Joint Channel Estimation and Multi-user Detection for SDMA OFDM Based on Dual Repeated Weighted Boosting Search

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***Abstract*—A joint channel estimation and Multi-User Detection (MUD) scheme is proposed for multi-user Multiple-Input Multiple-Output (MIMO) Space Division Multiple Access / Orthogonal Frequency-Division Multiplexing (SDMA/OFDM) systems. We design a Dual Repeated Weighted Boosting Search (DRWBS) scheme for joint channel estimation and MUD, which is capable of providing 'soft' outputs, directly fed to the Forward Error Correction (FEC) decoder. The proposed scheme reduces the complexity of the receiver, since it integrates the channel estimation and MUD into a single module and it forwards the Log-Likelihood Ratios (LLRs) to the channel decoder. It also provides an effective solution to the multi-user MIMO channel estimation and MUD problem in "rank-deficient" scenarios, when the number of users is higher than the number of receiver antennas. The simulation results demonstrate that the proposed scheme is capable of attaining a BER performace close to the ideal scenario of the Maximum Likelihood (ML) MUD associated with perfect channel knowledge.**

I. Introduction

Communication systems using multiple antennas at the transmitter and/or the receiver have recently received increased attention due to their ability to provide substantial capacity improvements, while achieving a low error rate and/or high data rate by flexibly exploiting the attainable diversity gain and/or the spatial multiplexing gain [1].

Space Division Multiple Access/Orthogonal Frequency-Division Multiplexing (SDMA/OFDM) systems [2, 3] combine the advantages of OFDM and SDMA, where we employ an array of antennas at the BS for detecting the received signal of multiple single-antenna aided MSs. As a result, a substantially improved uplink capacity is achieved, despite employing single-antenna based low-complexity MS transmitters [3]. However, the performance of these systems is critically dependent on the precision of the channel knowledge, which may be represented by Channel Impulse Response (CIR) or Frequency-Domain CHannel Transfer Function (FD-CHTF).

Over the past decade, intensive research efforts have been devoted to developing effective approaches for channel estimation or symbol detection for transmitter- and/or the receiver-diversity aided systems. Conventional methods usually carry out the channel estimation and signal detection separately, which may only attain suboptimal results. In order to achieve a near-optimal performance, joint channel estimation and data detection algorithms have recently received significant research attention [4–6]. These joint channel estimation and data detection methods have indeed shown an enhanced performance associated with resonable convergence rates, despite using relatively short pilot-symbol sequences. Among them, the iterative Expectation-Maximization (EM) algorithm [7] and diverse derivatives of this algorithm have been shown to strike an attractive trade-off between the performance attained and the complexity imposed. The classic EM algorithm was employed for joint channel estimation and data detection in [6, 8]. The authors of [9] proposed a joint symbol detection and channel estimation algorithm based on the Variational Bayesian Expectation-Maximization (VBEM) algorithm. A Space-Alternating Generalized Expectation-maximization (SAGE) based iterative receiver was designed for joint detection, decoding and channel estimation in [10]. However, the EM algorithm is unable to guarantee convergence to the globally optimal solution. Furthermore, Genetic Algorithm (GA) based near-optimal search schemes were also developed for channel estimation and data symbol detection at the receiver [4, 11, 12]. Finally, in [13], Repeated Weighted Boosting Search (RWBS) was employed to identify the unknown MIMO channel, while an enhanced ML sphere detector was used to perform ML detection of the transmitted data.

Against this background, in this paper we proposed a novel guided random search algorithm, which we refer to as the Dual Repeated Weighted Boosting Search (DRWBS) assisted Joint Channel Estimation and Multi-User Detection (DRWBS-JCEMUD) scheme designed for multi-user Multiple-Input Multiple-Output (MIMO) SDMA/OFDM systems. The proposed DRWBS-JCEMUD scheme consists of two components: channel estimator and symbol detector. The channel estimator carries out channel estimation using the current detected symbol, while the symbol detector carries out symbol detection using the current channel estimate. The process is carried out by iteratively exchanging information between the channel estimator and the symbol detector. Furthermore, the proposed DRWBS-JCEMUD scheme is capable of providing the Log-Likelihood Ratios (LLRs) of the coded bits, which can be directly fed to the Forward Error Correction (FEC) decoder.

