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PHASE-SHIFT MODULATION FORMATS IN OPTICAL COMMUNICATION SYSTEM

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Abstract— In this paper,we review different modulation formats for phase shift modulation techniques. The performance of non-return to zero differential phase shift keying, return to zero differential phase shift keying, and Differential Quadrature Phase shift Keying(DQPSK) modulation format for the optical communication system is analyzed.

Index Terms— Differential Phase shift Keying(DPSK), Differential Quadrature Phase shift Keying(DQPSK),Non-return to zero(NRZ), return-to zero(RZ), ON-OFF keying(OOK), Chromatic Dispersion(CD), Mach-Zehnder Modulator(MZM), Electro-absorption Modulator(E/OM),Mach-Zehnder Delay Interferometer(MZ-DI),Self Phase Modulation(SPM),Cross Phase Modulation(XPM).

1 INTRODUCTION

The key parameter of optical system is the product of bandwidth and distance. Increase in the channel capacity and dense channel spacing in DWDM systems can increase the capacity optical system . For long time on-off keying has been used in optical system. This type of modulation format has simple transmitters and receivers, as compared to systems needs some modifications in the system setup, which increases the system cost and complexity. But these DPSK and DQPSK system transmits information for high data rate and spectral efficiency for DWDM system. These types of modulation formats have integral better sensitivity of receiver . It can be received by using a balanced detector. These formats also reduce the distortion in signals such as self phase modulation and cross phase modulation.[1]. For high speed system a DPSK or DQPSK formats are used in which MACH-ZEHNDER delay interferometer (MZ-DI) is used because of narrow band filtering in high spectral efficient WDM transmission system. For DPQSK transmitter also both return to zero (RZ) and non return to zero (NRZ) types of pulse shaping scheme is used. The wavelength offset tolerance for high data rate DPSK and DQPSK modulation format has been demonstrated. According to that any wavelength offset between optical source and MZ-DI results in non-optimal interference at the output ports and this may be a cause to severe system degradation and receiver power penalties.

This paper will review the basics of differential phase shift keying system. First the fundamentals of DPSK format are covered and then DPSK system with RZ and NRZ format are described and comparing their performances.

2 DPSK FORMAT

PSK formats carry the information in the optical phase . At the receiver , the phase of previous bit is used as a reference of relative phase, results in differential phase shift keying(DPSK) The optical phase changes for DPSK system between the adjacent bits a optical phase shift of either a 0 or180 is encoded with the binary data.[2]. The whole bit slot is occupied by the optical power if each bit slot for NRZ-DPSK and as an optical pulse for RZ-DPSK. The main advantage of DPSK system is that it gives 3db lesser OSNR value for required bit error rate when comparing with ON-OFF keying.

There are some more benefits also exist of using DPSK modulation. A balance detection method for DPSK system has been used successfully for large tolerance to signal power variations in the receiver decision circuit because the decision threshold is independent of the input power. In balance detection, the robustness to narrow-band optical filtering in DPSK system is greater than the OOK system. The DPSK system are more elastic to non-linear effects than OOK system. The results from the fact that, the optical power is more evenly distributed as power is present in every bit slot in DPSK and the optical peak power is 3db lower than OOK in DPSK for the same average optical power. The other multilevel modulation formats such as differential quadrature phase shift keying enables the higher spectral efficiency and higher tolerance chromatic and polarization-mode dispersion.

2.1 Non-return -to-zero differential phase shift keying(NRZ-DPSK):

In optical phase shift keying, the phase of optical carrier is used for signal transmission . In initial times of optical communication system. The phase of phase based modulation was not stable enough to give a better performance because of poor semiconductor laser source.

Recently , by using single frequency laser source and optical a phase locking system the performance has been improved, DPSK is the mostly used format. In the NRZ-DPSK transmitter, the NRZ data is encoded in DPSK encoder. In this DPSK encoder a NOR gate followed by its 1 bit delayed XOR gate. This combination gives the encoded DPSK signal which is then used to operate an electro-optic phase modulator. The output of the electro-optic phase modulator is DPSK optical signal . This optical signal

