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Energy Efficient SC-FDMA Transmission Over MIMO Channels With MMSE Power Allocation And OFDMA Transmission

PG Student

M.Gunamozhi[1] and **Dr.S.GANESAN**[2]

[1]Student, [2]Professor
Dept of Electronics and Communication Engineering, Mailam Engineering College, Tindivanam.

Abstract—**This paper uses transmit algorithm for single carrier frequency division multiple access (SC–FDMA) transmission over frequency–selective multiple input multiple output (MIMO) channels. The filters are designed for optimum performance of MIMO minimum mean squared error decision feedback equalization (MMSE–DFE). It turns out that filters diagonalizing the overall channel is optimum, and in addition an optimum power allocation is performed which is similar in spirit to classical results for the optimum continuous–time transmit filter for linear modulation formats. It indicate that the proposed method will be beneficial for the block error rate performance of an SC–FDMA transmission scheme with strong channel coding and error–free decisions in the feedback path of MMSE–DFE, which can be precoding at the transmitter side.**

Index terms—**Block error rate performance Single–Carrier Frequency Division Multiple Access (SC–FDMA), Minimum Mean Squared Error Decision–Feedback Equalization (MMSE–DFE).**

I. INTRODUCTION

RELAY-assisted wireless communications have been explored for diverse ad hoc and cellular networks to improve the attainable spectral or energy efficiency of classic direct transmissions (DTs). Naturally, the availability of inactive mobiles as candidate relays has the potential to mitigate the effect of fading. The activation of multiple relays results in cooperative diversity. When dynamically reassigning the relays based on their location or channel quality, we arrive at t he concept of opportunistic relaying (OR)

Furthermore, orthogonal frequency-division multiplexing (OFDM)-style broadband frequency-division multiple-access (FDMA) systems, such as the Third-Generation Partnership Project Long Term Evolution (3GPP LTE) system's uplink single-carrier frequency-division multiple-access (SC-FDMA) scheme and orthogonal frequency-division multiple-access (OFDMA), conveniently facilitate near-instantaneous adaptive subband/subcarrier allocation and multiuser (MU) scheduling. This is achieved by exploiting the knowledge of the time-varying channel-state information (CSI) of the subbands or subcarriers – when communicating over frequency-selective fading channels. Moreover, because relay-assisted OFDM transmissions are subjected to two-hop fading channels, dynamically rearranging the subcarriers at multiple relays may offer some additional diversity gains by appropriately pairing the subcarriers of the two hops. This subcarrier pairing philosophy was employed in, for both amplify-and-forward (AF) and decode-and-forward (DF) relay-assisted single-user (SU) OFDM systems. This approach may also be applied in MU scenarios, such as in OFDMA, where the subcarriers of the two hops may be paired on a per-user basis, hence minimizing the multiuser interference (MUI). In addition, the corresponding resource allocation and MU scheduling may be carried out on a subband-group basis per user in the frequency domain (FD). Therefore, carefully assigning the subbands/subcarriers in the context of OR can improve the diversity gain by avoiding the extra multirelay interference while retaining the MUI-free nature of SC-FDMA and OFDMA systems.

Thispaper proposes two DRA strategies that were designed for the OR-assisted SC-FDMA uplink, where the ORs may invoke the soft-decision aid DF protocol,. We assume that the multiple relays can exchange the pilot aided channel-quality information (CQI) of all the users, facilitating the cooperation at the relays to carry out joint dynamic resource allocation (JDRA). Moreover, our assumption is that multiple relays participate in the multi way relaying (MWR) procedure for CQI exchange. We dedicate special attention to the "first-hop quality awareness" of our DRA schemes. In particular, we

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explore any potential extra selection diversity to reduce the transmit power required and/or to improve the attainable system performance. To this end, we combine DRS and DSA based on the associated first-hop transmission qualities.

Meanwhile, upon the “buffering delay awareness” of our interleaver-aided channel-coded systems, we quantify the benefits of OR combined with DSA in the context of interleaver-aided DF relaying for transmission over correlated fading channels in terms of reducing the interleaving delay and/or the total transmit power through joint OR and DSA.

