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A Carrier Generated Self Phase Modulation Reliant Rof System Employing RSOA As Modulator For Upstream RAUs And Incorporating DCF, FBG For Dispersion Compensation

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Abstract: A long reach and pulse width reduced radio over fiber architecture based on self phase modulation is demonstrated for duplex communication to serve radio access units (RAUs). A duplex architecture that operated on rate of 1 Giga bits per second has been verified and deliberated on performance parameters. Utmost work is accomplished to broadcast 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. Work is carried out to fulfill the demands of future generation high speed mobile communication systems that cater multiple RAUs at prolonged distances. Pulse width reduction efficiency is scrutinized for dispersion compensation fiber and fiber brag gratings in the proposed architecture. A well-known characteristic of reflective semiconductor optical amplifier is pressed into service to deliver data speed and cost effective systems. Reflective semiconductor optical amplifier (RSOA) serves the upstream radio access units and minimizes the cost of ROF system.

Keywords: Pulse width reduction (PWR), Base Station (BS), Millimeter waves (mm-waves), Dispersion compensation fiber (DCF), Fiber Bragg gratings (FBG)

I. INTRODUCTION

The rise of mobile communication is radically altering the internet requirement as well as wired and non-wired arrangement communications [1], [2]. Push forward by means of promising applications such as interactive video service, the mobile data traffic is projected to increase 13-fold between 2012 and 2017 [3]. These days 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 waves 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]. In multiple wavelength system, a degradation factor plays a vital role and termed as dispersion. Dispersion is, when several wavelengths are used to carry signals and circulate in optical medium, pulse width spreading and fiber nonlinearities deteriorate actual signal. Dispersion is the width increment of light pulses when they travel down through optical fiber, which results in distortion of the signal. This undesired spreading of pulses introduces Inter-symbol Interference (ISI). For pulse width reduction the utilization of dispersion compensated fiber (DCF) is a significant technique [10]. These optical fibers are specifically intended fibers with negative dispersion. Another method is the use of FBG, such a device reflects light when its wavelength corresponding to the grating period. The grating works as a mirror, selectively reflecting only one wavelength and transmitting all the others [11].

In this research article, we accentuate on the pulse width reduction and self phase modulation based carrier generation form single laser. We proposed a useful as well as competent scheme through the integration of nonlinearity based self phase modulation, to cut the expenditure and to offer a long reach system. Major degradation in the RoF communication which limits the accomplishment of prolonged distance transmission is due to pulse broadening and inter-symbol interference. To do the task of pulse reshaping, pulse width reduction is used incorporating DCF and FBG. 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 optical modulation in upstream eliminating the requirements of external modulators.