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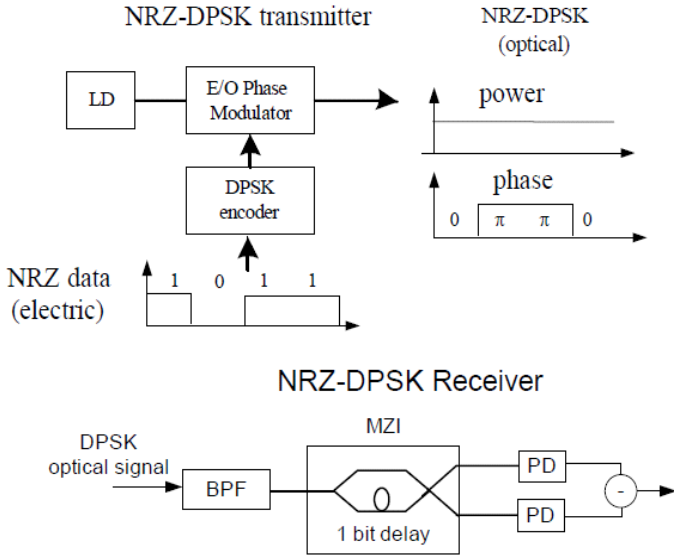
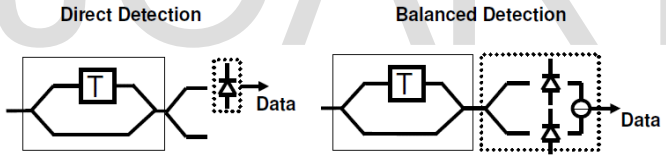
is modified according to the output of DPSK encoder by using E/O phase modulator. By keeping signal optical power constant, a change of Π phase in the optical carrier between the continuous data bit is given for a digital "1".

one bit mach-zehnder interferometer (MZI) is used to co-relate each bit with neighboring bit at the receiver and this converts the phase into intensity if two continuous bit are in same phase then they are added and gives a high level of signal and if two continuous bits are in phase difference of Π then they cancel each other and gives a low level signal.



Figure[1]. NRZ-DPSK Transmitter and receiver

A practical DPSK receiver use a MZI which has two balanced output ports a photo diode is used at each port the photo current of these photo diodes doubles the elev of signal when they combine so the sensitivity of receiver is enhanced by 3 db .



Figure[1]. DPSK receiver:(a)Direct detection,
(b) Balanced detection

In DPSK optical signal in carrier component is present in optical field spectrum and with NRZ coding optical find switch between "1" and "-1" in spite of the optical power cap constant. Because of the constant optical power the performance of DPSK is not affected by non-linear effects of optical power modulation. The non linear affects such as SPM and XPM do not effect much , but the effect of chromatic dispersion may occur. Phase modulation can be converted into intensity modulation through group velocity dispersion(GVD) and the SPM and XPM may contribute to wave form distortion to some extent. [4] The performance of DPSK system is limited by non-linear phase noise in a long distance DPSK system with optical amplifiers.

2.2 Return -to -Zero differential phase shift keying (RZ-DPSK):

RZ-DPSK has suggested to enhance the system tolerance to non-linear distortion for a long distance transmission. An optical pulse is present in each bit slot in this modulation format and encoding of binary data is as either zero or a pie phase shift between continuous bits. The width of optical pulses in RZ-DPSK is narrower then the bit slot. The RZ DPSK signal is generated by NRZ-DPSK system followed by 1 more intensity modulator. The block diagram for RZ-DPSK transmitter is shown in fig 2. In this first a conventional NRZ DPSK optical signal is generated and then by using a periodic pulse signal the NRZ DPSK optical signal is sampled at the same clock rate.

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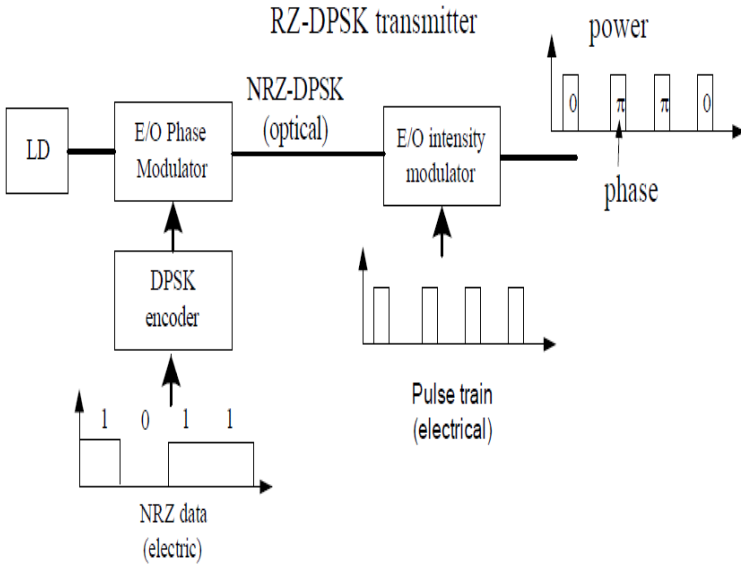
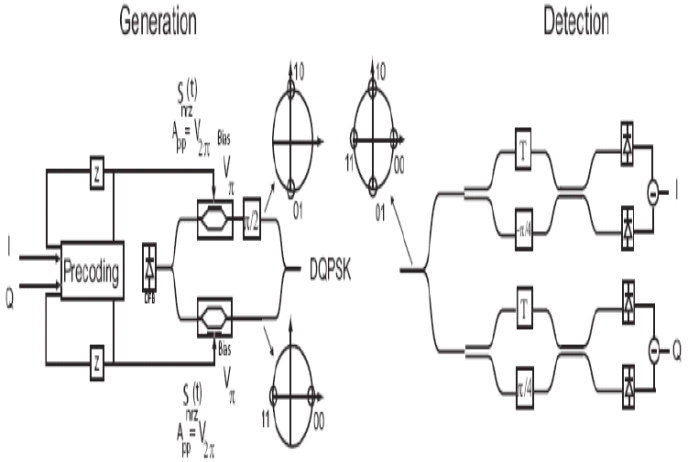