The rest of this paper is organized as follows. The system model of the multi-user MIMO OFDM/SDMA UpLink (UL) is described in Section II. The proposed DRWBS-JCEMUD scheme is elaborated on Section III. Our simulation results and discussions are presented in Section IV, while our conclusions

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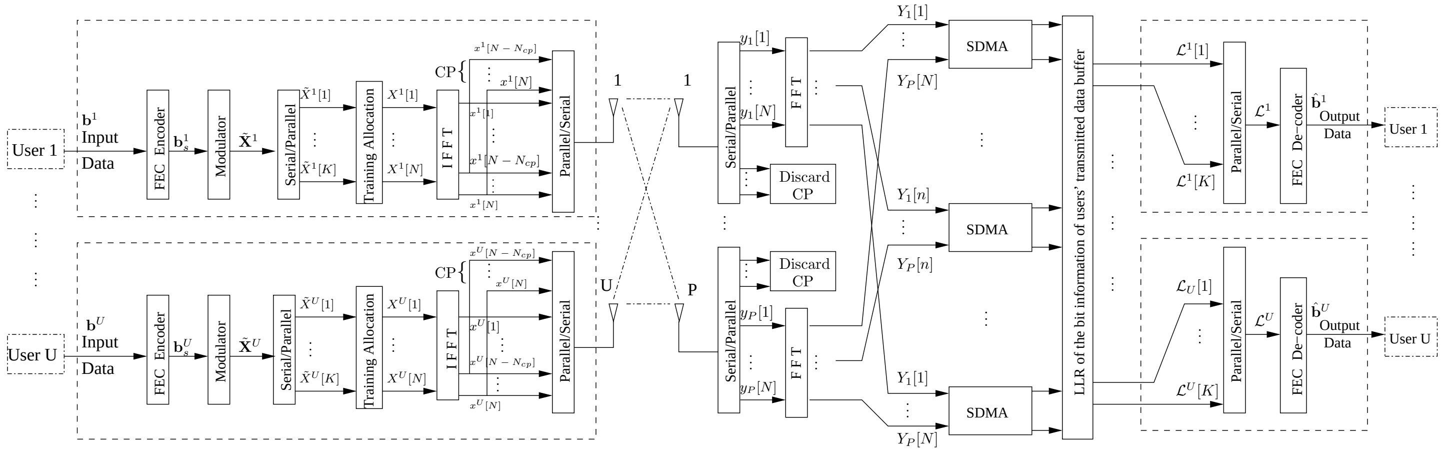

Fig. 1. Uplink system model for Multi-user MIMO SDMA/OFDM

are offered in Section V.

II. System Model

The multi-user MIMO OFDM/SDMA system considered supports U MSs simultaneously transmitting in the UL to the BS, as seen in Fig. 1. Each of the users is equipped with a single transmit antenna, while the BS employs an array of P antennas. It is assumed that a Time Division Multiple Access (TDMA) protocol organizes the division of the available Time-Domain (TD) resources into OFDM/SDMA Time Slots (TS). Instead of one, U MSs are assigned to each slot that are allowed to simultaneously transmit their streams of OFDM modulated symbols to the SDMA BS [2, 3].

More specially, all of the U MSs transmit independent data streams, which are encoded by a user-specific FEC encoder, as illustrated in Fig. 1. The information bits output by the FEC encoder are grouped and mapped to a stream of modulated data symbols. The modulated data $\mathbf{X}^{(u)}[k], k = 1, 2, \cdots, K$ of Fig. 1 are then Serial to Parallel (S/P) converted and the Frequency-Domain (FD) training symbols are concatenated at the begining of each frame. The parallel modulated data are further processed by the Inverse Fast Fourier Transform (IFFT) to form a set of OFDM symbols. After concatenating the Cyclic Prefix (CP) of N_{cp} samples, the TD signal is transmitted through a multipath fading channel and contaminated by the receiver's Additive White Gaussian Noise (AWGN).

