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Design And Performance Analysis Of Long Reach Bidirectional Multi-User Next Generation Passive Optical Network

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Abstract

In this research article, we demonstrated a long reach wavelength division multiplexed passive optical network with radio signal reception through heterodyning detection. Enhanced performance is presented of the access network by incorporating coherent optical orthogonal frequency division multiplexing which enables system to support high date rate such as 30 Gbps per wavelength. Moreover, in order to get optimal performance, pulse width reduction and avalanche photo-detector is employed and results reveals that proposed system successfully covers the distance of 150 km and supports 256 users in downstream and 128 users in upstream. Performance of the demonstrated system is evaluated in terms of Q factor, coverage area and obtained an excellent WDM passive optical network.

Key words- Coherent optical orthogonal frequency division multiplexing (CO-OFDM), Pulse width reduction (PWR), Quality factor (Q factor), Bit error rate (BER), Radio frequency (RF)

Introduction

Due to ever increasing rate in the high speed and bandwidth requirements of internet services, the wavelength division multiplexed passive optical network (WDM-PON) is popular owing to numerous advantages such as wide bandwidth, improved security, as well as reliability to sustain many users. On the contrary, wired less service is attracting focus due to the extra reliable as well as hustle free technology [1]. In order to take benefits of the fiber optic and mobile architecture wireless communication, combination of both wireless and fiber optic technology is a paradigm shift in the communication [2]. For the accomplishment of this goal, radio over fiber systems provides excellent way out. Integration of passive optical networks and radio over fiber is intend to support modulated RF signal and baseband signal at the same time in order to attain cater wired and wireless services [3]. An unlicensed spectrum of 60 GHz carrier frequency is prominent and premier in the wireless access. This falls in the millimeter wave region and exhibits enhanced bandwidth. Future access networks such as local area networks will also use this frequency band by means of enhancing IEEE 802.11ad standards [4]. Moreover, 60 GHz band has other advantages also such as the immunity to interference, reuse of frequency and enhanced security [5]. Next-generation wireless systems will have extra challenging noise as well as deformation necessities for the radio over fiber systems. To attain and support high speed, future systems will necessitate numeral procedures to be incorporated [6]. For example, without adding the radio signal, optical millimeter wave signal generation dependent on heterodyning techniques by means of beating two optical carriers separated by the desired frequency [7] is employed. Orthogonal frequency division multiplexing (OFDM), which is widely used in wireless communication, such as IEEE 802.16, long-term evolution (LTE) [8], will also be used in the RoF system. Optical orthogonal frequency division multiplexing (O-OFDM) brings the benefit of electronic equalization and robustness against multipath fading of legacy wireless OFDM systems into the optical domain to achieve impairments- tolerant ultra-high-speed optical systems [9]. Dispersion compensation is a well competent scheme to compensate the pulse width and reduce the inter symbol interference (ISI). So, in order to accomplish the 60 GHz mm-wave using coherent optical OFDM, pulse width reduction and optimal detection is required.

In this work, a high speed coherent optical orthogonal frequency division multiplexing based wavelength division multiplexed passive optical network is demonstrated. Data speed of 30 Gbps is achieved for eight wavelength division multiplexed channels in optical line terminal and also supports 256 x 8λ users in the downstream. Total 512 users in the upstream are reported and 120 km transmission with pulse width reduction module is attained. Optical heterodyning is a technique used to obtain 60 GHz signal at the receiver without adding any radio signal.

System setup

Proposed system design is based on the coherent optical orthogonal frequency division multiplexing based wavelength division multiplexed passive optical network. Architecture of the proposed work is described as under:

(a) OFDM Electrical Transmitter:
Data at 30Gbps is offered and is modulated using 4-QAM modulation for each transmitter and collectively send 240Gbps. The number of subcarriers is 512.These modulators provide the inputs of inverse fast Fourier transform. An interpolated waveform with well controlled spectrum is obtained by zero padding of IFFT inputs; this can be obtained through analog filters later than D/A converters.

(b) Optical modulator and filter:
Mach-Zehnder modulators (MZM) could be used as an optical modulator in optical-OFDM systems. By using an optical filter the lower optical sideband is removed, after modulation. The optical carrier is suppressed and so, the receiver sensitivity is improved. When optical carrier power is equal to the power of OFDM sideband, then the result is best receiver sensitivity.

