by the interpolation kernel. Here, we develop a new compressive sensing (CS) [26, 27] based interpolation method for CIR estimation. In the literature, the CS method has been successfully used for sparse channel estimation [28–31] if the number of non-zero CIR coefficients is about as many as the size of the measurement vector [32]. Since the original CIR is not sparse in our case, the new CS-based channel estimation method is performed by applying the discrete cosine transform (DCT) to build a sparse basis from a modified LS formulation. In addition to the advantage of a smaller FFT size, this new algorithm also contributes to recovering the chip-rate CIR without using any high-resolution interpolation kernels. The proposed two-stage MUI cancellation (MUIC) scheme is simulated with reference to the mandatory IEEE 802.11 a/n/ac specifications in the indoor environment for two and four users. The numerical results show that the new receiver has similar bit error rate (BER) performance to the conventional receiver, but with a lower complexity to implement the FDE.

The rest of this paper is organised as follows: Section 2 describes the system model in our framework. In Section 3, the mathematical model for the equivalent symbol-based FDE is proposed. The iterative two-stage MUIC algorithm and the MUI variance analysis are followed in this section. The new CS-based CIR estimation method is described in Section 4. Numerical results are explored in Section 5 and conclusion is drawn in Section 6.

2 CP-CDMA system model

Figs. 1*a–c* depict the transmitter and the receiver of a CP-CDMA system, respectively, where Fig. 1*b* shows the conventional receiver whereas Fig. 1*c* the despread-ahead receiver. The main difference is that the conventional receiver first solves the channel response problem and then performs despreading after the FDE. In contrast, the new receiver first despreads the received signal before the FDE and then solves the channel response problem. Let N be the data block length and L_c the spreading code length. Since the FDE in the conventional receiver operates at chip rate, its FFT size is $L = NL_c$. The FFT size of the new receiver is N because of the symbol rate operation. Owing to the factor L_c for multiusers, the despread-ahead receiver owns the advantage of a reduced complexity in terms of the FFT size.

In our framework, we consider a P-user CP-CDMA system. Denote the symbol index by n, $n = 0, 1, \ldots, N-1$. Suppose the transmitted symbol $d_n^{(u)}$ is spreaded by the code vector $\boldsymbol{c}^{(u)}$ where u is the user index and $1 \le u \le P$. If each symbol is spreaded into L_c chips, we can express $\boldsymbol{c}^{(u)} = \left[c_0^{(u)} c_1^{(u)} \cdots c_{L_c-1}^{(u)}\right]$, where $c_i^{(u)} \in (1, -1)$ with $0 \le i \le L_c - 1$. Denote the input block vector by $\boldsymbol{d}^{(u)} = \left[d_0^{(u)} d_1^{(u)} \cdots d_{N-1}^{(u)}\right]^{\mathrm{T}}$. After spreading, we can write the spreaded block vector as

$$\boldsymbol{s}^{(u)} = \boldsymbol{d}^{(u)} \oplus \boldsymbol{c}^{(u)} = \left[s_0^{(u)} s_1^{(u)} \cdots s_{L-1}^{(u)}\right]^{\mathrm{T}} \quad (1)$$

where $\oplus$ denotes the Kronecker product.

We assume an enough CP length N_g is added to the transmitted vector such that intersymbol interference can be avoided. We denote the CIR by $\boldsymbol{h}^{(u)} = \left[h_0^{(u)} h_1^{(u)} \cdots h_{L_g-1}^{(u)}\right]^{\mathrm{T}}$, where L_g is the number of chip-rate multipath channel taps and $L_g < N_g$. Suppose the channel response is time-invariant within a data block and CP is perfectly removed at the

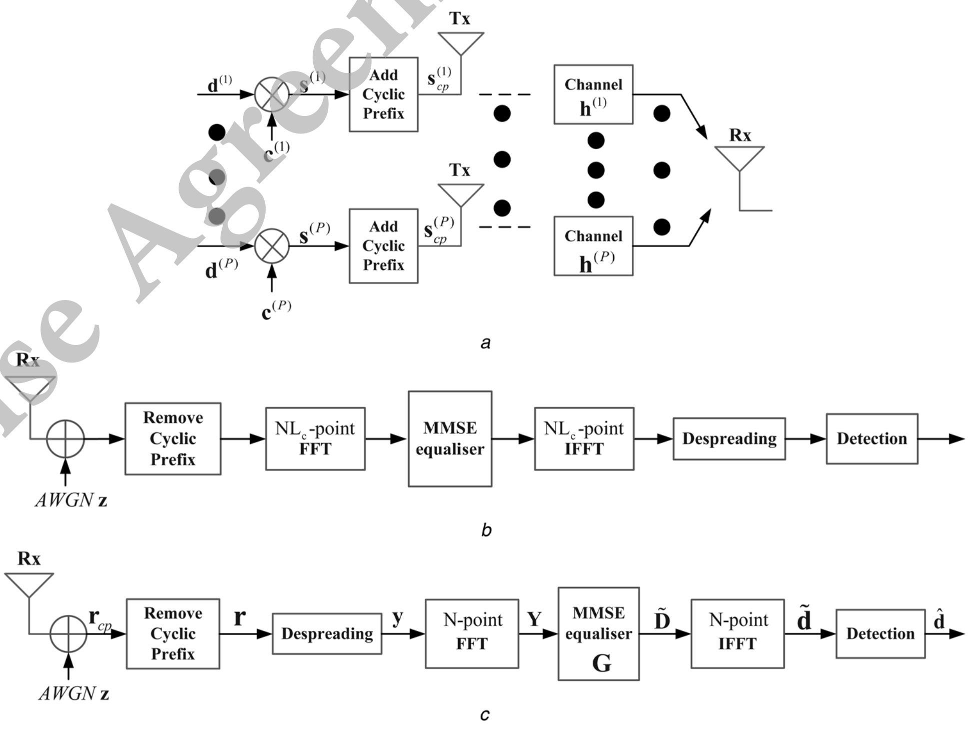

Fig. 1 *System model*

a Transmitter
b Conventional receiver
c New receiver

doi: 10.1049/iet-com.2013.0487