km transmission distance system performs equal with ULAF fiber and SMF cable.

IV. CONCLUSION

With obtained simulative results we conclude that proposed 8x112Gbps (0.896Tb/s) WDM ROF system performs well with ULAF cable up to 2500 km but

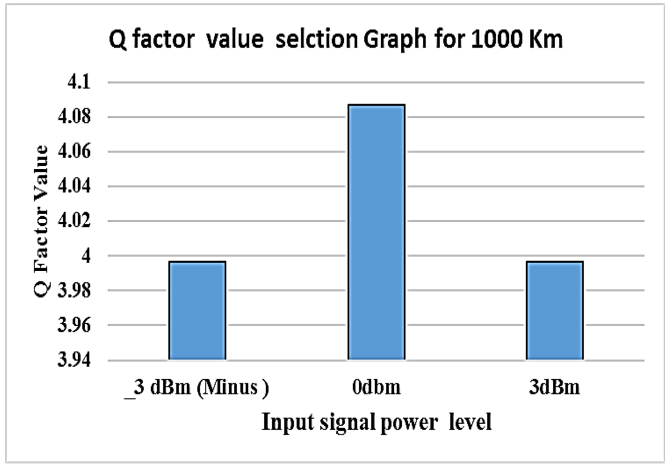

Figure: (7) The variation of Q factor with such input power levels

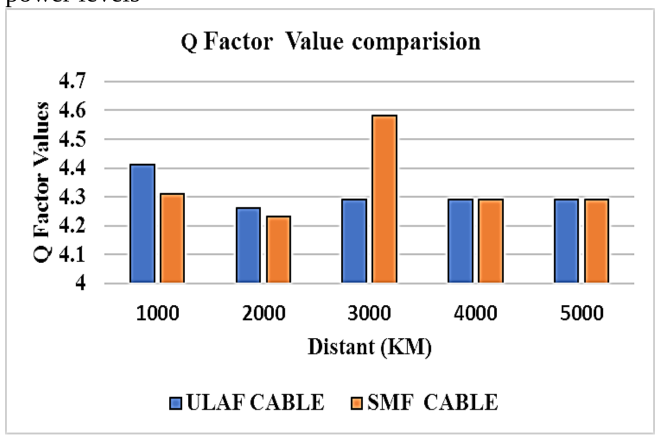

Figure:(8) Variation of Q Factor values Vs. channel span.

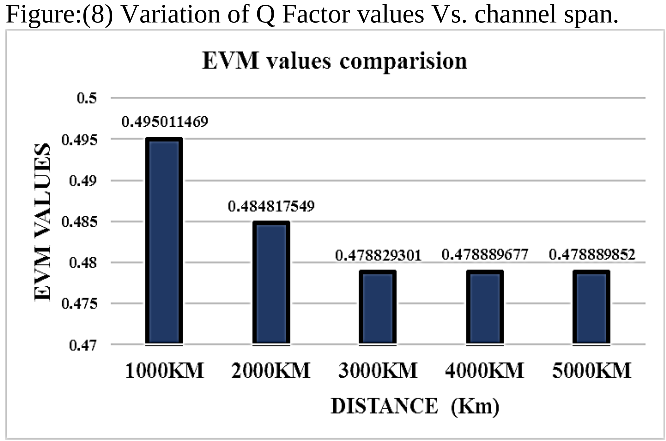

Figure:(9) Variation of Error Vector Magnitude values Vs. channel span.

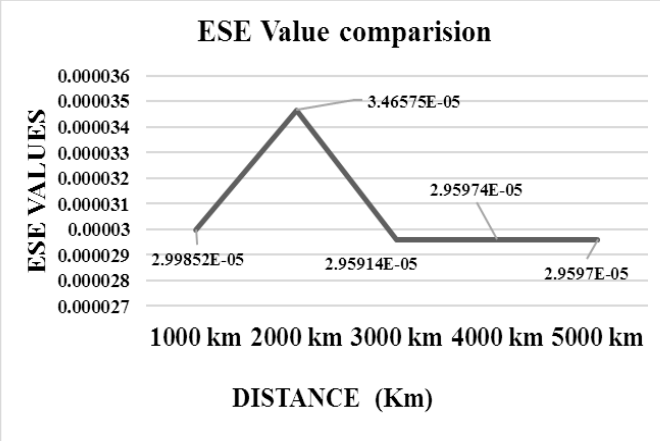

Figure:(10) Variation of estimated symbol error rate values vs. channel span.

particularly at 3000 km transmission distance SMF cable leaves behind performance of ULAF cable. So particularly at 3000 km as transmission distance use of SMF cable is preferable. Use of specific dispersion compensation technique in channel span, usage of DSP at receiver side can also be checked for possibilities of further enhanced performance of such system.

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