(c) Fiber link :
Loops used consisting of SMF and DCF .Symmetric dispersion compensation is used in this system. The length of fiber can be increased by increasing the number of loops.SMF specifications given in Table.1.

Table.1. System specifications

Parameters	Values
Data Rate	30Gbps/ Wavelength
Frequency	193.1THz
Sequence Length	8192
Sample Per Bit	4
Laser Power	12dBm
LO Power	12dBm
QAM	4QAM
Photo-detector	PIN, APD
No. of Subcarrier	512
FFT Points	1024
Amp.	EDFA
Gain	5dB
NF	4dB

Table. 2. SMF and DCF specifications

SMF Attenuation	0.2dB/Km
SMF Dispersion	17ps/nm/Km
DCF Attenuation	0.5dB/Km
DCF Dispersion	-85ps/nm/Km
DCF Aeff	22 um^2
SMF Aeff	70 um^2

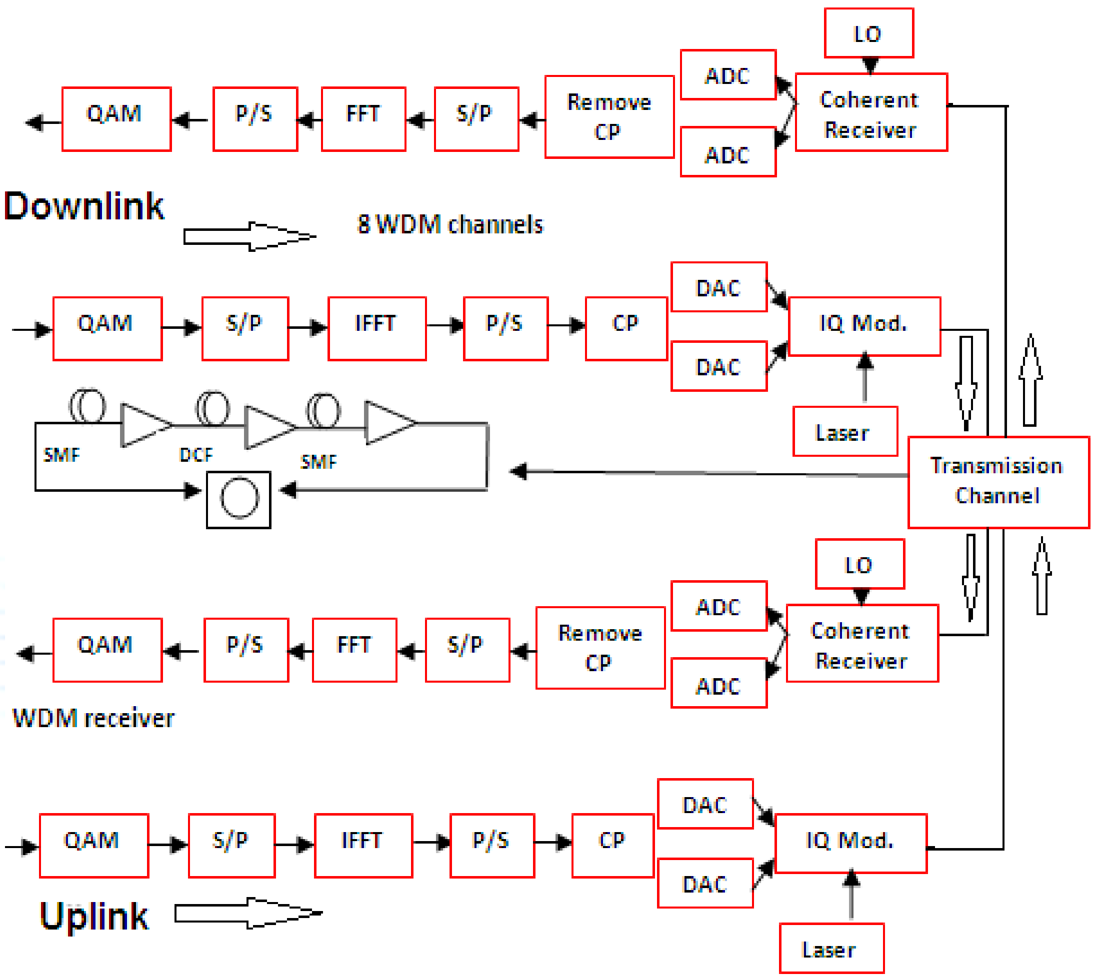

Figure.1: Bidirectional communication in WDM passive optical network

d) Receiver Model:

At the receiver, time-domain waveform which is proportional to the optical power is obtained using photodiode with 1 A/W responsivity. The photocurrent is converted into quadrature (Q) and inphase (I) components through mixing with 0 and 90 phase of a LO. The inverse procedures are carried out i.e. S/P, remove cyclic prefix, and FFT, in order to get the OFDM signals. Once in frequency domain, every channel is equalized to remove for amplitude and phase distortions. This can simply achieved through a separate multiplication for every QAM channel.

