Design of Non optical Carrier Single Sideband and wavelength reused DWDM passive optical network with Wired/Wireless Services Incorporating OFDM

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Abstract: *In this work, an integrated passive optical network and free space optical communication system based on no-carrier single sideband modulation is proposed. Optical orthogonal frequency multiplexing is employed with dense wavelength division multiplexing to support 16 channels over 300 km bidirectional single mode fiber to enhance spectral efficiency and reduce inter-symbol interference. Moreover, wavelength reuse is also realized to design cost effective optical network units. Results revealed that the proposed framework successfully accomplished the 300 km symmetrical distance and information rate of 20 Gbps with satisfactory range of BER.*

Key words: *non optical carrier single sideband modulation (NOC-SSB), Optical orthogonal frequency multiplexing (OFDM), free space optical communication (FSO), Dense wavelength division multiplexing (DWDM), SMF*

1. INTRODUCTION:

These days, prerequisites for high speed and high capacity system are expending with awesome pace, due to the greater use of internet services, peer to peer data transfer and online games [1]. To provide food the requests of current data transfer capacity hungry applications, potential and well skillful propelled tweak in optical systems is required. Orthogonal recurrence division multiplexing is a head way out and develops as a definitive answer for battle with the scattering issue and also give high phantom productivity [2].Passive optical networks are mainstream on account of the capacity to help high information rates and serve huge number of clients [3]. Passive optical offers the solid information transmission and give delayed separation transmission [4]. Attributable to various favorable circumstances of OFDM, it experiences the real constraining issue to such an extent that it is more inclined to fiber nonlinearities. From most recent couple of years, various methodologies are exhibited with regards to orthogonal frequency division multiplexing for passive optical networks [5-6]. Literature of OFDM system provides us that there are significantly three kinds of the OFDM such as direct detection, coherent detection and heterodyne detection. However, all the aforementioned types can be used in the systems based on the specifications or user demands [7]. To understand the cost effective system, direct detection and heterodyne reception are ideal beneficiaries [8]. In any case, regardless the utilization of single photo-detector in reception of OFDM signals and offers the cost effective modulation, it experiences short separation transmissions [9]. Due to phase matching at the receiver, CO-OFDM is considered as the unmistakable and potential contender for long separation transmissions [10]. Till now, different methodologies are exhibited to create a dependable OFDM signals incorporating double side band and single side band modulation [11]. Disadvantage in the former modulation such as double side band (DSB) modulation, is the bandwidth inefficiency and limiting effects of power fading because of dispersion effects [12]. Unexpectedly, single sideband balance offers more noteworthy insusceptibility or resistance to scattering impacts and procures less data transmission in the optical fiber [13]. Also, it is studied that the optical carrier to signal power ratio (CSPR) is vital parameter in the frameworks that utilized the single side band adjustment in OFDM. Nonlinearities are because of high power, in the fiber, cause the CSPR to expand and this wind up plainly instable in the heterodyne detection dependent OFDM passive optical networks [14].

But, these high power carriers, consequently, degrade the sensitivity and diminishing the power. Furthermore, the signal-signal beating noise also plays vital role and becomes severe due to square law detecting nature of photo-detector [15]. In hilly areas and military services etc, there is need to deploy a wireless technology to cater the high speed services [16] Free space optical communication in passive optical networks is a key innovation that rises as another option to fiber optic [17]. Integrated passive optical networks and wireless FSO based networks are definitive way out [18]. An integrated passive optical network and free space optical transmission by fusing single sideband carrier less modulation is proposed. Carrier less single sideband modulation signals are generated with the intensity modulator such as Mach-zehnder modulator and optical Bessel filter. Correlation of double and single sideband modulation has been proposed in terms of Q factor. We likewise explore the effect of diverse laser link distances and launched powers on the system.

