A Cost Effective Radio over Fiber System Employing RSOA for Upstream and Incorporating Self Phase Modulation for Carrier Generation

Pargat Singh1,Dr.Charanjit Singh2
Student1, Assistant Professor2
Dept. of ECE, Punjabi University
Patiala, Punjab

***ABSTRACT*- A cost effective radio over fiber system is proposed for bidirectional communication to cater six radio access units (RAUs). A bidirectional system that dispenses speed of 1 Gbps has been demonstrated and evaluated in terms of performance. Major work is carried out to transmit data from central office (CO) to mobile base station over 40 Km SMF-28 and from base station (BS) to radio access units over the fiber stretch of 300m. In this article, a prominent and premier property of semiconductor optical amplifier is utilized to fulfill the current demands of data speed and cost effective systems. RSOA serves the upstream radio access units and minimize the cost of ROF system.**

***INDEX TERMS*- RSOA (Reflective semiconductor optical amplifier, Radio over fiber (ROF) , Radio access units (RAUs) , Millimeter waves (mm-waves), Central office(CO)**

INTRODUCTION

The proliferation of smart mobile devices is fundamentally changing the Internet traffic patterns and both wireless and wired network infrastructure [1], [2]. Propelled by emerging applications such as interactive video service, the mobile data traffic is projected to increase 13-fold between 2012 and 2017 [3].Nowadays, wireless access network services have been evolved from voice as well as simple message to multimedia. In accumulation, these services have pursued deliverance from temporal and spatial curtailment due to limelight of the ubiquitous set of connections or networks [4]. To cater these demands, radio-over-fiber (RoF) system, the union between wireless network and conventional optical link, has been proposed as various system models and received attractiveness as one of the most competitive future network [5]. Wireless broadband access principles utilizing lower radio frequencies such as wireless LAN (Local area network), long term evolution (LTE) and Wi-Fi (wireless fidelity) are dominating due to worldwide existence and mobility [6]. However, lower frequency bands are fetching widely and congested so way-out to this problem is millimeter wave (mm wave) and is expected to be the future band in radio over fiber communication [7].Radio or millimeter waves attracted attention of researchers due to its transparent and reliable operation. RoF system provide large bandwidth and flexible architecture are needed for operation [8]. Majorly analogue radio over fiber system was employed for many baseband transmissions, however limits the reach and speed of the system because of chromatic dispersion and nonlinear effects [9].

It is indispensable that the access network should hold high speed, formats, protocols, as well as necessities. The customers will benefit from a widespread user interface that provides wireless access everywhere at any time with minimal delay and data processing. With allocating and scheming numerous wireless services in the central office (CO), RoF systems deliver ready-to use analog signals to remote access units (RAUs) with no differentiation in protocols, consequently reduce the cell site complexity and cost [10]. In picky fact, the millimeter-wave small cell system can provide advantage the most from RoF structural design due to its features in low attenuation and cost [11]. Besides analog RoF systems, digitized RoF systems, in the light of recent open BS specifications such as the Common Public Radio Interface (CPRI). However, the digital RoF links are at least an order of magnitude more expensive than analog RoF links, as a result of the high line rates required for wideband radio channels [12].

In this research article, we emphasize on the cost and generation of multi-slices of spectrum form single laser by incorporating self phase modulation. RoF platform that accommodates both legacy wireless services and mm-waves, and we presents a practical and competent scheme with the incorporation of SPM and RSOA, to reduce the cost and to present a long reach system. In order to accomplish the data demands, proposed a system employing self-phase modulation (SPM) to generate multiple carriers for BRoF system. Furthermore, SPM has also been used to design stable, less complex and ultra fast wavelength converters. Advantage of SPM and RSOA is (1) SPM has been employed to generate mm waves (2) Bidirectional RoF signal transmission to six radio access units is accomplished with one light source at control unit (3) RSOA makes system cost effective and used for upstream modulation ,which eliminating the requirements of external modulators.