II. EXISTING SYSTEM

The difference between a turbo equalizer SC-FDMA and a standard equalizer is the feedback loop from the decoder to the equalizer. Due to the structure of the code, the decoder not only estimates the information bits a, but it also discovers new information about the coded bits b. The decoder is therefore able to output extrinsic information, \tilde{b} about the likelihood that a certain code bit stream was transmitted. Extrinsic information is new information that is not derived from information input to the block. This extrinsic information is then mapped back into information about the transmitted symbols x for use in the equalizer. These extrinsic symbol likelihoods, \tilde{x}, are fed into the equalizer as a priori symbol probabilities.

The equalizer uses this a priori information as well as the input signal y to estimate extrinsic probability information about the transmitted symbols. The a priori information fed to the equalizer is initialized to 0, meaning that the initial estimate \hat{a} made by the turbo equalizer SC-FDMA is identical to the estimate made by the standard receiver. The information \hat{x} is then mapped back into information about b for use by the decoder. The turbo equalizer SC-FDMA repeats this iterative process until a stopping criterion is reached.

III. PROPOSED SYSTEM

In single–user SC–FDMA transmission over a frequency–selective MIMO channel. Here, Nt = 2 transmit antennas are assumed for simplicity and because this is the most relevant case for an uplink transmission.

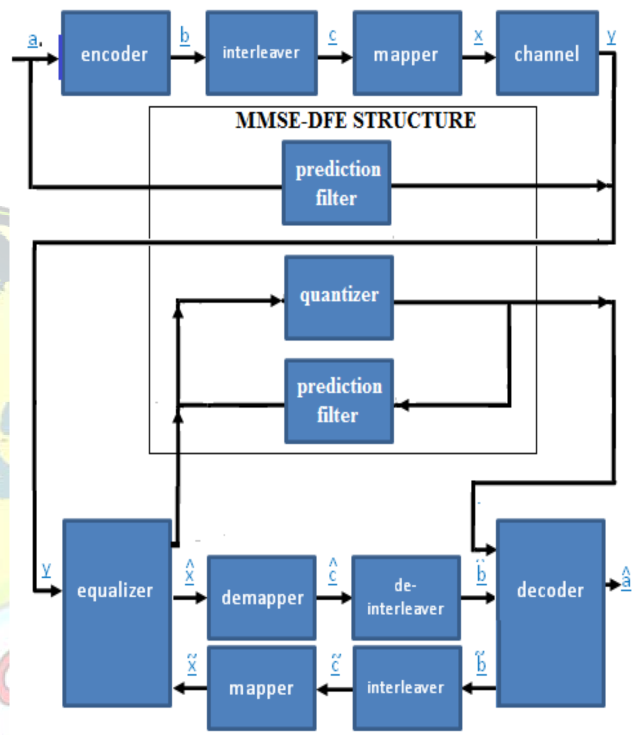

Fig1 Block Diagram of Proposed System

Here, Nt = 2 transmit antennas are assumed for simplicity and because this is the most relevant case for an uplink transmission. Nevertheless, all results can be generalized to an arbitrary number of transmit antennas in a straightforward way. Nr = 2 denotes the number of receive antennas. After channel encoding of binary symbols and interleaving, Gray mapping to a quadrature amplitude modulation (QAM) signal constellation is applied. An M–point discrete Fourier transform (DFT) is applied to each block.

Subsequently, the frequency domain symbols are mapped onto N subcarriers (N > M), with an assignment to M consecutive subcarriers beginning at the 0th subcarrier, resulting in frequency domain vectors Bi of size N [5]. By an N–point inverse (I) DFT. To enhance the performance of MMSE–LE, a MIMO noise (error) prediction–error filter may be inserted after the MMSE linear equalizer as shown in Fig. The introduced post cursor inter symbol interference is removed by decision feedback after the quantizer Q producing decisions ^a[k] for a[k], resulting in an MMSE–DFE structure, where

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the feedback filter coefficient matrices are identical to those of the prediction filter.

