# Trade-Off Between Complexity and BER Performance of a Polynomial SVD-Based Broadband MIMO Transceiver

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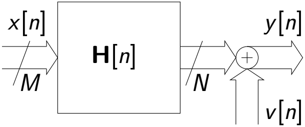
# Overview

# Motivation

- To achieve high data rate wireless communications
- Communication channels no longer be considered as narrowband
- Equalisation/precoding for broadband MIMO systems is crucial
- Aim — A high performance equalisation/precoding solution for broadband MIMO systems

# Introduction




The broadband MIMO system can be described by a polynomial channel matrix

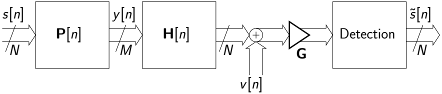
$$\mathbf{H}(z) = \sum_{l=0}^{L} z^{-l}\mathbf{H}_l \, , \tag{1}$$

- OFDM-based solutions ⟶ narrowband subsystems
- Block precoding/equalisation — [Scaglione-1999]

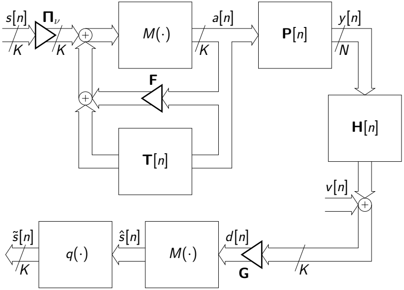
Drawbacks — extra redundancy, lower data throughput

# Existing Non-block-Based Approaches

- V-BLAST approaches [Lozano-2002, Choi-2004]
- Linear & THP [Joham-2007]




**Linear precoding**




**THP precoding**

# Problem Formalisation

The approach of this paper is done in two stages:

- Stage (1) — *CCI Mitigation*

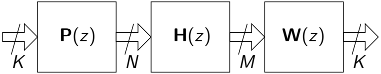
The system in (1) can be diagonalised using a novel polynomial SVD (PSVD) [McWhirter-2007] such that

$$\mathbf{H}(z) = \mathbf{U}(z)\mathbf{D}(z)\tilde{\mathbf{V}}(z) \qquad (2)$$

where $\mathbf{U}(z)$ and $\mathbf{V}(z)$ are paraunitary matrices, i.e.,

$$\tilde{\mathbf{U}}(z)\,\mathbf{U}(z) = \mathbf{U}(z)\,\tilde{\mathbf{U}}(z) = \mathbf{U}(z)\,\mathbf{U}^H(z^{-1}) = \mathbf{I} \qquad (3)$$

Defining a precoder $\mathbf{P}(z) = \mathbf{V}(z)$ and an equaliser $\mathbf{W}(z) = \tilde{\mathbf{U}}(z)$, the overall MIMO broadband system $\mathbf{H}(z)$ can be reduced to a diagonalised system $\mathbf{D}(z)$



# Problem Formalisation (Contd.)

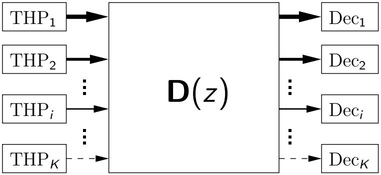
- Stage (2) — *ISI Mitigation*

$\mathbf{D}(z)$ is a diagonalised and spectrally majorised system such that

$$\mathbf{D}(z) = diag\left\{D_0(z), D_1(z), \cdots D_{K-1}(z)\right\} \quad (4a)$$

$$D_0(e^{j\Omega}) \geq D_1(e^{j\Omega}) \geq \cdots \geq D_{K-1}(e^{j\Omega}) \ \forall\Omega \quad (4b)$$

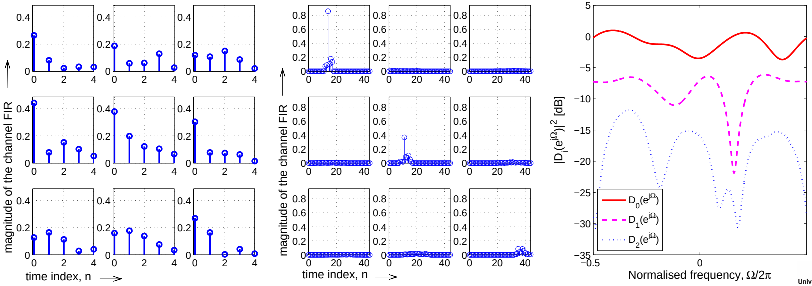
where $K = \min(M, N)$



# An Illustrative BSVD example

(a) Sample 3x3 fourth order MIMO channel probe,
(b) An approximately diagonalised system with SISO subsystems

(c) Magnitude responses along the main diagonal



# PSVD Approximation

- Since the diagonalisation in (4a) is not ideal, so we deal with the more reallistic received signal of the $i$th symbol stream $y_i[l]$, $i = 0, \cdots, K-1$, as

$$y_i[l] = \sum_{\nu=0}^{L_i} d_{ii}[\nu] \cdot x_i[l-\nu] + \sum_{\substack{m=0 \\ m \neq i}}^{K-1} \sum_{\nu=0}^{L_{im}} d_{im}[\nu] \cdot x_m[l-\nu] + \xi_i[l] \quad (5)$$

- The task now is to investigate a sufficient no. of iteration (NoI) by which we can rely on a simplified version of the PSVD method

