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***Research paper***

# Fiber Bragg Grating and Channel Spacing Effect in WDM Radio over Fiber System Using DPSK Modulation Format

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**Abstract**

Fiber Bragg Grating (FBG) is distributed reflector written in short length of optical fiber to reflect specific wavelengths of light and transmit the other components of spectra. By using FBG method in dispersion compensation can boost significantly the system performance. High capacity transmission and low effective cost of Radio over Fiber technique (Rof) are resulted from the combination of the optical communication capacity and the mobility of wireless networks. In this research article, an investigation of radio over fiber transmission for 50 km-long optical fiber operated at 10 Gb/s data rate and modulated under efficient DPSK modulation technique. The effect of Fiber Bragg Grating as chromatic dispersion compensation and channel spacing in WDM on optical communication system is analyzed and evaluated. The system performance is evaluated in terms of eye diagram. The outcomes of our simulation shows that Four unequal spacing channels radio over fiber system with ideal dispersion FBG has the best performance in terms of Q-factor and BER.

***Keywords***: *FBG, WDM, DPSK, RoF, dispersion.*

## 1. Introduction

Since 1990, the researchers have been developing various methods and techniques to transmit large amount of information over long optical communication system at high bit rate and fast internet for multimedia applications and broad band wireless access. Rof is one of efficient technology. In RoF technology, the light is modulated with radio frequency (RF) signal.
The modulated signal is transmitted over an optical fiber to improve the capacity and mobility of high-speed wireless communication system. Wave division multiplexing (WDM) is technique used to multiplex many optical signals with different wavelengths of the laser source over single optical fiber [1].
Dispersion is the most restriction factor in optical link, so the cancellation is achieved using dispersion compensation fiber such as passive element [2]. DPSK has less effect to the nonlinear effects and dispersion problems so, it is one of the proposed modulation [3].
Many methods like unequal channel spacing, dispersion compensation fiber with efficient digital modulation techniques have been proposed as a candidate solutions of these restrictions [4],[5].
The integration of unequal channel spacing under duo-binary modulation format was presented [6].
Different factors which impact FWM like input power, channel spacing and fiber dispersion were reported [7].
Numerical simulation of WDM properties was investigated [8]. The investigation was based on comparison between optical MSK and DQPSK format.
Channel spacing and DCF effect on four wave mixing optical transmission system was simulated [9].
RoF technique can be improved using DWDM [10]. Multiplexed RoF was used to reduce the electronic components for base band signal detector [11].
Comparison of DPSK, CPFSK, MSK and OQPSK format was reported in [12]. The simulation of RoF system using interferometer was presented in [13]. Performance is analyzed in PAM intensity modulation system based on DCF for optical transmission system [14].

## 2. Transmitter- Receiver Design

The design of RoF technique using DPSK modulation is shown in Fig.1 (a). The pseudorandom bit sequence (PRBS) generator generates the modulation baseband signal ($f_b$) at bit rate of 10 Gb/s.
The PRBS has 64 sequence length and 256 samples/bit, the baseband signal will be used to modulate a high radio frequency ($f_c$). Using electrical modulation, the process of modulation is done.
At carrier frequency ($f_c$), the spectrum of data signal will be shifted. Differential Phase Shift Keying (DPSK) is the non-coherent type of BPSK which using two symbols 1 and 0 with single carrier signal.
The main property of DPSK that the synchronization between the receiver and the transmitter is eliminated by combing the two parts of transmitter operation:
Differential encoding of the input data, phase shift keying of the sequential stream of data,the electrical modulated signal will be posted to band pass Bessel filter to attenuate all the undesired components of frequency.
Machzehnder modulator (MZM) is an external modulator device which is used the output filtered signal for modulating the laser, the light of laser is carrier frequency generated at laser diode. The frequency of laser ($f_s$) is equal to 193.1 THz at cw power of 10 mw, in optical modulation, the upper optical and lower optical