PROPOSED ARCHITECTURE

For the realization of bidirectional RoF system, a commercial Optiwave optisystem simulation tool is used. Optisystem suit is a pioneering optical fiber communication (OFC) system simulation package to design, test and optimize virtually with any type of optical link in physical layer of broad spectrum.

Proposed system consists of a light source operated at 193.THz center frequency and data from pseudo random bit sequence generator is modulated with external modulator and optical pulses from laser source. Total rate of binary bits 1'as and 0's is 1 Gbps and time of each bit is 1ns or 100ps. Six data generators are multiplexed and amplified with power booster (EDFA) having gain of 15dB and noise figure 4dB. Gain controlled erbium doped fiber amplifier is incorporated due to its fixed gain. Multiplexed and amplified data streams are fed into highly nonlinear fiber to get broad spectrum. Length of HNLF is considered 500m and it is observed that with the increase of HNLF, SPM becomes more effective and severe. Self phase modulation is a nonlinear effect and because of Kerr's effect, high power light pulse when traveled through HNLF causes a phase delay that has the same temporal shape as the high power light signal. The time-dependent phase change caused by SPM is related with a alteration of the spectra. If the pulse is in the beginning is unchirped, SPM leads to an increase in optical bandwidth, whereas spectral compression can consequence if the original pulse is down. Subsequent to broadening of optical spectrum, the signal is transmitted all the way through an arrayed waveguide grating (AWG). AWG is to carryout function of carriers filtering and split the signal into twelve subcarriers. Fig. 1.1 depicts the architecture of proposed model and Fig. 1.2 represents the optical spectrum before and after self phase modulation in HNLF.

