International Journal of Advanced Computer Research
ISSN (Print): 2249-7277 ISSN (Online): 2277-7970
Volume-5 Issue-20 September-2015

Investigation in the dispersive medium of the FRFT and its effect on WDM system

Saif H. Abdulwahed*
Communication Engineering Department, Al- Hussein University College, IRAQ

Received: 03-July-2015; Revised: 24-July-2015; Accepted: 02-August-2015

Abstract

The Fractional Fourier Transform is a time–frequency distribution and an extension of the classical Fourier transform; it's used to make a reduction in the fiber nonlinear impairments by pre distorted signal before they launched into the fiber in WDM systems. Time domain FRFT can be implemented by using time lens according to the optical time–space duality theory. It consists of two phase modulators and a dispersive medium between them, the dispersion value of the dispersive medium has been varied from 10 ps/nm/km to 90 ps/nm/km (by 10 ps/nm/km for each step) and each value compared with the BER of the system, for a specific system configuration (4 channels, 300 Km, DPSK modulation format, 100 GHz channel spacing and 10Gb/s bitrate) results that in a dispersion value of 40 and 80 ps/nm/km the best system performance was found (improvement about 1.3 orders in BER at SNR of 10 dB).

Keywords

Fractional Fourier transforms (FRFT), Optical system, Dispersive medium, Wavelength Division Multiplexing (WDM).

1. Introduction

100 Gbit/s/channel and above long-haul optical fiber transmission is becoming more and more popular in order to meet the ever-increasing demand of information. At this speed, the optical signal is severely degraded when transmitted in the fiber due to both the linear and nonlinear distortions, thus limiting the transmission bit rate distance product [1,2].

*Author for correspondence

As is known, the linear distortions include chromatic dispersion (CD) and polarization-mode dispersion (PMD) while self-phase modulation (SPM), cross phase modulation (XPM) and four-wave mixing (FWM) are considered the most among nonlinear distortions. Since dispersion is the most important linear effect, the dispersion-compensating fiber (DCF) which is commonly employed in fiber-optic transmission links has been developed to offset dispersion of transmission fiber over a wide frequency band. In this paper, a proposed scheme called pre-distortion technique Fractional fourier Transform (FRFT) has been applied to mitigate fiber nonlinearity impairments. The pre-distortion method which is based on optical time-domain fractional Fourier transform (FRFT), an extension of Fourier transform (FT), provides a new angle to understand the fiber nonlinearity suppression. An FRFT module with proper configuration will pre-distort those input optical pulses before they are launched into the fiber.

The FRFT operation which depends on a parameter $L_{NL}=(\gamma P_0)^{-1}$ can be interpreted as an angle γ of rotation from the time domain plane to the destination domain plane [3]. When operated by an FRFT of which γ is neither 0 nor $\pi/2$, the signal will be transformed into a special domain between time domain and frequency domain, containing both time and frequency components to equalize related fiber impairments and improve system performance.

The optics community started working on FRFT since 1993. Ozaktas and Mendlovic [4] first suggested a technique for optical implementation of FRFT based on a physical definition utilizing the propagation of light beams through quadratic graded-index media. A piece of graded index (GRIN) fiber of proper length can realize a Fourier transform. And cutting the piece of GRIN into fractional pieces will correspond to implement the fractional Fourier transforms [5,6]. Lohmann[7] gave the definition of optical FRFT based on the characteristics of rotation in phase space of Wigner distribution function. As the two optical setups, which consist of free space and lenses can realize the rotation; they can be used to contribute to performing an FRFT [8]. By using the space–time duality theory [9], well-known concepts and experiments developed in the framework of communications can be transferred to the temporal domain thereby providing new ways for analyzing and processing optical time signals [10,11].

2. Implementation of optical FRFT using "OptiSystem version 11.0"

In the paper [12], Haoran Cheng suggested the use of the bulk-optics system of Fig. 1 for implementing the FRFT. All these parameters are exist in optisystem software, but The phase modulators need a parabolic electric driving signal to drive them, OptiSystem version 11.0 did not have an arbitrary waveform generator to generate the parabolic electric signal, so a configuration has been proposed as shown in the upper part of figure (2). It consists of Pseudo-Random Bit Sequence Generator (PRBS), sine pulse generator, binary NOT gate and binary OR gate.

