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A new family of two-dimensional codes for optical CDMA systems

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Abstract

The design of a new family of two-dimensional single pulse per column codes for optical code division multiple access (OCDMA) networks is reported. The 1-D modified pseudo-noise codes have been known to be orthogonal and their generation and system design based on these codes is rather simple. But their performance is limited due to the bandwidth constraints if the code length increases. Hence, using these 1-D modified pseudo-noise codes, modified 2-D pseudo-noise matrix codes (MPMCs) are generated. The system performance is evaluated for two, three and four simultaneous users using the link with all the sources responsible for degradation included: attenuation, chromatic dispersion, non-linear refractive effects, non-linear scattering and four-wave mixing. The effect of the non-linear and lossy dispersive medium over the system performance is shown by plotting the BER with respect to the link length for the systems designed using encoders/decoders base on 1-D modified pseudo-noise codes and our MPMCs. The performance is compared for the two types of codes by finding the crosstalk due to interfering users simultaneously operating in the network.

Keywords: Differential detection; Multi-access interference; Optical code division multiple access (OCDMA); Single pulse per row (SPPR) codes; Two-dimensional W-T codes

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1. Introduction

For high-speed access and local-area networks, the passive broadcast optical networks have been considered the most promising. Optical code division multiple access (OCDMA) is one such scheme with many attractive features (Fig. 1). The codes used for designing the encoders/decoders for fiber-optic communication systems are the (0, 1) codes because of the non-negativity of the optical fiber channel.

The PN codes like gold codes as well as the maximal length codes suffer from the multi-access interference problem as the number of 0's and 1's in these codes are not equal so the modified PN codes have been developed [1], but these belong to the class of one-dimensional codes. Because of the poor performance with the one-dimensional codes, many two-dimensional code families have been proposed [2–4] and designed for different kinds of detection schemes such as IM/DD and differential detection [5]. In [2], the prime codes have been used for time-spreading and optical orthogonal codes for frequency hopping patterns to obtain better crosstalk properties. But still the BER performance is not very convincing for 1 Gbps data rates as only a few users can be behaviour accommodated for BER of

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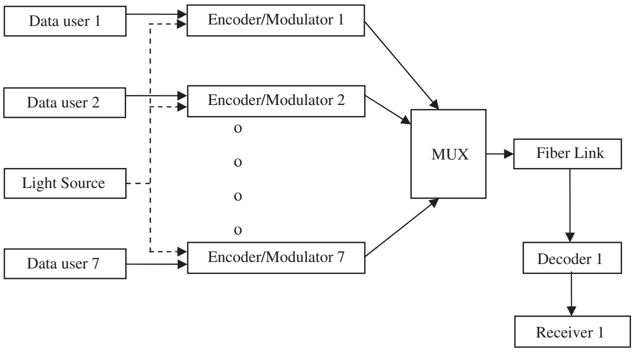


Fig. 1. A generalized OCDMA system.

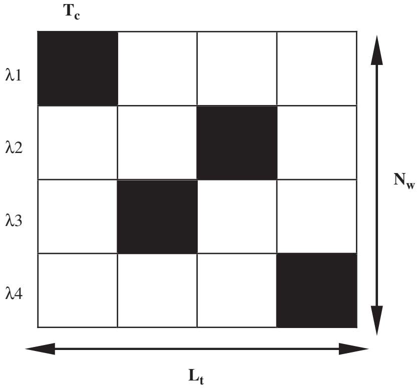
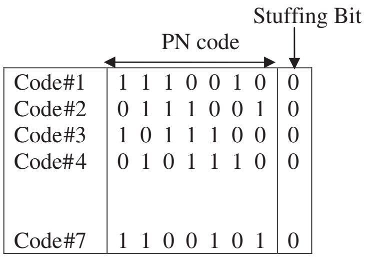
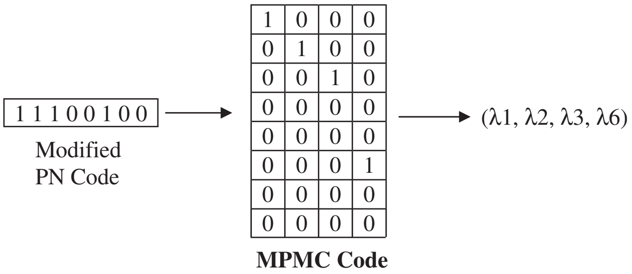


Fig. 2. Example of unbalanced SPPR code with $N_w = 4$ and $L_t = 4$. T_c is duration of a time chip [6].



Code#1	1 1 1 0 0 1 0	0
Code#2	0 1 1 1 0 0 1	0
Code#3	1 0 1 1 1 0 0	0
Code#4	0 1 0 1 1 1 0	0
Code#7	1 1 0 0 1 0 1	0

Fig. 3. Modified PN code of length 8 [1].



1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	1
0	0	0	0
0	0	0	0

Fig. 4. Deriving the 2-D MPMC code from the 1-D modified PN code.

1e−9, even with the use of differential detection. In [6,7] one-dimensional and two-dimensional codes have been proposed, but despite their good correlation properties, these have very long temporal lengths. More is the temporal length of the code, i.e. more the number of time chips, more will be the bandwidth expansion or lower the data rates supported.

In [1], the one-dimensional modified pseudo-random codes are generated from the pseudo-random codes, by stuffing of a zero bit in the end of each code. The family of the pseudo-random codes is generated by clock-wise shifting of the chips of the first pseudo-random code of the family.

In this paper, the generation of the family of two-dimensional modified pseudo-noise matrix codes (MPMCs) from the one-dimensional modified pseudo-noise code family of [1] is presented and the analysis of this code family is given. These generated codes have a single pulse in each of the columns of the matrix; hence these are suited for designs using fiber gratings. The example of a single pulse per column code is shown in Fig. 2.

2. Code design

The difference of our 2-D MPMCs from the modified PN codes (Fig. 3) is that these 2-D codes carry the optical pulses only in the chip slots which are 1's, as per their position in the code whereas the modified PN codes carry the wavelengths in the '1' and the complement wavelengths in the '0' bit periods [1,3]. So, although differential detection has been used with modified PN codes, still because of the presence of the signal during the whole of the '1' and '0' bit periods, there is considerable crosstalk interference among the users and hence the performance is limited.

Fig. 4 shows the conversion of the 1-D modified PN code into an 8-by-4, 2-D unbalanced MPMC W-T code. After each '1' chip, n zero chips are stuffed. Here, n is equal to the number of wavelengths used and these numbers of wavelengths are equal to the size of the modified PN code or its integral multiple. The elements of the 1-D code are written downwards. Because the addition of any number of zeroes equally in between all the 1's of the code does not change its correlation properties, so this code also has the same correlation properties as the original 1-D modified PN code. The translation of the 1-D code into the 2-D matrix code of a

Table 1. Important system parameter values

System parameter	Peak pulse power	Bitrate/user	Optical pulse width	First wavelength	Channel spacing	Chip period
Value used	1 mW	2.5 Gbps	0.02 ns	1548.6 nm	0.4 nm	0.1 ns