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side bands will be shifted. The upper side band frequency $f_s + f_c + f_b$ and $f_s + f_c - f_b$ for the lower side band frequency, the band width of band pass Bessel filter is equal to 1.5 multiplied by $f_b$. The signal will be transmitted over single mode fiber, the transmitter section consists of 4 such channels separated at certain equal or unequal frequency spacing, in receiver side as shown in Fig.1 (b), the received signal is passed through band pass Bessel filter which operates at frequency of 193.1 THz and band width of 10 GHz, Then, the filter signal is posted to PIN photo detector to convert the optical signal to electrical signal. The base band signal is connected to the low pass Bessel filter to attenuate the higher frequency, the cut off frequency of the low pass Bessel filter is equal to 0.75* $f_b$, after the electrical signal is detected and regenerated the signal is monitored using BER analyzer and eye diagram analyzer.

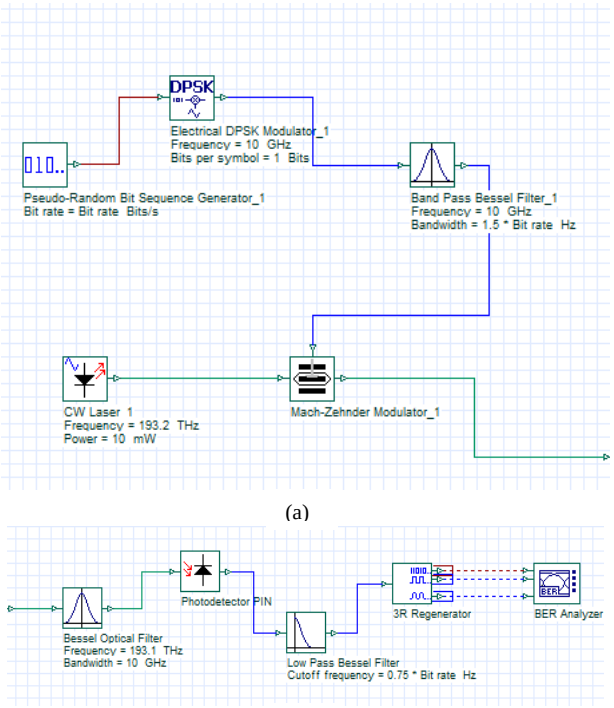



**Fig.1:** (a) DPSK modulation transmitter (b) Receiver

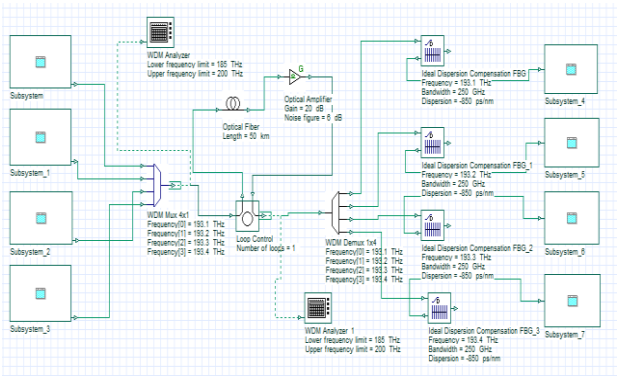
## 3. Simulation Details

The simulation setup is implemented using optisystem 10. Four channels WDM on optical fiber transmission system. Four WDM channels are Multiplexed- De multiplexed using ideal WDM multiplexer over optical fiber of 50 km long, the multiplexed signals are passed.

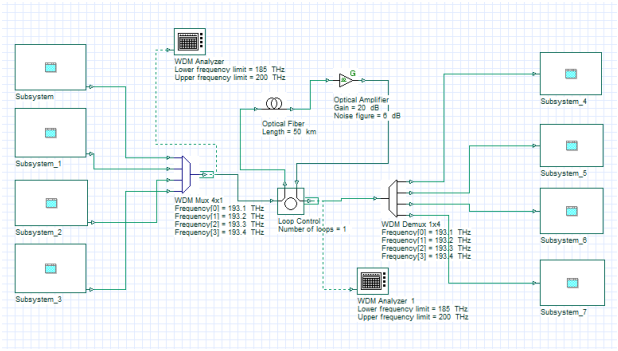
The optical fiber has attenuation equals to 0.2 dB/km and the dispersion is 17 ps/nm-Km. The gain of optical amplifier is 20 dB. The operating central wave length of a laser diode is 1550 nm.