A. MMSE–DFE

Single–carrier frequency–division multiple access (SC–FDMA) transmission has been selected for the uplink of the E–UTRA Long Term Evolution (LTE) mobile communications system. SC–FDMA enjoys a low peak–to–average power ratio (PAPR) enabling a low–complexity implementation of the mobile terminal and is employed along with multiple–input multiple–output (MIMO) techniques in LTE. Another advantage of SC–FDMA is that relatively simple frequency–domain minimum mean–squared error linear equalization (MMSE– LE) techniques can be applied for signal recovery, if a frequency–selective MIMO channel is present producing intersymbol interference (ISI). Incorporating additional MMSE noise (error) prediction tailored for single–carrier transmission techniques with cyclic convolution, cf. e.g., an MMSE decision–feedback equalization (MMSE–DFE) structure results with enhanced performance compared to MMSE–LE.
In order to fully exploit the potential benefits of MIMO transmission, closed–loop transmit beamforming might be employed. A pragmatic eigenbeamforming algorithm using unitary precoding matrices in conjunction with uniform power allocation across all subcarriers has been introduced for SC–FDMA MIMO transmission with MMSE–LE in. Optimum beamforming for SC–FDMA transmission with MMSE–LE has been proposed in. In this paper, we design the frequency response of a cyclic spatio–temporal beamforming filter optimizing the performance of MMSE–DFE for a given transmit power constraint.

B. SYSTEM MODEL

If additional beamforming is employed at the transmitter side, a cyclic 2×2 matrix filter is applied to input vector b2]T in each time step.

This can be implemented equivalently in the M–point DFT domain for subcarriers=2 f0; 1; : : : ;M1g by forming sequences A~1and A~2Via

$$\left[\tilde{A}_1[\mu]\ \tilde{A}_2[\mu]\right]^T = \mathbf{P}[\mu]\left[A_1[\mu]\ A_2[\mu]\right]^T$$

with a 2×2 beamformer frequency response matrix Pand using sequences A~iinstead of Aifor subcarrier assignment.

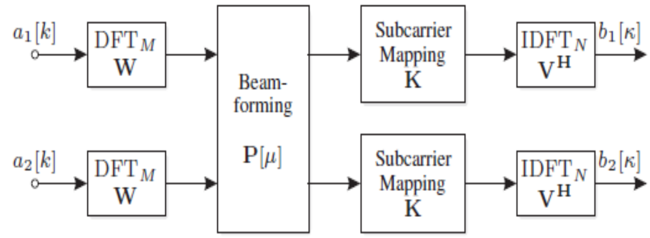

Fig 2 SC–FDMA Transmitter WithBeamforming

A cyclic prefix of length Lc is added to vectors bi and the sequences bi;ccorresponding to bi;c_= bi: : : bibT i]T form an SC–FDMA transmit block. The signal at the lth receive antenna, l 2 f1; 2; : : : ; NRg, is

$$r_l[\kappa] = \sum_{i=1}^{2}\sum_{\lambda=0}^{L-1} h_{l,i}[\lambda]\, b_{i,c}[\kappa-\lambda] + n_l[\kappa],$$

where the overall discrete–time subchannel impulse response $h_{l,i}$of length L characterizes transmission from the ith transmit antenna to the lth receive antenna. $n_l$denotes spatially and temporally white Gaussian noise of variance =2 n.

IV. SINGLE-CARRIER FDMA TRANSMISSIONS

Space–Time (ST) coding has by now been well documented as an attractive means of achieving high data rate transmissions with diversity and coding gains in wireless applications; see, e.g., , for tutorial treatments. So far, ST codes are mainly designed for frequency-flat channels. However, future broad-band wireless systems will communicate symbols with duration smaller than the channel delay spread, which gives rise to frequency-selective propagation effects. Targeting broad-band wireless applications, it is thus important to design ST codes in the presence of frequency-selective multipath channels.
Unlike flat fading channels, optimal design of ST codes for dispersive multipath channels is complex because signals from different antennas are mixed not only in space but also in time. Christo Ananth et al. [7] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation

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where the assumption of existence of "ground-truth" reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

On the flat fading FDMA subchannels, many authors have applied ST coding for transmissions over frequency-selective channels, including that assumes channel knowledge, and that require no channel knowledge at the transmitter. The ST trellis codes of are employed in, across FDMA subcarriers, while the orthogonal ST block codes (STBCs) of, are adopted by on each FDMA subcarrier.

Although using ST codes designed for flat fading channels can at least achieve full multi antenna diversity, the potential diversity gains embedded in multipath propagation have not been addressed thoroughly. Recently, in FDMA-based systems, it was first claimed in , and then , that it is possible to achieve both multi antenna and multipath diversity gains of order equal to the product of the number of transmit antennas, the number of receive antennas, and the number of FIR channel taps. However, code designs which guarantee full exploitation of the embedded diversity were not provided.

