

Evaluation of Wavelength Division Multiplexing System using Different Modulation Formats

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Abstract: In this paper, we have demonstrated the eight channel WDM system using NRZ, RZ and duobinary modulation formats. The WDM system has been analyzed by varying the input power from 0 to 20dBm for different modulation formats in order to find the modulation format for a high data rate optical transmission system. Furthermore, it is found that duobinary modulation is much better than Return-to-Zero and NRZ and the system gives better performance at 40Gbps.

Keywords: Duobinary, Non-return-to-zero, Return-to-zero, Wavelength-division-multiplexing, Quality Factor.

I. INTRODUCTION

Wavelength Division Multiplexing is the technique to fulfil the requirements of the telecommunications industry such as high-capacity networks, high transfer rates and broad bandwidth. In optical fibre communication systems the applications are extended and new avenues are open with help of WDM technique [1]. Preferably the wavelength division multiplexing transmission technology is becoming the long distance operators [2]. In optical fibre communication, WDM is a technique that multiplexes multiple optical carrier signals on a single optical fibre by using dissimilar wavelengths of laser light to carry dissimilar signals (described by its wavelength). In fibre-based optic system, nonlinear effects are of great importance and have become an area of academic research. Optical duobinary encoding is an effective method in high-speed optical transmission system, to increase the dispersion tolerance, in order to improve spectral efficiency and reduce sensitivity nonlinear effects [3]. Modulation format defines the characteristics of an optical signal which is transmitted over the transmission link. Until few years, the choice of optical modulation format for nearly all optical transmission systems was return to zero, NRZ and duo-binary modulation [4]. In IMDD optical fiber communications system, NRZ has been the most important modulation format for last few years. The reasons for using NRZ in fiber optic communications were: i) it is insensitive to laser phase noise (relative to phase shift keying); ii) For transmitter and receiver bandwidth, it requires a relatively low electrical bandwidth compared with return to zero [5]. The return to zero pulse occupies just a part of the bit slot, so it has a broad spectrum and has a duty cycle of less than 1. The RZ signal amplitude between adjacent 1's returns to zero [6]. Duobinary modulation is the best example of encoding format, also called as phase encoding format. It is a method of transmitting R bits/sec using R/2 Hz of bandwidth. But according to Nyquist in order to transmit R bits/sec without ISI, we need to have bandwidth of R/2 Hz. An important advantage of a duobinary-based system is to provide a practical means for obtaining transmission close to the Nyquist limit of spectral efficiency for a given baud rate [7].

A. Return to zero Modulation

In the RZ format, each pulse that represents bit 1 is shorter than the bit slot, and its amplitude returns to zero before the bit duration is over. Pulse width remains the same in the case of RZ format. RZ is used in far away communication signals in which the signal drops to zero between each pulse. This takes place even if a number of consecutive "0" or "1" occurs in the signal. The RZ pulse code modulation signal is self-clocking [8]. Therefore, separate clock does not need to be sent alongside the signal, but suffers from using twice the bandwidth to obtain the same data-rate as compared to NRZ format. The main characteristic of RZ modulated signals is a relatively broad optical spectrum, resulting in a reduced dispersion tolerance and a reduced spectral efficiency. RZ pulse enables an increased fairness to fiber nonlinear effects. The transmitter of RZ modulation is as shown in fig. 1.

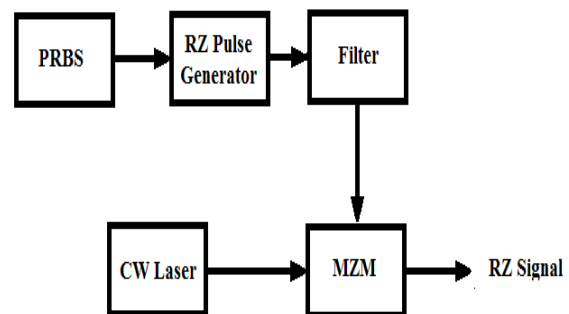


Fig. 1 RZ Transmitter

B. Non Return to zero Modulation

In NRZ modulation, the pulse is held between the whole bit slot and the amplitude of the NRZ are not two or more consecutive bits. Therefore, the pulse width depends on bit pattern [9] changes. In the commercial systems or in early days, NRZ used in fiber optic communication systems, because a) it has the simplest configuration for transmitter and receiver b) it requires a relatively low bandwidth of the transmitter and the receiver as compared to return to zero, c) it is insensitive to the laser phase noise, d) low

costs. Unfortunately, NRZ modulation format is not suitable for high data rate and long-haul optical systems. In the case of a large number of channels, NRZ modulation may be better. NRZ modulation transmitter is as shown in fig. 2.