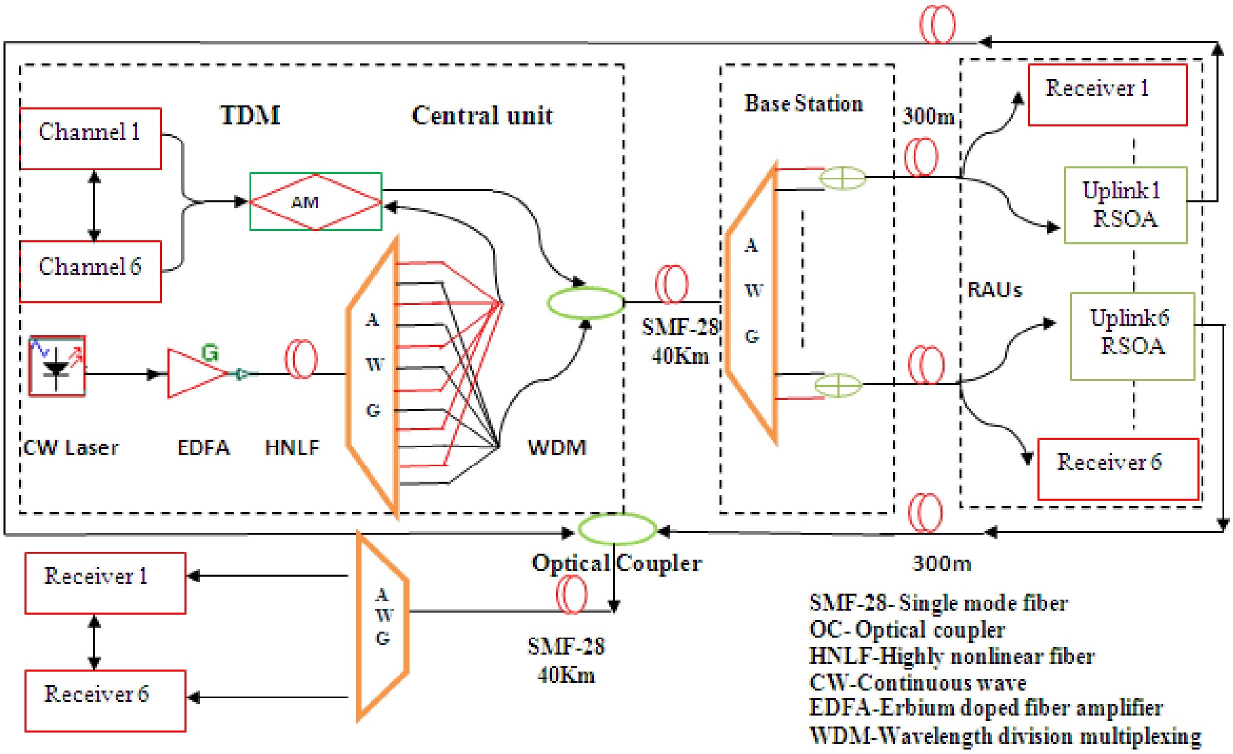

Figure 1.1 Depiction of proposed system architecture

Six pseudo-random bit sequence (PRBS) generators are in the system to generate binary data for downlink (DL) or downstream transmission. All the channels are multiplexed in time domain and are carrying speed of 1 Gbps. The OTDM signal, with odd carriers produced after SPM and AWG is modulated with electrical NRZ signal using AM. All even carriers are used as a WDM channels and are combined with modulated OTDM signal by incorporating couplers. The un-modulated WDM carriers play a important role for radio access units. These un-modulated WDM carriers are as well used for upstream data communication, each working at 167 Mbps. Two identical 40 Km long SMF-28 are carrying data and connect central unit and base station for bidirectional communication. This is the architecture and working of system central unit.

Now base station is a main unit to provide linking between the central office and six radio access units. Arrayed waveguide grating is employed to distribute twelve modulated and unmodulated signals. TDM signals are modulated and WDM signals are unmodulated. Each modulated λ1–λ11 optical carrier is combined with the particular λ2–λ12 carrier. Combined signals are communicated over 300-m optical fibers in the direction of six different radio access units (RAUs). Fig. 1.1 represents the base station section consisting of AWG. Each radio access unit receives the combined signals of modulated and unmodulated data, split into two different signals incorporating optical filters. OTDM signal is fed to receiver section which consisting of PIN photo detector and followed by low pass Bessel filter. Radio signal is observed after photo detector with the help of radio frequency analyzer. Time delays used to alternate the width of the overlapping area which is fed to photo detector Main idea to change the width to generate radio signal or millimeter wave. Because every optical signal is frequency chirped, consequently, altering the emergence region linking two pulses varies the carrier frequency of the mm-wave signal generated through RHD (radio heterodyne detection) [13].The radio wave after PIN is boosted with trans impedance amplifier and filtered by means of a Gaussian shaped BPF. Radio signal is transmitted after band pass filter to main station with antenna. The signal is then passed through a low-pass filter (LPF) for bit-error rate (BER) calculation. Bit error rate represents the errors in the received signals and decides the Q-factor, threshold and SNR etc. WDM carrier signal is unmodulated and further transmitted for modulation in upstream direction. Radio signal form access units emerge at RAUs and modulated with uplink data using RSOA (reflective semiconductor amplifier). RSOA is for modulation of electric data and also provide amplification. Use of this particular amplifier reduces cost of the overall system to greater extent. The modulated upstream signal of each radio access unit is transmitted to base station all the way through a separate 300-m optical fiber. At the base station, the WDM optical signals of the six RAUs are combined by optical coupler. The combined WDM signal transmitted toward central unit over a separate 40-km optical fiber. Demultiplexing of the signals to respective port has been done by arrayed waveguide grating. The signal is then passed through a low-pass filter (LPF) for bit-error rate (BER) calculation. Bit error rate represents the errors in the received signals and decides the Q-factor, threshold and SNR etc.

1. RESULTS AND DISCUSSION

Proposed system architecture is evaluated with the premier optical simulation tool Optiwave Optisystem. Here, the results of the proposed simulated system of RoF System have been discussed. System consists of an EDFA optical amplifier to boost the input laser signal for SPM. Fig. 1.2 depicts the laser signal before and after HNLF. System specifications and HNLF parameters are given in table 1.1 and table 1.2.