# SISO-THP Schemes

1. Non-Block Based Method — $F_i(z)$ and $B_i(z)$ can be computed using spectral factorisation theorem [Fischer-2005]
2. Block Based Method — $\mathbf{W}_i$ and $\mathbf{B}_i$ and $\mathbf{G}_i$ can be computed using QR-Decomposition [Lee-2005]

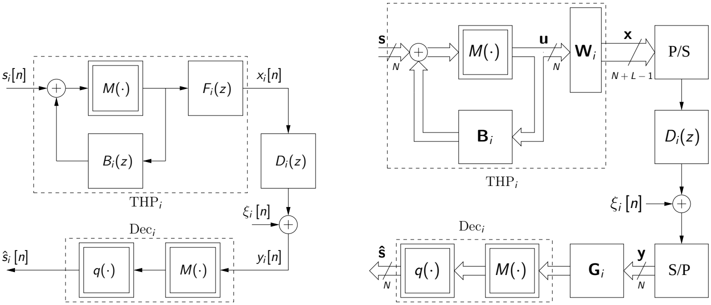



Figure: SISO-THP transceivers using spectral factorisation (right) and block transmission (left)

# Spectral Factorisation Vs. Block Transmission

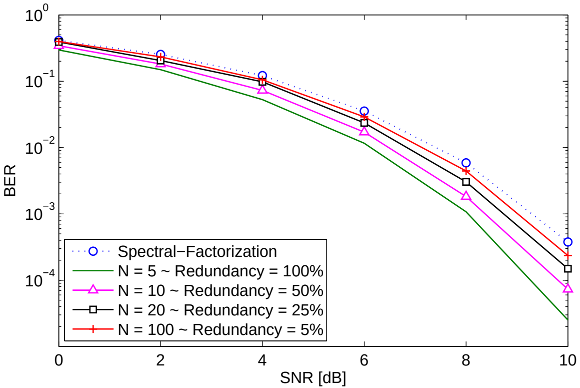



Figure: BER performance for a 5-tab SISO system using both spectral factorisation and block transmission

# SISO-THP "QPSK"

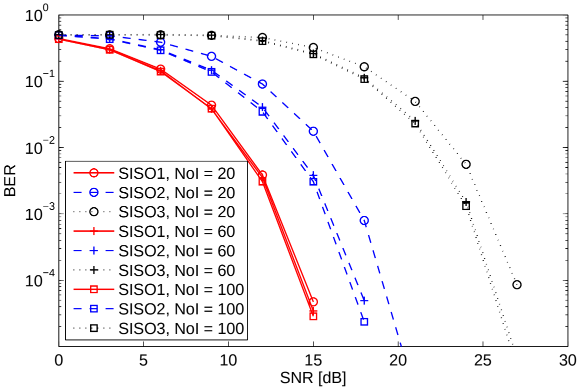



Figure: SISO-THP performance of the individual subchannels with varying NoI to a 3x3 MIMO system and "QPSK" transmission

# SISO-THP "16QAM"

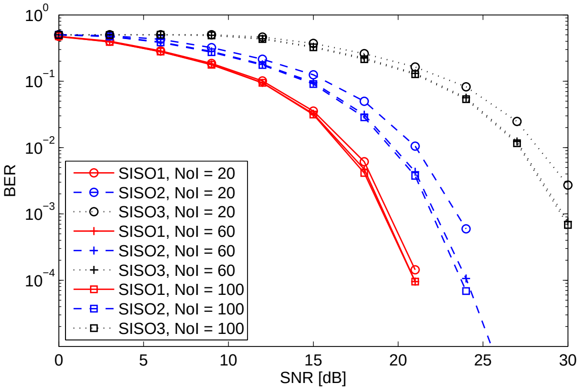



Figure: SISO-THP performance of the individual subchannels with varying NoI to a 3x3 MIMO system and "16QAM" transmission

# SISO-THP “64QAM”

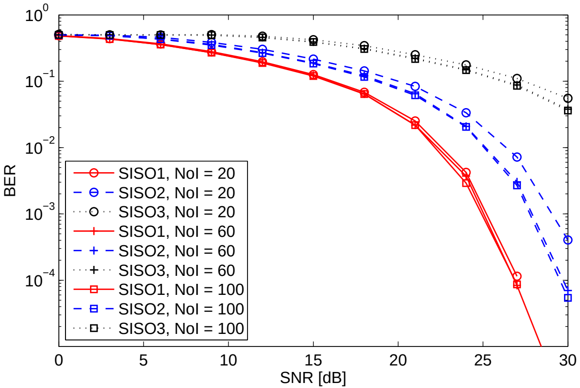



Figure: SISO-THP performance of the individual subchannels with varying NoI to a 3x3 MIMO system and “64QAM” transmission

# Conclusions

- A study on the approximate fulfilment of the novel Polynomial SVD (PSVD) algorithm to diagonalise a broadband MIMO system into a number of independent frequency selective SISO subsystems is considered highlighted by the impact on the system performance
- Due to the iterative nature and the finite number of the PSVD algorithm steps, a sufficient number of iterations (NoI) is investigated
- Two nonlinear ZF-THP precoding alternative schemes for the resultant ISI SISO subchannels are compared
- Simulation results show that a moderate NoI can sufficiently fulfil the PSVD performance

# Questions

- Thank You — Any Questions