The main objective of this simulation is to determine the effect of Fiber Bragg Grating and Channel Spacing Effect in WDM Radio over Fiber System using DPSK Modulation Format in optical transmission system. External modulator is used to modulate laser sources on an optical fiber link.

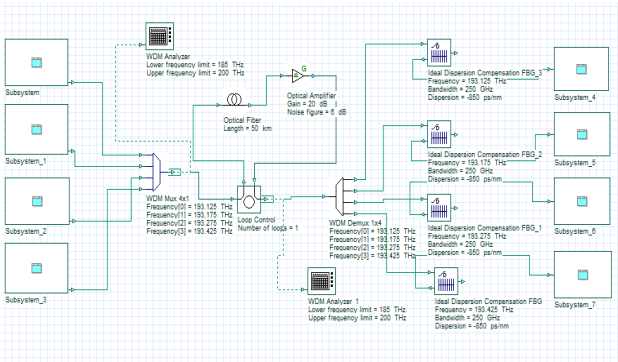
Four channels are multiplexed and transmitted over 50 km optical link. Figures 2(a), 2(b), 2(c) and 2(d) show the setup of four equal spacing channels radio over fiber system with ideal dispersion compensation FBG, four equal spacing channels radio over fiber system without ideal dispersion FBG, Four unequal spacing channels radio over fiber system with FBG and Four unequal spacing channels radio over fiber system without FBG.



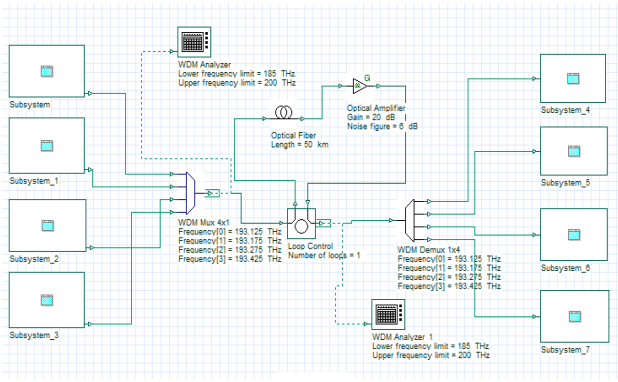

(a)




(b)




(c)



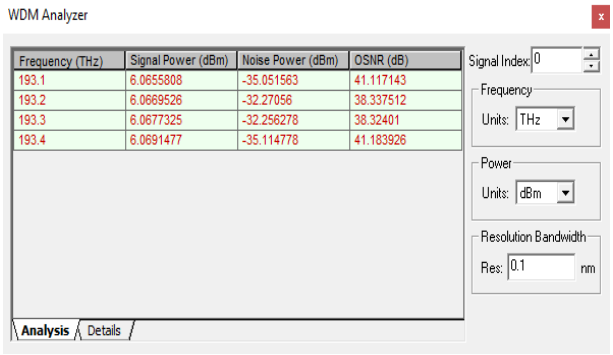

(d)

**Fig.2:** Radio over Fiber system (a) equal channels with FBG (b) equal channels without FBG (c) unequal channels with FBG (d) unequal channels without FBG

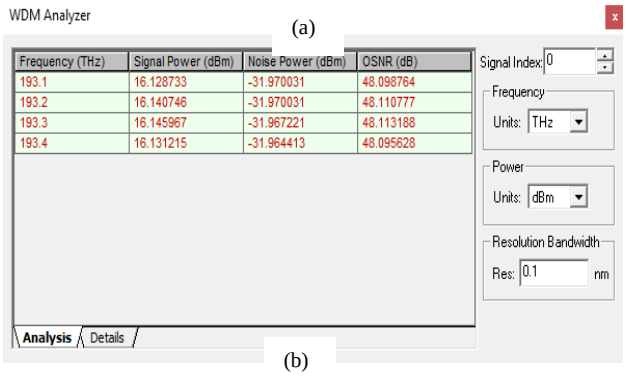
The main reason to suggest the use of FBG is to compensate the chromatic dispersion effect of adaptive Radio over Fiber over long distance optical transmission system. In case of equal spacing frequency, spacing is 100 GHz and in case of unequal spacing frequency is 50, 100, 150 GHz.

WDM analyzer is used to analyze the frequency, signal power (dBm), noise power (dBm), OSNR (dB) in both different cases equal spacing channel and unequal spacing channel for the system in transmitter side and the system in the receiver side. Tables 1a, 1b, 1c and 1d illustrate the values of the WDM analyzer.

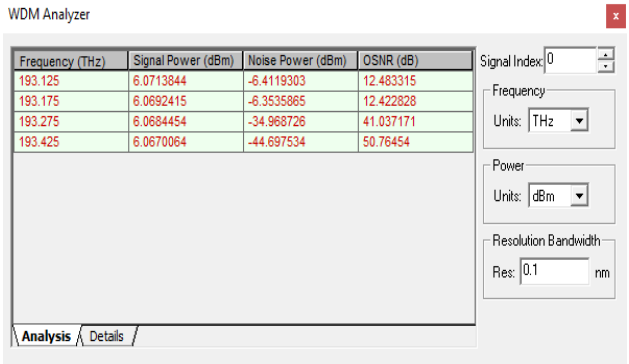
**Table 1:** WDM analyzer (a) transmitter equal channels (b) equal channels after optical fiber (c) transmitter unequal channels (d) unequal channels after optical fiber



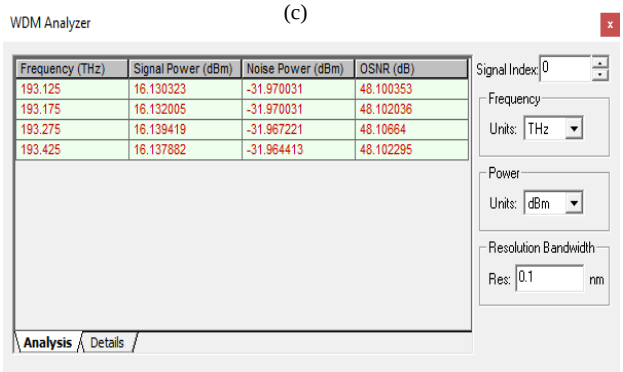

(a)




(b)




(c)




(d)

## 4. Results and Discussion

Figures 3(a), 3(b), 3(c) and 3(d) illustrate the Quality factor and Bit Error Rate analysis of the system using eye diagram under Different schemes for channels ch1, ch2, ch3 and ch4. Differential Phase Shift Keying modulation is used in all the setups.

The observations are summarized in Tables 2a and 2b. Since higher Q- factor and lower BER are the two essential performance evaluations for selecting best scheme. It is clear that the better case is unequal spacing with FBG. Thereby the evaluation is tacking in account increasing the possibility of number of users in the communication system.

Q-factor have been measured for all the simulated channels under the impact of equal and unequal channels spacing and with combination of ideal EBG or without it as shown in figure3(a), 3(b),3(c), 3(d). Basically, Q-factor can be defined by division the average power of the received signal level to the Root-Mean–Square of the noise power at the level of the decision circuit in receiver side. In other side, the BER is the term used to count the number of wrong received bits to total transmitted bits.

Figures are mentioned above are the graph drawn between Q factor versus time. It is clear that the Max.Q- factor for channel 3 in case of unequal channel spacing with cascading of FBG is 25.229 and BER of 9.48603 $e^{-141}$, which is a very good Q -factor and good BER It is clear that unequal channel spacing improves the Q factor for four channels wave division multiplexing at 4 times 10 Gb/s bit rate.