Table 1.1 System specifications

Parameters	***Values***
No. of channels	12 carriers
Bit rate	1 Gbps
Transmitter power	0 dB
Distance	40Km+300m (Both DL & UL)
Modulation type	Non return to zero
Spectral broadening through	Self phase modulation
Upstream modulator	RSOA
Time window	1.6x10-8
Photo detector	PIN

Table 1.2 HNLF specification

Parameters	***Values***
Length	500m
Attenuation	0.55dB/Km
Dispersion	0 (ps/nm/km)
Dispersion Slope	0.032(ps/nm2/km)
Effective area	11um2
n2	2.6e-019
Reference wavelength	1550nm
Polarization mode Dispersion	0.2ps/km

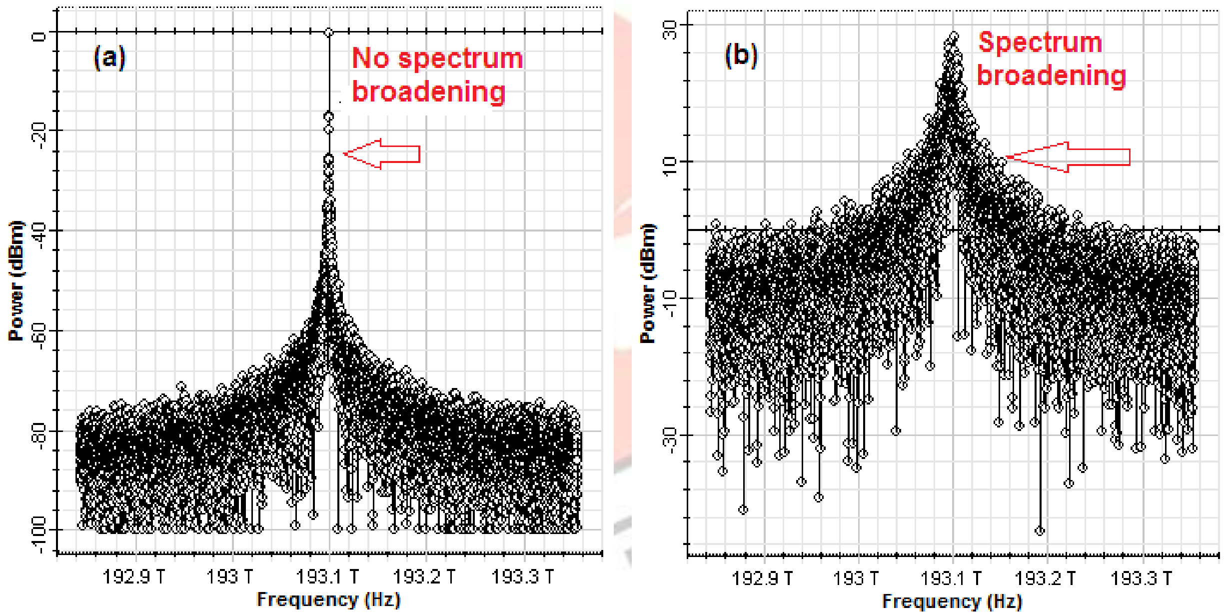

Figure 1.2 Depiction of optical spectrums after (a) CW Laser (b) HNLF (SPM)

Analysis has been taken on 0dB and varied distance in the interval of 10km, 20 Km, 30 Km, 40 Km and 50 Km for downstream as well as upstream communications. Optical channel is connected to semiconductor optical amplifier due to its small size and on chip integration. SOA makes system less bulky and less complicated. On the contrary, for upstream no amplifier has been used. Results are observed in terms of Q-factor and BER (bit error rate). It is observed that as the distance is increased, quality of the signal decreased as shown in table.1.3. Analysis has been carried for two different photo detectors APD and PIN to find the best suited detector. Effect on bit error rate is opposite to quality. BER increases as distance increased and introduce more noises. Q-factor inversely varies with distance, data rate and line width.

