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DESIGN AND OPTIMIZATION OF CPFSK-OFDM BASED RADIO OVER FIBRE SYSTEM

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ABSTRACT: Radio over fibre is an advanced technology which combines RF communication system and optical fibre communication system. Orthogonal Frequency Division Multiplexing (OFDM) technology commits to be a fundamental technique for accomplishing high data rate when it is integrated with RoF**.** Conventionally, Quadrature Amplitude Modulation (QAM) is commonly adopted in optical OFDM communication system. However, OFDM-QAM suffers from large inter -carrier interference (ICI) resulting in degradation of the system performance in terms of reduced Quality Factor. Also OFDM suffers from nonlinearities occurring along the transmission line. In this paper, the Continuous Phase Frequency Shift Keying (CPFSK) modulation technique with OFDM in place of QAM to reduce the non linearity effects in the RoF system and to lower ICI to get better performance of the RoF system is presented. The constant envelope of CPFSK does not have direct impact of the non-linearity .This paper investigates the integration of OFDM with RoF for achieving high data rates and the transmission of the signal over long haul optical fibre with CPFSK as the modulation in OFDM based RoF System .The performance of the system is studied and analyzed in terms of Quality Factor, Bit-Error-Rate (BER)

KEYWORDS: Radio over fibre (RoF),Orthogonal Frequency Division Multiplexing (OFDM) Amplitude Modulation (QAM) , Continuous Phase Frequency Shift Keying (CPFSK) .

I. INTRODUCTION

Radio over fibre (RoF) is an analog optical link transmitting modulated RF signals. In RoF, RF signal is transmitted from from central station (CS) to base station (BS) at the receiver.

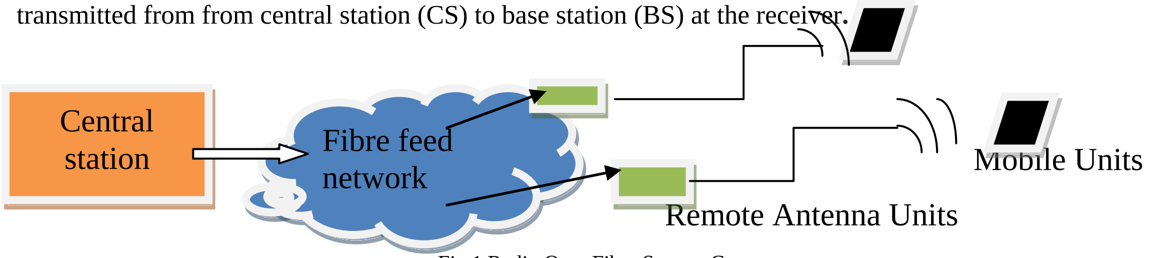

Fig.1 Radio Over Fibre System Concept

The wireless Radio Frequency (RF) signal is converted into an optical signal in an electrical-to-optical (E-O) converter at the Central Station .The optical signal is transmitted through the fibre and detected at the RAP(remote access point), where an optical-to-electrical (O-E) converter recovers the original RF signal, which is amplified and transmitted from the RAP antenna to the Mobile Station (MS)**[1].**Signal is modulated during O-E conversion in two ways, either direct modulation or by using external modulators like **MZM**(Mach–Zehnder Modulator)**[3].**

OFDM(Orthogonal Frequency Division Multiplexing):
Orthogonal frequency division multiplexing (OFDM) is a multiplexing technology, for satisfying the increasing demand of large capacity and high data rate of the system.

