SPACE-TIME TRELLIS CODING WITH CPM

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Summary

We consider the specific scheme of trellis codes where space-time coding and continuous phase modulation are used. Non-linear continuous phase modulation has desirable constant envelope properties and considerable potential in space-time coded systems. The transmitter and receiver parts of this scheme are described. The space-time encoder is feed forward and is defined over a finite field. The space-time encoder and the modulation is incorporated into a single trellis encoder. This allows state combining, which leads to realization complexity reduction.We investigate the conditions where the full diversity of the system is obtained.

Key words: Coding theory. Continuous phase modulation. Space-time coding.

1. Introduction

Space-time coded systems developed in the last ten years have been designed primarily using linear modulation. Non-linear continuous phase modulation has desirable constant envelope properties and considerable potential in space-time coded systems.

The work in this paper is focused on developing and analyzing an integrated space-time coded continuous phase modulated (STC-CPM) system. The coding of the space-time encoder and the modulation is incorporated into a single trellis encoder. This allows state combining, which leads to complexity reduction due to the reduced number of states.

2. Coding Scheme

Significant improvement in spectral efficiency is attainable by increasing the number of antennas used at the transmitter and the receiver. A technique that employs coding across multiple transmit antennas is space-time coding (STC). To date STC has improved quality but not spectral efficiency. Minimum shift keying (MSK), a particular form of continuous phase modulation (CPM) , is an excellent signaling format for use in space-time coded systems. The promise of good performance by space-time trellis coded CPM systems is illustrated by Cavers in [1].

This paper is present an in depth review of the current state of space-time trellis coded CPM research. The space-time coded CPM system presented in Figure 1.

The space-time encoder, pulse amplitude mappers (PAM) are required to map the space-time encoded data $J_{i,n} \in \{0,1,\ldots, M-1\}$ to the channel symbols $\alpha_{i,n} \in \{-(M-1),-(M-3),\ldots M-1\}$ for $1 \leq i \leq L_t$.

The modulation index is set to $h = \frac{v}{p}$ where v and p are relatively prime integers. Then, the physical phase is constrained to lie on a trellis.

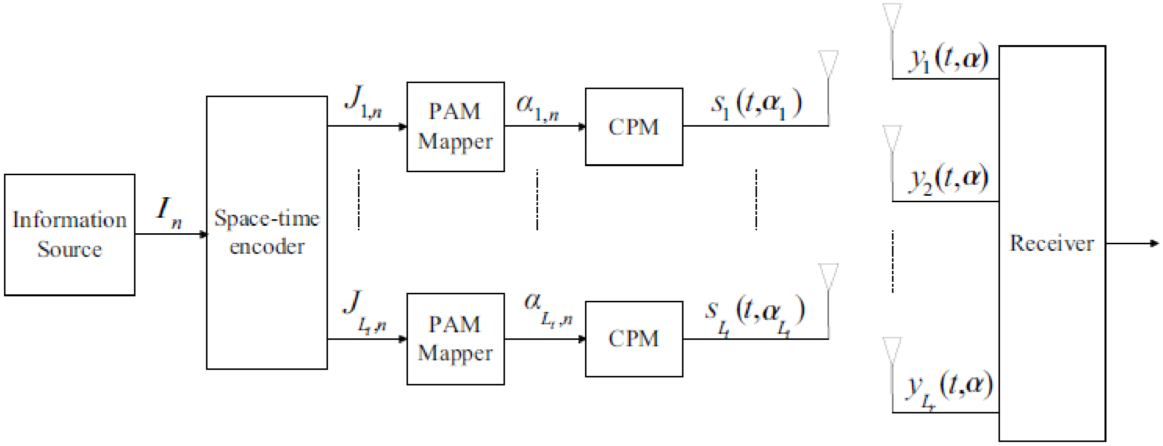

Fig.1. Space-time coded CPM system

The state of the phase at the i- th transmit antenna is dependent on the vector

$$S_{i,n} = \left[\tilde{\theta}_{i,n}, \alpha_{i,n-1}, \dots, \alpha_{i,n-L+1}\right] \quad 1 \le i \le L_t \tag{1}$$

where $\tilde{\theta}_{i,n}$ is defined by Equation

$$\tilde{\theta}_{i,n} = \left[\pi h \sum_{j=0}^{n-L} \alpha_{i,j}\right] \bmod 2\pi \,. \tag{2}$$

Each vector described by Equation 1 for $1 \le i \le L_t$ has $2pM^{L-1}$ possible states.