At the BS, the CP is discarded from every OFDM symbol and the resultant signal is fed into the corresponding Fast Fourier Transform (FFT) based receiver of Fig. 1. Let $Y_p[s,k]$ denote the signal received by the p-th receiver antenna element in the k-th subcarrier of the s-th OFDM symbol, which is given as the superposition of the different users' channel-impaired received signal contributions plus the AWGN, expressed as [3]:

$$Y_p[s,k] = \sum_{u=1}^{U} H_p^u[s,k] X^u[s,k] + W_p[s,k], \tag{1}$$

where $H_p^u[s,k]$ denotes the frequency domain channel transfer factors (FD-CHTFs) of the link between the u-th user and the p-th receiver antenna in the k-th subcarrier of the s-th OFDM symbol.

As a benefit of the cyclic prefix, the SDMA/OFDM symbols do not overlap and hence SDMA processing can be applied on a per-carrier basis, as depicted in Fig. 1. Each SDMA subcarrier's signal may be described as [2],

$$\begin{bmatrix} \tilde{X}^1[s,k] \\ \vdots \\ \tilde{X}^U[s,k] \end{bmatrix} = \mathcal{F}_{SDMA}\left(\begin{bmatrix} Y_1[s,k] \\ \vdots \\ Y_P[s,k] \end{bmatrix}, \begin{bmatrix} \hat{H}_1^1[s,k] & \dots & \hat{H}_1^U[s,k] \\ \vdots & \dots & \vdots \\ \hat{H}_P^1[s,k] & \dots & \hat{H}_P^U[s,k] \end{bmatrix} \right), \tag{2}$$

where $\hat{H}_p^u[s,k], u = 1, \cdots, U, p = 1, \cdots, P$, is the estimated value of the FD-CHTF. Various algorithmic alternatives for this generic SDMA detector are available, which cover a wide range of performance versus complexity trade-offs, such as those represented by the MMSE OFDM/SDMA, per-carrier Successive Interference Cancellation (pcSIC) OFDM/SDMA and ML OFDM/SDMA [2]. In the following section, we outline our DRWBS-JCEMUD scheme designed for multi-user MIMO OFDM/SDMA systems.

III. The DRWBS-JCEMUD scheme proposed for Multi-user MIMO OFDM/SDMA Systems

The Repeated Weighted Boosting Search (RWBS) [14] constitutes a guided random search based global optimization algorithm. The basic philosophy of the RWBS algorithm is that by commencing from a search-pool of the potential solutions which was initially randomly chosen, the algorithm continues by replacing the 'lowest-quality' solutions of the population with the "best" potential solutions generated by diverse nature-inspired combinations/mutations of the candidate solutions in the pool, until the process converges. The weighting of the candidate-solutions used in creating their convex combinations is appropriately controlled, in order to reflect the "fitness" of the corresponding potential solutions. This process is repeated a number of times or for numerous "generations" in order to improve the probability of finding the globally optimal solution. However, the classic weighting operation is unable to simultaneously reflect the "fitness" of both the channel and data estimate. In order to circumvent this problem, we proposed the DRWBS-JCEMUD scheme, which alternately estimates the channel and the users' data and mutually exchanges these estimates between both populations in order to find the joint optimum.

The proposed DRWBS-JCEMUD scheme is illustrated in Fig. 2 and the the flowchart for the RWBS algorithm is further illustrated in Fig. 3. We assume that the first two OFDM symbols of all the U users are completely filled by known pilot symbols using the optimum training sequences of [15]. These

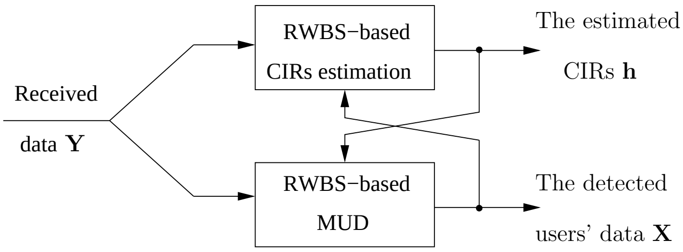

Fig. 2. Structure of the proposed iterative joint channel estimator and multi-user detector

training symbols are used for obtaining rough initial estimate of the FD-CHTFs. Since the OFDM technique divides the available bandwidth into parallel subchannels that experience frequency-flat fading, we can carry out the joint channel estimation and MUD on a per-carrier basis. To simplify the corresponding expressions, we omit the OFDM symbol index s as well as the subcarrier index k, and simply write Y_p, X^u and H_p^u instead of $Y_p[s,k], X^u[s,k]$ and $H_p^u[s,k]$. However, again, the following analysis is conducted on a subcarrier basis. More specificially, the operation of the DRWBS-JCEMUD scheme is detailed as follows:

We assume that the population sizes are P_H and P_X for the FD-CHTF and for the U users' data, respectively. The maximum number of generation is N_G. The initial FD-CHTF population contains the U Least-Square (LS) estimates [15] acquired with the aid of the training symbols. Then the initial estimates of the users' data are obtained by the MMSE OFDM/SDMA MUD [2]. The corresponding algorithmic steps are formulated in more detail as follows:

1) **Generation initialization** commencing from: $\hat{\mathbf{H}}_1^{(g)} = \hat{\mathbf{H}}_{best}^{(g-1)}, \hat{\mathbf{X}}_1^{(g)} = \hat{\mathbf{X}}_{best}^{(g-1)}$, the remaining $(P_H - 1)$ and $(P_X - 1)$ individuals are then created by the mutation operator, which is the same as the GA's mutation operator [4], yielding

$$\hat{\mathbf{H}}_i^{(g)} = MUTATE\left(\hat{\mathbf{H}}_1^{(g)}\right), i = 2, \cdots, P_H, \quad (3)$$

$$\hat{\mathbf{X}}_j^{(g)} = MUTATE\left(\hat{\mathbf{X}}_1^{(g)}\right), j = 2, \cdots, P_X, \quad (4)$$

where g represents the generation index.

2) Calculate the **cost function value** of each individual for all combinations of the FD-CHTF and users' data as follows:

$$J_{\hat{\mathbf{H}}_i}^{(g)} = J_{MSE}\left(\hat{\mathbf{H}}_i^{(g)}, \hat{\mathbf{X}}_{best}^{(g)}\right) = \left\|\mathbf{Y} - \hat{\mathbf{H}}_i^{(g)}\hat{\mathbf{X}}_{best}^{(g)}\right\|, \quad i = 1, 2, \cdots, P_H, \quad (5)$$

$$J_{\hat{\mathbf{X}}_j}^{(g)} = J_{MSE}\left(\hat{\mathbf{H}}_{best}^{(g)}, \hat{\mathbf{X}}_j^{(g)}\right) = \left\|\mathbf{Y} - \hat{\mathbf{H}}_{best}^{(g)}\hat{\mathbf{X}}_j^{(g)}\right\|, \quad j = 1, 2, \cdots, P_X, \quad (6)$$

where $\hat{\mathbf{X}}_{best}^{(g)}$ and $\hat{\mathbf{H}}_{best}^{(g)}$ are determined by

$$\hat{\mathbf{X}}_{best,t}^{(g)} = \arg\min_{\hat{\mathbf{X}}_j^{(g)}} J_{MSE}\left(\hat{\mathbf{H}}_{best,t-1}^{(g-1)}, \hat{\mathbf{X}}_j^{(g)}\right), \quad (7)$$

$$\hat{\mathbf{H}}_{best,t}^{(g)} = \arg\min_{\hat{\mathbf{H}}_i^{(g)}} J_{MSE}\left(\hat{\mathbf{H}}_i^{(g)}, \hat{\mathbf{X}}_{best,t}^{(g)}\right). \quad (8)$$

Furthermore, the received data $\mathbf{Y}$, the estimate of the U users' data $\hat{\mathbf{X}}_j^{(g)}$ and the MIMO FD-CHTF $\hat{\mathbf{H}}_i^{(g)}$ of the individuals are given by

$$\mathbf{Y} = \left[Y_1, Y_2, \cdots, Y_P\right]^T, \quad (9)$$

$$\mathbf{X}_j^{(g)} = \left[X_j^{1(g)}, X_j^{2(g)}, \cdots, X_j^{U(g)}\right]^T, \quad (10)$$

$$\hat{\mathbf{H}}_i^{(g)} = \begin{bmatrix} \hat{H}_{1i}^{1(g)} & \ldots & \hat{H}_{1i}^{U(g)} \\ \vdots & \ldots & \vdots \\ \hat{H}_{Pi}^{1(g)} & \ldots & \hat{H}_{Pi}^{U(g)} \end{bmatrix}. \quad (11)$$

