Mitigation of distortion in FH-OCDMA Networks with Various Modulation Techniques

SURINDER SINGH, CHAKSHU GOEL*
Department of Electronics and Communication Engineering,
Sant Longowal Institute of Engineering and Technology,
Longowal, Sangrur, Punjab
Shead Bhagat Singh College of Engg. & Technology,
Ferozpur, Punjab
INDIA
Surinder_sodhi@rediffmail.com http://www.sliet.ac.in

Abstract: - In this paper, four channels of frequency hoped optical code division multiple access system are simulated for OOK, BPSK with residual carrier, BPSK with sub carrier and QPSK at 30 Mb/s with channel spacing of 0.05 GHz. It is evaluated that FH-OCDMA using BPSK with sub carrier is greatly mitigate the distortion as compared to OOK, BPSK with residual carrier, QPSK system. The quality of signal is further enhanced by variation of FWHM with fixed gain EDFA, saturable gain EDFA and optimized SOA.

Key-Words: - OCDMA, OOK, BPSK, QPSK, EDFA, SOA, FWHM.

1 Introduction
In the late 1970s, fiber began to replace coaxial cable as the transmission medium in the trunk systems of telecommunication networks, bringing many advantages both technical and economic. Only optical techniques with passive optical networks (PONs) in particular can provide sufficient bandwidth for this requirement. In order to make full use of the available bandwidth in optical fibers and to satisfy the bandwidth demand in future information networks, it is necessary to multiplex low rate data streams onto optical fiber to increase the total throughput.

The OCDMA offers an interesting alternative for local area networks (LANs) because neither time management nor frequency management of all nodes is necessary. The OCDMA can operate asynchronously without centralized control and does not suffer from packet collision with low latencies. In contrast to optical time division multiple access (OTDMA) and wavelength division multiple access (WDMA), the maximum transmission capacity is determined by the total number of slots in OCDMA.

The OCDMA allows flexible network design because the BER (bit error rate) depends on the number of active users [1]. A variety of approaches to OCDMA have been suggested by researcher in [2-3], they share a common strategy of distinguishing data channels not by wavelength or time slot, but by distinctive spectral or temporal code or signature impressed onto the bits of each channel. Suitably designed receivers isolate channels by code-specific detection.

Many OCDMA communication schemes have been proposed in the last two decades. The most attractive incoherent schemes are direct sequence (DS), spectral amplitude coding (SAC), and fast frequency hopping (FFH) OCDMA systems. Salehi et al. [4] reported that the performance of this system is poor because of the correlation properties of the uni-polar codes used, which contributes to a high level of multiple access interference (MAI). The SAC scheme is a more recent technique in OCDMA systems where the spectrum of a broadband source is amplitude encoded. In these systems, MAI can be canceled by balanced detection and code sequences with fixed in-phase cross correlation as reported by Wei et al. [5]. However, its performance is still limited by phase induced intensity noise (PIIN) [6]. Frequency separation between successive chip pulses is required in FFH-CDMA system to reduce the side lobe effects of the gratings. This limits the maximum number of users in the system. Further more, the spatial distance between the gratings and the number of gratings limits the users data bit rate in the system. Moreover in all the previous systems, they are either non-reconfigurable or need
complicated reconfigurable encoders [4, 7-8]. A new OCDMA scheme is better for reducing multiple access interference (MAI) and enhancing performance using modified pseudorandom noise (PN)-coded fiber Bragg gratings with bipolar OCDMA decoders is better [8]. Griffin [9] comments that the performance of broadband optical sources is ultimately limited by the interference between these broadband sources. Simith et al. [10] reported that the thermal nature of broadband optical sources that limits the performance of spectrum-sliced WDM systems also limits spectral-amplitude CDMA systems. Wang et al. [11] proposed an optical threshold technique in the system that could eliminate the out-of-peak MAI and secondary beat noise to improve the performance significantly. Wang and Wada [12] investigated experimentally that impairments of inter-symbol interference and beat noise in coherent time-spreading optical code-division-multiple-access are sweeping the data-rate from 622 Mbps up to 10 Gbps with 511-chip super structured fiber Bragg grating with BER improvement. Wang and Kitayama [13] show that the performance of coherent systems is limited by the beat noise. With increasing the coherent ratio $kt$, the effect of beat noise decreases in incoherent systems, and they eventually become free of beat noise. Wang et al. [14] demonstrated the DPSK-OCDMA scheme with balanced detection could be superior over the coherent OOK-OCDMA.