2. SYSTEM SETUP

Figure 1 depicts the design of optical orthogonal frequency division multiplexing based passive optical network by using both wired and wireless technologies. Non optical carrier single sideband modulation is fused in the framework to make framework data transfer capacity proficient and in addition more tolerant to scattering impacts. Information speed of the bidirectional latent optical system is taken as 20 Gbps for downstream and 20 Gbps in the uplink course. As a matter of first importance, so as to begin the correspondence pseudo random data generator is used which generates the binary data bits such as tributaries of 1's and 0's. Serial bits are modulated with coherent optical orthogonal division multiplexed modulation. Quadrature amplitude modulator is set after serial data bits generator and map the signal into parallel bits. Keeping in mind the end goal to suppress the impacts of inter-carrier interference, cyclic prefix are incorporated. Digital to analog conversion is required for signal modulation and performed by DAC, signal are up-converted to optical frequency by placing two intensity modulators (MZMs). A continuous wave laser is operated in C-band (1530 nm-1570 nm), due to the minimum scattering in this frequency band. In addition, low power (- 5 dBm) framework is intended to smother the warm impacts in the laser at high power levels. Laser line-width is kept at 0.15 MHz to understand a handy framework. Non carrier single sideband signal is acknowledged after OFDM signal modulation through Bessel filter for every wavelength. Wavelengths considered in this work are 16 and frequency spacing's among WDM channels are 50 GHz. Multiplexed signals are transmitted over single mode fiber (SMF-28) of 300 km in downstream that has attenuation of 0.2 dB/km and dispersion of 16.75 ps/nm/km. System details are recorded in Table 1.

Table 1 Parameters of OFDM-PON communication

Parameters	Values
Data rate Downstream	20 Gbps
Data rate upstream	20 Gbps
Distance downstream	300 km
Distance upstream	`300 km
Modulation	CO-OFDM
OFDM subcarriers	512
FFT/IFFT points	1024
WDM channels	16
Frequency spacing	50 GHz
Signal for transmission	Non carrier single sideband modulation
Wireless distance	1 km

Receiver section comprises of de-multiplexer and consolidated to course particular wavelength to specific output port with the reference to multiplexer. After de-multiplexer and prior to OFDM demodulator, each received wavelength is separated into two signals with the power splitter. One branch of power splitter is fed to coherent optical OFDM demodulator and another is bolstered to another 1:2 power splitter for free space optical channel (FSO) and wavelength reuse. Free space optical channel has 5 cm transmitter and 20 cm receiver antenna with 1 mrad beam divergence. FSO transmission covers the separation of 1 km and after that demodulated by OFDM beneficiary. Demodulator section comprises of local oscillator for phase matching, photo-detectors to detect imaginary and real signals, m-array threshold detector to detect multilevel signal followed by QAM decoder. A constellation analyzer is engaged to calculate error vector magnitude (EVM). It is significant that no optical amplifier to realize the proposed communication is used. Ultimate conclusion component BER analyzer is put at last with the end goal that it gives Q factor and BER.

3. Non optical carrier single sideband modulation principle

Non optical carrier single sideband modulation in passive optical networks is well able approach to suppress the nonlinear impacts and to make carrier dispersion tolerant. Single sideband modulation can accomplish with the optical filtering of double sideband signal. Optical filter basically dispense the one sideband of DSB signal and thus provide the single sideband signal. It is observed that the aggregation of the different wavelengths alongside sidebands in optical fiber cause the development of nonlinear impacts and possess huge transfer speed. Along these lines, keeping in mind the end goal to make framework transfer speed effective and scattering/nonlinearities tolerant, single sideband tweak is required. Figure 2 represents the illustration of no carrier single sideband modulation signal generation.

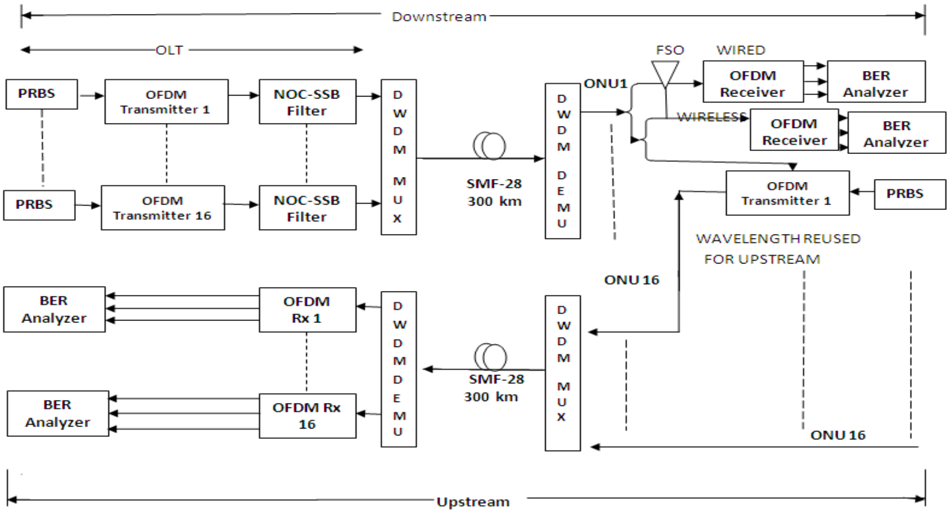


Figure 1 Representation of wavelength and orthogonal division multiplexed bidirectional passive optical network and free space communication