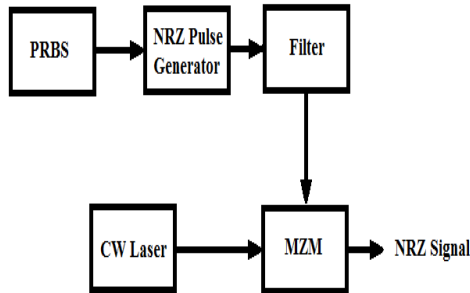


Fig. 2 NRZ Transmitter

C. Duobinary Modulation

A very attractive modulation format is optical duo-binary that provides high spectral efficiency and dispersion tolerance. Duobinary modulation may be described as a combination of a conventional phase shift keying and amplitude shift keying modulation. In this case, Duobinary modulation turns out to be superior choice because it is more resilient to dispersion and is also easy to design [10]. Depending on the implementation, the optical duo-binary transmission has a reduced spectral width and can be understood as a multi-level transmission with phase encoded bits. In duobinary modulation, the optical phases of “1” bits that are separated by an odd number of “0s” differ by π radians. The transmitter of Duobinary modulation is as shown in fig. 3.

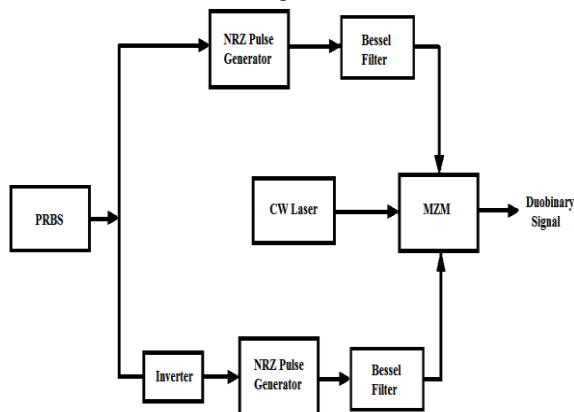


Fig. 3 Duobinary Transmitter

II. SIMULATION SETUP

The system setup consists of eight channel WDM system transmitting data at 40 Gbps per channel. The 40 Gbps data stream is generated using PRBS generator of 64 samples per bit. The frequency range is 193.1 THz to 193.8 THz. The optical carrier wave generated by CW laser is modulated externally by MZ modulator that generates NRZ, RZ and duobinary modulated data depending on the pulse generator used. The incident power is 20 dBm per channel. The eight channels are filtered at the transmitter using optical filters of bandwidth 20 GHz

& multiplexed for transmission onto a single fiber link of 25 km and erbium doped fiber amplifier. Erbium-doped fiber amplifier boosts the signal before received by the PIN photo diode with 1A/W responsivity. The signal is then amplified by Bessel filter with 30 GHz cut off frequency. At the end of the WDM system, BER analyser is used to obtain the Q-factor and Bit Error Rate.

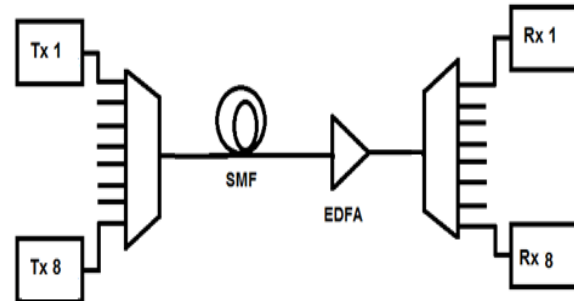


Fig. 4 System setup of eight channel WDM system

III. RESULT AND DISCUSSIONS

In this paper, the parametric performance and comparison of different modulation format in optical fiber transmission system is done. The investigation presented in [11] was restricted to the bit rate of 10Gbps. We have extended the work to bit rate of 40Gbit/s with transmission distance of 25 km.

