OPTICAL MULTIMEDIA CDMA SYSTEM WITH NOVEL MULTIPLEXING TECHNIQUES

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ABSTRACT: *Four novel multiplexing techniques (VSM, PSM, RPM, OIM) of an optical multimedia CDMA system have been proposed by using prime codes with different code lengths. PSM and VSM have the advantages of easily adding and controlling the inserting code system, but with a limited successful number. RPM can dynamically add the inserting codes into the original codes at the price of a complicated algorithm and lower multiplexing speed. For example, VSM, PSM, RPM, and OIM can insert the number of inserting P3-code to be 2, 3, 4, and 15 into the simultaneous number of original P7-code being 7 with the successful number of 10 for the original P7-code system. So OIM is the best model to process the multimedia CDMA system.* © 1999 John Wiley & Sons, Inc. Microwave Opt Technol Lett 22: 424–426, 1999.

Key words: *multimedia; optical CDMA; prime code; multicode*

1. INTRODUCTION

Multiple users within fiber optical networks are allowed to access simultaneously by using the optical code-division multiple-access (CDMA) system [1] which widely utilizes prime codes [2] and optical orthogonal codes [3]. The former has the advantage of easily implemented encoders and decoders [4]. In this letter, we propose novel multiplexing techniques for a multimedia CDMA system by using the optical prime code [2, 4] to increase the system capacity. In [5], the simulation study of different codes system-division multiple access (DCSDMA) for optical communication was proposed for only the fixed time-slot insertion (FTSI) methods, which include the vertical sequence model (VSM) and the parallel sequence model (PSM). The dynamical time-slot insertion (DTSI) methods, which include the random permutation model (RPM) and the optimal insertion model (OIM), are proposed in this letter. The DTSI methods outperform the FTSI methods from the simulation results in this letter.

This work is organized as follows. In Section 2, we give a brief system description, and present four novel multiplexing techniques (VSM, PSM, RPM, OIM). In Section 3, we present and discuss the results obtained from the numerical simulations, and Section 4 contains our conclusions.

2. SYSTEM DESCRIPTION

The block diagram of a multimedia CDMA system is shown in Figure 1. This system can multiplex the inserting code system with a smaller code length (P_S) into the original code system with a larger code length (P_L). Take P_7 and P_3, for example; there are NP7 users in the original system ($\text{User1}, \ldots, \text{User}_{\text{NP7}}$ use the prime code P_7 with a code length of 49). The monitor center (MC) will determine a

