# Iterative Algorithm Design for MIMO-OFDM Receivers Based on Hybrid Inference Techniques

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# Iterative Algorithm Design for MIMO-OFDM Receivers Based on Hybrid Inference Techniques

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## I. Introduction

In this contribution, we apply a message-passing technique proposed in [1] combining variational message passing (VMP) and the sum-product (SP) algorithm to the design of receivers for MIMO-ODFM systems. From a probabilistic model, we obtain a receiver performing iterative channel weight and noise precision estimation, equalization and data decoding. The messages exchanged among the receiver's constituent blocks are univocally defined by the message computation rules for the given model. The numerical assessment of our solution corroborates the high performance of the proposed algorithm and its superiority to heuristic approaches.

## II. Signal Model

We consider an OFDM system with $M$ transmit chains and $N$ receivers. For the $m$th transmitter, a sequence of information bits $\boldsymbol{u}_m$ is encoded and interleaved, yielding a sequence of coded bits $\boldsymbol{c}_m$. The sequence $\boldsymbol{c}_m$ is then complex modulated, resulting in a vector of complex-modulated data symbols which is multiplexed with pilot symbols yielding the vector $\boldsymbol{x}_m$. The symbols are transmitted in an OFDM frame consisting of $L$ OFDM blocks with $K$ subcarriers each. After OFDM demodulation, the received signal reads

$$\boldsymbol{y} = \sum_{m=1}^{M} \boldsymbol{x}_m \odot \boldsymbol{h}_m + \boldsymbol{w} \tag{1}$$

where $\boldsymbol{h}_m$ is a vector containing the complex channel weights for the channel corresponding to the $m$th transmitter, $\boldsymbol{w}$ represents zero-mean AWGN with covariance matrix $\lambda^{-1}\boldsymbol{I}$ and $\boldsymbol{a} \odot \boldsymbol{b}$ denotes the Hadamard product of vectors $\boldsymbol{a}$ and $\boldsymbol{b}$.

## III. MIMO-OFDM Receiver Based on Combined VMP-SPA

In this section, we apply the combined VMP-SP algorithm proposed in [1] to the signal model (1). To that end, we first describe the underlying probabilistic model to which the message-passing technique will be applied. The system function of our model is the joint pdf of all parameters, which can be factorized as

$$p(\boldsymbol{u}, \boldsymbol{c}, \boldsymbol{x}, \boldsymbol{h}, \lambda, \boldsymbol{y}) = \underbrace{p(\boldsymbol{y}|\boldsymbol{h}, \boldsymbol{x}, \lambda)}_{f_{\mathrm{O}}} \underbrace{p(\boldsymbol{h})}_{f_{\mathrm{C}}} \underbrace{p(\lambda)}_{f_{\mathrm{N}}} \underbrace{p(\boldsymbol{x}, \boldsymbol{c}, \boldsymbol{u})}_{f_{\mathrm{M}}}. \tag{2}$$

Factor $f_{\mathrm{O}}(\boldsymbol{y}, \boldsymbol{h}, \boldsymbol{x}, \lambda) \triangleq p(\boldsymbol{y}|\boldsymbol{h}, \boldsymbol{x}, \lambda)$ denotes the likelihood of the channel weights $\boldsymbol{h}$, the noise precision $\lambda$ and the transmitted symbols $\boldsymbol{x}$ given the observations $\boldsymbol{y}$; factor $f_{\mathrm{C}}(\boldsymbol{h}) \triangleq p(\boldsymbol{h})$ contains the assumed prior model of the channel weights; factor $f_{\mathrm{N}}(\lambda) \triangleq p(\lambda)$, likewise, contains the assumed prior model for the noise precision parameter $\lambda$; finally, factor $f_{\mathrm{M}}(\boldsymbol{x}, \boldsymbol{c}, \boldsymbol{u}) \triangleq p(\boldsymbol{x}, \boldsymbol{c}, \boldsymbol{u})$ denotes the modulation and code constraints.

In order to apply the combined VMP-SP algorithm, we need to define which factor nodes are assigned to the VMP set $\mathcal{A}_{\mathrm{VMP}}$ and which are assigned to the SP set $\mathcal{A}_{\mathrm{SP}}$. We select the following splitting: $\mathcal{A}_{\mathrm{VMP}} \triangleq \{f_{\mathrm{O}}\} \cup \{f_{\mathrm{C}}\} \cup \{f_{\mathrm{N}}\}$ and $\mathcal{A}_{\mathrm{SP}} \triangleq \{f_{\mathrm{M}}\}$, i.e. the observation factor node, together with the channel weight and noise precision prior models are assigned to the VMP set, and the factor nodes containing the modulation and code constraints are assigned to the SP set. For more details, see [2].

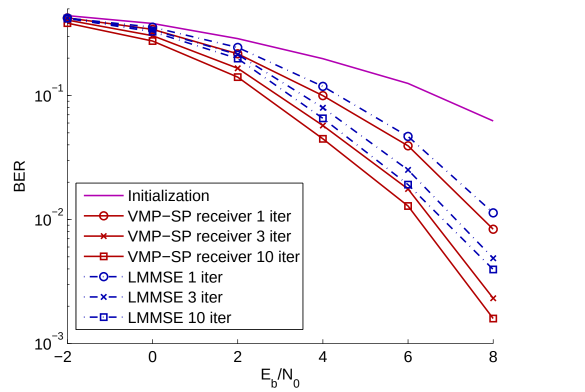


Fig. 1. BER as a function of $E_b/N_0$ for the VMP-SP receiver with 16-QAM modulation: 13 pilot symbols are inserted per OFDM frame; $M = N = 2$, $K = 75$, $L = 7$; channel model: 3GPP Extended Typical Urban; channel coding: convolutional code with rate $1/3$.

## IV. Numerical Results

The BER performance of our proposed VMP-SP receiver is benchmarked against an iterative LMMSE-based receiver with similar complexity in Fig. 1. The VMP-SP receiver achieves gains in the range of 1.5 to 2 dB in $E_b/N_0$ with respect to the reference receiver for relevant BER ranges.

## References

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