Maximum likelihood decoding rules for STBC: Generalized framework for detection and derivation of accurate upperbounds

Gholam Reza MOHAMMAD-KHANI*, Guillaume FERRE*, Jean-Pierre CANCES*, Vahid MEGHDADI*

Abstract

In this paper we propose first a generalized framework for the Maximum Likelihood decoding of STBC. Using algebraic tools we then derive a new matrix model particularly well suited to the description of MIMO systems. After giving our particular detection rules we determine a new accurate upperbound for the BER performances of STBC transmitting schemes. Performance results are given which show the accuracy of the derived upperbound.

Key words: Mobile radiocommunication, Decoding, Maximum likelihood, Block code, Space diversity, Space and time signal, Rayleigh fading, Matrix method, Upper bound.

DÉCODAGE À MAXIMUM DE VRAISEMBLANCE :
RÈGLES DE DÉTECTION ET CALCUL DE BORNES SUPÉRIEURES
POUR LE TAUX D’ERREUR PAR SYMBOLE

Résumé

Ce papier aborde le problème du décodage des codes temps-espace en blocs, les règles de décodage sont rappelées et une formulation matricielle particulièrement simple est obtenue pour une programmation rapide. Cette modélisation matricielle nous permet d’obtenir un calcul de borne supérieure du TEB sur canal de Rayleigh non sélectif en fréquence. Les performances obtenues sont excellentes et montrent la précision des bornes obtenues.

Mots clés : Radiocommunication service mobile, Décodage, Maximum vraisemblance, Code bloc, Diversité spatiale, Signal spatio-temporel, Évanouissement Rayleigh, Méthode matricielle, Limite supérieure.

Contents

I. Introduction
II. System description
III. Complex STBC orthogonal design
IV. Maximum likelihood decoding of STBC
V. SER performances (derivation of accurate upperbounds)
VI. Simulation results
VII. Conclusion
References (12 ref )


ANN. TÉLÉCOMMUN., 59, n° 9-10, 2004 1/22
I. INTRODUCTION

Transmit diversity using space-time coding has been studied extensively as a method of combating impairments in wireless fading channels [1-5]. Space-time (ST) coding has been proved effective in combating fading, and enhancing data rates. Exploiting the presence of spatial diversity offered by multiple transmit and/or receive antennas, ST coding relies on simultaneous coding across space and time to achieve diversity gain without necessarily sacrificing precious bandwidth. Space-time trellis coding was at first introduced to combine signal processing at the receiver with coding techniques appropriate to multiple transmit antennas. Specific space-time trellis codes designed for 2-4 transmit antennas perform extremely well in slow-fading environments and come close to the outage capacity [6-8]. However, the main drawback of such encoding schemes is the complexity of the decoding algorithm which grows exponentially with transmission rate in the case of a fixed number of transmit antennas.

To overcome the prohibitive complexity of STTC, simple diversity transmission schemes based on the construction of orthogonal design matrices have been proposed [9-11]. Using such diversity schemes in combination with a FEC encoder leads to similar performances as those obtained with STTC. The construction of orthogonal design matrices gives birth to STBC (Space Time Block Code) encoding techniques which are, for example, planned for the next generation of cellular radiomobile systems.

The proposed paper deals with the SER (Symbol Error Rate) performances of STBC encoding schemes. We propose first a generalized framework for the Maximum Likelihood decoding of STBC. Using algebraic tools we then derive a matrix model particularly well suited to the description of MIMO systems. The obtained model enables to obtain remarkably simple maximum-likelihood decoding algorithms based only on linear processing at the receiver. Using this matrix modeling, we find a new accurate upperbound for the SER performances of STBC transmitting schemes. Simulation results are given and show the accuracy of the derived upperbound.

The paper is organized as follows: in Section II we derive a mathematical model for the description of MIMO systems, Section III gives an overview of STBC design techniques, Section IV contains the maximum-likelihood detection rules for the decoding of STBC signals, Section V is devoted to the derivation of accurate upperbounds and simulation results are eventually given in Section VI.

Notations: In this paper superscript $\dagger$ stands for transpose complex conjugate and $^T$ for transpose operation.

II. SYSTEM DESCRIPTION

Figure 1 illustrates the studied MIMO system. We consider the case of a wireless communication system where the mobile station is equipped with $n$ transmit antennas and the base station is equipped with $m$ receive antennas. The STBC coding rate is assumed equal to $k/l$ that means that each packet $(x_1, x_2, \ldots, x_k)$ of $k$ symbols corresponds to $l$ STBC transmitted symbols $(c_1, c_2, \ldots, c_l)$ at the $i$th transmit antenna. The coefficient $\alpha_{i,j}$ is the path gain from