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A Novel Transmission Scheme for Reliable Cooperative Communication

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Abstract—Cooperative communication scheme can be substituted for multiple-input multiple-output (MIMO) technique when it may not be able to support multiple antennas due to size, cost or hardware limitations. In other words, cooperative communication scheme is an efficient method to achieve spatial diversity without multiple antennas. For satisfaction of rising QoS, we propose a reliable cooperative communication scheme with M-QAM based Dual Carrier Modulation (M-DCM), which can increase diversity gain. Although our proposed scheme is very simple method, it gives us frequency and spatial diversity. Simulation result shows our proposed scheme obtains diversity gain more than the conventional cooperative communication scheme.

Keywords—cooperation, diversity, M-DCM, OFDM.

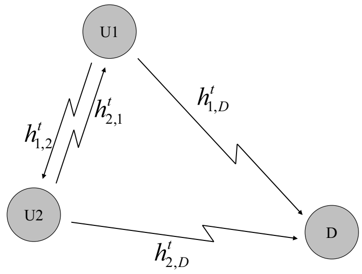

Fig. 1. The system model.

I. Introduction

RECENTLY, the advantages of multiple-input multiple-output (MIMO) technique have been widely acknowledged in wireless communication systems [1], [2]. However, it may not be able to support multiple antennas due to size, cost or hardware limitations [3]. To overcome the drawbacks of MIMO systems, there is a method which is called cooperative communication scheme. It allows single antenna devices to reap some of the benefits of MIMO systems.

Cooperative communication scheme is an efficient method to achieve spatial diversity although the user devices cannot be equipped with multiple antennas. Consequently, it provides another effective way of improving spectral and power efficiency of the wireless communication systems without the additional complexity of multiple antennas [4], [5]. The main idea of this cooperative diversity is to use multiple single antenna terminals as a virtual antenna array, realizing spatial diversity. In various ways of cooperative communications [6], [7], decode-and-forward (DF) cooperation scheme, which has been proposed in [8], has been widely studied. In DF cooperation scheme, retransmission of signal at the relay brings us full diversity because it passes through different channel.

In this paper, we propose the reliable cooperative communications scheme with M-QAM based Dual Carrier Modulation (M-DCM), which is more efficient at the diversity point of view than the DF cooperation scheme. DCM which was first introduced in the WiMedia ultra-wideband (UWB) system for higher data rate modes is one of the effective methods to utilize the frequency selectivity in the orthogonal frequency division multiplexing (OFDM) system [9]. In a DCM encoder, every $log_2 M$ information bits are modulated by two differently mapped M-ary quadrature amplitude modulation (M-QAM) modulators to have a symbol pair. It is noticed that their constellations are designed to maximize the minimum Euclidean distance between a symbol pair, which makes M-QAM based DCM (M-DCM) have the same bit error rate (BER) performance as $\sqrt{M}$-QAM in an additive white Gaussian noise (AWGN) channel. Moreover, if elements of a symbol pair are properly interleaved and are carried on far-off subcarriers, they hardly suffer from deep fading at the same time. As a result, DCM gives a certain level of frequency diversity [10]. In our proposed scheme, each user obtains partner's information bits which partner broadcasted, and then users modulate M-DCM symbols using its partner's and own information bits. Lastly, user 1 transmits first M-DCM symbol, and user 2 transmits second M-DCM symbol. From this operation, our proposed scheme obtains frequency and spatial diversity.

II. System Model

We consider that user 1 (U1) and user 2 (U2) transmit orthogonal frequency division multiplexing (OFDM) symbols to destination (D) as Fig. 1. In Fig. 1, $h^t_{i,j}$ is the channel coefficient from user i to j in t^{th} time slot (TS). It is modeled as independent and identically distributed (i.i.d.) for different i $(i = 1, 2)$ and j $(j = 1, 2, D)$ in fast fading channel.

For the OFDM symbols, the information bits of i^{th} user $(i = 1, 2)$ which is denoted $\mathbf{b}_i$ = [$b_i(1)$, $b_i(2)$, ..., $b_i(N_{INF})$] are encoded for error correcting to $\mathbf{c}_i$=[$c_i(1)$,$c_i(2)$, ..., $c_i(N_{INF}/R_c)$] by convolutional encoder whose code rate is R_c, where N_{INF} is defined as the number of information bit. Then, $\mathbf{c}_i$ is interleaved to $\mathbf{d}_i$=[$d_i(1)$,$d_i(2)$, ..., $d_i(N_{INF}/R_c)$] for avoidance of burst error, and $\mathbf{d}_i$ is modulated to get symbol frames $\mathbf{s}_i$=[$s_i(1)$,$s_i(2)$, ..., $s_i(N)$], where $N = N_{INF}/(R_c \times M)$; M is defined as the number of bits per constellation point.