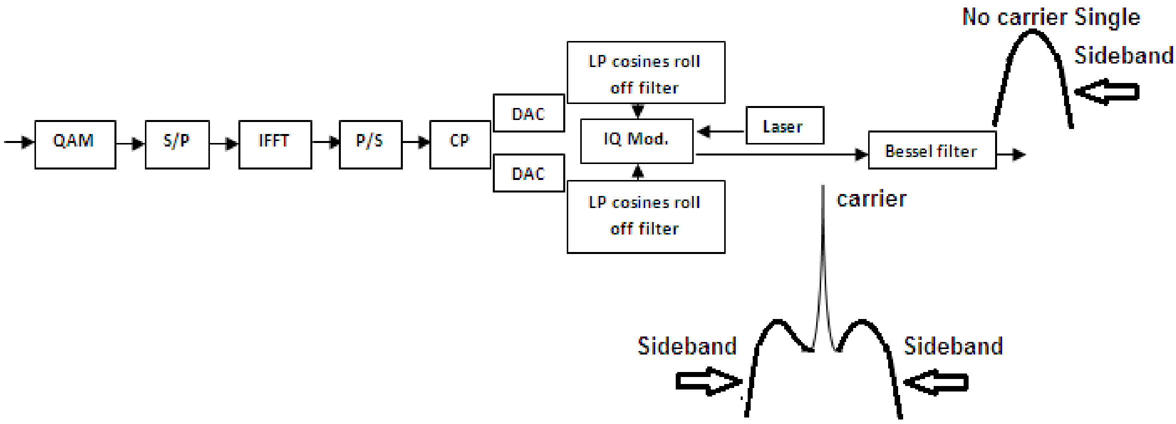
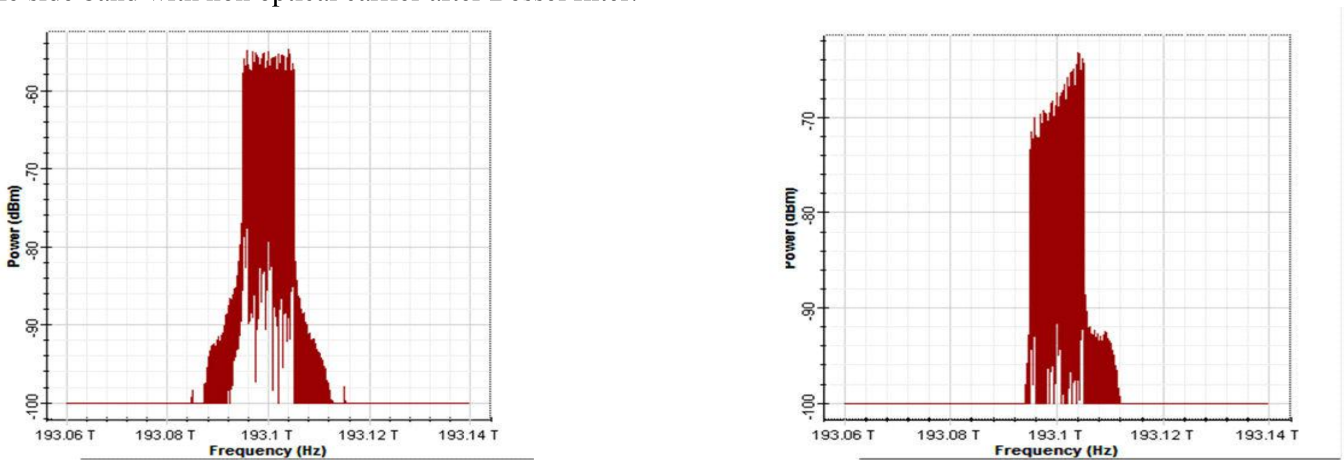