Table1.3 Distance versus Quality (Downstream)

Table1.4 Distance Vs BER (Downstream)

Distance(km)	***PIN detector***	***APD detector***
10	13.26	15.89
20	10.05	12.21
30	7.49	11.11

40	6.17	7.42
50	5.11	6.06

Distance(km)	*PIN detector*	*APD detector*
10	2.3x10-40	5.1x10-61
20	3.2x10-24	9.9x10-35
30	3.09x10-14	7.6x10-29
40	4.81x10-8	3.4x10-13
50	1.48x10-7	4.4x10-10

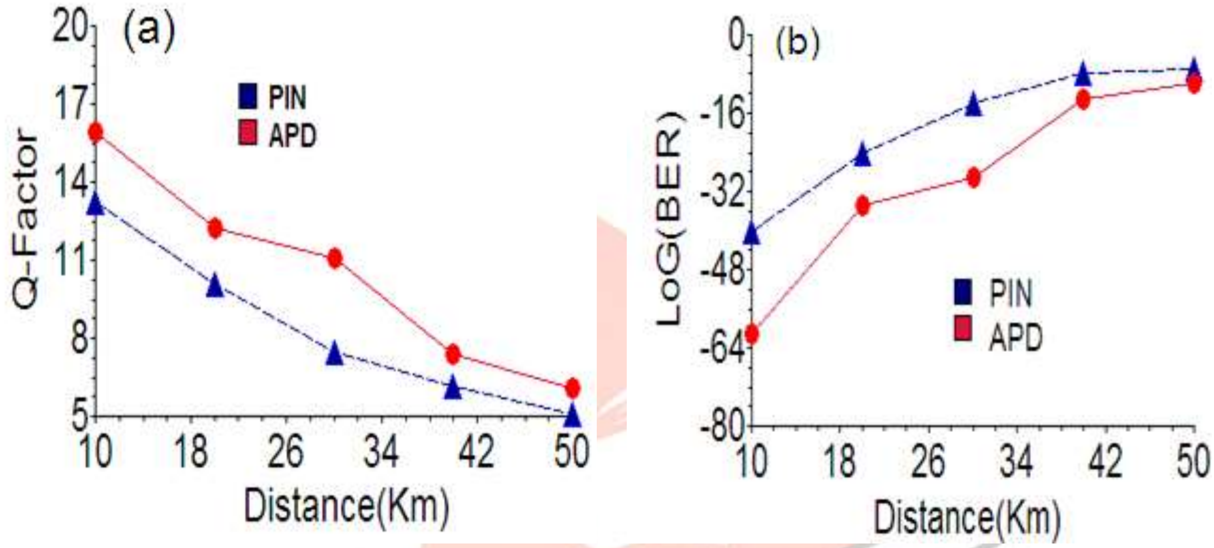

Figure 1.3 Graphical representation of distance (km) versus (a) Q-factor (b) LoG(BER) for downstream

In optical communication systems, only optical signal to noise ratio (OSNR) could not accurately measure the system performance, especially in WDM systems. Typically, quality factor Q is a one of the important indicators to measure the optical performance by which to characterize the BER. Now, similar observation has been taken for uplink or upstream data. In uplink data from radio access units is modulated on WDM carriers with channel spacing of 10 GHz. Reflective semiconductor optical amplifier is the key factor to reduce cost of the system and modulate data without use of any electro absorption or mach zehnder modulator. Evaluation of different link length is also evaluated for uplink data transmission. Length of SMF-28 is varied from 10-50 Km with the difference of 10Km. Two photo detectors are also considered one after another same as downlink.