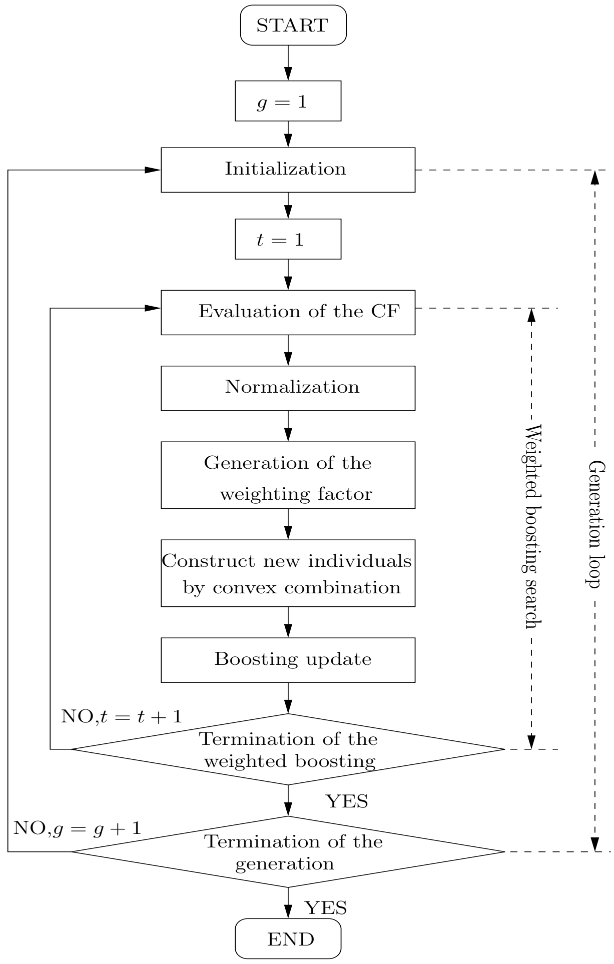

Fig. 3. Flowchart for the RWBS algorithm

3) **Normalize** the Cost Function (CF) value as follows:

$$\bar{J}_{H_i}^{(g)} = J_{\hat{\mathbf{H}}_i}^{(g)} / \sum_{i'=1}^{P_H} J_{\hat{\mathbf{H}}_{i'}}^{(g)}, i' = 1, 2, \cdots, P_H, \quad (12)$$

$$\bar{J}_{X_j}^{(g)} = J_{\hat{\mathbf{X}}_j}^{(g)} / \sum_{j'=1}^{P_X} J_{\hat{\mathbf{X}}_{j'}}^{(g)}, j' = 1, 2, \cdots, P_X. \quad (13)$$

4) Compute the **weighting factor** β_{H_t} and β_{X_t} according to:

$$\eta_{H_t} = \sum_{i=1}^{P_H} \delta_{H_i}(t-1)\bar{J}_{H_i}^{(g)}, \beta_{H_t} = \frac{\eta_{H_t}}{1 - \eta_{H_t}}, \quad (14)$$

$$\eta_{X_t} = \sum_{j=1}^{P_X} \delta_{X_j}(t-1)\bar{J}_{X_j}^{(g)}, \beta_{X_t} = \frac{\eta_{X_t}}{1 - \eta_{X_t}}, \quad (15)$$

where $\delta_{H_i}(t-1)$ and $\delta_{X_j}(t-1)$ are the distribution weights of the GA-style individuals representing the FD-CHTF and data of the U users, while t represents the iterations index in the weighted boosting search. The initial distribution weights are assumed to be $\delta_{H_i}(0) = 1/P_H$ and $\delta_{X_j}(0) = 1/P_X$, respectively.