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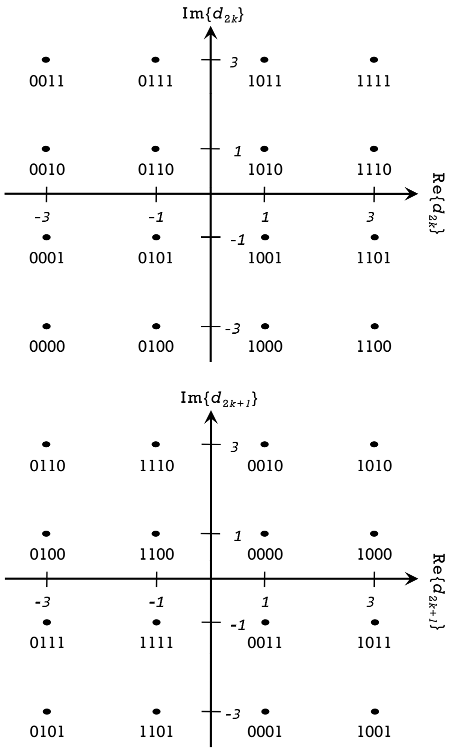

Fig. 2. The constellation of DCM.

Lastly, $\mathbf{s}_i$ is passed through IFFT which FFT size is N_{FFT} to get the OFDM symbols which is denoted $\mathbf{S}_i$=[$S_i(1)$,$S_i(2)$, ..., $S_i(N_s)$], where $N_s = N_{INF}/(R_c \times M \times N_{FFT})$ is the number of the symbols in a frame.

III. Cooperative Communications with Dual Carrier Modulation

For the comparison with the novel cooperative scheme, we consider the conventional scheme which is DF cooperative scheme. It will help to contrast with our proposed scheme at the diversity point of view.

A. Conventional Scheme

In the DF cooperation scheme, U1 and U2 broadcast their own data each in $(n-1)^{th}$ TS and n^{th} TS. Then each partner decodes their partner's data and then U1 and U2 retransmit their partner's data each in $(n+2)^{th}$ TS and $(n+1)^{th}$ TS as Fig. 3(a). Because the symbol passed through the different channel, the DF cooperation scheme can obtain the spatial diversity gain.

B. Proposed Scheme

In this sub-section, we propose the reliable cooperative communications scheme with *M*-DCM which can increase the diversity gain than the conventional scheme. For easier understanding about proposed scheme, a QPSK symbol is given below.

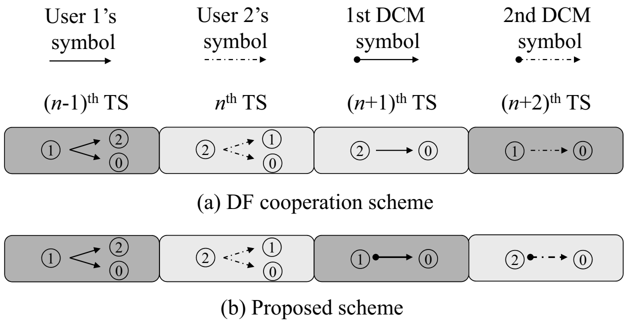

Fig. 3. The transmission scheme.

In the first and second period, U1 and U2 broadcast their own symbol in each time. Then they modulate DCM symbols using its patner's and own information bits as Table I. Lastly, U1 transmits the first DCM symbol in the third period and U2 transmits the second DCM symbol from in the fourth period.

In the destination, receiver obtains four symbols during four periods (U1's QPSK symbol, U2's QPSK symbol, the first DCM symbol, and the second DCM symbol). Our demodulation method is differentiated from conventional DCM demodulation method. The difference between conventional DCM demodulation and our demodulation is that our method additionally uses simple symbols which are broadcasted in the first and second period. The demodulation method is quite simple. Demodulated codeword is determined by the smallest value among sum of distance between four received signals and each constellation. Because we additionally use simple symbols which are broadcasted in the first and second period, we obtain time diversity besides frequency and spatial diversity.

IV. Simulation Results

In this section, the non cooperation scheme with one antenna and the DF cooperation scheme are utilized for the performance evaluation of our proposed scheme. We assume perfect equalization, complete synchronization, and no inter-channel interference (ICI). Moreover, we assume that the link variation is quasi-static at least one OFDM symbol.