Figure 2 Illustration of the generation of no carrier single sideband modulation signal (NC-SSB)

4. RESULTS AND DISCUSSIONS

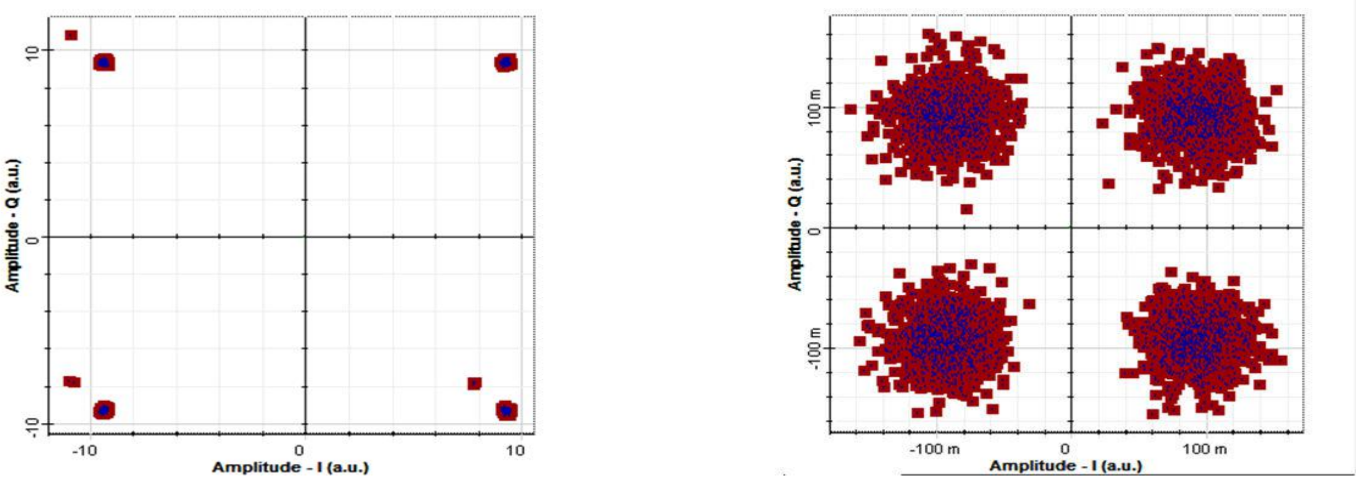
Keeping in mind the end goal to understand a non optical carrier single sideband modulation in passive optical network, a comprehensive simulation tool Optiwave optisystem14.2 is utilized. Optical spectrum analyzer is the carrier signal accessing visualizer that depicts the frequency as well as power for each carrier. Figure 3 (a) represents optical spectrum analyzer shows double side band after OFDM modulator at transmitter side and Figure 3 (b) indicates single side band with non optical carrier after Bessel filter.



(a) (b)

Figure 3 Optical spectrums of first channel OFDM signals for (a) Double sideband signal (b) Non optical carrier single sideband modulation signal (NOC-SSB)

Figure 4 (a) represents the constellation diagrams of 20 Gbps at 40 GHz signal bandwidth of NOC -SSB DWDM OFDM PON system at transmitter after 4QAM modulation and Figure 4 (b) demonstrates the constellation diagrams of 20 Gbps at 40 GHz signal bandwidth of NOC -SSB DWDM OFDM PON system at receiver side.



(a) (b)

Figure 4 shows the constellation diagrams of 20 Gbps at 40 GHz signal bandwidth of NOC -SSB DWDM OFDM PON system at (a) after transmitter (b) receiver

Figure 5 represents the optical spectrum analyzer yield after multiplexer in the downstream and shows the 16 WDM wavelengths with channel spacing of 50 GHz. OSA analyzers are placed in the system after short interims to access the signal for correct analysis of the carrier signals. Figure 6 depicts the execution of the bidirectional integrated passive optical network and free space optical communication transmission at different distances in terms of Q factor. Execution of OFDM downstream link and upstream transmission is analyzed to find the maximum supported distance within acceptable range of Q factor. It is apparent that with the improvement or increment in the transmission connect length; estimation of the Q factor disintegrates in both downstream and also upstream transmission.