5) **Update the distribution weights**

$$\delta_{H_i}(t) = \begin{cases} \delta_{H_i}(t-1)\beta_{H_t}^{\bar{J}_{H_i}^{(g)}}, & \beta_{H_t} \leq 1, \\ \delta_{H_i}(t-1)\beta_{H_t}^{1-\bar{J}_{H_i}^{(g)}}, & \beta_{H_t} > 1. \end{cases} \quad (16)$$

$$\delta_{X_j}(t) = \begin{cases} \delta_{X_j}(t-1)\beta_{X_t}^{\bar{J}_{X_j}^{(g)}}, & \beta_{X_t} \leq 1, \\ \delta_{X_j}(t-1)\beta_{X_t}^{1-\bar{J}_{X_j}^{(g)}}, & \beta_{X_t} > 1, \end{cases} \quad (17)$$

and then normalize them as follows

$$\bar{\delta}_{H_i}(t) = \delta_{H_i}(t) / \sum_{i'=1}^{P_H} \delta_{H_{i'}}(t), i = 1, 2, \cdots, P_H, \quad (18)$$

$$\bar{\delta}_{X_j}(t) = \delta_{X_j}(t) / \sum_{j'=1}^{P_X} \delta_{X_{j'}}(t), j = 1, 2, \cdots, P_X, \quad (19)$$

and let

$$\delta_{H_i}(t) = \bar{\delta}_{H_i}(t), i = 1, 2, \cdots, P_H, \quad (20)$$
$$\delta_{X_j}(t) = \bar{\delta}_{X_j}(t), j = 1, 2, \cdots, P_X. \quad (21)$$

6) **Construct the new individuals representing the FD-CHTF and the users' data** as follows:

$$\mathbf{H}_{P_H+1}^{(g)} = \sum_{i=1}^{P_H} \delta_{H_i}(t)\hat{\mathbf{H}}_i^{(g)}, \quad (22)$$

$$\mathbf{H}_{P_H+2}^{(g)} = 2\hat{\mathbf{H}}_{best,t}^{(g)} - \mathbf{H}_{P_H+1}^{(g)}, \quad (23)$$

$$\mathbf{X}_{P_X+1}^{(g)} = sign\left(\sum_{i=1}^{P_X} \delta_{X_j}(t)\hat{\mathbf{X}}_j^{(g)}\right), \quad (24)$$

$$\mathbf{X}_{P_X+2}^{(g)} = sign\left(2\hat{\mathbf{X}}_{best,t}^{(g)} - \sum_{j=1}^{P_X} \delta_{X_i}(t)\hat{\mathbf{X}}_j^{(g)}\right) \quad (25)$$

7) **Replace the worst individual** representing the U FD-CHTF $\hat{\mathbf{H}}_{worst,t}^{(g)}$ and users' data $\hat{\mathbf{X}}_{worst,t}^{(g)}$ with $\hat{\mathbf{H}}_{i^*}$ and $\hat{\mathbf{X}}_{j^*}$, where $\hat{\mathbf{H}}_{worst,t}^{(g)}, \hat{\mathbf{X}}_{worst,t}^{(g)}, \hat{\mathbf{H}}_{i^*}$ and $\hat{\mathbf{X}}_{j^*}$ are given by

$$\hat{\mathbf{H}}_{worst,t}^{(g)} = \arg\max_{\hat{\mathbf{H}}_i^{(g)}} J_{MSE}\left(\hat{\mathbf{H}}_i^{(g)}, \hat{\mathbf{X}}_{best,t}^{(g)}\right), \quad (26)$$

$$\hat{\mathbf{X}}_{worst,t}^{(g)} = \arg\max_{\hat{\mathbf{X}}_j^{(g)}} J_{MSE}\left(\hat{\mathbf{H}}_{best,t}^{(g)}, \hat{\mathbf{X}}_j^{(g)}\right), \quad (27)$$

$$\hat{\mathbf{H}}_{i^*}^{(g)} = \arg\min_{\hat{\mathbf{H}}_{i'}^{(g)}} J_{MSE}\left(\hat{\mathbf{H}}_{i'}^{(g)}, \hat{\mathbf{X}}_{best,t}^{(g)}\right),$$
$$i' = P_H + 1, P_H + 2, \quad (28)$$

$$\hat{\mathbf{X}}_{j^*}^{(g)} = \arg\min_{\hat{\mathbf{X}}_{j'}^{(g)}} J_{MSE}\left(\hat{\mathbf{H}}_{best,t}^{(g)}, \hat{\mathbf{X}}_{j'}^{(g)}\right),$$
$$j' = P_X + 1, P_X + 2. \quad (29)$$