In our simulations, we simply consider that signal to noise ratio (SNR) of U1 to D link is equal to the that of U2 to D link. The power of the transmitted symbol is normalized, in other words, the total power for transmission is the same each other. A rate 1/2 convolutional encoder with generator (13, 17)$_8$ is used in our simulation. The length of information bits per symbol is $N_{INF} = 512$ (when QPSK is used) or $N_{INF} =$

TABLE I
The construction of DCM symbol.

U1 symbol's bits	U2 symbol's bits
x_1x_2	y_1y_2
DCM symbol's bits	
$x_1y_2x_1y_2$	

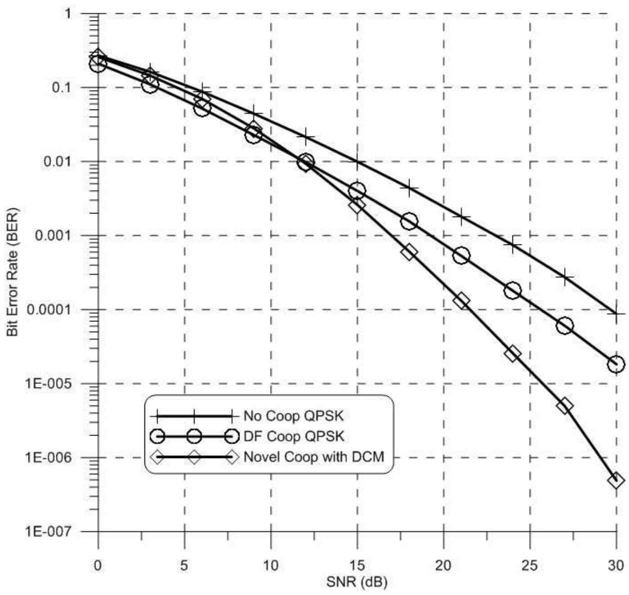

Fig. 4. The BER performance using QPSK in fast Rayleigh fading.

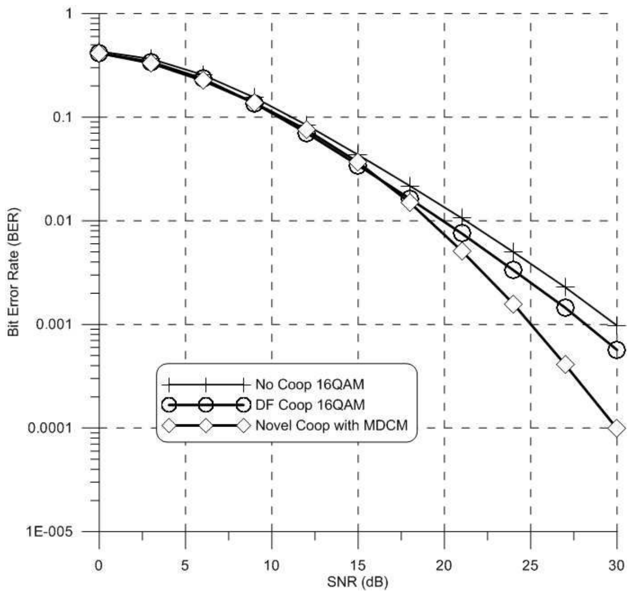

Fig. 5. The BER performance using 16QAM in fast Rayleigh fading.

1024 (when 16QAM is used). The FFT size is $N_{FFT} = 512$ and the guard interval (GI) length is $N_{GI} = 16$.

We provide the simulation result of various schemes in fast Rayleigh fading channel in Fig. 4 and Fig. 5. It shows that our proposed scheme outperforms other schemes as anticipated for using any modulation order. It is also displayed that proposed scheme obtains 4 dB gain at 10^{-4} when main modulation order is 2 (QPSK) and 3 dB gain at 10^{-3} when main modulation order is 4 (16QAM).

From above simulation result, it can be shown that the proposed cooperation scheme with M-DCM has good performance.

V. Conclusion

Although cooperative communication is a quite appealing technique for achieving the spatial diversity without multiple antennas in wireless communication system, requirement of reliability or consumption of low power is on the increase. We have presented the reliable cooperative communications scheme with M-DCM, which gives us diversity gain more than the conventional cooperative communication scheme even though it is very simple method. Simulation result shows the proposed scheme obtains diversity gain more than the conventional cooperative communication scheme.

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