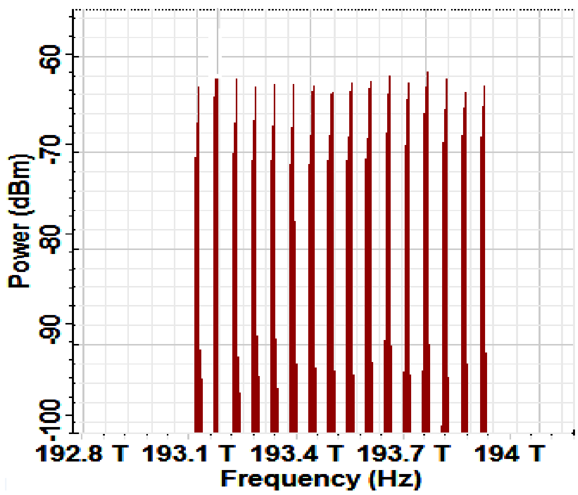


Figure 5 Optical spectrums of 16 WDM channels

Attenuation, dispersion along with the nonlinear effects is the key issues that deteriorate the performance of the system. Results uncovered that the downstream got flag displays better Q factor when contrasted with the upstream transmission factor degradation in optical network unit to optical line terminal transmission is due to the double distance transmission of the carrier as compared to downstream. Because, in this work, wavelength reuse is proposed to eliminate the laser sources required for 16 channels in the ONU and also maintenance issues. So, round trip of the 16 wavelengths in the downstream and upstream communication is 600 km. Results reveals that both downstream and upstream transmission covers 300 km within acceptable Q factor limits.

Figure 7 represents the LoG (BER) curve with respect to the distance variation in the downstream wired OFDM signal. Distance is varied from 50 km to the 350 km with the difference of 50 km. It is evident that the more error emerges in the downstream as well upstream with the enhancement in the distance. As the aforementioned discussion, increase in the single mode fiber also increase the attenuation, dispersion and nonlinear effects such as four wave mixing, self phase modulation, cross phase modulation etc. Observation form the investigation shows that the errors increase in the upstream transmission with distance increase. However, the less errors are in case of downstream signal reception and it is noteworthy that BER of 10^{-9} reported at the 300 km. beyond the distance of 300 km, Q does not follow the limits of international telecom union.

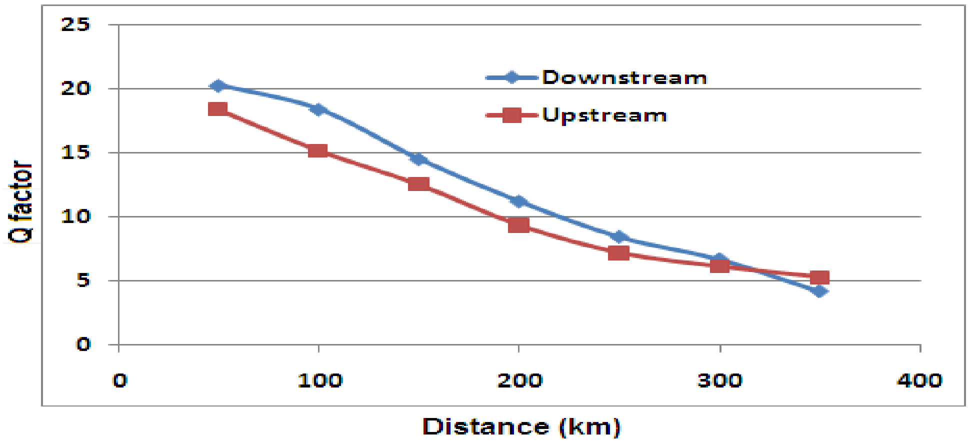


Figure 6 Graphical representation of distance versus Q factor for downstream and upstream in WDM-OFDM passive optical network