Functioning

A PRBS provide data for 8 different laser transmitters and convert to parallel data with the help of QAM. After serial to parallel conversion, data is modulated with real and imaginary signals by MZM modulator and concept of orthogonal phenomenon provided by OFDM modulator. Signals are transmitted for downstream on dispersion compensation module of 60Km in one loop consisting of SMF 25Km DCF 10 Km and SMF 25Km. Now signal reach to receiver of OFDM and emerges through de-multiplexer for the routing of specific wavelength to respective port with reference to multiplexed wavelengths. Transmission is a\carried through 120 km and then each wavelength is distributed to 256 users with the passive splitter 1:256 in downstream. In upstream, number of users supported are 128 for each wavelength.

Results and discussions

Proposed bidirectional wavelength division multiplexed passive optical cal network incorporating coherent optical orthogonal passive optical network is investigated in this work. System is evaluated on different link distances and input powers levels. Also, effect of pulse width reduction module is also studied. Figure 2 depicts the optical spectrum analyzer for eight wavelength division multiplexed channels with the channel spacing of 100 GHz. Power on each carrier with respect to the frequency is represented.

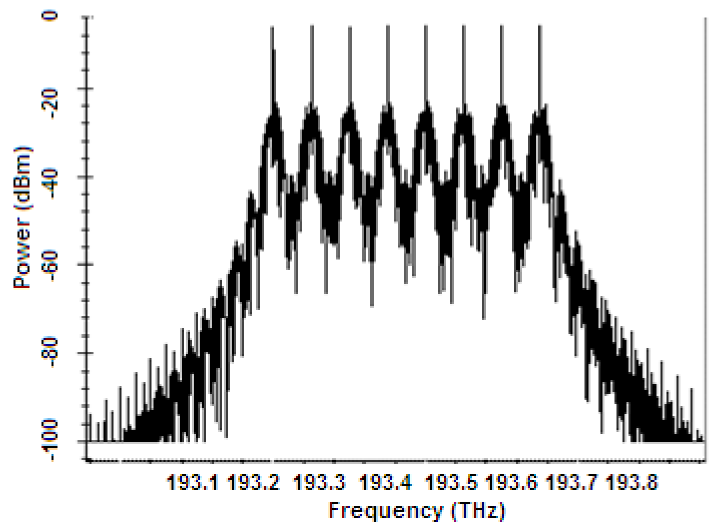

Figure 2: Optical spectrum analyzer illustration for eight WDM channels after multiplexer

Figure 3 represents the performance of the proposed architecture at different link lengths in downstream by incorporating pulse with reduction scheme for varied channel spacing's. Q factor is taken for evaluation and it is observed that there is significant decrease in the quality, if we prolong the link length. Distance is increased from 10 km to 50 km and due to the effects of attenuation, pulse broadening and kerr's effects, results deteriorated. Frequency spacing in wavelength division multiplexing plays a key role and steered the output performance. We have varied the spacing from 100 GHz to 200 GHz, in order to investigate and analyze the impact on the performance. It is evident that 200 GHz require more bandwidth and WDM channels cause less interference due to large spacing, in turn provide better Q factor. However, irrespective of the high Q factor, this wide frequency spacing waste the overall bandwidth. In order to realize and enhance the efficiency of bandwidth use, 100 GHz or dense spacing's are suggested by using optimal methods to suppress interference of symbols.