The simple design of achieves full diversity, but it is essentially a repeated transmission, which decreases the transmission rate considerably. On the other hand, for single-antenna transmissions, it is shown in that a diversity order equal to the number of FIR taps is achievable when FDMA transmissions are linearly precoded across subcarriers. An inherent limitation of all multi carrier (FDMA) based ST transmissions is their non constant modulus, which necessitates power amplifier back-off, and thus reduces power efficiency. In addition, multicarrier schemes are more sensitive to carrier frequency offsets relative to their single-carrier counterparts. These two facts motivate well ST codes for single-carrier transmissions over frequency-selective channels, that have been looked upon recently in, with block coding and using trellis coding. ST block codes for single-carrier block transmissions in the presence of frequency-selective fading channels.

We propose novel transmission formats, that subsume those in, as special cases. Furthermore, we show that a maximum diversity up to order is achieved in a rich scattering environment, where is the number of transmit antennas, is the number of receive antennas, and is the number of taps corresponding to each FIR channel. With single receive and two transmit antennas, our transmission offers a capacity-achieving scheme. Being counterparts of orthogonal STBCs, but for frequency- selective channels, our proposed schemes enable simple linear processing to collect full antenna diversity, and incur receiver complexity that is comparable to single-antenna transmissions. Interestingly, our transmissions enable exact application of Viterbi's algorithm for maximum-likelihood (ML) optimal decoding, in addition to various reduced-complexity suboptimal equalization alternatives. Equally important, when our ST transmissions are combined with channel coding, they facilitate application of iterative (turbo) equalizers. Simulation results demonstrate that joint exploitation of space-multipath diversity leads to significantly improved performance in the presence of frequency-selective multipath channels.

A. MMSE–LE FOR SC–FDMA

MMSE–LE for a MIMO SC–FDMA transmission has been outlined in the optimum filtering matrix for joint processing of vectors Rl is given by, delivering estimates yi, i 2 f1; 2g, with yi = ai + ei, where the error sequences eihave variances =2 e;i, i 2 f1; 2g. Essentially, MMSE equalization can be realized by picking the relevant frequency components, applying frequency– domain MIMO MMSE filtering independently to each frequency component, and subsequent IDFT operations. The covariance matrix of the error vector e = e2]T, ee= EfeeHg, can be calculated to

$$\mathbf{\Phi}_{ee} = \frac{\sigma_n^2}{M} \sum_{\mu=0}^{M-1} (\mathbf{H}^H[\mu]\,\mathbf{H}[\mu] + \zeta\,\mathbf{I}_2)^{-1},$$

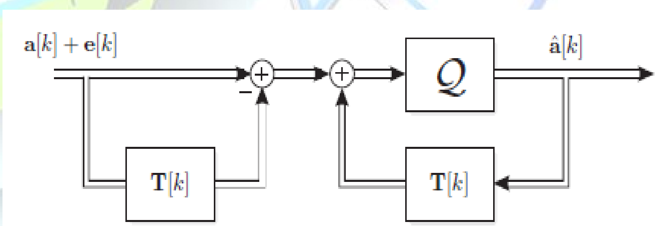

Fig 3 Structure of MIMO DFE Receiver

After MMSE–LE, a bias which is characteristic for MMSE filtering is removed and soft output for subsequent channel decoding is calculated from the equalized symbols yi. In case of additionalbeamforming.

B. MMSE–DFE FOR SC–FDMA

To enhance the performance of MMSE–LE, a MIMO noise (error) prediction–error filter may be inserted after the MMSE linear equalizer as shown in Fig. 2. The introduced postcursor intersymbol interference is removed by decision feedback

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after the quantizerQ producing decisions ^afor a, resulting in an MMSE–DFE structure, where the feedback filter coefficient matrices are identical to those of the prediction filter T.
The signal after prediction–error filtering is described by

$$\mathbf{u}_p[k] = \mathbf{T}_e[k] \otimes \mathbf{a}[k] + \mathbf{w}_p[k],$$

where a = a2]T, Teare the coefficients of the prediction–error filter, Te = I2, Te = T, k 2 f1; 2; : : : ; qpg(T: predictor coefficient matrices, qp: predictor order), and wpis the error signal of the MMSE– LE output filtered with the prediction–error filter.
The optimum predictor coefficients are obtained from the multichannel Yule Walker equations