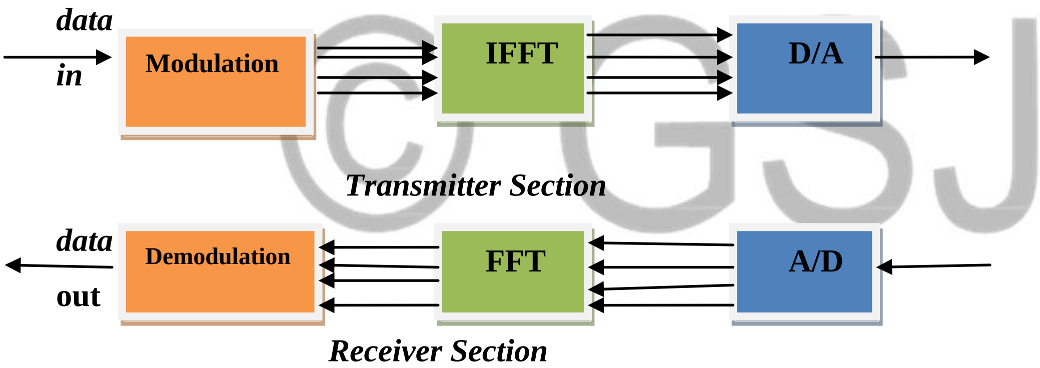

Fig. 2 Modulation and demodulation of OFDM

Fig. 2 shows the OFDM modulation and demodulation process. A bit sequence with rate R is parallelized into N different channels, each with a different frequency. Whole bit rate is divided for each single channel at a bit rate of R/N. The data in each channel is to represent an information symbol and then multiplied by its corresponding frequency. The addition of these parallel information symbols will make one OFDM symbol.
Each subcarrier is separated by 1/Ts from its neighbours. When this occurs, the orthogonality condition is being achieved so a great spectral efficiency for the transmission is achieved. This way, the subcarriers can be recovered at the receiver without much inter-carrier interference (ICI) despite strong signal spectral overlapping, by means of the orthogonality condition as in equation[1]

$$\int_{-T/2}^{T/2} cos\left(\frac{2\pi nt}{T}\right) cos\left(\frac{2\pi mt}{T}\right) dt = 0, m = n \qquad [1]$$

The transmitted signal of an OFDM system for one OFDM symbol period as a following form **[4]**

$$s(t)=Re\{\sum anh(t)exp(j2\pi fnt+\emptyset)\} \qquad [2]$$

where
a n :denote the transmitted data symbol for the n-th subcarrier;
h(*t*): denote the pulse shaping filter response;
fn :denote the *n*-th subcarrier frequency and $fn = fc + n\Delta f$.

. However, the OFDM modulator and demodulator can be implemented easily by the Inverse Fast Fourier transform (IFFT) and Fast Fourier transform (FFT) respectively. The time domain coefficients *cm* can be computed by IFFT as

$$Cm=1/\sqrt{N}\sum_{N=0}^{N-1} an\exp(-j2\pi nm/N) \quad [3]$$

where:

an: denote the input of the IFFT block which is the data symbol for *n*th subcarrier;
cm: denotes the m-th output of the IFFT block.

CPFSK(Continuous Phase Frequency Shift Keying):

CPFSK is distinguished from other formats by its continuously constant amplitude, and as such it offers an interesting case for mitigating nonlinear refraction effects in fibre.
A CPFSK signal is defined as

$$s_m(t) = \sqrt{2W/T}\,\mathrm{Cos}(w_0 t + d_m \frac{\pi g t}{T} + x_m)$$

[4]

For, MT ≤ t ≤ (M+1) T

Where $f_0 = \frac{w_0}{2\pi}$ the carrier frequency ,d_m the m-th bit/symbol($d_m = +1\ or -1$), g is modulation index and x_m is the phase represented as:

$$x_m = [x_{m-1} + (d_{m-1} - d_m)\pi g m]\ mod\ 2\pi \quad [5]$$

Where x_0=0 and the phase term simply establishes a continuity at interval ends with respect to phase.

II. RELATED WORK

Name of the paper	Paper no	Parameters	Findings
Hybrid OFDM and Radio-Over-Fiber Transport System Based on a Polarization Modulator	[1]	• OFDM-QPSK • FFT:256 • DFB laser:1545.8nm • Bit rate:1.25Gbps • Distance:25km	• Power penalty:0.3dB • BER:5.67E-05
Modelling and Simulation of OFDM Scheme for Radio over Fibre (RoF)	[5]	• OFDM with 16-QAM • FFT:1024 • Bit rate:10 Gbps • Distance:100 km	• Received power :71.16 • Quality factor :32Db • BER:3.07E-63
Compensation of modulation distortion in microwave radio-over-fibre systems using chromatic dispersion	[7]	• 16 -QAM • Data rate 122.5 Mbps • DFB laser-1559.42 nm	• BER (Bit Error Rate):4.1E-05 • Q-Factor:19.10dB
Design of full duplex radio over fibre (Fi-Wi) link through FBG	[11]	• CPFSK • DPSK • FBG • 200electrical frequency • CW Laser power:20 dBm	• BER of DPSK:1.60E-71 CPFSK:1.07E-82 • Quality factor for DPSK:19.22 dB CPFSK:44.45