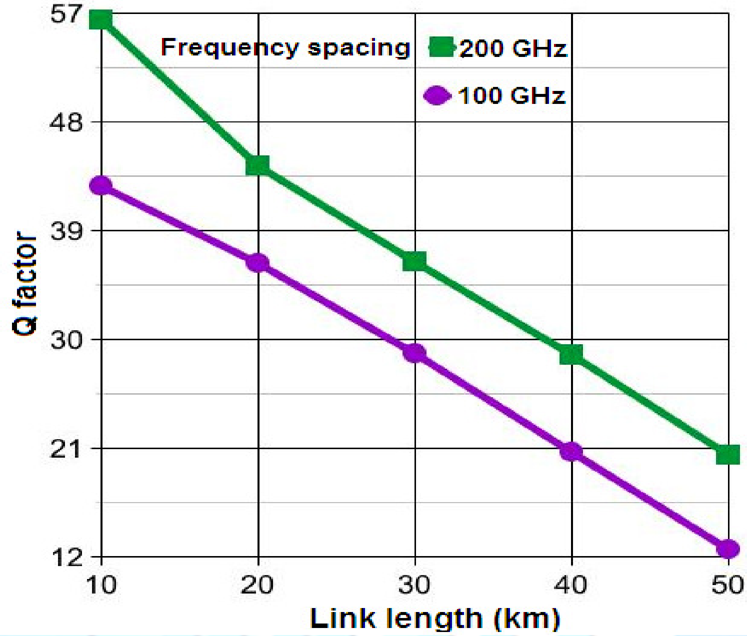

Figure 3 Effect of frequency spacing's of WDM channels on the proposed system in terms of Q factor at varied link lengths

Figure 4 represents the comparison of the two systems, in fist case, by incorporating pulse width reduction and in second, without the use of any ISI compensation scheme. For the analysis, distance is iterated from 10 km to 50 km and Q factor is investigated for the aforementioned cases.

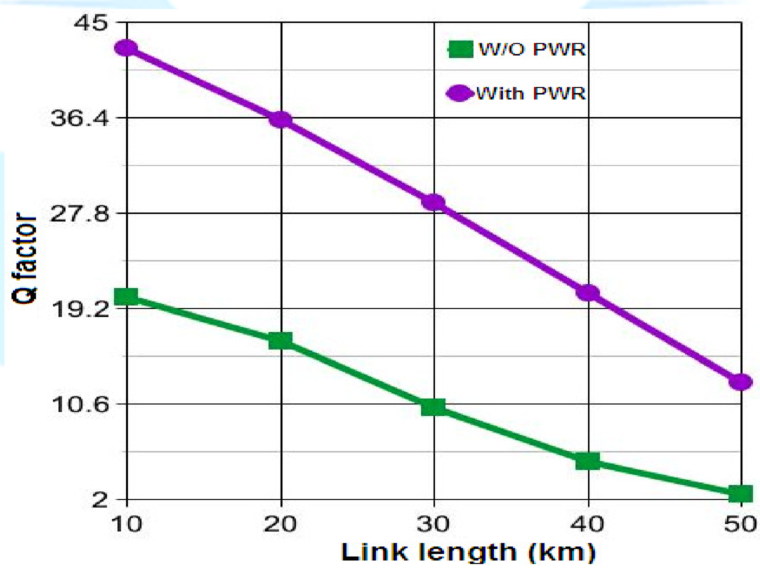

Figure 4 Comparison of the transmission line with and without pulse width reduction in terns of Q factor at varied ink distances

Results revealed that the better Q and enhanced output is attained when the PWR is employed and system can cover more than 50 km with acceptable Q factor limit. This means the inter symbol interference is an most important issue to be addressed in order to design high speed system. There is significant difference between the both cases and much deteriorated results obtained in without PWR. So, to accomplish long distance and high speed transmission, pulse width reduction is recommended.

Figure 5 depicts the effect of users that are supported by the proposed system after multiplexer. It is seen that if the users are increased in the power distribution, signal gets weak and power received to receiver section decreases, thus, Q also decreases. Investigation is carried out by increasing users from 64 to 256 and Q is noted down. Results presented that the splitting ration enhancement led decrease in Q factor. Maximum Q is obtained for 64 users per wavelength and it degrades as we split more users. Minimum Q is seen for 256 users and after 50 km link distance system stops providing acceptable Q.

