EFFECT OF FOUR WAVE MIXING ON AP-DCDM-WDM FIBER OPTIC SYSTEM AT DIFFERENT CHANNEL SPACING

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ABSTRACT : *To cope with growing need of bandwidth and high data rate, efforts are made to make the communication systems efficient. Fiber optic communication uses very high frequency carrier usually in THz, so it is the best choice for high capacity and high data rate communication systems. Several multiplexing techniques are developed in quest to use the available bandwidth efficiently for intended users. Wave-length Division Multiplexing (WDM) is a common technique used for sharing the media among the users. Absolute Polar Duty Cycle Division Multiplexing (AP-DCDM) over WDM is a multiplexing technique which promises better spectral efficiency. Non linearities in fiber optic communication are major issues, especially the effect of four wave mixing. This paper presents the effect of four wave mixing on 40 Gbps AP-DCDM over WDM fiber optic systems. The system was tested by simulating the AP-DCDM-WDM design in Optisystem software and MATLAB code. From the results the effect of four wave mixing on the system is presented under different configurations such as input power per channel and channel spacing mainly. Simulation results have shown that AP-DCDM-WDM systems have greater tolerance to dispersion and have better receiver sensitivity than other conventional techniques. The effect of Four Wave Mixing (FWM) on AP-DCDM-WDM system is also lesser then other conventional techniques on basis of simulation.*

KEY WORDS: AP-DCDM, Channel Spacing, Fiber Optic Systems, Four Wave Mixing Effect

I. INTRODUCTION

The use of optical communication when considered in a broad sense takes us to the time when no other system for communication was available in common such as using fire beacons, light mirrors or smoke signals to convey information [6].

In 1830 when telegraphy was invented, it was a huge break through and electrical communication prevailed over optical communication [6]. Wire pairs were used to carry the information and accomplish the communication between sender and receiver using electromagnetic carrier frequencies. As the need for capacity and high data rate increased, co-axial cables came in to the picture before mid of 20th century and had been in use for quite long as it was possible with these cables to transmit high data rate, usually in MHz and few hundred voice channels. It was the time when electrical communication systems were dominating, but the ever growing hunger for high capacity and fast data rate led to the invention of microwave communication system which uses high carrier frequencies in electromagnetic spectrum normally in range of GHz.

II. ABSOLUTE POLAR DUTY CYCLE DIVISION MULTIPLEXING (AP-DCDM)

Day by day, need of large bandwidth for high speed data transfer is growing rapidly. To give enough bandwidth to each user and to accommodate more users sharing bandwidth at one time is one of the major issues.

To study the effect of Four Wave Mixing (FWM) on AP-DCDM-WDM fiber optic system is the main objective of this paper. Testing the AP-DCDM-WDM system for different configuration, and analyzing the results obtained will give fair idea of how the four wave mixing is affecting the system and its spectral efficiency. Moreover, adjustment can be made to the system so that the effect of four wave mixing is minimized.

The effect of FWM on the AP-DCDM-WDM fiber optic system was analyzed using Optisystem software and MATLAB code. The BER was calculated for each user in the system. The results obtained from simulation of the system using Optisystem and MATLAB code are discussed in details in methodology.

II.I. AP-DCDM system for four users

Before optical communication, time division multiplexing was the optimized multiplexing technique for communication systems. After fiber optic cable is being used more widely for high speed data transfer, wavelength division multiplexing does the job [4]. But using AP-DCDM, which is from the family unit of duty cycle division multiplexing over WDM Channels increased the channel count because of using narrow filters [4]. It basically works on the principle of polar signaling and different return to zero duty cycles. In other words, it uses bipolar signals with different duty cycles to differentiate between users or channels. Fig. 2.1 shows the system [5].

In this technique, the polarity of subsequence users is opposite which results in a unique multilevel pattern at the multiplexer output [5]. Because of this uniqueness it becomes easier at the receiver end to recover the data for each user. AP-DCDM technique can be used with guard bands as well as without guard bands as per requirement [11]. Also this technique is different from other conventional techniques due to the fact that users share the same transmission medium, in the same time-period with same carrier wavelength but using different duty cycles, which results in uniqueness that is discussed above [11].