2 Simulations Setup for Various modulation based OCDMA Networks

A 4-channel transmitter generates OOK encoded sub-carrier signals at 30 Mb/s in the 1 GHz range. The electrical signal is sent to an external optical modulator and directly detected, in a back-to-back (no fiber) configuration. The non-linearity introduced by the external modulator gives rise to clipping effects that can be seen both on the received eye diagram and received spectra. As shown in figure 1, each data source at 30 Mb/s at pseudo-random sequence degree of 7. Further these four data source output fed to amplitude modulator. Each amplitude modulator has fixed carrier amplitude and modulator sensibility but carrier frequency are 1, 1.05, 1.1 and 1.15 GHz. Here, single optical source is used, which is shared by four OOK channels. Transmitter section consists of four continuous wave Lorentzian laser sources at 1550 nm, which are fed to dual arm MZ modulator with excess loss -3dB. This modulator also receives input from laser source which gives CW power of 3 dBm. The output of modulation is short optical pulses forming optical signal. At the receiver pin photodiode with quantum efficiency of 0.7 is used to detect the signal. Then signals are separated by band pass electrical Bessel filter with 30 MHz bandwidth.

In PSK OCDMA system is use same component except modulator. Here phase modulator is use as shown in figure 2. After simulation, the received electrical spectrum of all four channel of PSK-OCDMA system shows no noise spikes as compared to OOK-OCDMA. With increase in loss, the power level of signal goes on decreases which will add more distortion in the received signals.

Eye opening and closure are evaluated from the simulation for variation in laser power as shown in figure 3 and 4. The eye opening for PSK-OCDMA is more as compared to OOK-OCDMA as in figure 3. It is observed that PSK-OCDMA is better choice to combat the noise. These results show good agreement with reference [14]

2.1 BPSK-OCDMA with residual carrier

The BPSK-OCDMA with residual carrier system is formed same as shown figure 1 with change in transmitter section. The transmitter section consists of four continuous wave Lorentzian laser sources at 1550 nm, which are fed to dual arm MZ modulator with excess loss of 3 dB and offset voltage of 5 volt. This modulator also receives input from laser source which gives continuous wave (CW) power of 3 dBm.

2.2 BPSK-OCDMA with sub carrier

The transmitter section consists of four and continuous wave Lorentzian laser source at 1550 nm, which is are fed to dual arm MZ modulator with excess loss 3dB. This modulator also receives input from laser source which gives CW power of 3 dBm. The output of modulation is short optical pulses forming optical signal.

2.3 QPSK-OCDMA

A 4-channel transmitter generates QPSK signals at 30 Mb/s in the 1 GHz range. The electrical signal is sent to an external optical modulator and directly detected. The non-linearity introduced by the external modulator gives rise to clipping effects that can be seen both on the received eye diagram and received spectra. As shown in figure, each data source at 30 Mb/s at pseudo-random sequence degree of 7. Further these four data source output fed to phase shift modulator
Figure 1: Simulation set up of OOK-OCDMA system

Figure 2: Simulation set up of PSK-OCDMA system

Figure 3: Eye opening of received signal versus variation of input laser power for different OOK and PSK-OCDMA system

Figure 4: Eye opening of received signal versus variation of input laser power for different OOK and PSK-OCDMA system

Figure 5: Eye opening of received signal versus input power signal

Figure 6: Eye closure of received signal versus input power signal
3 Comparison different PSK scheme in OCDMA system

This chapter is dedicated to the comparison of BPSK-OCDMA with sub carrier, BPSK-OCDMA with residual carrier and QPSK-OCDMA. As the eye opening represents the clarity of received signal in terms of quality and BER. The higher the value of eye opening of received signal means the signal is recognized at receiver without any distortion and noise. Figure 5 shows the eye opening of received signal variation with applied input signal power for different phase shift keying in OCDMA system. It is observed that BPSK-OCDMA with sub carrier signal has higher eye opening for all applied input signal power. It is also observed that for BPSK-OCDMA with sub carrier signal has constant eye opening for all applied input signal. BPSK-OCDMA with residual carrier signal has poor eye opening for received signal. The QPSK-OCDMA signal has better eye opening as compared to BPSK-OCDMA with residual carrier signal.