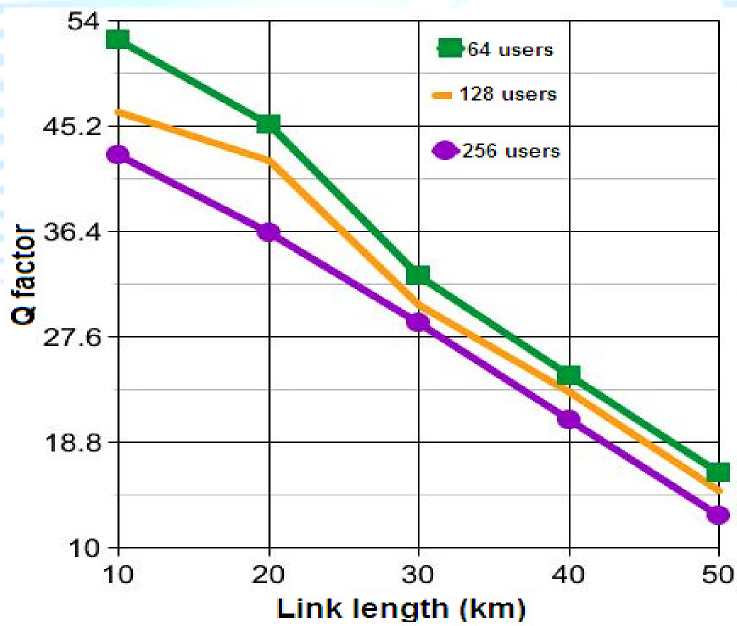

Figure 5 Effect of users on the Q factor in the downstream at varied link lengths

BER analyzer makes decision and show errors and Quality factor. Transmission has done with central office to user end, now reverse is also done from users end to central office. Similar transmitters are taken into account for upstream transmission for 8 wavelengths and transmitted over 50 Km on same dispersion compensation module. Figure 6 provide the investigation performance of different photo-detectors such as p-i-n and APD. From literature, it is studied that the quantum efficiency and effect of shot, thermal noise steered the final performance. Thus, analysis has been done for these two amplifiers.

It is noted that in case of using PIN detector, system can support 50 Km over single mode fiber and dispersion compensation fibre. Whereas APD performs better and prolongs distance to 150 Km within acceptable BER range. All the noises are considered such as shot, quantum, thermal and ASE noise for both detectors. Less error is noted in APD detection and more in PIN. Maximum distance covered in case of PIN is 50 Km and 150 Km in case of APD.

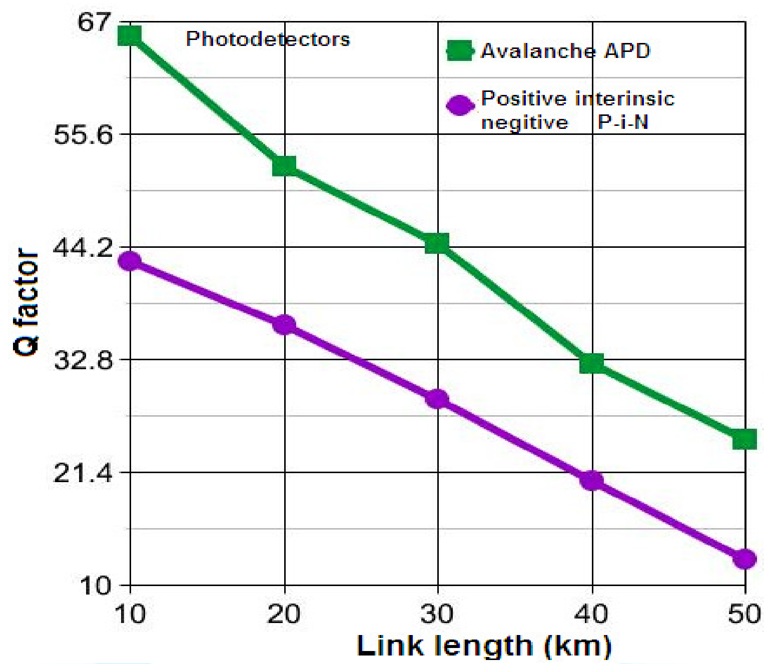

Figure.6 Effects of photo-detectors on the performance of proposed system on downlink

Conclusion

We demonstrated and investigated a wavelength division passive optical network incorporating coherent optical orthogonal division multiplexing, which delivers the important advantage of simultaneously supporting wired and wireless services. Proposed system successfully supports the data speed of 30 Gbps per channel (wired) and 256 users for each wavelength over 50 km transmission distance in the downstream. Optical network unit also consisting of eight wavelengths, supports 128 users in the upstream for each wavelength. Optimized results are obtained with incorporation of pulse width reduction in the transmission and avalanche photo-detector. Using this combination, long reach transmission of 150 km is achieved within acceptable limits of BER. A 60 GHz millimeter wave is obtained at the receiver after heterodyning detection and provides good solution for wireless services such as WiFi.

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