The sine pulse generator is used to generate parabolic electric driving signal with the help of Binary NOT and Binary OR gates. The reason behind the use of these gates is that the PRBS did not give a stream of binary ones only it gave a random stream of binary ones and zeroes, and that did not make the sine pulse generator to produce a parabolic signal cause the sine pulse generator produce one half cycle when it receive binary one and no half cycle when it receive binary zero ,so by use these gates the sine generator would receive a stream of binary ones only and that by connecting these gates as shown in figure (2).

Now binary one still not changed when it passes through these gates while binary zero will invert to one. In this way the sine pulse generator can receive a stream of binary ones only and thus give a parabolic electric signal as shown in figure (3). The dispersive medium between the two phase modulators has parameters; these parameters are listed in table (1). The main aim of this paper is to show how can be choose the suitable value for dispersion of the dispersive medium in FRFT and its effects in mitigate the fiber nonlinearities.

3. Design and Simulation results

To observe the effect of the FRFT (with different values of dispersion in dispersive medium), an optical system with 4 channels, each with Differential Phase Shift Keying (DPSK) as a modulation format, 10 Gb/s as bitrate, the channel spacing 100 GHz, five spans and each with 60 Km (the length of the system is 300 Km) has been chosen as an arbitrary system as shown in figure (4). The bit error rate (BER) versus signal to noise ratio (SNR) curves and input power (P) versus Q-factor curves has been chosen to observe the improvements in the system.

In the system described above (figure 4) the values of the dispersion in the dispersive medium of FRFT were chosen in range (10 – 90) (ps/nm/km) versus the BER and the result was shown in figure (5). As seen from figure (5), the best result we can get is when the dispersion of the dispersive medium is 40 ps/nm/km, 80 ps/nm/km and the worse result that's found in case of 10 ps/nm/km and 60 ps/nm/km (the top of the curve). So the curves of BER Vs SNR were introduced to show the improvement in the system in each case. Now, to confirm the results, input power versus Q-factor curve has been introduced for each case as shown in figure (7).

Table 1: Parameters of Dispersive medium

Parameter	Value
Dispersive optical fiber	
Length	100 m
Attenuation	0.1 dB/Km
Dispersion	VARIABLE (Ps/nm/Km)
Differential group dely	0.2 Ps/Km
Effective area	80 um^2