8) **Determine whether to terminate the weighted boosting search**. If we have $\|\mathbf{H}_{P_H+1} - \mathbf{H}_{P_H+2}\| < \xi_H$ and $\mathbf{X}_{P_H+1} = \mathbf{X}_{P_H+2}$, $\hat{\mathbf{H}}_{best}^{(g)} = \hat{\mathbf{H}}_{best,t}^{(g)}, \hat{\mathbf{X}}_{best}^{(g)} = \hat{\mathbf{X}}_{best,t}^{(g)}$ go to the next step, else set $t = t+1$ and return to step 2), where ξ_H is the accuracy that has to be reached before terminating the weighted boosting search.

9) **Determine whether to proceed to the next generation**. If we have $g < N_G$, then set $g = g + 1$ and go to Step 1), else curtail the search and use the final solutions: $\hat{\mathbf{H}} = \hat{\mathbf{H}}_{best}^{N_G}, \hat{\mathbf{X}} = \hat{\mathbf{X}}_{best}^{N_G}$.

Again, it is worth pointing out that the proposed DRWBS-JCEMUD conveniently generates the LLRs associated with the uth-user's bit upon invoking the maximum-approximation [3], which yields

$$\mathcal{L}_u \approx -\frac{1}{\sigma_n^2}\left[\left\|\mathbf{Y} - \hat{\mathbf{H}}\hat{\mathbf{X}}_{u\to 0}\right\| - \left\|\mathbf{Y} - \hat{\mathbf{H}}\hat{\mathbf{X}}_{u\to 1}\right\|\right], \quad (30)$$

where the notation of $\hat{\mathbf{X}}_{u\to b}, b = 0, 1$ suggests that the uth-user's bit is b, while the other users' bits are the same as those in $\hat{\mathbf{X}}$. More explicitly, the best individual X in the DRWBS-JCEMUD's final generation creates two groups, where the first (or second) group is constituted by all the individuals that have a value of 0 (or 1) for the uth user's bit information. The MUD's soft output for the uth bit can then be used for calculating the corresponding LLR of the uth user's bit. The resultant ouput LLR can then be directly fed to the channel decoder for improving the multi-user MIMO OFDM/SDMA system's performance.

IV. Simulation Results and Discussions

In this section, we will investigate the achievable performance of the multi-user MIMO OFDM/SDMA system using the proposed DRWBS-JCEMUD scheme. As an example, a simple four-path Rayleigh fading channel model was employed for each transmit-antenna–receive-antenna link, where the associated delay profile was negative exponentially decaying with the path delays of $0, 1, \cdots, (L-1)$ samples and the delay profile was specified by $E\{\alpha_l^2\} = \exp(-l/10)$. Each CIR-tap of the links experienced independent Rayleigh fading and it was assumed to be time-invariant within an OFDM frame between two pilot-blocks, implying that the channels were assumed to be constant for the duration of one frame, but they were faded at the beginning of each frame. Moreover, a half-rate, 5400-block length binary Low Density Parity Check (LDPC) code was employed and the modulation scheme was BPSK for all users. However, different users may employ different modulation schemes. The four algorithmic parameters of the DRWBS-JCEMUD scheme were found empirically and the values used in our simulation were $P_H = P_X = U + 1, N_G > 50$, while the accuracy required for terminating the weighted boosting search for the FD-CHTF was $\xi_H = 0.005$.

Moreover, two simulation cases were considered in this paper. The first one is the "full-rank" scenario, where the BS has an array of $P = 4$ antennas, while supporting $U = 4$ UL MSs simultaneously transmitting data. However, it is also important to consider the challenging "rank-deficent" case, when we have more users than the number of receiver antennas, because more users would like to access the system than the number of BS UL receiver antennas P. Hence we also considered a "rank-deficient" scenario of $P = 2$ receive antennas, while supporting $U = 4$ UL MSs.

