UNIVERSITY OF MORATUWA

BEAMFORMING TECHNIQUES FOR THE DOWNLINK OF SPACE-FREQUENCY CODED DECODE-AND-FORWARD MIMO-OFDM RELAY SYSTEMS

By

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DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university. Furthermore, this does not contain any material previously published or written or orally communicated by another person except where due reference is made in the text or in the figure captions or in the table captions.

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To the best of our knowledge the above particulars are true and accurate.

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Abstract

Multiple-input multiple-output (MIMO) techniques can be used to achieve diversity gain, multiplexing gain and/or array gain. Particularly, diversity coding techniques (e.g. Space-Time (ST), Space-Frequency (SF) coding) have received tremendous attention as effective means of achieving spatial diversity gain in MIMO systems. However, in the presence of spatial correlations the diversity gain of ST/SF coding diminishes. Beamforming techniques can be used to achieve array gains in MIMO systems. Hence, in correlated channels beamforming techniques can be combined with ST/SF coding to further improve the performance.

In this thesis, we develop beamforming techniques relying on statistical channel state information at the transmitter (CSIT) for space-time (ST) / space-frequency (SF) coded MIMO systems to minimize the pair-wise error probability. We propose beamforming techniques for SF coded MIMO-OFDM systems in correlated frequency-selective Rician fading channels. We propose two novel beamforming techniques for this channel model.

Furthermore, distributed beamforming techniques are developed for correlated Rayleigh flat-fading channels, relying on full-instantaneous CSIT as well as statistical CSIT. Moreover, we extend these techniques for SF coded MIMO-OFDM relay networks in correlated Rician fading channels and propose optimal beamforming techniques relying on full-instantaneous CSIT. Also, suboptimal beamforming techniques relying on statistical CSIT are developed. The variation of error performance is thoroughly investigated and the simulation results confirm that all the proposed beamforming techniques achieve significant performance advantages over MIMO systems using ST or SF coding only.

To my dear Mother, Father, Brother, Sarangi and Romeo

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Acronyms

Following abbreviations or acronyms have been used in this thesis.

Abbreviations/acronyms	Meaning
MIMO	Multiple-Input Multiple-Output
SISO	Single-Input Single-Output
OFDM	Orthogonal Frequency Division Multiplexing
STC	Space-Time Coding
OSTBC	Orthogonal Space-Time Block Coding
SFC	Space-Frequency Coding
DSTC	Distributed Space-Time Coding
DSFC	Distributed Space-Frequency Coding
CSIT	Channel State Information at the Transmitter
CSIR	Channel State Information at the Receiver
QPSK	Quadrature Phase Shift Keying
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
ML	Maximum Likelihood
ISI	Inter-Symbol Interference
PEP	Pair-wise Error Probability
SER	Symbol Error Rate
BER	Bit Error Rate
SNR	Signal-To-Noise Ratio
MRC	Maximum-Ratio Combining
AWGN	Additive white Gaussian Noise
FIR	Finite Impulse Response
DF	Decode and Forward
AF	Amplify and Forward
LTE	Long Term Evolution
3GPP	Third Generation Partnership Project
SCM	Spatial Channel Model
WiMAX	Worldwide Interoperability for Microwave Access
LOS	Line Of Site

Nomenclature

Following symbols or notations have been used in this thesis.

Notation	Meaning
$(\mathbf{X})^H$	Conjugate transpose of matrix $\mathbf{X}$
$(\mathbf{X})^*$	Complex conjugate of matrix $\mathbf{X}$
$(\mathbf{X})^T$	Transpose of matrix $\mathbf{X}$
$\mathrm{tr}(\mathbf{X})$	Trace of matrix $\mathbf{X}$
$\\|\mathbf{X}\\|_F$	Frobenius norm of matrix $\mathbf{X}$
$\det(\mathbf{X})$	Determinant of matrix $\mathbf{X}$
$\lambda_i(\mathbf{X})$	i-th Eigenvalue of matrix $\mathbf{X}$
$r(\mathbf{X})$	Rank of matrix $\mathbf{X}$
$\mathbf{X} \geq 0$	$\mathbf{X}$ is positive semidefinite matrix
$\otimes$	Kronecker product
$P(A)$	Probability of event A
$\sum$	Summation
$\prod$	Product
$\mathbf{I}$	Identity matrix
E_b/N_0	Bit energy to noise power spectral density ratio
$\mathrm{E}(Y)$	Statistical expectation of random variable Y
$\mathrm{vec}(\mathbf{X})$	vectorization operator
exp	Exponential
diag	Diagonalization
j	Square root of -1
Boldface uppercase letter	Matrix
Boldface lowercase letter	Vector
$[x]^+$	$= \begin{cases} x & \text{if } x \geq 0 \quad x \in \mathbb{R} \\ 0 & \text{if } x < 0 \quad x \in \mathbb{R} \end{cases}$