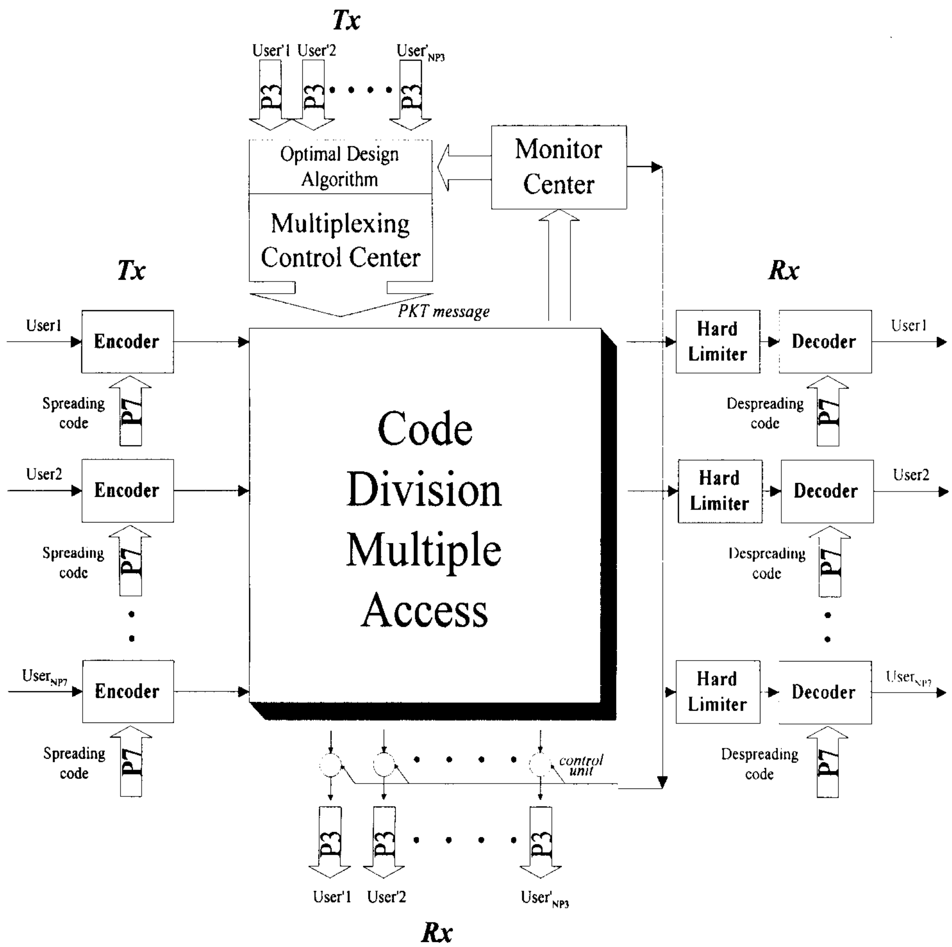

Figure 1 Multimedia optical CDMA system

suitable time slot by the optimal design algorithm to multiplex the inserting P_3 prime code (User1, ..., $User_{NP3}$ with a code length of 9) into the original P_7 prime code system.

2.1. The Fixed Time-Slot Insertion (FTSI) Method. The multiplexing structure for the FTSI method is shown in Figure 2. K and N denote the time slot and the simultaneous number of the inserting P3-code system, respectively. Without influencing the transmission of the original P7-code system, the maximum number of inserting P3-code is $\text{Max}(N) * \text{Max}(K) = 3 * 5 = 15$. The vertical sequence model (VSM) can insert the P3-code from different groups [1] to prohibit interference by the P3-code itself in a column vector (i.e., filling up the simultaneous number N) as shown in Figure 3(a). The parallel sequence model (PSM) can insert the P3-code from different groups in the row vector (i.e., filling up the time slot K) as shown in Figure 3(b).

2.2. The Dynamical Time-Slot Insertion (DTSI) Method. The random permutation model (RPM) and optimal insertion model (OIM) are DTSI methods which dynamically control the inserting positions of the inserting codes as shown in Figure 3(c) and (d), respectively. They use the characteristics of P7-Sum to add the appropriate P3-code into the spacing chip (the value of this chip is 0). RPM investigates the P7-Sum to find the position of the spacing chip to allow the code to be added in, and searches another nonzero chip (it will not destroy the next spacing chip) from the inserting code system. From this point, we will determine what kind of P3-code can be added to reduce the interference and increase the number of the inserting codes. OIM also needs to