Fig. 4 shows the attainable Mean Square Error (MSE) of the FD-CHTF versus the SNR for the DRWBS-JCEMUD scheme. As expected, the proposed DRWBS-JCEMUD

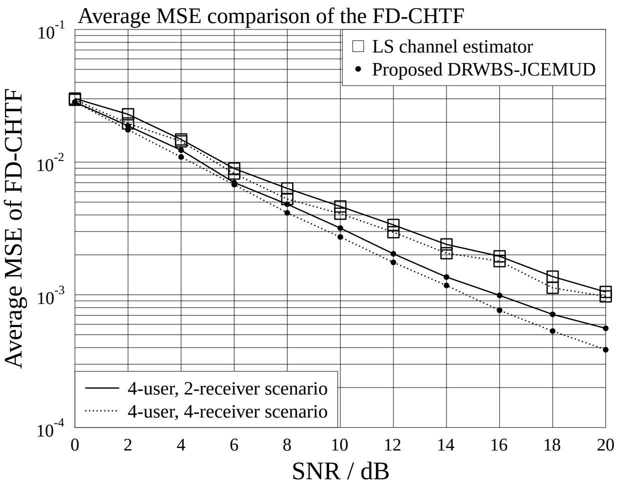

Fig. 4. MSE performance for a time-invariant channel, which has a constant envelope for 87 consecutive OFDM symbols. Both “full-rank” and “rank-deficent” cases were considered.

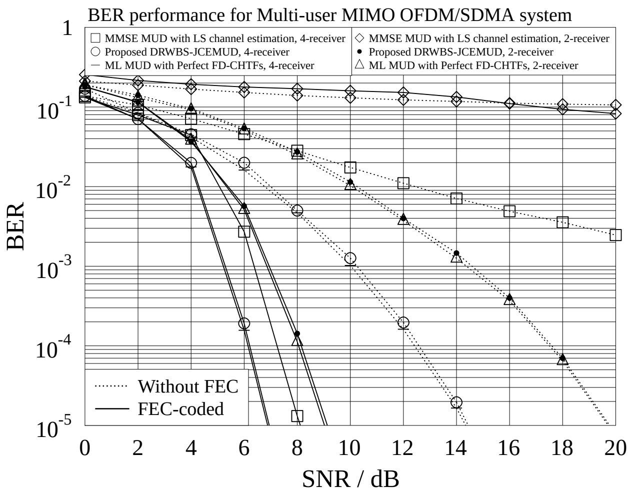

Fig. 5. BER performance versus different SNRs of the uncoded and LDPC-coded multi-user MIMO OFDM/SDMA system. The system supports four MS simultaneously transsmitting data to the BS. We consider two cases that the BS employs two antennas and four antennas. The optimal ML detetion with perfect channel knowledge were also given as a reference

scheme achieved a useful improvement over the initial channel estimate, especially in the range of $SNR > 8dB$.

In order to provide an overall impression of the attainable system performance, we evaluated the system’s Bit-Error-Ratio (BER) in Fig. 5 both with and without channel coding, as shown using solid and dashed lines, respectively. Observe in Fig. 5 that our scheme approaches the BER performance of the ideal case associated with perfect channel information, both with and without FEC coding, regardless of the number of antennas employed at the BS. An additional important observation is that, as expected, the system employing $P = 4$ antennas achieved a substantial performance gain, compared to the system employing $P = 2$ antennas, as a benefit of its increased spatial diversity, especially in the SNR range above $4dB$.

V. Conclusion

In this paper, we proposed a guided random search scheme for multi-user MIMO OFDM/SDMA systems, which we referred to as DRWBS-JCEMUD. The proposed scheme is capable of generating soft LLRs, which can be fed to the channel decoder. Our simulations demonstrated that the joint channel estimation and data detection scheme advocated is capable of attaining a BER performace close to the ideal scenario associated with perfect channel information, both with and without FEC coding. Our simulation results also demonstrated that the proposed DRWBS-JCEMUD scheme is capable of operating in “rank-deficent” scenarios.

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