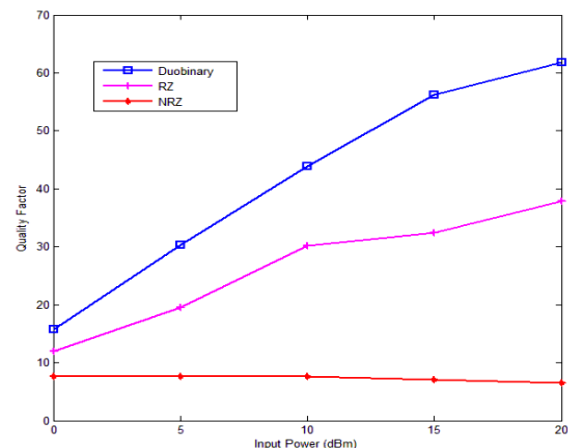


Fig. 5 Quality factor versus Input Power

Figure 5 depicts that the quality factor increases initially with the launched input power reaches a peak value. From the graph, we can see that as the launched power is increased, the quality factor also increased in duobinary and RZ format. However, in the NRZ modulation, with increasing input power, quality factor does not change and remains constant.

Figure 6 shows the variation in quality factor with the bit rate for duobinary, NRZ and RZ modulation. It can be concluded, that the quality factor increases with the decrease of the bit rate of all modulation formats. When we increase the bit rate from 5Gbps to 40Gbps, the quality factor is reduced from 15.4 to 6.57 for duobinary, from 14.5 to 8.75 for RZ and from 12.00 to 5.49 for NRZ modulation format.

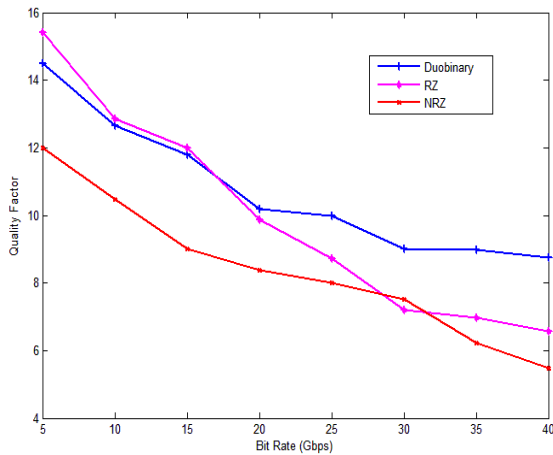


Fig. 6 Quality Factor versus Bit rate

It has also been observed that at 40Gbps, quality factor is more in case of duobinary modulation as compared to RZ and NRZ modulation format.

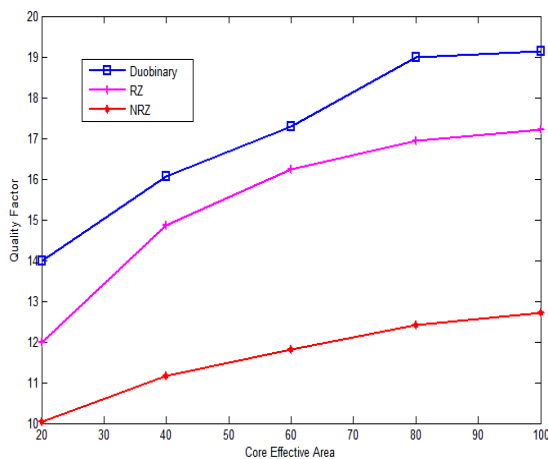


Fig. 7 Core Effective area versus Quality Factor

Figure 7 shows the impact of effective area of the core on quality factor at different modulation formats, such as duobinary, non-RZ and return to zero. According to the analysis, as we increase the effective area from $20 \mu\text{m}^2$ to $100 \mu\text{m}^2$, the quality factor of duobinary, NRZ and RZ is increasing, i.e. from 13.98 to 19.15 in duobinary, from 12.00 to 17.21 in RZ and 10.05 to 12.71 in NRZ modulation format. The reason behind this is to increase the effective area of the core, the interference between the lower input frequencies, and therefore the quality factor is increased. It has also been observed, Q factor increases more in duobinary compared to RZ and NRZ, the effective core area of $100 \mu\text{m}^2$. Q factor is 19.15 for duobinary, 17.21 for RZ and 12.71 for NRZ at $100 \mu\text{m}^2$, because Duobinary has a narrow spectrum and three-level signals, so there is a small phase matching, thus Q-factor increased considerably.

IV. CONCLUSION

This paper evaluates the performance of eight channel WDM system for different modulation formats such as duobinary, RZ and NRZ. From the obtained results, it is concluded that Q factors are got improved against the bit rate, transmission distance and core effective area with

Duobinary modulation format which will offer a significant performance benefit. It is also observed that in the presence of chromatic dispersion, duobinary modulation is a much more resilient modulation format as compared to NRZ and RZ modulation.

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