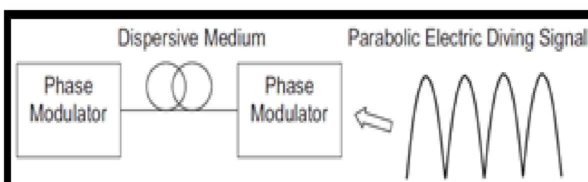

Figure 1: Configuration of the implementation of FRFT

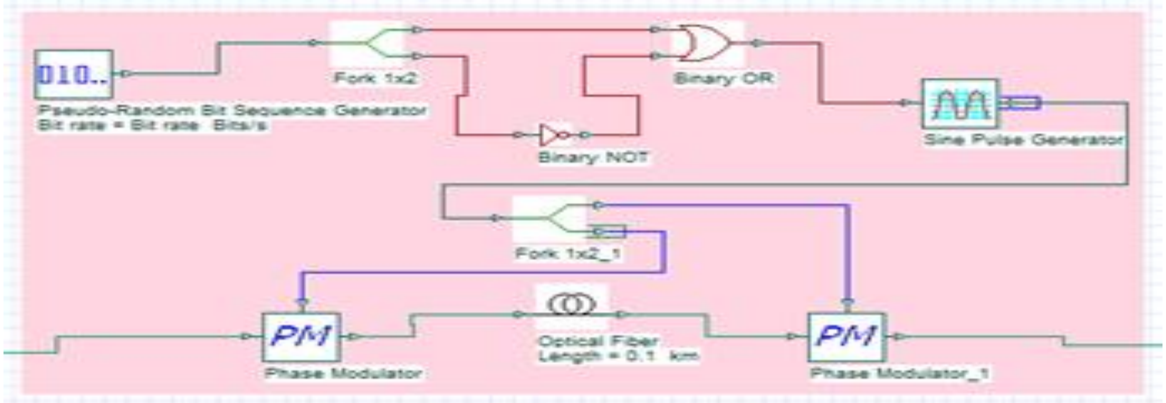

Figure 2: Configuration of FRFT using optisystem software

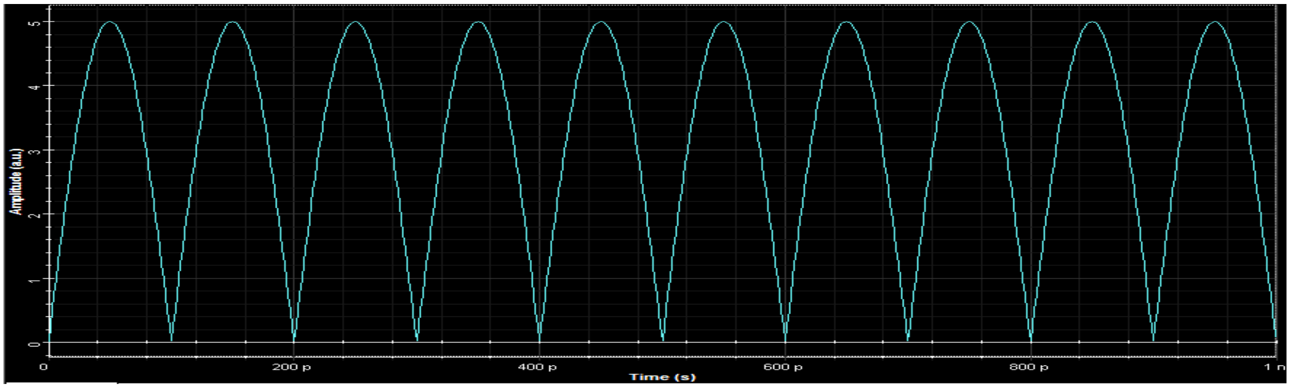