The space-time encoder is feed forward, has constraint length ν, and is defined over a finite field. The overall transmitter may be represented by a super trellis and the state of the trellis at time nT is

$$S_{i,n} = \left[\tilde{\theta}_{i,n}, \tilde{\theta}_{L_{t,n}}, I_{n-1}, \dots, I_{n-L-\nu+1}\right], \tag{3}$$

where the information symbols, I_n, are binary. This super trellis has $(2p)^{L_t}2^{\nu+L-1}$ states and may take on $p^{L_t}\, 2^{\nu+L-1}$ of these during any given interval. For example, consider M-ary CPFSK with $h = \frac{1}{M}$, which we denote as M-CPFSK, used with the delay diversity space time code. Delay diversity with L_t transmit antennas has a constraint length of $L_t - 1$. CPFSK is full response, that is, $L = 1$ and with $h = \frac{1}{M}$, variable $p = M$. The number of states in the super trellis for this system using the space-time coded CPM scheme proposed in [2] is

$$S_T = (2p)^{L_t}2^{\nu+L-1} = (2M)^{L_t}2^{L_t-1} = M^{L_t}2^{2L_t-1} \tag{4}$$

In [2], design criteria are presented for space-time coded CPM in quasi-static fading, for a small number of parallel spatial channels. The PEP is shown to have an upper bound analogous to that derived for linearly modulated space-time codes, with a different distance matrix. The signal distance matrix for space-time coded CPM is defined as:

$$S = \begin{vmatrix} \int_0^{N_cT} |\Delta_1(t)|^2\,dt & \cdots & \int_0^{N_cT} \Delta_1(t)\Delta_{L_t}^{*}(t)\,dt \\ \vdots & \ddots & \vdots \\ \int_0^{N_cT} \Delta_{L_t}(t)\Delta_1^{*}(t)\,dt & \cdots & \int_0^{N_cT} |\Delta_{L_t}(t)|^2\,dt \end{vmatrix} \qquad (5)$$

where $\Delta_i(t)$ is the continuous time difference between the transmitted and the decoded signal from the i-th transmit antenna. The PEP bound is derived as:

$$P(\alpha \to \check{\alpha}) \le \frac{\binom{2L_r\rho-1}{L_r\rho-1} N_0^{L_r\rho}}{\left(\prod_{i=1}^{\rho}\lambda_i\right)^{L_r}} \qquad (6)$$

where λ_i are the non-zero Eigen values of the signal distance matrix, and ρ is the number of non-zero Eigen values or equivalently, the rank of the signal distance matrix.

The transmit diversity, d, of a space-time coded CPM system in quasi-static fading is limited [3, 4] by:

$$d \le 1 + \left| L_t - \frac{R_S}{\log_2(M)} \right|, \qquad (7)$$

where M is the size of the CPM alphabet, R_S is the system throughput in bits per symbol period and L_t is the number of transmit antennas. Conditions for full spatial diversity to be achieved in space-time coded CPM systems are discussed in [2].

For the minimum rank of all signal distance matrices to equal the number of transmit antennas, such that full spatial diversity is achieved, a necessary and sufficient condition is to make all continuous time differences from all antennas linearly independent over the complex field C. Systems that satisfy this condition and guarantee full diversity include:

- Zeros symmetry. Delay diversity is a special case of zeroes symmetry;
- Using different CPM schemes on each transmit antenna. However, this method may require more bandwidth and be more complex;
- Memoryless repetition coding with different mapping rules on each antenna. The number of transmit antennas must be less than the alphabet size. This method does not work for linearly modulated space-time codes.

References:

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უწყვეტფაზიან მოდულაციაზე დაფუძნებული სივრცით-დროითი გისოსისებრი კოდირება

მარიამ სორდია

საქართველოს ტექნიკური უნივერსიტეტი

რეზიუმე

განხილულია კონკრეტული გისოსისებრი კოდირების სქემა, სადაც გამოყენებულია სივრცით-დროითი კოდირება და უწყვეტფაზიანი მოდულაცია. არაწრფივ უწყვეტფაზიან მოდულაციას გააჩნია მუდმივივი მომვლების სასურველი თვისებები და მნიშვნელოვანი პოტენციალი სივრცით-დროით კოდირებულ სისტემებში გამოსაყენებლად. აღწერილია ასეთი სქემის როგორც გადამცემი, ასევე მიმღები მხარე. სივრცით-დროითი კოდერი აგებულია წინმსწრები ფუნქციით და განსაზღვრულია სასრულ ველზე. სივრცით-დროითი კოდერი და მოდულაცია გაერთიანებულია ერთ გისოსისებრ კოდერში. ეს იძლევა მდგომარეობების გაერთიანების საშუალებას, რასაც მივყავართ რეალიზაციის სირთულის შემცირებამდე. განხილულია ის პირობები, რომლის დროსაც სისტემა აღწევს სრულ განცალკევებას.

РЕМЕННО-ПРОСТРАНСТВЕННОЕ РЕШЕТЧАТОЕ КОДИРОВАНИЕ НА БАЗЕ СИГНАЛОВ ЧМ-НФ

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Резюме

Рассматривается конкретная схема решетчатого кодирование, где используется временно-пространственное кодирование и частотная модуляция с непрерывной фазой. Нелинейная модуляция с постоянной фазой имеет полезное свойство постоянной огибающей и значительный потенциал для использования в системах временно-пространственного кодирования. Описывается как передающая, так и приемная сторона такой схемы. Временно-пространственный кодер имеет функцию упреждения и определяется над конечным полем. Временно-пространственный кодер и модуляция объединяются в один решетчатый кодер. Это позволяет объединять состояния, что приводит к уменьшению сложности реализации. Рассматриваются условия, при которых для системы обеспечивается полное разнесение.