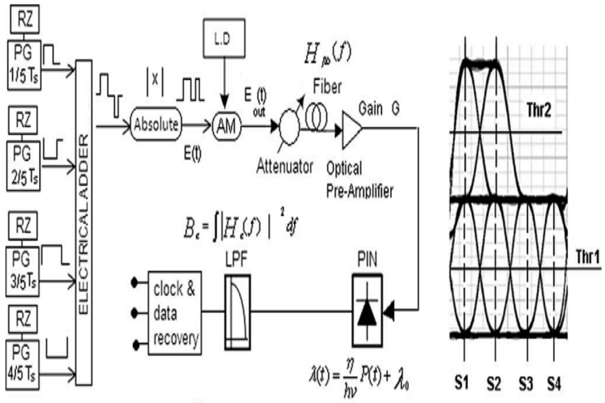

Fig. 2.1 AP-DCDM system for four users [5]

II.II. AP-DCDM Less Prone to Dispersion

AP-DCDM technique reduces the spectral width and it has small spectral width, due to this fact, has greater spectral efficiency and tolerance towards dispersion [5]. In Fig. 2.2, the dispersion tolerance is shown for 40 Gb/s 50% duty cycles RZ and 40Gb/s G AP-DCDM [5].

In AP-DCDM technique, the uses of narrow filters provide less inter channel coherent cross talk. AP-DCDM is a new technique which can be implemented over WDM systems to get the optimized system efficiency [11].

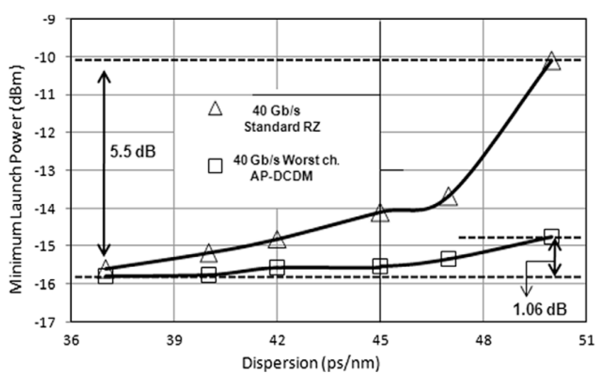

Fig. 2.2 Dispersion tolerance [5]

II.III. Four Wave Mixing (FWM)

Non-linear response of the bound electrons of the material to the applied optical field governs the phenomenon of four wave mixing [9]. Severe problem occurs when optical waves interact parametrically. In a multi-channel system, the beating of two or more optical waves give rise to one or more new frequencies on the expense of original signal [9]. This effect (FWM) is independent of bit rate. It depends on the channels spacing and fiber dispersion [9]. Increasing channel spacing decreases FWM effect and decreases dispersion. This effect is show in Fig. 2.3.

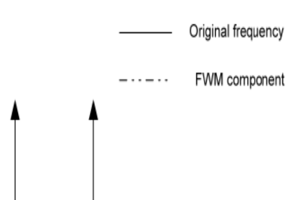

Fig. 2.3 Effect of four wave mixing on two channels

III. METHODOLOGY

III.I. Simulation setup for AP-DCDM-WDM System

After finishing the simulation for RZ-WDM system and NRZ-WDM system, and getting the results for the effect of four wave mixing, the final objective of the paper that is, on AP-DCDM-WDM System was simulated. Here Absolute Polar Duty Cycle Division multiplexing is used with WDM to achieve better performance under the effect of four wave mixing yet at high bit rate. In this setup 4 RZ pulse generators are used with the following configuration from first user to the fourth shown in table 3.1.

The four RZ Pulse generators with the above mentioned configuration are first combined by an electric adder and passed through an electric absolute circuit to remove the bi polar nature of the signals and then the signal goes into fork which on its output feds one signal to the AM modulate so that the signal is modulated with one external CW laser using AM modulator and the other is fed into matlab component.