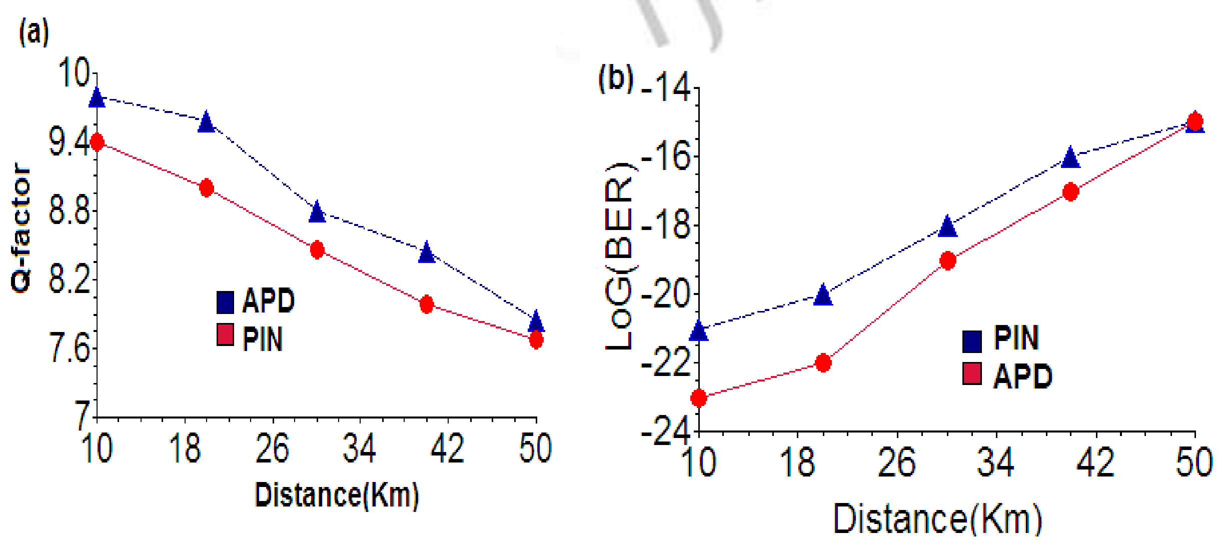

Figure 1.4 Graphical representation of distance (km) versus (a) Q-factor (b) LoG(BER) for upstream

The bit error rate variation among different channels WDM as well as OTDM depicted in Fig. 1.6. It represents the average no. of ones with their Quality and bit errors along with signal to noise ration, eye closer penalty etc. Noise can be attributed to the fluctuations observed on the peak of the broadened eye. Received power for upstream and downstream is shown in fig 1.5. It is clearly observed that with then increases of link distance, received power decreases.

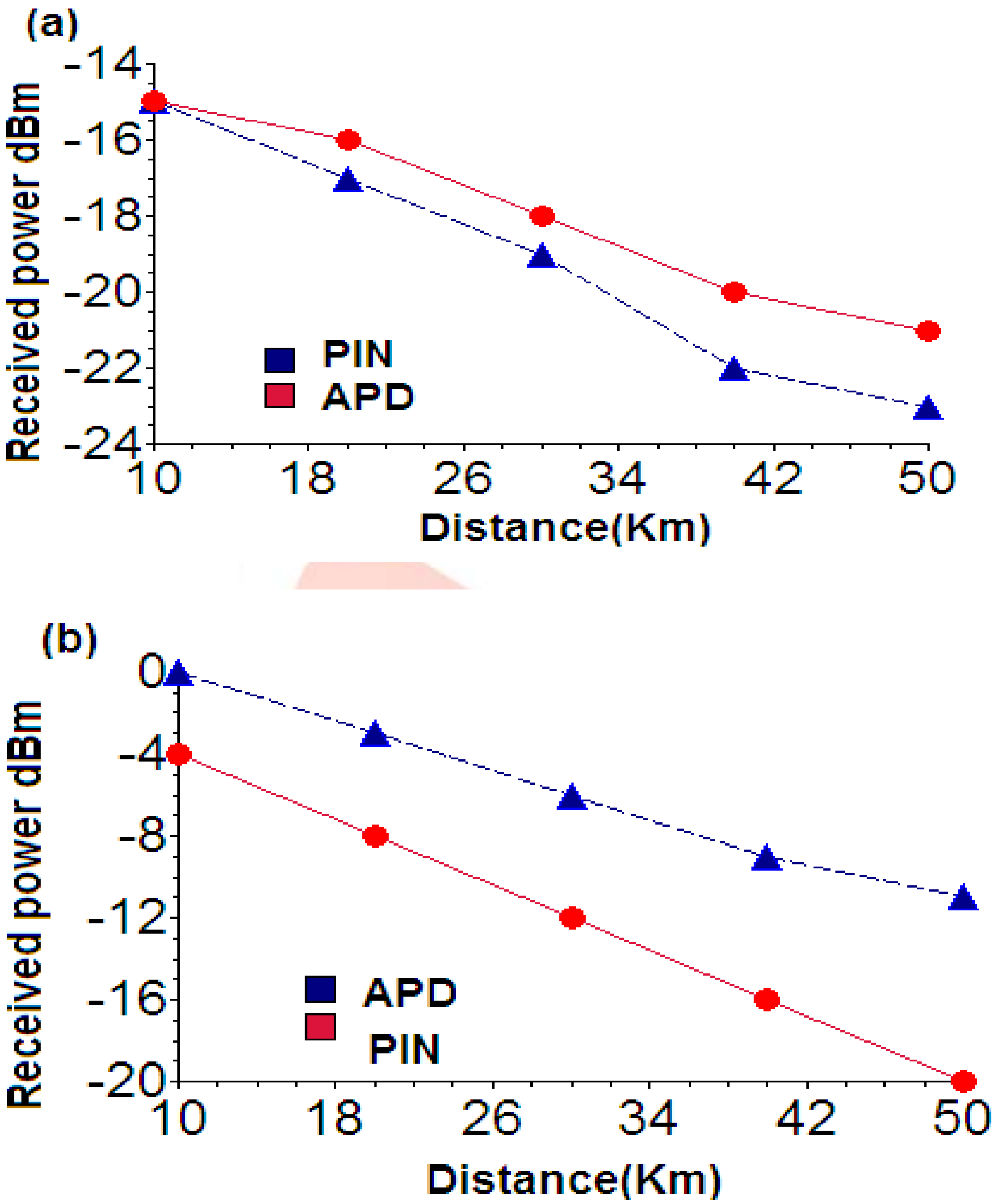

Figure 1.5 Graphical representation of Received power (dBm) versus distance(Km) for (a) Downstream (b) Upstream

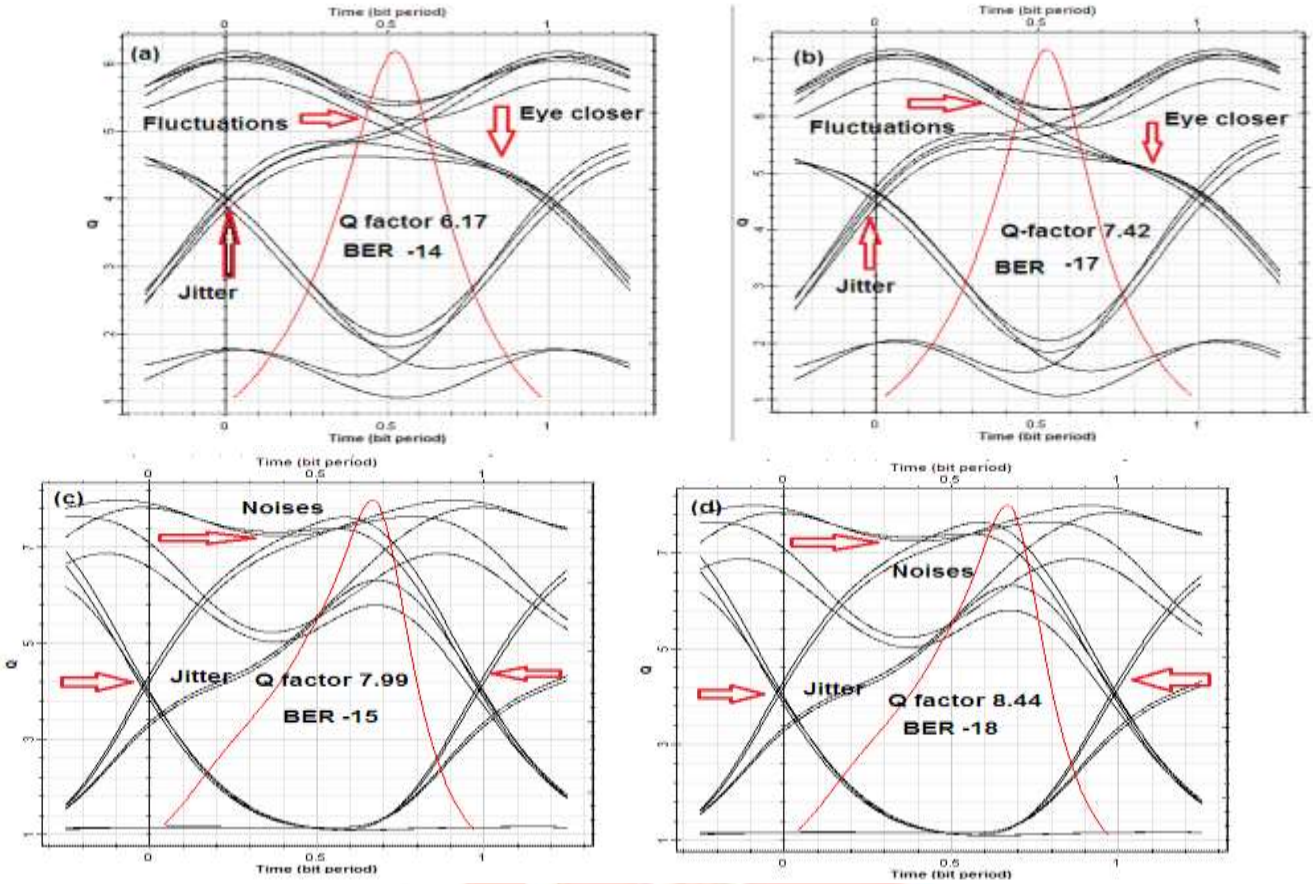

Figure 1.6 Eye diagram for (a) Downstream incase of PIN (b) Downstream (APD) (c) Upstream (PIN) (d) Upstream (APD)

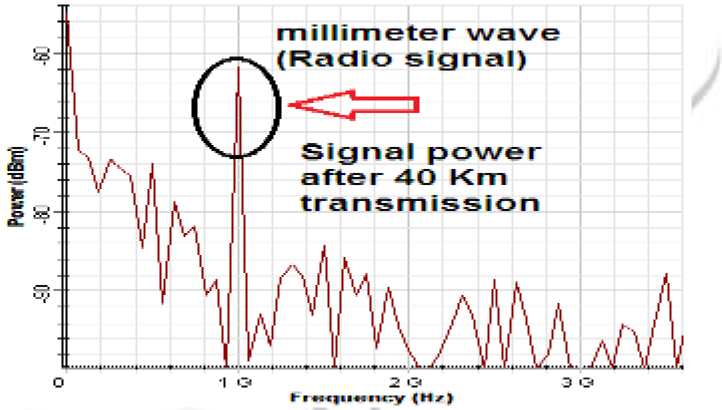

Figure 1.7 millimeter wave signal after photo detector in downstream RAUs

CONCLUSION

A bidirectional or duplex radio over fiber system for mobile communication is demonstrated with the carrier generation from fiber nonlinearity self phase modulation. A speed of one Gbps data is transmitted to cater the demands of future generation. Total six radio access units are considered and each carry 167 mbps data speed. Major work is carried out to transmit data from central office (CO) to mobile base station over 40 Km SMF-28 and from base station (BS) to radio access units over the fiber stretch of 300m. In this article, a prominent and premier property of semiconductor optical amplifier is utilized to fulfill the current demands of data speed and cost effective systems. RSOA serves the upstream radio access units and minimize the cost of ROF system. BER performance depicts that system for both upstream and downstream works with 10-9 BER and in acceptable limits. It may also concluded that proposed system architecture even work for prolonged distance by reducing optical fiber dispersion as compared to the distance taken in this research article.

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