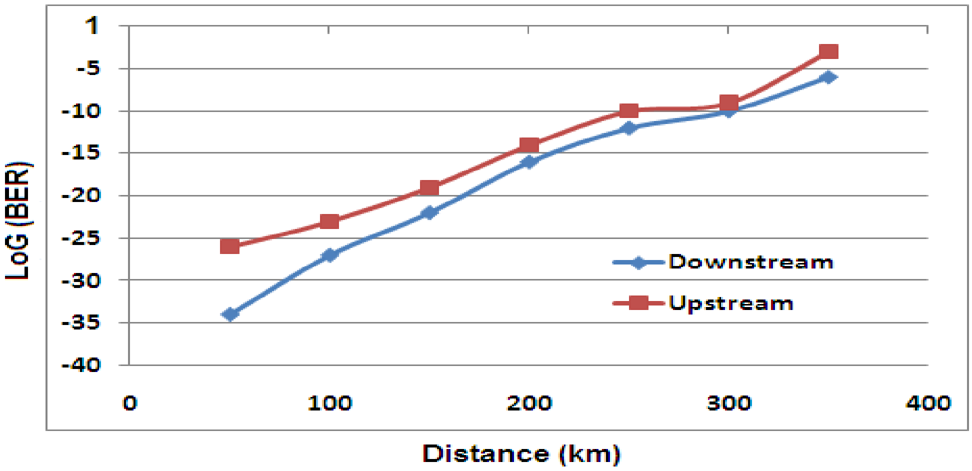


Figure 7 LoG (BER) versus distance performance in the NOC-SSB-WDM-OFDM-PON

Free space optical transmission is the potential candidate to resolve the fiber deployment issues in the current optical network systems. In this work, in order to eliminate the wired transmission after optical units, free space optical communication is proposed after 300 km wired link length. Figure 8 represents the graph for the two cases such as only wired communication and wired along with FSO communication. Joint case of wired and wireless communication performance falls below the only wired communication system. This is due the attenuation of the air and atmospheric turbulences.

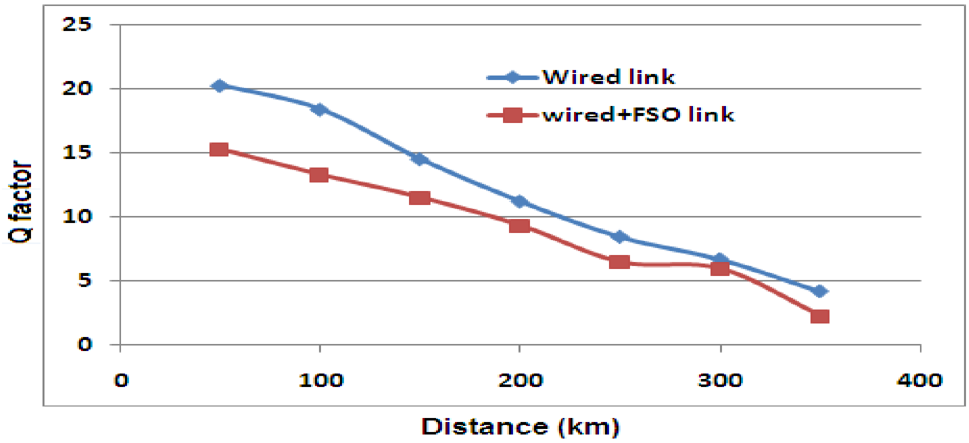


Figure 8 Graphical representation of distance versus Q factor of wired transmission and wired + FSO transmission

Figure 9 shows the optical signal to noise ratio of the proposed non optical carrier single sideband modulation in the downstream and upstream transmission. There is significant decrease in the OSNR with the increase of the distance due to coupling of noises at greater distances. Noise power is greater in the upstream transmission, as a result it decrease the optical signal to noise ratio. Downstream transmission performance is superior to the upstream transmission in the wavelength division multiplexed passive optical network incorporating free space optical communication.

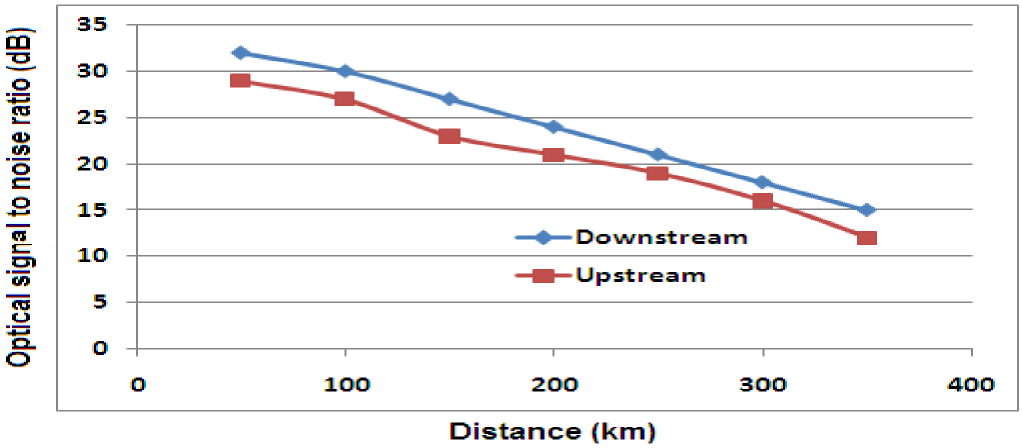


Figure 9 Graphical representation of optical signal to noise ration versus distance