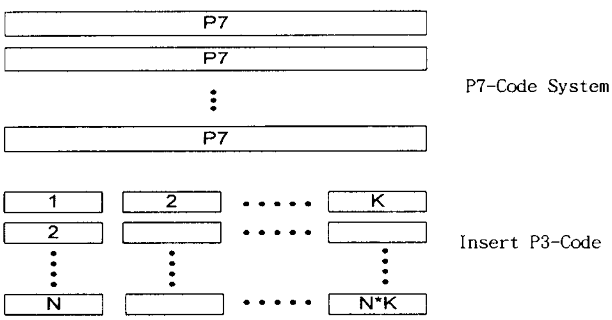

Figure 2 Multiplexing structure for fixed time-slot insertion method

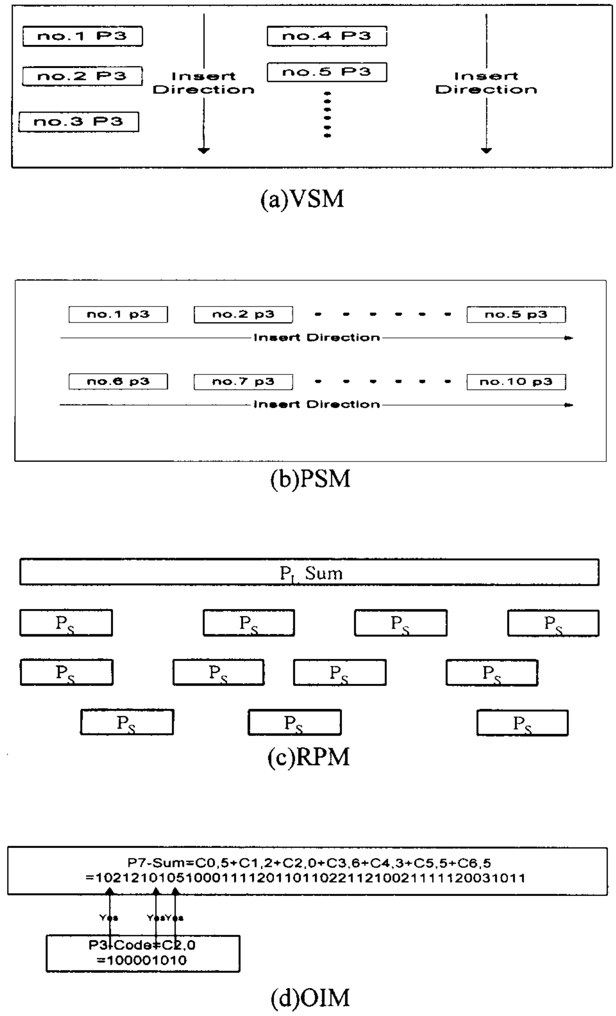

Figure 3 Different multiplexing models. (a) VSM. (b) PSM. (c) RPM. (d) OIM

search the spacing chip with the value of "0" in P7-Sum (the first inserting position), and search the next value of "0" or value larger than 2 in P7-Sum (the second inserting position). Choosing a value larger than 2 is better for not destroying the next spacing chip, which can be used by another inserting

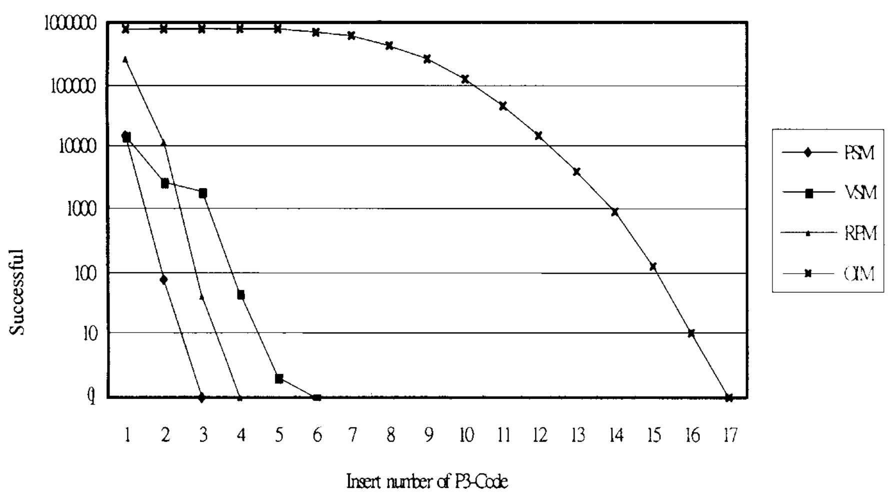

Figure 4 Simulation results

P3-code, with a value of "0." The OIM checks the first and second inserting chip positions to match the corresponding chip positions of the P3-codes to find the available inserting position for P3-codes. OIM only needs one circle to find the inserting codes. On the other hand, RPM continues to search the inserting code recursively until it cannot find any inserting position within one circle, and this searching procedure will then stop. Therefore, OIM is more efficient than RPM in searching the inserting codes.

3. SIMULATION RESULTS

Taking the original P7-code system with the simultaneous user number of 7 (NP7 = 7) [1], we can obtain the successful number of P7-code (from the total successful number of 823543 for P7) versus the inserting number of P3-code, as shown in Figure 4. For example, VSM, PSM, RPM, and OIM can insert the number of inserting P3-code to be 2, 3, 4, and 15 into the simultaneous user number of P7-code (being 7) with the successful number of 10 for the original P7-code system. According to the simulation results, the interference in PSM is more serious than other models. PSM can only insert the number of inserting P3-code to be 2 (by adding the number of inserting P3-code as 3 in the PSM, this multimedia CDMA system will fail). On the other hand, the successful number of a P7-code system for inserting the number of P3-code (being 3) in VSM is 1847.