The modulated signal is then fed to one channel of WDM multiplexer and this setup is repeated for as many times as required or available number of channels over WDM.

For this design, the dispersion value was kept to zero so only the four wave mixing effect is calculated as the BER of the system. The length of the single mode fiber is 80 km. The effective area of the fiber is 64 um^2. The bit rate is 10 Gbps for each user and the bandwidth of WDM multiplexer is 50 GHz. To calculate the BER with zero dispersion, a MATLAB component was used which was attached to a matlab file. Optisystem provides the facility of connecting the layout setup to the matlab files. Matlab file has the appropriate code to do the task and hence the effect of four wave mixing is examined for different power per channel and different channel spacing.

Table 3.1 RZ Pulse Generators Configuration

Main | Simulation

Disp	Name	Value	Units	Mode
	Rectangle shape	Exponential		Normal
	Amplitude	1	a.u.	Normal
	Bias	0	a.u.	Normal
	Duty cycle	0.25	bit	Normal
	Position	0	bit	Normal
	Rise time	0.05	bit	Normal
	Fall time	0.05	bit	Normal
Disp	Name	Value	Units	Mode
	Rectangle shape	Exponential		Normal
	Amplitude	-1	a.u.	Normal
	Bias	0	a.u.	Normal
	Duty cycle	0.5	bit	Normal
	Position	0	bit	Normal
	Rise time	0.05	bit	Normal
	Fall time	0.05	bit	Normal
Disp	Name	Value	Units	Mode
	Rectangle shape	Exponential		Normal
	Amplitude	1	a.u.	Normal
	Bias	0	a.u.	Normal
	Duty cycle	0.75	bit	Normal
	Position	0	bit	Normal
	Rise time	0.05	bit	Normal
	Fall time	0.05	bit	Normal
Disp	Name	Value	Units	Mode
	Rectangle shape	Exponential		Normal
	Amplitude	-1	a.u.	Normal
	Bias	0	a.u.	Normal
	Duty cycle	1	bit	Normal
	Position	0	bit	Normal
	Rise time	0.05	bit	Normal
	Fall time	0.05	bit	Normal

The simulation setup for second channel of WDM 4 X 1 multiplexer is shown in Fig. 3.1.

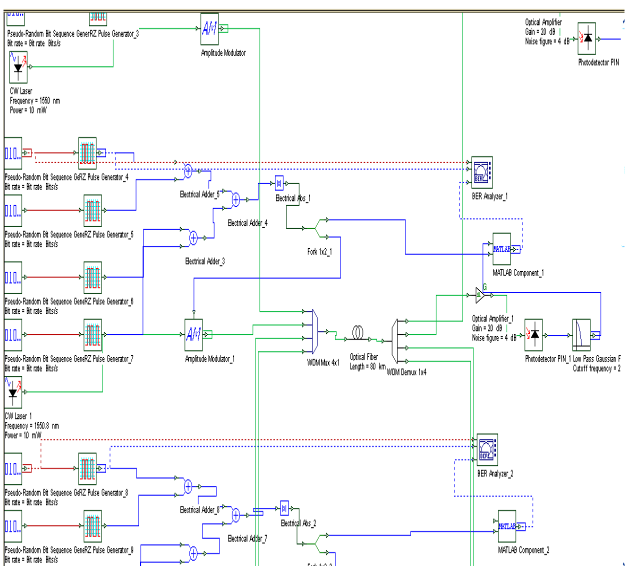

Fig 3.1

IV.I. Effect of Channel Spacing

To make the optical communication system efficient it is necessary to select the optimal channel spacing between the channels so that the transmitted signal under different conditions is not destroyed and the receiver must be able to understand what was transmitted. For this fact, different channel spacing were tried so to observe how it effects the FWM effect on AP-DCDM-WDM system. The input power per channel was kept constant to 1 mW.

Initially the system was tested by making the channel spacing to 0.4 nm. The eye diagram obtained after the simulation is shown in fig 4.1.1.

