Prime Sequence Codes를 이용한 chirped 2.5Gb/s 광 CDMA 신호에 대한 색분산 패널티로 전송 이행 분석

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요 약

가입자망과 메트로 광 가입자망에서 광범위한 적용범위에 대해 광 기술을 선도하는 기존의 WDM은 증가하는 사용자 수를 수용하는 데 어려움을 가지며 WDM은 채널간의 잡음에 의한 제한과 유효 채널의 최대가 WDM 채널에서 광 증폭기 이득의 균일성에 의해 제한받는다. 따라서 사용자 수를 증가시키고 데이터량을 확장시킬 수 있는 CDMA 기술 도입이 하나의 대안으로 요구된다. 본 논문에서는 SMF에서 수십 km 거리를 갖는 가입자망에서 prime sequence code를 사용한 2.5Gb/s 광 CDMA 신호의 색분산 패널티에 대해 연구하였다. 시스템 모델에서, 색분산 패널티, 파형과 디코드된 신호의 아이 다이어그램(eye diagram)이 결과로써 보여지며, prime sequence code 수의 증가에 대해 Chirp 파라미터를 갖는 코드화된 신호의 색분산 패널티를 보인다. 이러한 접근은 pseudo-orthogonality를 가지는 비동기식 광 CDMA의 디자인에 특히 적합할 것이다.

1. INTRODUCTION

Optical access networks have been considered as very attractive infrastructures to satisfy the increasing traffic demands. Up to now, a various types of structures and techniques have been proposed based on time-division-multiple access (TDMA) or wavelength-division-multiple access (WDMA). However, due to inherent structures their own, the cost per an user is quite so high that alternative approaches for high-speed access network with low cost need to be investigated as the optical code-division-multiple access (OCDMA) systems which the individual codes are assigned to each user at the transmitter and matched codes are also assigned at the receiver[1]. OCDMA systems enable to access multi-users simultaneously and asynchronously using the single wavelength which promise occupying the lower bandwidth than that of WDMA.

In this paper, we evaluated and analyzed the fiber dispersion penalty of 2.5 Gb/s OCDMA signals changing chirping parameters of ring laser which must give the useful criteria for the proper chip length, data rate, transmission distance, and chirping parameter in designing the optical access network using OCDMA techniques.

2. TRANSMISSION SYSTEM MODEL

We considered a system model as shown in Fig. 1. The optical source was assumed short pulse, generated from ring laser or MLLD with short pulse width and modeled with Gaussian function. The signal bandwidth of OCDMA signals are so broad that the fiber dispersion penalties can be determined by the base band signal. . The short pulse with 2.5 Gb/s repetition rate are encoded in the time domain and modulated with 2.5 Gb/s pseudo random bit sequence (PRBS) 2^7-1 which is represented by

$$X_{cdma}(t)=\sum_k a_k C(t) \tag{1}$$

where a_k = 0, 1 and $C(t)$ is a Gaussian input pulse for 2.5 Gb/s signal. Encoder results in time spreading the signal $X_{cdma}(t)$. This algebraic construction on the prime sequence code begins with the Galois Field GF(p) = $\{0,1,\ldots,p-1\}$ of prime number p. A prime sequence S_i = ($s_{i,o}$, $s_{i,1}$, ... , $s_{i,p-1}$) is constructed by $s_{i,j}=i\cdot j$ (mod p), where $i, j \in$ GF(p)− the Galois field of p. Each prime sequence S_i is mapped into a binary sequence C_i = ($c_{i,o}$, $c_{i,1}$, ... , $c_{i,p-1}$) and this is given by below equation [2].

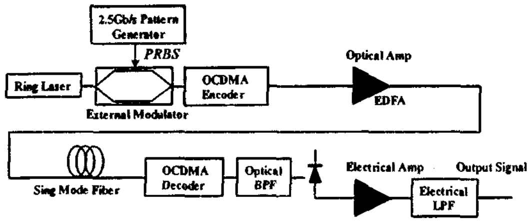


Fig. 1 Considered Optical CDMA System Model

$$C_{i,k} = \begin{cases} 1, & for\ i = s_i j + jp \quad (j=0,1,\square\ p-1) \\ 0, & \text{otherwise} \end{cases} \qquad (2)$$

Each bit period generated by a PPG(Pulse Pattern Generator), is subdivided into small units, chips N = p^2. In the paper written by Wing C. Kwonng, the peak of the cross-correlation function is therefore at most two and the number of marks per code sequence and the auto-correlation peak both equal p in GF(p) [2].