II. 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.

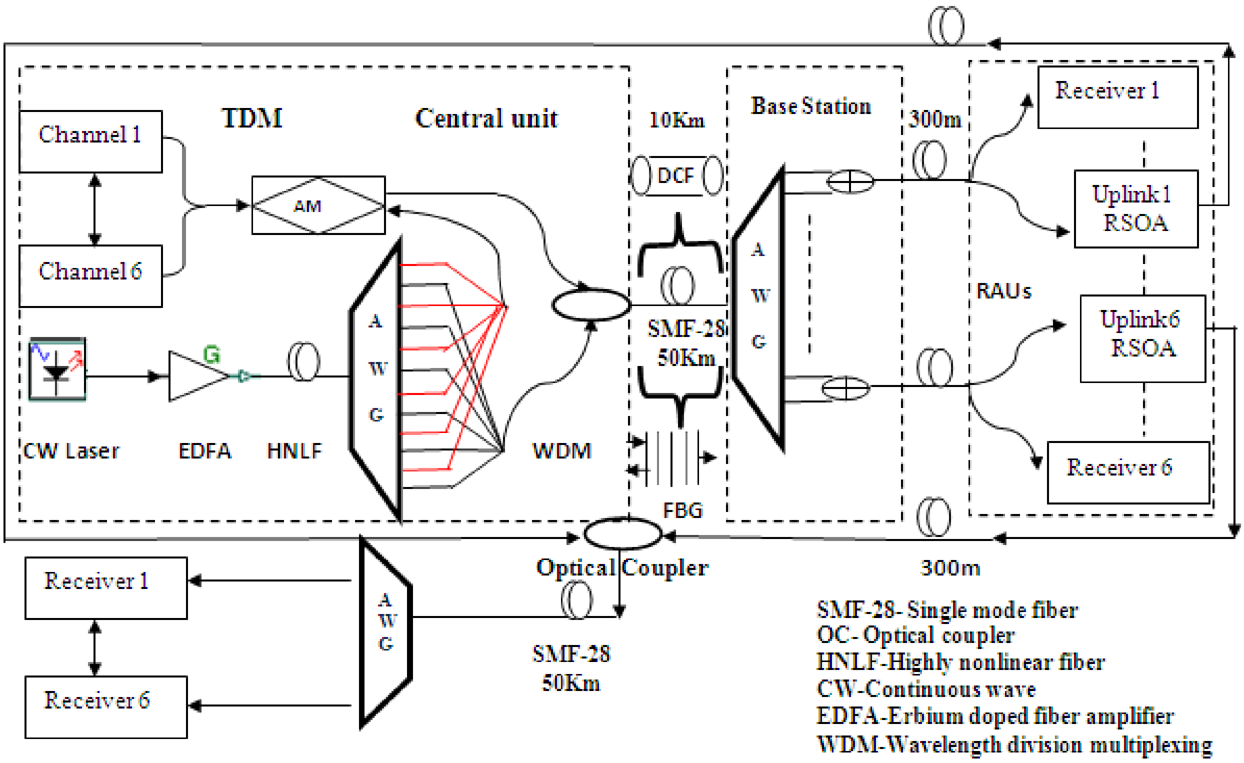

Figure 1.1 Depiction of proposed system architecture

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. A DCF followed by SMF is placed after calculation in order to reduce the pulse spreading due to dispersion effects. Fiber Bragg grating is also a dispersion compensation module and incorporated after optical fiber when DCF is not used. This is the architecture and working of system central unit.

Length of Dispersion compensation fiber =

$$D_{SMF} * L_{SMF} + D_{DCF} * L_{DCF}$$

Table 1.1 System specifications

Parameters	*Values*
No. of channels	12 carriers
Bit rate	1 Gbps
Transmitter power	1 mw (0db)

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

Where D_{SMF} is dispersion of single mode fiber in ps/nm/km and L_{SMF} is length of SMF. Similarly, D_{DCF} is dispersion of DCF in ps/nm/km and L_{DCF} is range of DCF.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).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.

III. RESULTS AND DISCUSSION

Proposed system architecture is evaluated with the premier optical simulation tool Optiwave Optisystem.

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

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, DCF and FBG parameters are given in table 1.1, table 1.2, and table 1.3.

Table.1.3 Specifications of DCF and FBG

Parameters	***Values***
Length of DCF	10Km after 50Km SMF
Attenuation(dB/Km)	0.5
Dispersion(ps/nm/km)	-85
Dispersion slope(ps/nm2/km)	0.075
Polarization mode dispersion (ps/km)	0.2
Non linear effects	Included
FBG dispersion(ps/nm)	-850
Insertion loses(dB)	4
Bandwidth(GHz)	2

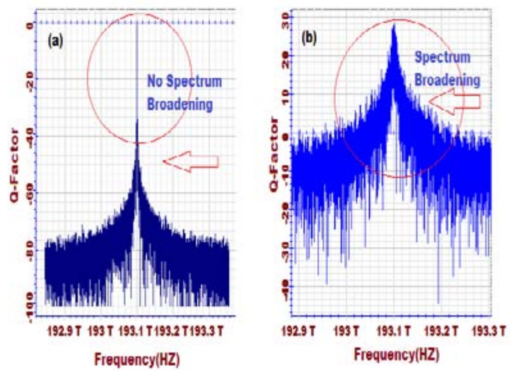

Figure 1.2 Depiction of optical spectrums after (a) CW Laser (b) HNLF (SPM)

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)

Distance(km)	***PIN***	***APD***
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

Table1.4 Distance Vs BER (Downstream)

Distance(km)	***PIN***	***APD***
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

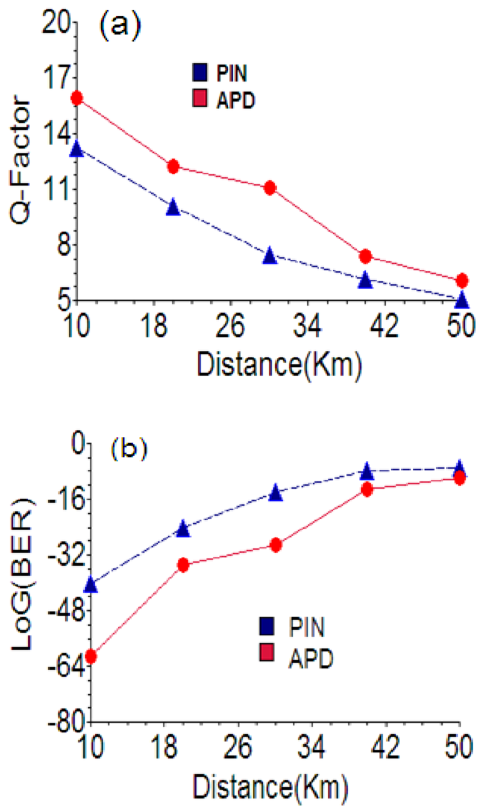

Figure 1.3 Graphical representation of distance (km) versus (a) Q-factor (b) LoG(BER) for downstream

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.