Eye diagrams are drawn for all setups. Multiplexed signal eye diagrams are shown in figures 3(a), 3(b), 3(c) and 3(d), from the figure 3(c), it is clear that the distortion is reduced at the receiver side as the optical fiber length is increased, the received signal will be distorted, the reason for the distortion is to the presence of different dispersion in the fiber, in fact, high factor will create wide eye opening. Generally, Filters are used to remove unwanted signals at the receiver side, figure 3(c) shows good eye opening which is good jitter indication.

**Table 2:** *Q factor and BER* (a) *equal channels with and without FBG* (b) *unequal channels with and without FBG*

(a)

| EQUAL CHANNELS | WITHOUT FBG | | WITH FBG | |
|---|---|---|---|---|
| Frequency | Q factor | BER | Q factor | BER |
| 193.1 | 3.88344 | $5.11241e^{-005}$ | 9.69627 | $1.25362e^{-022}$ |
| 193.2 | 3.85115 | $5.8454e^{-005}$ | 9.49415 | $9.20856e^{-022}$ |
| 193.3 | 3.87494 | $5.29171e^{-005}$ | 24.5921 | $7.66293e^{-134}$ |
| 193.4 | 3.8886 | $5.00725e^{-005}$ | 12.1364 | $3.37034e^{-034}$ |

(b)

| unequal channels | Without FBG | | With FBG | |
|---|---|---|---|---|
| frequency | Q factor | BER | Q factor | BER |
| 193.125 | 4.8592 | $5.54558e^{-007}$ | 13.5187 | $5.97373e^{-042}$ |
| 193.175 | 4.72678 | $1.07958e^{-006}$ | 14.0086 | $6.77868e^{-045}$ |
| 193.275 | 3.71974 | $9.89227e^{-005}$ | 25.2293 | $9.48603e^{-141}$ |
| 193.425 | 3.43055 | 0.000300306 | 4.48949 | $3.5679e^{-006}$ |

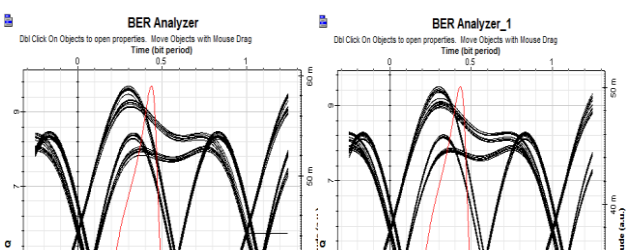
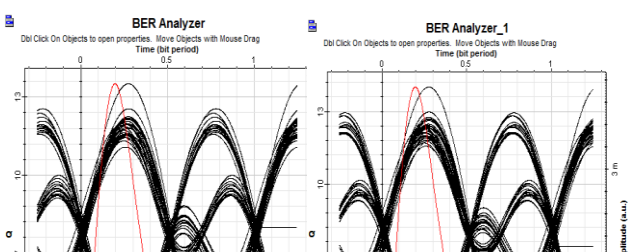


**Fig 3:** *Eye diagram represented Q factor and BER* (a) *equal channels with FBG* (b) *equal channels without FBG* (c) *unequal channels with FBG* (d) *unequal channels without FBG*




## 5. Conclusion and Future Work

A Radio over Fiber system has been designed and simulated using the optisystem software and its parameters such as Q-factor and BER has been compared for this makes the proposed system to be simple, low cost and wide broadband. In this research article, the effect of channel spacing on the efficiency of dispersion compensation fiber represented as FBG has also been analyzed by observing eye diagrams for both equally spaced and unequally spaced channels.

It is concluded that the RoF system incorporating DPSK modulation, WDM and ideal dispersion FBG is efficient technique for detection of baseband signal. The optical transmission system has the potential for applying in new generation convergent wireless-wired optical networks in the future.

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