		• Distance:20km	dB
CF technique with CPM mappers in OFDM systems for reduction of PAPR.	[8]	• CPFSK as the modulation • Modulation indices = 1/2	• CPM mappers offer superior PAPR performance compared to memoryless mappers in an OFDM system

CF technique with CPM mappers in OFDM systems for reduction of PAPR.	[8]	• CPFSK as the modulation • Modulation indices = 1/2	• CPM mappers offer superior PAPR performance compared to memoryless mappers in an OFDM system
A Study of Dispersion Compensation of Polarization Multiplexing-Based OFDM-OCDMA for RoF	[13]	• OFDM-64QAM • FFT:512 • CP:1/32 • DFB laser • PRBS-32768 bits • Distance:80km	• BER:3.00E-05 • method can effectively suppress interference of the signal from remaining dispersion

III. WORK DONE

In this paper, the design and investigation of Optical Orthogonal Frequency Division Multiplexing (OFDM) integrated with Radio Over Fibre (RoF) has been done. Continuous Phase Shift Keying has been employed as modulation technique in OFDM system. Conventional system used QAM as the modulation in OFDM system.

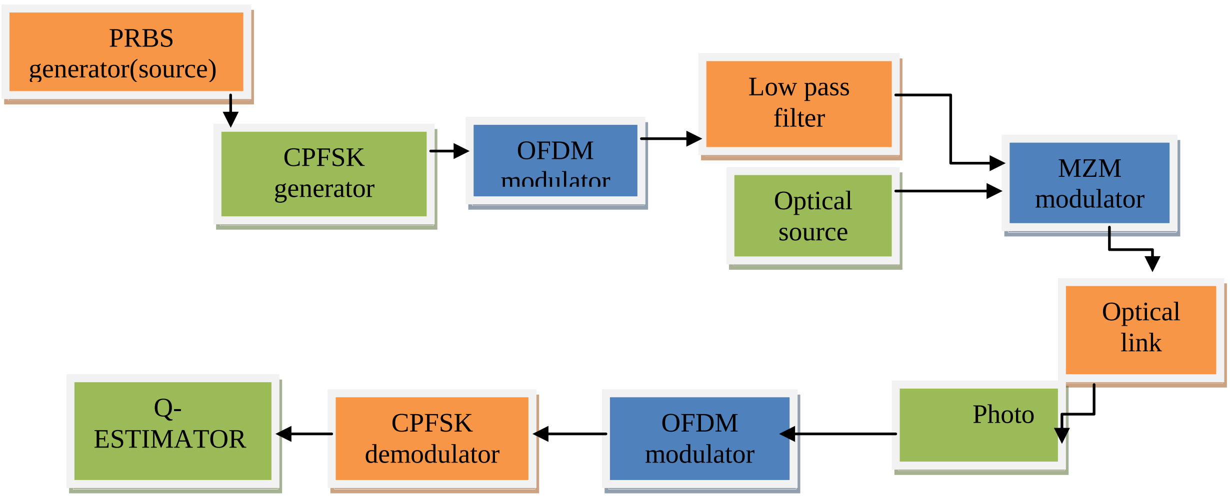

Fig. 3 Block Diagram of OFDM based RoF System Model

At the transmitter of an OFDM system, data are portioned in the frequency domain and an IFFT is used to modulate the data into the time domain At the receiver, an Fast Fourier Transform is used to get the sent data.

Design and implementation CPFSK –OFDM based Radio Over Fibre System:
In the transmitter section, pseudo-random sequence generator used to generate a logical signal which is then modulated by the modulation technique used in the system. Output signal is then passed through a band-pass filter which is further sent to an external modulator preferably Mach-Zehnder Modulator(MZM) which modulates laser optical signal. This is step E/O conversion, where optical modulator is used in this system model is LiNb MZM. CW laser is used to deliver signal of continued optic waves. After transmitter section ,signal is sent through optical fibre of different lengths and is further amplified using booster or pre-amplifiers .
At the receiver, optical filter is used which is further connected to photodiode to convert light signal back to electrical signal The PIN photodiode component is used to convert an optical signal into an electrical current based on the devices responsivity. This resulted signal is then passed through low pass filter to remove unwanted noise and finally displayed on the probe used.

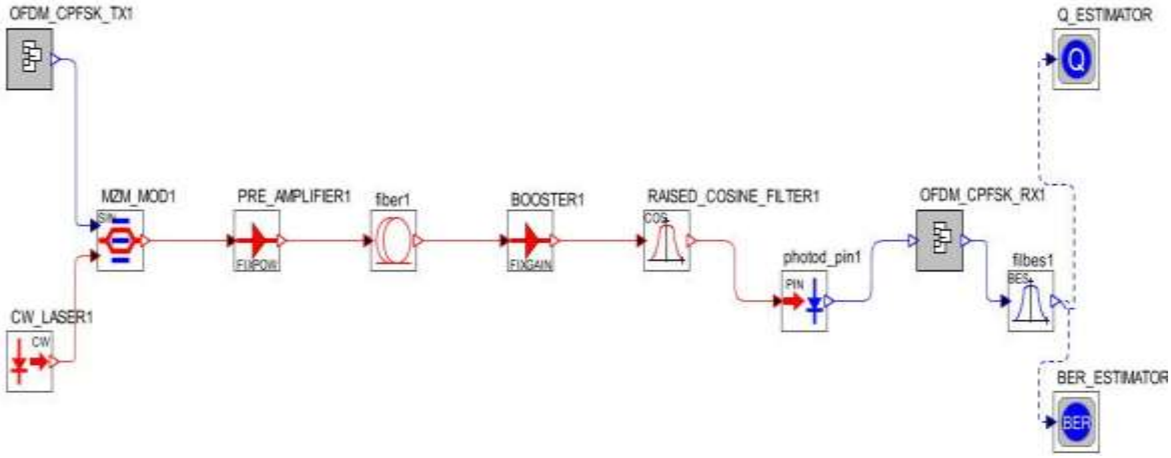

Fig. 4 The Block Diagram of CPFSK-OOFDM-RoF System

Fig.4 shows the setup configuration of the OOFDM-RoF system for a 100 km SMF length and a dispersion of 16ps/nm/km. The OOFDM-RoF transmitter is constructed for CPFSK (2 bit-per-symbol) at a data rate of 10Gbps. Table 1 provides the OFDM transmission parameters, which consist of 512 subcarriers with FFT value of 1024. The output of the OFDM is modulated by using a CPFSK modulator as stated in equation [6]

$$V_{out}(t)=G[I_1(t)\cos(2\pi f_c t+\theta_c)-I_2(t)\sin(2\pi f_c t+\theta_c)]+b \quad [6]$$

where G is the gain, I_1 and I_2 are the electrical input signals, b is the bias,

f_c stands for the carrier frequency, and θ_c is the carrier phase

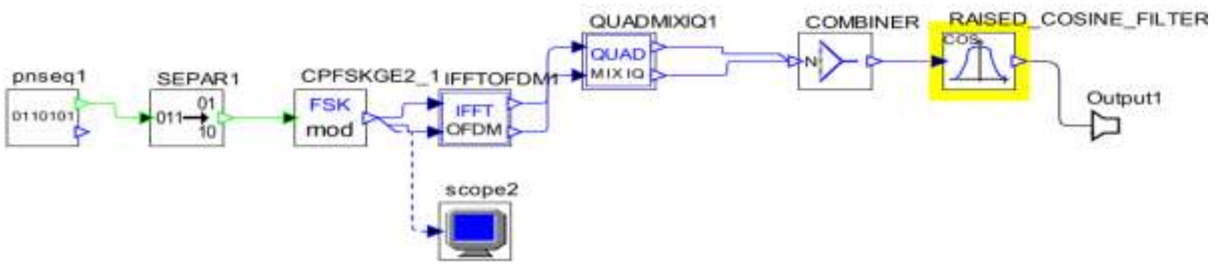

Fig. 5 Inside view of the transmitter

This part consists of CPFSK sequence generator to generate bit sequence of OFDM signal with 4 bits/symbol .OFDM modulation uses 512 subcarriers at CPFSK and 1024 points of FFT. Scheme of simulation RF-OFDM transmitter is shown in Fig 5.

Table 1 OFDM –CPFSK transmitter modulation parameters

PARAMETERS	VALUES
Bit rate	10Gbps
No of subcarriers	512
IFFT points	1024
Cyclic prefix	0.8
CPFSK frequency of modulator	20GHz
Baud Rate of OFDM transmitter	20GHz

The lithium niobate (LiNb) Mach-Zehnder Modulator with extinction ratio 3dB is used to modulate the OOFDM-RoF-transmitter with a 7.5 GHz radio frequency (RF) carrier to the optical carrier by using a continuous wave (CW) laser diode signal of 193.41THz. The power of the CW laser diode is set at 0dBm. The optical signal is then transferred over the SMF with dispersion of 16 ps/nm/km, signal attenuation of 0.2dBm/km, and a dispersion slope of 0.075 ps/nm2/km. To amplify the optical power signal, fixed gain amplifier is placed on the SMF link to amplify the power of the optical signal. Length of optical fibre link taken as 100 km.

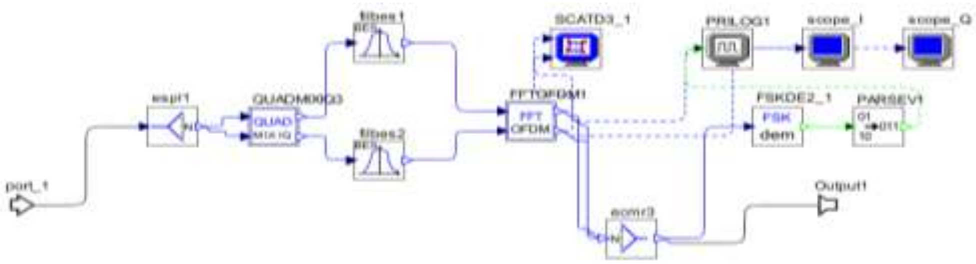

Fig 6 Inside view of the receiver of the system

This part is inverse of the process of RF OFDM transmitter, it consists of OFDM demodulator and CPFSK demodulator. Carrier frequency signal as result of conversion O/E received will be de-multiplexed to get output signal.. Scheme of simulation RF OFDM receiver is presented in Fig.6

At the receiver, a PIN Photodiode (PD) is used to convert the incoming optical signal to electrical signal. The parameters of the PD are as follow: responsivity of 1A/W, 10 nA dark current, a centre frequency of 193.41THz.
The electrical RF signal is then demodulated by OFDM block demodulator. Finally, CPFSK decoder is used to decode the signal in order to get binary signal.

IV. EXPERIMENTAL RESULTS

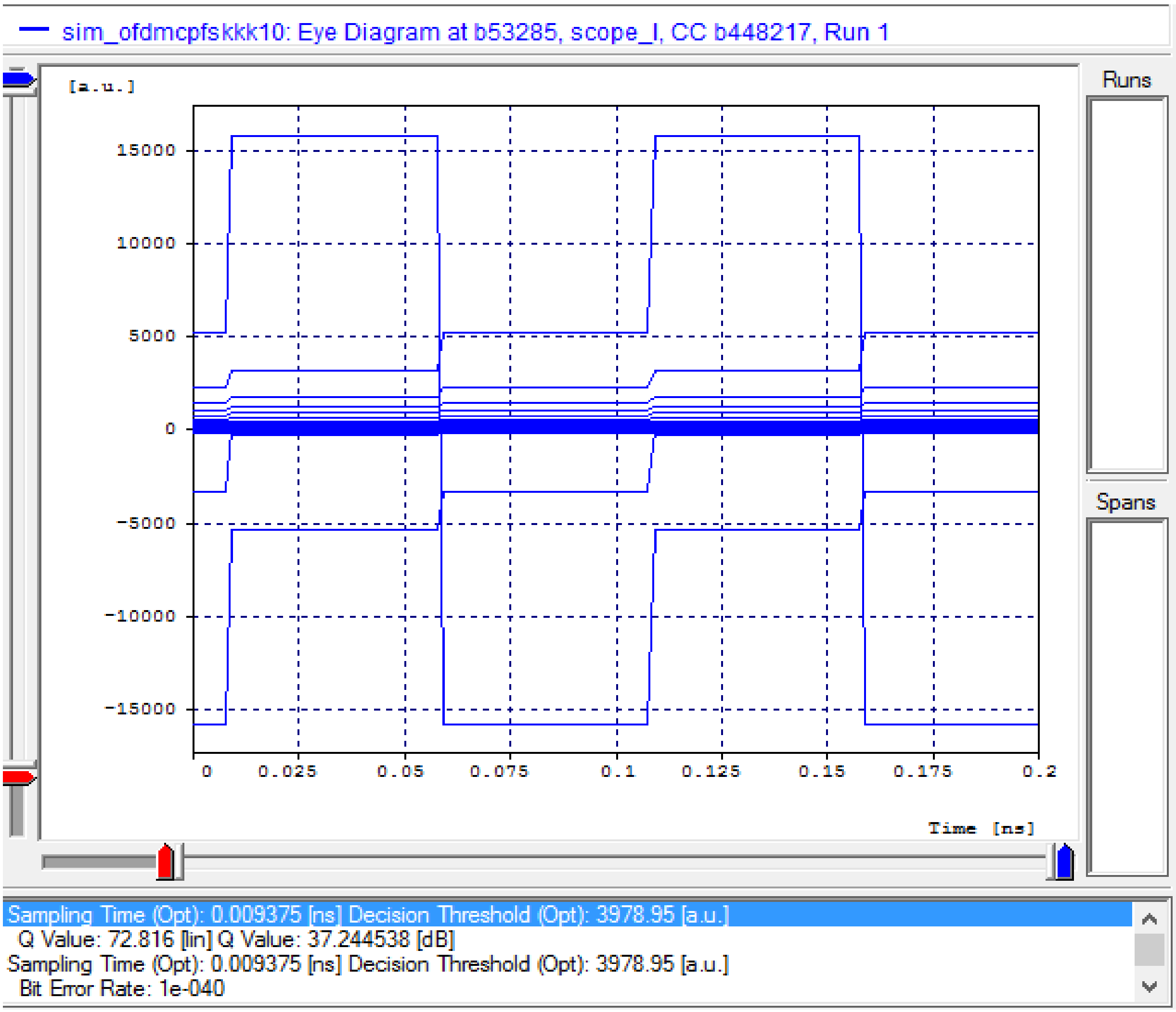

Fig.7 Eye diagram CPFSK-OFDM based RoF system

Fig.7 display the eye diagram for CPFSK-OFDM based RoF system which shows the quality factor of 37.24 dB with Bit Error Rate of 1e-40.Eye diagram shows the intercepted logical signals which form a shape like human eye.Quality factor has achieved a good value with much reduced BER.