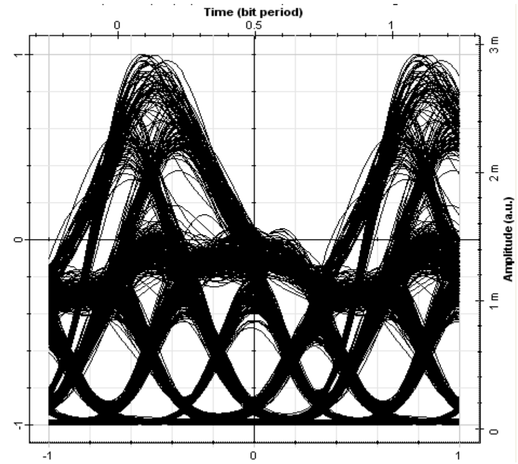

Figure 4.1.1 Eye Diagram for Channel Spacing of 0.4 nm

The eye diagram tells that when the channel spacing is set to 0.4 nm between the channels, the effect of four wave mixing is slightly affecting the system. Therefore seeing the fact, the system was modified and channel spacing was increased to 0.8 nm and the results obtained from the amendments made to the system are shown in fig 4.1.2.

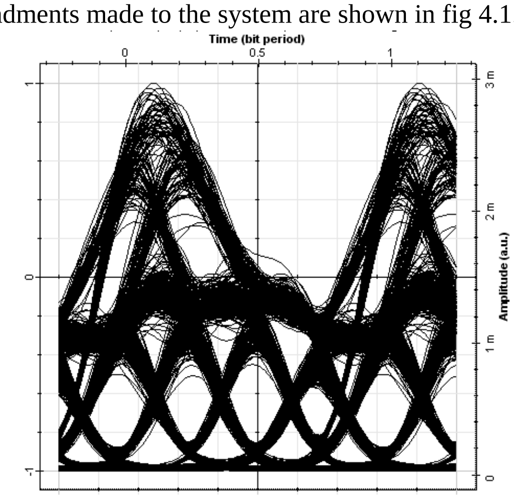

Fig 4.1.2 Eye Diagram for Channel Spacing of 0.8 nm

The results obtained after simulating the system for channel spacing of 1.2, 1.4 and 1.6 nm, are shown in fig 4.1.3, fig 4.1.4 and fig 4.1.5 respectively. And the overall system response to these values for channel spacing is given by the fig 4.1.6.

Observing the eye diagrams for different channel spacing between the channels and the result shown in fig 4.61, it is obvious that as the channel spacing increases the effect of four wave mixing on AP-DCDM-WDM system reduces. The standard channel spacing used are 0.4 nm, 0.8 nm and 1.6 nm, while 0.8 nm channel spacing is used more commonly. While examining the system for effect of four wave mixing, it was observed that as when certain parameters are changed, these changes make difference to the effect of four wave mixing on AP-DCDM-WDM system. By