Figure 3: Parabolic Electric driving signal

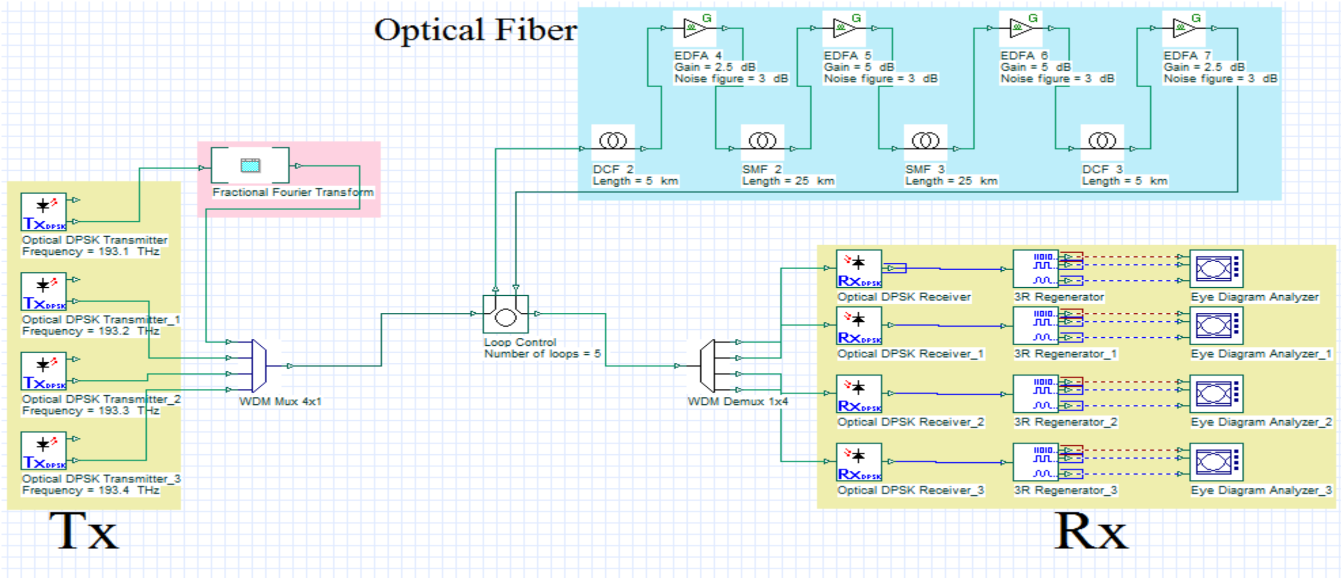

Figure 4: System configuration

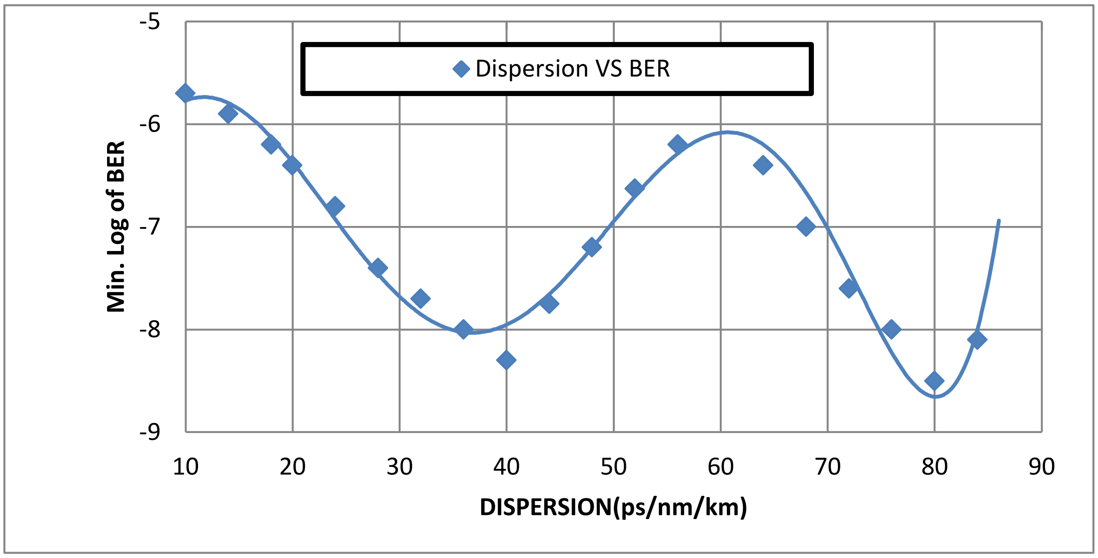

Figure 5: Dispersion value of dispersive medium Vs BER