Before transmitting encoded signal into SMF, the optical signal is amplified by erbium-doped fiber amplifier (EDFA), and SMF is modeled as a low pass filter with flat amplitude response and linear group delay within the data bandwidth. So, the transfer function of SMF transmission is denoted by

$$H(f) = e^{-j\pi D(\lambda)\left(\frac{-\lambda^2}{c}\right)Lf^2} = e^{-j\alpha f^2} \qquad (3)$$

where

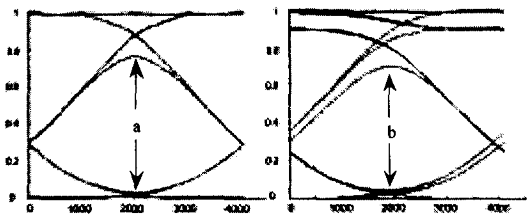
$$\alpha = \pi D(\lambda)\frac{\lambda^2}{c}L \qquad (4)$$

$$f = \nu - \nu_c \qquad (5)$$

parameter ν is the optical frequency, ν_c is the optical carrier frequency, L is the fiber length, λ is the operating wavelength, and c is the speed of light. In this case, dispersion parameter, D is 15 *ps/nm·km* and β_3 is negligible. The peak power of time-spread signal is quite so low that fiber nonlinearities are neglected [3]. We consider the chirped CDMA signal broadening over SMF. Full width at half maximum (FWHM) of the pulse related to the parameter T_0 is given by

$$T_{FWHM} = 2(\ln 2)^{1/2}T_0 \approx 1.665T_0 = \frac{1}{B \cdot N} \qquad (6)$$

In this work, T_0 represents the chip width T_0 = 15ps In this paper, RL or MLLD as as optical source and SMF as transmission line are assumed. Thereby , chirp is mark or space and typical



(a) (b)

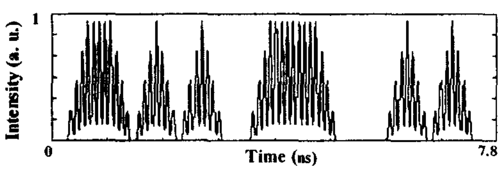
Fig. 2 Eye diagrams before (a) and after (b) transmission (distance = 40 km, C = 0)

β_2 = -20ps²/km is used.

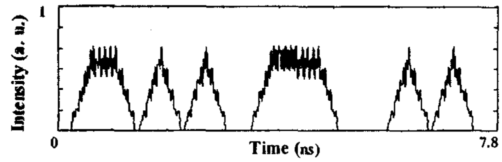
Optical dispersion penalty is estimated by calculating the amount of eye degradation at the output of the electrical filter. The electrical dispersion penalty P_D is defined by the following:

$$P_D = 10\log\left(\frac{a}{b}\right) \qquad (9)$$

where a is the eye opening of the back-to-back signal without any distortion while b is the eye opening of the transmitted signal over an optical fiber of 40km in Fig.2□ a) Back to Back, 2□ b). Both signals are through filter with 1.7GHz bandwidth. The optical dispersion penalty is equal to the electrical dispersion penalty for all coherent system [3]. The OCDMA signal after SMF is launched into the pre-amplified optical receiver which consists of optical pre-amplifier and conventional optical receiver. The optical bandwidth is selected to be broader than and equal to the electrical bandwidth corresponding to be 0.707 times of bit rate and all filters are fourth-order Bessel type.