Figure 10 (a) and (b) depicts the investigation of the system for different launched power levels and results are evaluated for Q factor and BER. First and foremost the input laser power is varied from -10 dBm to 10 dBm with the power different of 5 dBm. Figure 10 (a) represents the downstream and upstream transmission performance with respect to the launched power levels. It is seen that the as the more power couple to the optical fiber, Q factor enhances due to the attenuation overcoming by the carriers. However, nonlinear effects are also cause that arises on the high powers input to the fiber. In this case, downstream performs better than downstream.

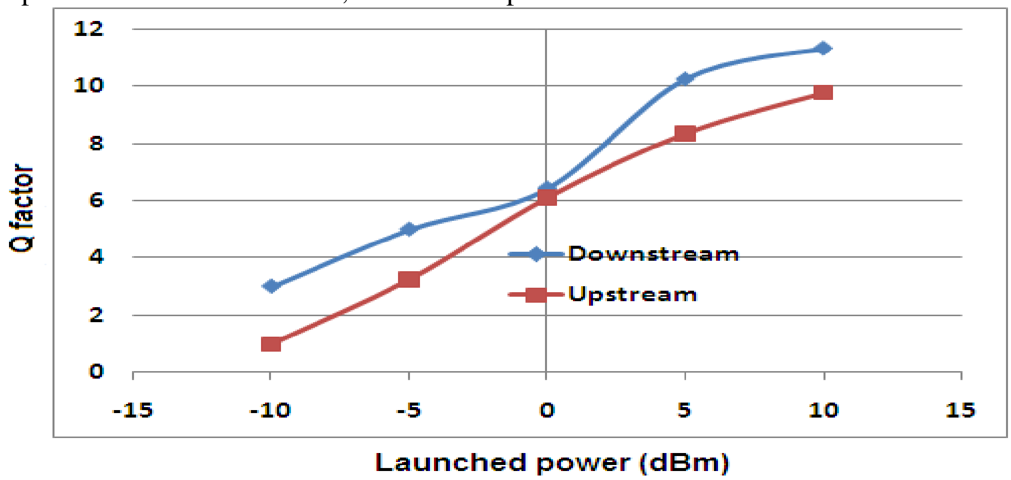


Figure 10 (a) Launched power versus Q factor for downstream and upstream

Further LoG (BER) is analyzed for diverse laser powers in the proposed system. It is observed that at lower power levels, more error are there due to dominating effects of attenuation, dispersion etc. But, as launched power more coupled to the fiber, BER decreases sharply and least errors are found at 10 dBm. It is also seen that further increase in the power levels beyond the 10 dBm not improve the results more. Thus 10 dBm is the launched power that is acceptable in the system to get results without the degrading effects of nonlinearities.