$$\begin{bmatrix} \mathbf{A}[0] & \mathbf{A}[1] & \cdots & \mathbf{A}[q_p-1] \\ \mathbf{A}[-1] & \mathbf{A}[0] & \cdots & \mathbf{A}[q_p-2] \\ \vdots & \vdots & \ddots & \mathbf{A}[1] \\ \mathbf{A}[-q_p+1] & \mathbf{A}[-q_p+2] & \cdots & \mathbf{A}[0] \end{bmatrix} \begin{bmatrix} \mathbf{T}^H[1] \\ \mathbf{T}^H[2] \\ \vdots \\ \mathbf{T}^H[q_p] \end{bmatrix} = [\mathbf{A}^T[-1] \quad \mathbf{A}^T[-2] \cdots \mathbf{A}^T[-q_p]]^T,$$

with the cyclic autocorrelation matrix sequence of the error signal of MMSE–LE (with corresponding periodical extension)

$$\mathbf{A}[k] = \frac{\sigma_n^2}{M} \sum_{\mu=0}^{M-1} (\mathbf{H}^H[\mu]\mathbf{H}[\mu] + \zeta \mathbf{I}_2)^{-1} e^{j\frac{2\pi}{M}k\mu}.$$

V. SIMULATION RESULTS

With regard to the pilot-based CSI to be exchanged among the relays, the differences of the FHQA JDRA schemes are related to the amount of the knowledge required with respect to the of S–R links. In particular, the JDRA-1 scheme requires only each relay's ordered set of K users, as determined by their S–R channel gains, whereas the JDRA-2 mode considers the CQI of all S–R links gleaned from all relay.

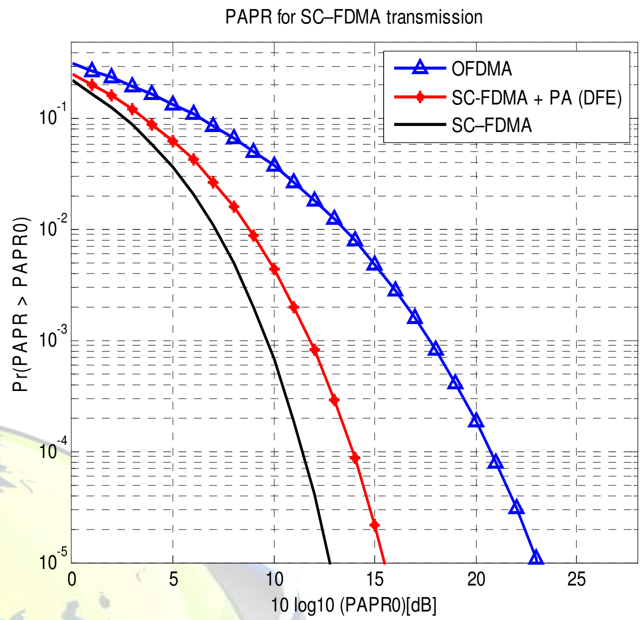

Fig 4 PAPR for SC-FDMA Transmission

Both FHQA JDRA schemes have the following three main functions: 1) relay selection; 2) subband allocation; and 3) user assignment. Explicitly, for both JDRA schemes, the subband allocation is based on the second-hop quality, whereas the user assignment depends on the first-hop quality. The relay selection of JDRA-1 is based on the second-hop quality, whereas the relay selection of JDRA-2 relies on the first-hop quality. Therefore, the JDRA-1 method predominantly relies on the second-hop quality, whereas JDRA-2 relies on the first-hop quality. As a result, the attainable performance of both JDRA-1 and JDRA-2 is limited by the quality of its dominant channels.

VI. CONCLUSION

In this paper, we have proposed and investigated two novel FHQA JDRA schemes to improve the reliability and energy efficiency of the soft-DF-based OR-assisted SC-FDMA uplink. By exploiting the first-hop quality for the joint design of DRS and DSA at the relays, the proposed FHQA JDRA algorithms outperform the conventional DRS-DSA and achieve up to 2-dB power reduction in channel-coded systems. When using a SC-FDMA DT benchmark, both FHQA JDRA schemes attain an ERG of 91% upon invoking a single-antenna BS and an ERG of up to 7.4% offered by the JDRA-2 scheme in the multi antenna-aided scenario, whereas their counterparts consume significantly more power. Furthermore, to decrease the buffering delay and reduce the transmit power, the inter leaver depth of the proposed coded OR systems may be shortened by increasing the number of relays and invoking

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the soft-DF protocol when communicating over highly correlated fading channels.

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