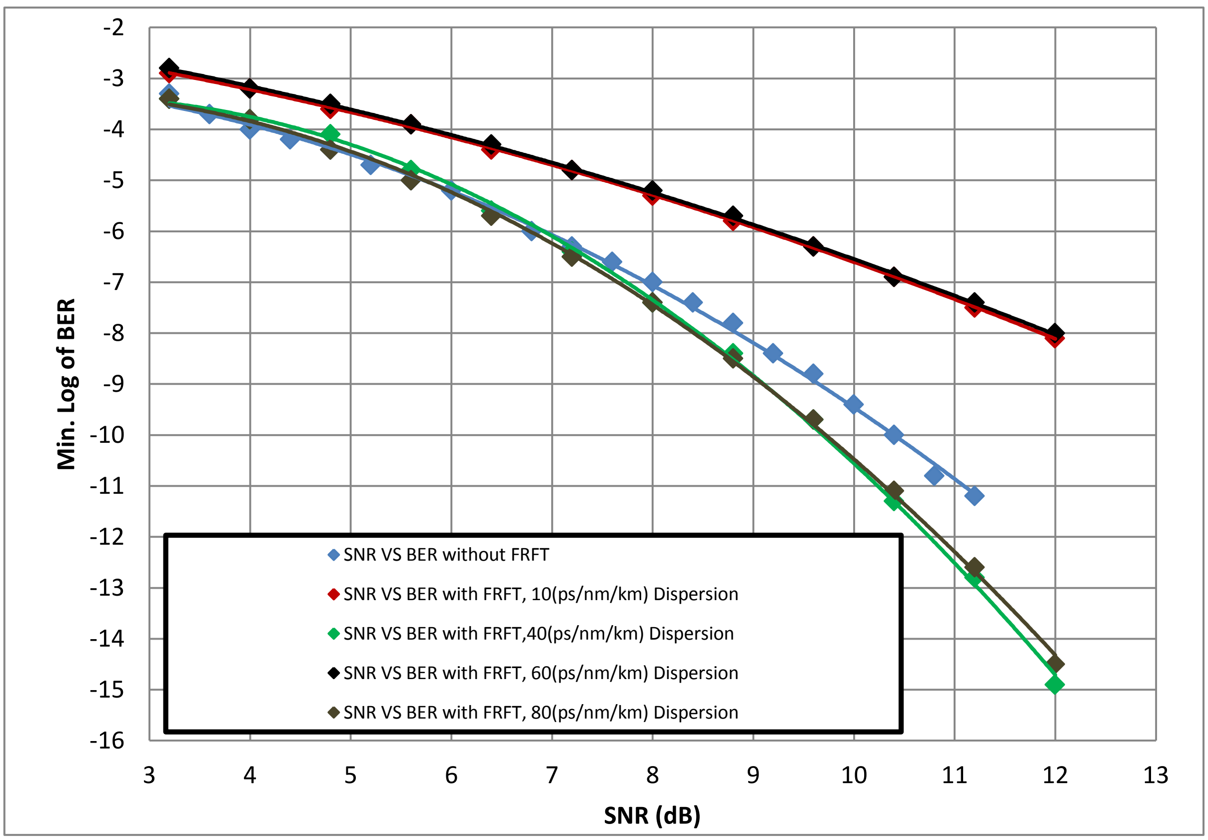

Figure 6: BER Vs SNR for different values of dispersion (for the dispersive medium between the two phase modulators in FRFT) for system without and with FRFT