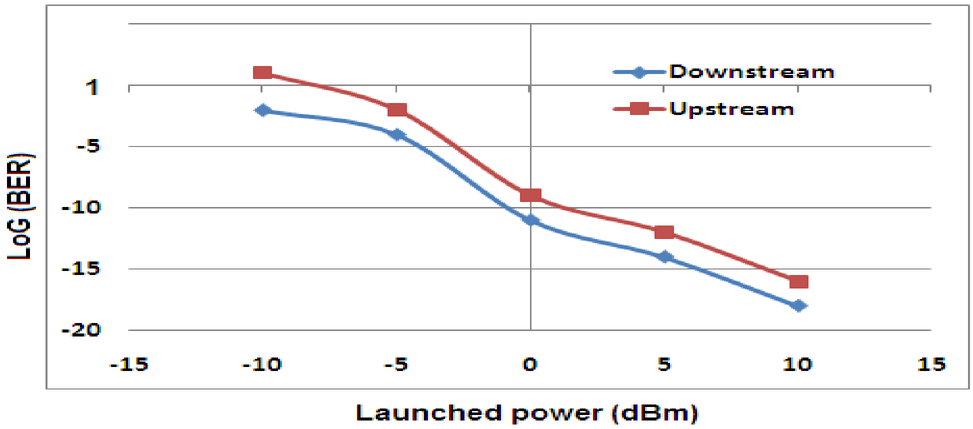
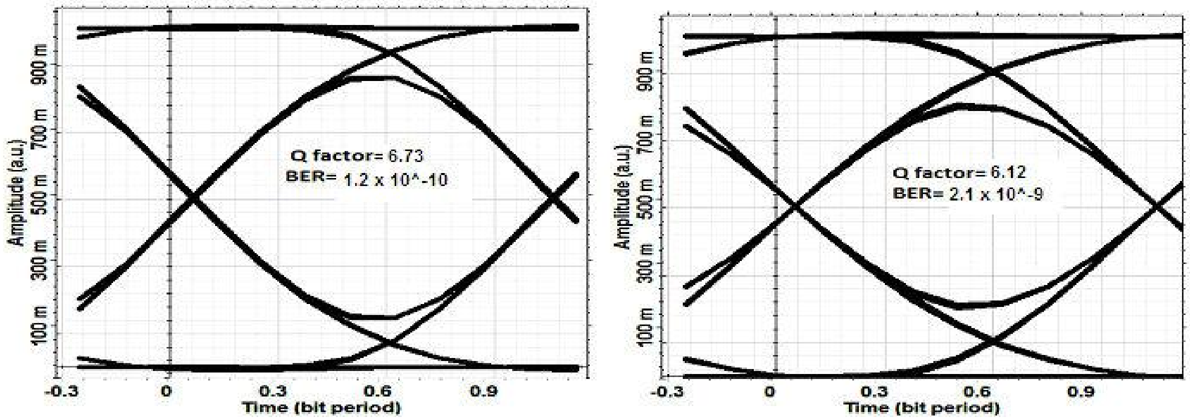


Figure 10 (b) LoG (BER) versus launched power representations

Figure 11 (a) and (b) represents the eye diagram of the downstream signal and upstream at 300 km respectively.



(a) (b)

Figure 11 Eye diagram of (a) downstream (b) upstream at 300 km

Eye diagram opening is more in case of the downstream as shown in the Figure 11 (a) and less in upstream. Q factor reception is emerged in downstream and eye opening is directly proportional to the eye opening. Figure 12 demonstrates a RF spectrum of free space optical link operating at 20 Gbps, where usually the main source of penalty is atmospheric attenuation. FSO channel is operating at the range of 1 km with 0.1 dB/km attenuation.

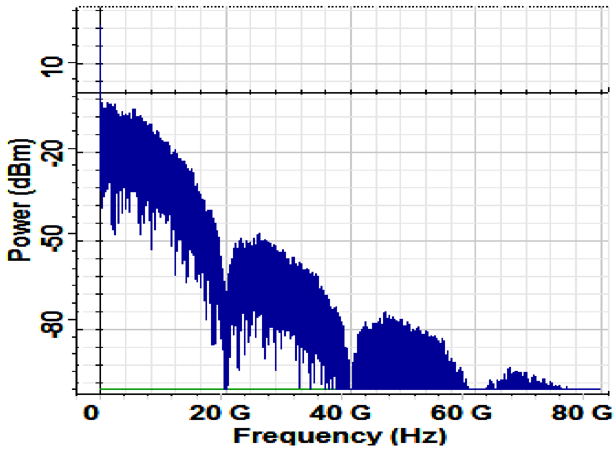


Figure 12 Radio frequency spectrums after FSO reception

5. CONCLUSION:

In this research article, an integrated passive optical network (PON) and optical wireless transmission by utilizing data transfer capacity proficient and scattering tolerant single sideband carrier less modulation is Illustrated. Proposed system successfully covered 300 km distance in upstream and downstream at symmetrical information rate of 20 Gbps. It is observed that downstream transmission performs superior to upstream due to extra losses experienced by upstream signal due to re-modulation. Also free space optical communication is integrated in the WDM-PON to resolve the fiber deployment issues for small distance networks and covered 1 km with Q factor 6.1. Investigation revealed that the result enhanced at high powers, at small distances and using non optical carrier single sideband modulation.

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