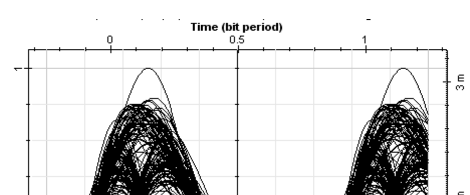

Figure 4.1.3 Eye Diagram for Channel Spacing of 1.2 nm

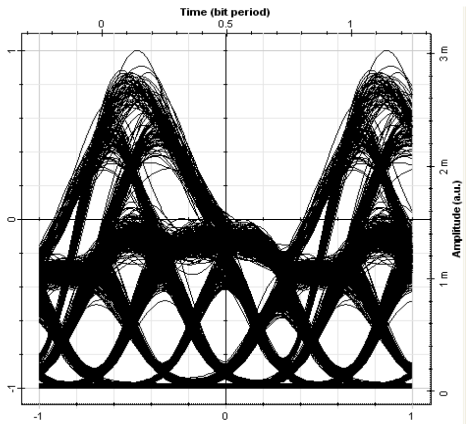

Figure 4.1.4 Eye Diagram for Channel Spacing of 1.4 nm

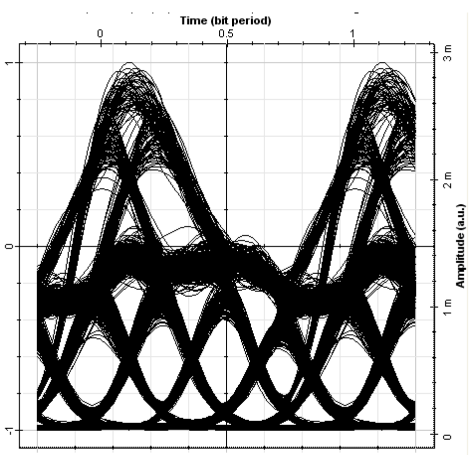

Figure 4.1.5 Eye Diagram for Channel Spacing of 1.6 nm

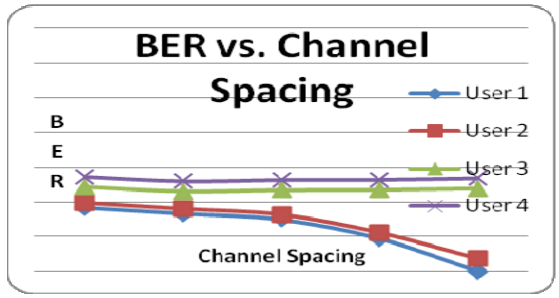

Figure 4.1.6 BER vs. Channel Spacing

increasing the effective area of the optical fiber the effect of four wave mixing decreases and vice versa. The use of unequal channel spacing is another way to reduce the effect of four wave mixing, though spectral efficiency becomes an issue.

IV.II. Reducing the Effect of FWM by Spacing Channels unequally

As discussed earlier, one way of reducing the effect of four wave mixing is to use the unequal channel spacing techniques between the channels of the WDM channels. Simulation of the AP-DCDM-WDM System for equal channel spacing of 0.4 nm and 0.8 nm is done and the results were shown. The same system configuration were tested for unequal channel spacing with frequencies of 1550 nm, 1551 n, 1552.2 nm and 1553.5 nm. The result of the unequal channel spacing is compared with equal channel spacing for the same system in figures 4.2.1, 4.2.2 and 4.2.3. This comparison clearly shows the difference in the eye diagrams. This conclude with the fact that unequal channel spacing is useful when input power per channel is required to be increased, yet the effect of four wave mixing is tolerable.

V. CONCLUSION AND RECOMMENDATION

V.I. Conclusion

In this project 40 Gbps AP-DCDM over 4 channels WDM system was analyzed for performance under the effect of four wave mixing which is the main non linearity in optical fiber communication system. The channel spacing was 0.8 nm.

It is obvious from results that as the input power per channel increases the effect of four wave mixing increases. For longer distance the input power per channel is required for signal strength, for this purpose the unequal channel spacing technique could be used to reduce the effect of four wave mixing.

Also results showed that when the channel spacing increases the effect of four wave mixing decreases. With narrow channel spacing the effect of four wave mixing is more severe and signal gets distorted.

Also it is evident from results when the number of channels increases, the effect of four wave mixing increases.

Comparing the results of AP-DCDM-WDM system, with RZ-WDM and NRZ-WDM system, it is clear that AP-DCDM-WDM has more spectral efficiency and is less prone to effect of four wave mixing, while on the other hand NRZ-WDM system is better in performance than RZ-WDM system where the criteria of performance is, receiver sensitivity, effect of dispersion and effect of four wave mixing.

V.II. Recommendations

To the best of my knowledge, work on studying the effect of four wave mixing on AP-DCDM-WDM system has not been done before. There is a lot of scope of further work on the system.

The AP-DCDM-WDM fiber optic system elaborated in this paper report and the effect of four wave mixing on it was done when the AP-DCDM system was used without guard band. So, it is recommended to study the effect of four wave mixing on the AP-DCDM-WDM fiber optic system with guard band.

Also in quest of making the spectral efficiency better, techniques for reducing the effect of four wave mixing can be proposed such as in the presence of dispersion, the effect of power per channel can be tested.

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