(a) back to back



(b) after 60 km SMF

Fig. 3 Waveforms after optical CDMA decoder

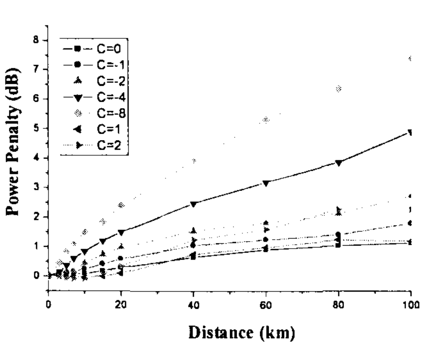


Fig. 4 Dispersion Penalty with propagated distance vs. transmission distance for a chirped ring laser

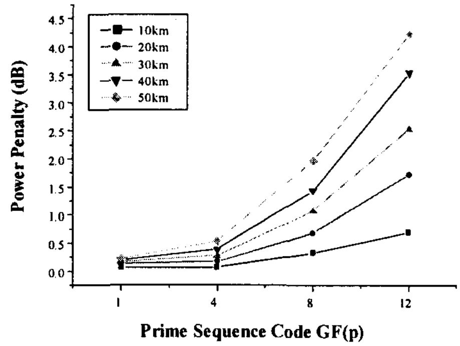


Fig. 5 Chromatic dispersion penalty at each distance vs. Prime sequence code GF(p) (C = 0)

The data bit stream out of output node still remains the original information previous SMF after decoding in Fig. 3-(b). After that, receiving this bit stream pass through low pass Bessel filter with 1.7GHz 3-dB bandwidth.

3. CONCLUSIONS

Most of this paper has deal with prime sequence codes for optical CDMA system considered chromatic dispersion using computer simulation.

In our study, we focus on ring laser source which has both of negative and positive chirp with SMF considered negative group velocity parameter (GVD). The results show the dispersion penalty with propagated distance for each chirp value, in Fig. 4. In about chirp = -2, dispersion penalty is about 1.5-dB at SMF 40 km. While in chirp free, 1-dB penalty appears at 100 km in codeword C_2 = (1 0 0 0 0 0 1 0 1 0 0 0 0 0 1 0) of GF(4).

While in case of negative chirp, pulse compression give rise to negative dispersion penalty (less than □ .01dB) at a few km. And in case of other three codewords except C_2 of GF(4) the chromatic dispersion penalty is similar to that of C_2. The error range among different codewords in GF(4) is smaller than 0.5-dB and that in GF(p) is also the same case.

In Fig. 5, the results show the variance of dispersion penalty at a few tens distance (km) as p of GF(p) increases for access network. If p of Galois field increases, the chip rate should be high and give some interference easily due to chromatic dispersion. So, according to circumstances (distance and dispersion penalty), we can design GF(p) in adapting to CDMA system. From the results, as the distance of optical transmission increase, so dispersion penalty in considered OCDMA system increase gradually. The absolute value of negative chirp need more power dispersion penalty. Moreover, at the same time, as chirp value goes low, dispersion penalty is also increased and performance degrades.

In conclusion, the number(p) of prime code at the same 2.5 Gb/s data rate determines optical dispersion penalty and our works show what is feasible number of psuedo-orthogonal codes at each a few distances for optical CDMA according to design performance limited.

REFERENCES

[1] Guu-Chang Yang and Kwong, W.C., 黠erformance comparison of multiwavelength CDMA and WDMA + CDMA for fiber-optic networks," *Communications, IEEE Transactions on*, vol. 45, no. 11, pp. 1426-1434. Nov. 1997.

[2] Wing C. Kwonng, Guu-Chang Yang and Jia-Guo Zhang □ " Prime-Sequence Codes and their Optical CDMA Coding Architecture□ *Communications, 1995. ICC '95 Seattle, 'Gateway to Globalization', 1995 IEEE International Conference on,* Vol. 3, pp. 1317 □ 321, 1955.

[3] Elrefaie, A.F., Wagner, R.E., Atlas, D.A. and Daut, D.G., 븮hromatic dispersion limitations in coherent lightwave transmission systems,□ *J. Lightwave Technol.*, vol. 6 no. 5, pp. 704 □ 09, May. 1988.

[4] Govind P. Agrawal, *Fiber-Optic Communication Systems, 2nd ed.*, Wiley, New York, 1997 ..