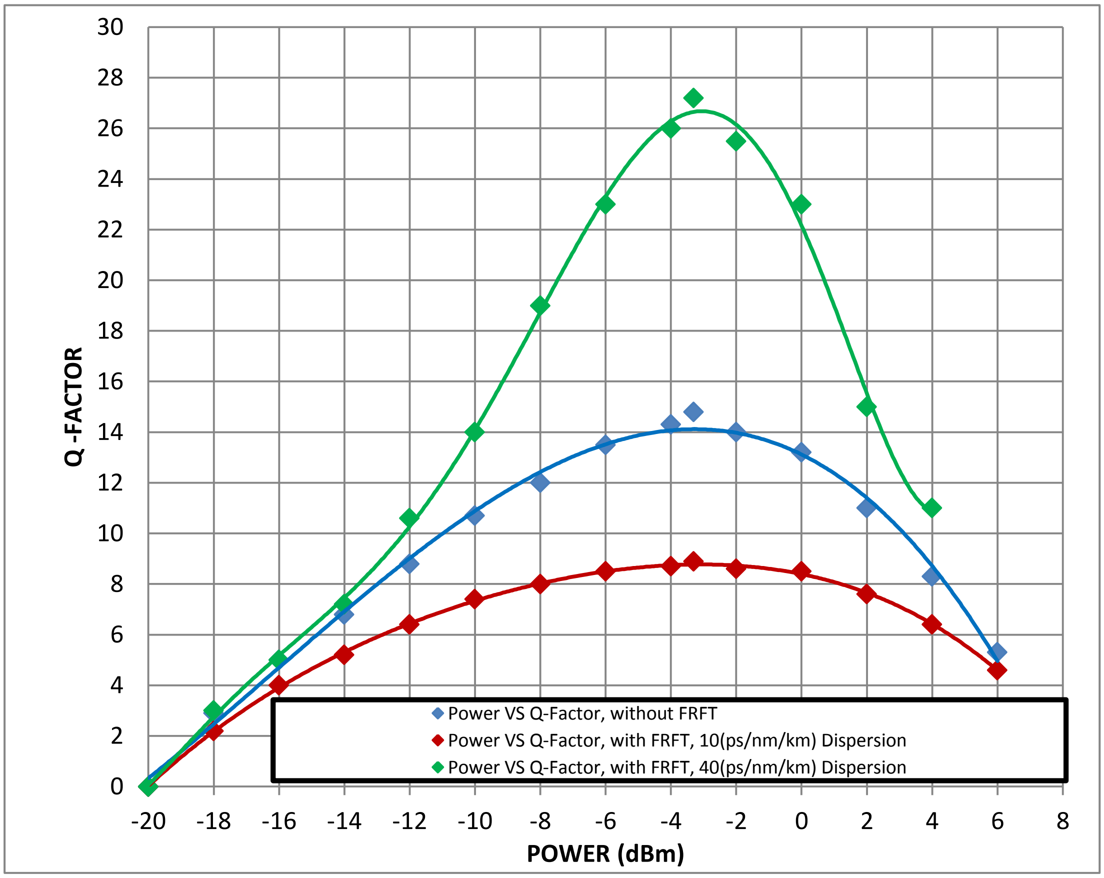

Figure 7: Power Vs Q-factor for different values of dispersion (for the dispersive medium between the two phase modulators in FRFT) for system without and with FRFT

4. Conclusion

FRFT is a powerful method and it is used to mitigate the optical fiber nonlinearities specially in Wavelength Division Multiplexing (WDM) system and that depends on several parameters like the length of the dispersive medium between the phase modulators, the phase shift of the phase modulators, the number of system channels, the spacing between channels, the type of modulation format that used in the system and the value of dispersion in a dispersive medium (as in our case), so after all these parameters the improvement was shown, for example, at SNR 10 dB the BER improves by (1.3 orders) in case of FRFT (with 40 ps/nm/km dispersive medium) than the case without of FRFT, also we can see that the system deteriorate when the value for dispersion of the dispersive medium is 10 ps/nm/km.

References

[1] Han, Qingsheng, Wei Li, and Minghui Yang. "An optical waveform pre-distortion method based on time domain fractional Fourier transformation." Optics Communications 284.2 (2011): 660-664.
[2] F. Forghieri, R.W. Tkach, A.R. Chraplyvy,"Fiber nonlinearities and their impact on transmission systems", in Optical Fiber Telecommunications IIIA, I.P. Kaminow, T.L. Koch (Eds.), Academic Press, San Diego, 1997.
[3] L. B. Almeida, "The Fractional Fourier Transform and Time-Frequency Representations" IEEE Transactions on Signal Processing, Vol. 42, No. 11, November, 1994.
[4] D. Mendlovic, H.M. Ozaktas,"Fractional Fourier transformations and their optical Implementation I", J. Opt. Soc. Am. A, 10. pp.1875-1881, 1993.
[5] H.M. Ozaktas, D. Mendlovic," Fourier transforms of fractional order and their optical

interpretation II", J. Opt. Soc. Am. A, 10. pp. 2522-2531, 1993.
[6] Ozaktas, Haldun M., and David Mendlovic. "Fourier transforms of fractional order and their optical interpretation." Optics Communications 101.3 (1993): 163-169.
[7] A.W. Lohmann, B.H. Soffer,"Relationships between the Radon, Wigner and Fractional Fourier transform", J. Opt. Soc. Am. A, 11. pp. 1798-1801, 1994.
[8] Lohmann, Adolf W. "Image rotation, Wigner rotation, and the fractional Fourier transform." JOSA A 10.10 (1993): 2181-2186.
[9] Kolner, Brian H. "Space-time duality and the theory of temporal imaging." Quantum Electronics, IEEE Journal of 30.8 (1994): 1951-1963.
[10] Cuadrado-Laborde, Christian, et al. "Pulse propagation analysis based on the temporal Radon–Wigner transform." Optics communications 266.1 (2006): 32-38.
[11] Cuadrado-Laborde, C., et al. "Fractional Fourier transform dual random phase encoding of time-varying signals." Optics Communications 281.17 (2008): 4321-4328.
[12] H. Cheng, W. Li, Y. Fan, Z. Zhang , S. Yu and Z. Yang," A novel fiber nonlinearity suppression method in DWDM optical fiber transmission systems with an all-optical pre-distortion module," ELSEVIER journal Optics Communications,290,pp.152-157, 2 November 2012.

Saif Hussam Abdulwahed was born in Baghdad in 9/1/1990, he had a master degree in communication engineering / University of technology / Baghdad and now he the rapporteur of communication engineering department in AL-HUSSEIN University college, member of the Society of Scientific & Technical Competencies and member in the IRAQI ENGINEERS UNION.
Email: shark_iraq@yahoo.com