Figure[2]. RZ-DPSK Transmitter and receiver

This modulation is also known as intensity modulated DPSK because of an another bit synchronized intensity modulator in addition. As in this format the optical intensity of signal is not constant so the output signal may have the effect of SPM . The width of optical pulse is less then the bit slot in RZ DPSK as compared to an RZ DPSK. So RZ DPSK has a wide optical spectrum because of which this will introduce the sensitivity to chromatic dispersion (CD) . In long distance optical system, periodic dispersion compensation is used and RZ modulation format makes it easy to find the optimum dispersion compensation because of its regular bit pattern [5]

3 Differential Quadrature phase shift Keying(DQPSK)

DQPSK is a multilevel format use din optical communication system proposed later. In this format four phase shifts 0,+Π/2,-Π/2, Π) are transmitted at a symbol rate of half the total bit rate. A DQPSK transmitter consists two parallel MZMs phase modulator. Fig 3 shows the setup of transmitter for DQPSK. The transmitter of DQPSK has a continuous laser source and a splitter is used to split the light from the source into two path. These two paths have equal intensity of light. The two MZMs work as phase modulators so the output of one path of MZM modulator shifts the phase of optical signal by Π/2 phase and a adder gives the output optical signal. A serial DQPSK transmitter setup is also possible[6].By using this type of transmitter setup, we get almost perfect phase shift of Π which does not depend upon the drive overshoot and ringing. One more important advantage of using this transmitter is that it works on binary electronic drive signal and these can be easily generated at high speed as compared to multilevel drive wave forms.



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Figure[3]. NRZ-DQPSK Transmitter and receiver

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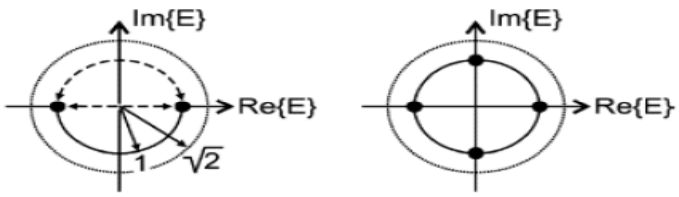
To generate RZ DQPSK a pulse carver can also be used. the DQPSK and DPSK have identical optical system but for transmission at fixed bit rate the optical spectrum of DQPSK is compressed in frequency due to halved symbol rate by a factor of 2. This compressed spectrum of frequency can give high spectral efficiency, high tolerance to chromatic dispersion and longer symbol duration which makes DQPSK more robust to phase modulated dispersion (PMD).

To receive the DQPSK signal at the receiver, signal split into two signal of equal value. Balanced receiver are used in parallel with differentially biased delay interferometers which demodulates those two binary data streams of DQPSK signals. The symbol duration for DQPSK demodulation in equal to the MZ-DI delay, which is twice of the bit duration.



Figure[4] shows the optical symbol diagram for DPSK and DQPSK modulation [2].

4 CONCLUSION

In this paper the performance of NRZ-DPSKK, RZ-DPSK, DQPSK for optical communication system is studied. It is observed that NRZ modulation format does not have a best dispersion tolerance among other formats. The RZ pulse shape enables an increased robustness to optic-fiber nonlinear effects and because of its broader spectrum it has a lower dispersion tolerance. As we studied DPSK and DQPSK modulation formats in details. When using balanced receiver in phase modulated systems, they have integral 3db enhanced receiver sensitivity. In DQPSK receiver by using MZ-DI high bit rate and high spectral efficiency can be realized. It is also studied that use of a MZM phase modulator is useful in low driving voltage.

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