4. CONCLUSIONS

Considering the multimedia CDMA system with the FTSI method, VSM is better than PSM. The FTSI method is faster than the DTSI method. But the DTSI method can insert more codes than the FTSI method at the price of breaking the limitation of a fixed time slot. OIM needs one circle to determine the inserting code, and RPM needs more than one circle to find the suitable inserting code. Therefore, considering the multimedia CDMA system with the DTSI method, RPM is better than OIM. We conclude that OIM is the better way to process the multimedia CDMA system in consideration of the total system capacity and algorithm efficiency.

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REFERENCES

1. J.H. Wu and J. Wu, Synchronous fiber-optical CDMA using hard-limiter and BCH codes, J Lightwave Technol 13 (1995), 1169–1176.
2. P.R. Prucnal et al., Spread spectrum fiber-optic local area network using optical processing, J Lightwave Technol 4 (1986), 547–554.
3. F.R.K. Chung et al., Optical orthogonal codes: Design, analysis, and applications, IEEE Trans Inform Theory 35 (1989), 595–604.
4. J.G. Zhang and G. Picchi, Tunable prime-code encoder/decoder for all-optical CMDA applications, Electron Lett 29 (1993), 1211–1212.
5. Y.-H. Lee, Simulation study of different codes systems division multiple access (DCSCMA) for optical communication, Microwave Opt Technol Lett (1999, accepted).

AN ANALYTICAL STUDY OF THE CUTOFF CONDITIONS AND THE DISPERSION CURVES OF A WAVEGUIDE WITH A CROSS-SECTIONAL SHAPE RESEMBLING AN ELLIPSE COMPRESSED ALONG THE MINOR AXIS

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ABSTRACT: *In this paper, we present an analytical study of the modal characteristics, cutoff conditions, and dispersion curves of a special type of an optical waveguide with a cross-sectional shape resembling an ellipse compressed along the minor axis (ECMI). Using the boundary conditions for the proposed waveguide under weak guidance, the cutoff equation and the modal characteristic equation have been obtained. From the cutoff equation, we find the number of modes propagating for the guiding region. Also, from the modal characteristic equation, we obtain the dispersion curves for some low-order modes.* © 1999 John Wiley & Sons, Inc. Microwave Opt Technol Lett 22: 426–429, 1999.

Key words: *modal characteristics; cutoff condition; weak guidance; optical fiber; dispersion curves; sustained modes; normalized propagation constant*

INTRODUCTION

The standard circular cross-sectional optical waveguide has been studied extensively [1–7]. This standard optical waveguide, called an optical fiber, is used in communication systems. But in recent years, light-wave propagation through various types of symmetrical and nonsymmetrical, noncircular cross sections of the waveguide have constituted an important specialized area in light-wave technology. Initially, only two types of noncircular cross section, namely, the planar and the elliptical, were studied widely [8–12]. These waveguides are very useful in the field of integrated optics. But in recent years, various noncircular waveguides having unconventional shapes such as rectangular, triangular, pentagonal, annular, Piet–Hein, cardiodic, hypocycloidal, and others have been studied by many investigators [13–25]. More recently, Singh, Ojha, and Singh [26] have studied the modal dispersion characteristics of an optical waveguide with a guiding region cross section bounded by two Archimedian spirals. In the present paper, we present an analytical study of the modal characteristics, cutoff conditions, and dispersion curves of a special type of an optical waveguide with a cross-sectional shape resembling an ellipse compressed along the minor axis. Using the boundary conditions for the proposed waveguide under the weak guidance approximation, the cutoff equation and the modal characteristic equation have been obtained. From the cutoff equation, we find the number of modes propagating through the guiding region; from the modal characteristic equation, we obtain the dispersion curves for some low-order modes.

THEORY

Figure 1 shows the transverse cross section of the proposed waveguide, having a core refractive index n_1 and cladding