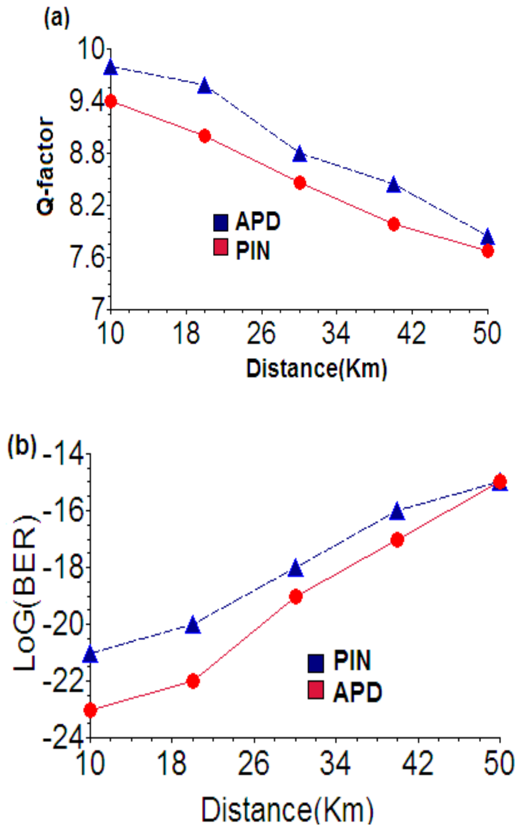

Figure 1.4 Graphical representation of distance (km) versus (a) Q-factor (b) LoG(BER) for upstream

The bit error rate variation among different channels WDM as well as OTDM depicted in Fig. 1.7. 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.

Pulse width reduction is a important issues in the proposed system design. In order to compensate the effects of pulse broadening, a dispersion compensation fiber and fiber brag gratings are used. Also on the basis of their performance a comparative analysis also has been done. DCF as a pulse width reduction module varied from 2-10 Km as the SMF increase from 10-50 Km. All the lengths of DCF are calculated and measured specifically to exhibit better performance. At 50Km transmission distance results are compared with and without DCF. It is seen that after 50 Km SMF with DCF quality of reception is 10.42 and without 5.50. So, great enhancement in Q-factor is observed. Second case is to evaluate the pulse width reduction by using FBG. Here also a improvement can be seen and Q-factor with and without FBG is 9.22 and 5.50 respectively. From the outcomes we suggest that DCF is better than FBG in terms of pulse width reduction. Fig 1.7 represents the Eye diagram of system with DCF<FBG and without these modules.

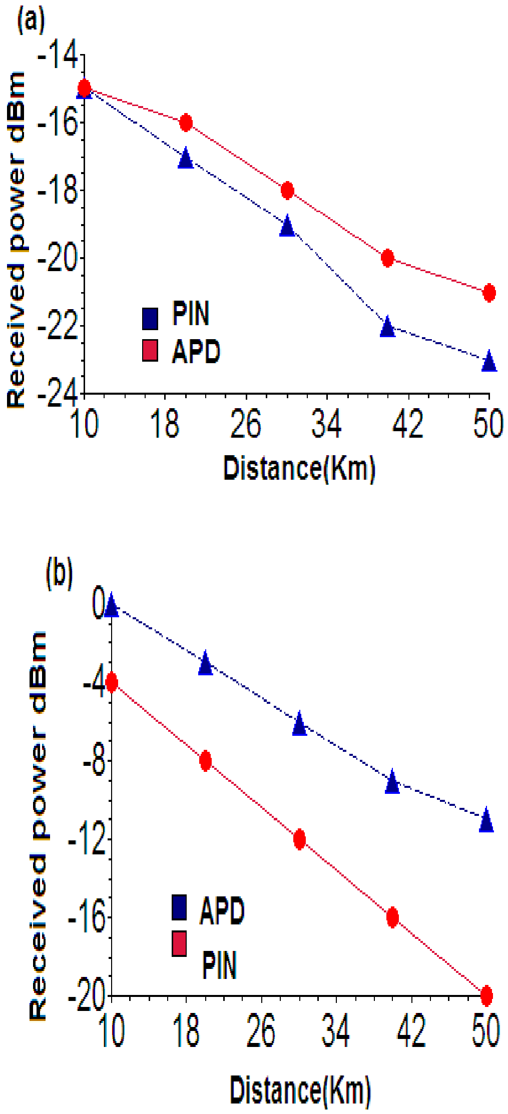

Figure 1.5 Graphical representation of Received power (dBm) versus distance(Km) for (a) Downstream (b) Upstream

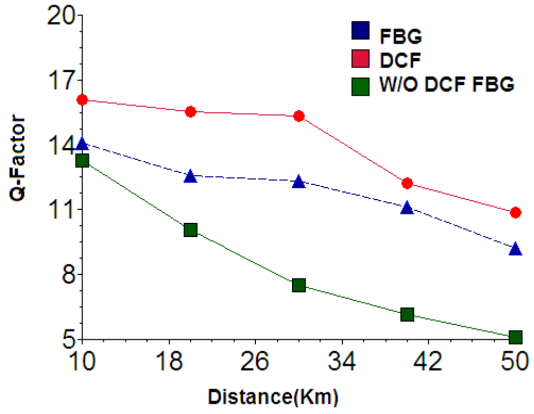

Figure 1.6 Graphical representation of Q-factor versus distance(Km) for DCF and FBG

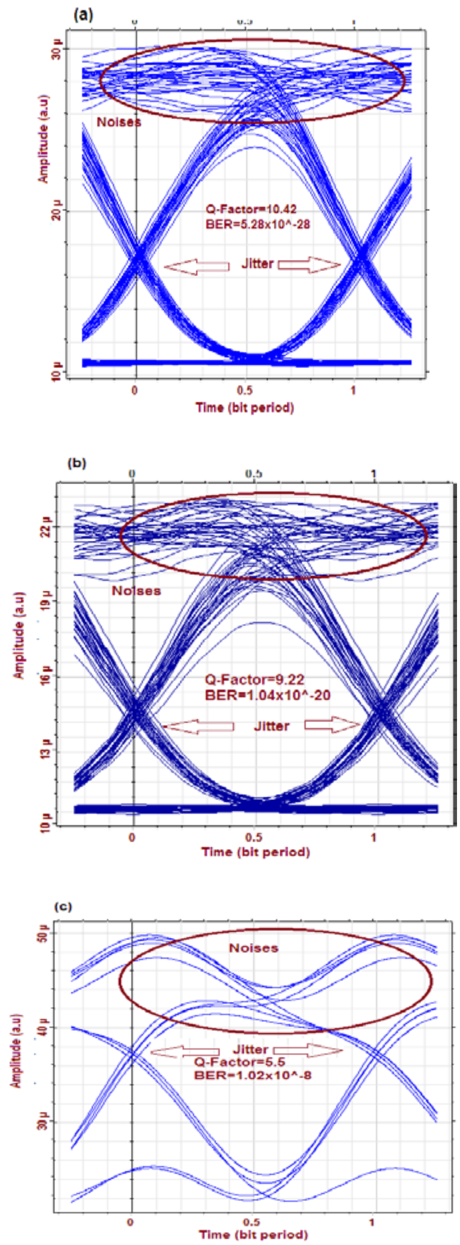

Figure 1.7 Eye diagram for (a) DCF (b) FBG (c) W/O DCF and FBG at 50 Km

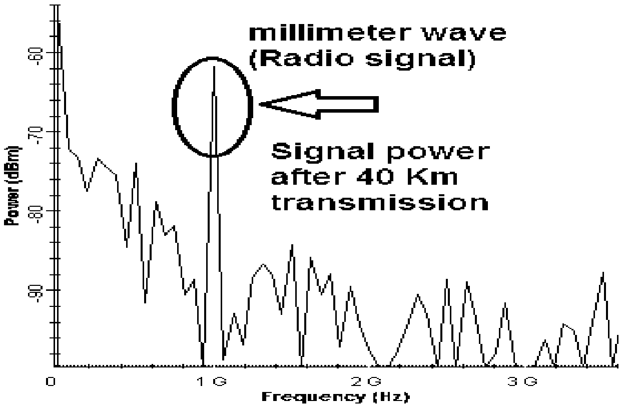

Figure 1.8 millimeter wave signal after photo detector in downstream RAUs

IV.CONCLUSION

Bidirectional radio over fiber transmission of signals over coherent pulsed self phase modulation reliant optical carriers generation has been demonstrated. Signals were transmitted at the accumulated pace of 1 Gbps in duplex RoF system. This work focused on the cost effective approach to generate and communicate signals in BRoF architecture. We proposed a useful as well as competent scheme through the integration of nonlinearity based self phase modulation, to cut the expenditure and to offer a long reach system. Major degradation in the RoF communication which limits the accomplishment of prolonged distance transmission is due to pulse broadening and inter-symbol interference. Pulse width reduction efficiency is scrutinized for dispersion compensation fiber and fiber brag gratings in the proposed architecture. It is observed that system works for 50Km with good quality when DCF is incorporated in the system. Comparison revealed that FBG is used for PWR but DCF performs superior to FBG.

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