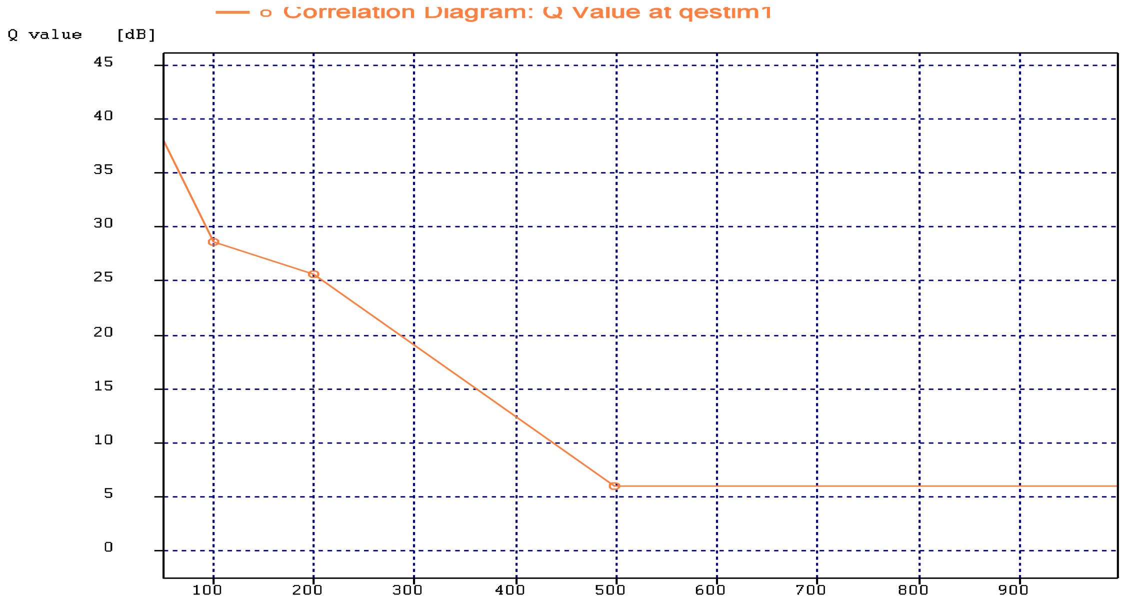

Fig. 8 Quality factor variation with length up to 500 km for 10 Gbps data rate

Fig. 8 displays the variation of quality factor with increasing length up to 500 km. From the above graph it can be seen that for up to 200 km quality factor remains at approx 25 dB and after 200 km, it starts decreasing fast and achieved lowest value of quality factor at 500 km. OFDM signal is able to go through SMF until 500km with amplification without much degradation of the signal, for 10 Gbps bit rate.

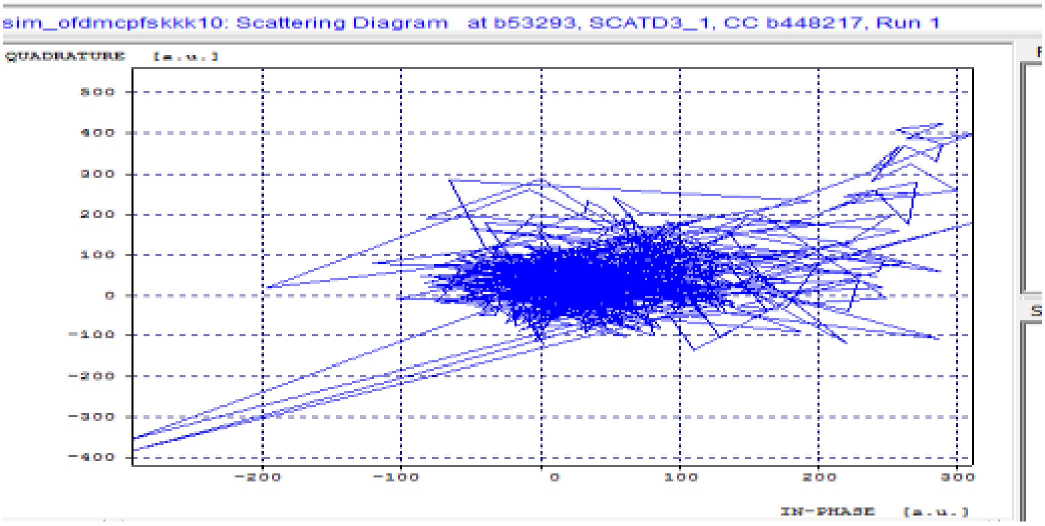

Fig. 9 Scattering diagram for CPFSK-OFDM based RoF System with 10 Gbps bit rate

Fig. 9 displays the constellation diagram of signal for CPFSK digital modulator at the receiver and shows distortion in the signal for longer distance. Constellation diagram is measured between in phase and quadrature phase on x and y axis respectively.in the above graph a lot of distortion in the signal for much longer distance can be seen.

V. CONCLUSION

In this paper implementation of CPFSK-OFDM based RoF system has been done .From the results it can be seen that this system gives a quality factor of 37.24 dB with BER of 1e-40.Analysis of the proposed system with variation in the distance has been done which shows that for 200 km quality factor remains at approx 25 dB and after 200 km, it starts decreasing fast and has achieved lowest value of quality factor at 500 km.

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