While in case BPSK-OCDMA with residual carrier signal and QPSK-OCDMA signal, there is improvement in eye opening with increase in applied input signal.

Figure 6 shows the eye closure of received signal variation with input power signal. Eye closure represents disturbances and noise in the system. Same results are obtained as in figure 5. There is minimum eye closure obtained in BPSK-OCDMA with sub carrier as compared to BPSK-OCDMA with residual carrier and QPSK-OCDMA. The figure 5 and 6 are observed for FWHM (four wave half maxima) of 10 MHz of laser. The maximum eye opening is observed around $10^{-3}$ for BPSK-OCDMA with sub carrier signal.

Figure 7 shows the eye opening of received signal variation with FWHM of laser. Here, the maximum eye opening is observed around $10^4$ for FWHM up to 4 MHz for BPSK-OCDMA with sub carrier signal. While in case BPSK-OCDMA with residual carrier and QPSK-OCDMA, higher eye opening is observed up to 5 MHz FWHM of applied laser. Figure 8 shows the eye opening of received signal variation with FWHM of laser. It is observed that minimum eye closure of around 2 dB is obtained for BPSK-OCDMA with sub carrier signal.

From above, it is observed that BPSK-OCDMA with sub carrier gives better quality of signal as compared to other OCDMA systems.

Figure 9 shows the eye diagram with physical EDFA in the path. It is observed that quality of received signal is 9.33 dB. From eye diagram as shown in figure 10, the mitigation of noise can be achieved with saturable gain EDFA in the path. The quality of received signal is around 12.72 dB with saturable gain EDFA in the path for BPSK-OCDMA signal with sub carrier.

With utilization of fixed gain EDFA as shown in figure 11, there is less distortion has been observed. The improvement in quality of received signal is around 17.85 dB with fixed gain EDFA in the path for BPSK-OCDMA signal with sub carrier.

Further mitigation of noise can be achieved, by increasing the pseudo random sequence degree from 6 to 28 with fixed gain EDFA in the path for BPSK-OCDMA signal with sub carrier. The quality of received signal is 18.505 dB as shown in eye diagram of figure 12. If no amplifier is used in the path as shown in figure 13, then good quality of 18.51 dB is observed with power penalty.
Therefore, mitigation to noise is more at the cost of drop in power. By using optimized semiconductor optical amplifier (SOA) [15], there is great mitigation of noise for received signal. We got quality more than 23.52 dB as shown in figure 14. Therefore, it is concluded that by using optimized SOA in the path for BPSK-OCDMA signal with sub carrier has mitigated the various noises. Hence, improvement in signal to noise ratio is observed for the system. Therefore, it may utilized for long distance transmission.

4 Conclusions

Using PSK data format and balanced detection in coherent OCDMA, there is combat to beat noise as well as MAI, and overcome OOK-OCDMA system. The effects of beat noise and other types of additive noise in optical-code-division multiple-access (OCDMA) networks has been analyzed and simulated for different keying scheme.

It is evaluated that PSK system has better performance as compared to OOK system. Further, from eye opening of received signal, it observed that the BPSK with sub carrier has maximum eye opening of $10^{-3}$ for all input power signal with 10 MHz FWHM of laser with minimum eye closure of
around 2.3 dB for BPSK with sub carrier. With laser FWHM up to 5 MHz, the eye opening of BPSK with sub carrier is more than 10^10.

The quality of signal increase with use of physical EDFA saturable to gain EDFA & further fixed gain EDFA in the path without any single mode fiber. By using optimized SOA, there is great mitigation to noise for received signal and quality more than 23.52 dB.

References: