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MIMO-OFDM FOR ARBITRARY MULTIPLEXING RATES BASED ONDYNAMIC SUB CARRIER MAPPING

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ABSTRACT

Multiple-input multiple-output (MIMO) wireless technology in combination with the orthogonal frequency-division multiplexing (MIMO-OFDM) is an attractive air interface solution for next-generation wireless local area networks (WLANs). Among the various resources in MIMO multicarrier systems the multiplexing rate assignment is related to the rate of transmissions. Here we proposed a new hybrid cyclic delay diversity (HCDD) scheme for multiple inputs multiple output (MIMO)-orthogonal frequency division multiplexing (OFDM) systems. Here we can achieve non integer multiplexing rate by assigning sub carriers and we can also select required number of transmitting antennas and adjusting diversity and multiplexing gains to matching various user requirements. In order to bridging the multiplexing rate with diversity gain here we propose dynamic sub carrier mapping for subcarrier allocation for multiplexing rate achievements. The advantage of proposed system is presented in the applications of scalable video broadcasting (SVB).

Keywords—MIMO-OFDM,DSTTD,CDD,SCDD,diversity multiplexing-tradeoff.

1. INTRODUCTION

Multiple-input multiple-output (MIMO) antenna techniques can improve system capacity, enhance link reliability and reduce interference. Improvements to system capacity and link reliability in MIMO systems result from the spatial multiplexing (SM) gain and the diversity gain respectively. Spatial multiplexing gain is contributed by the parallel transmissions of independent data streams in the multiple pairs of transmitting and receiving antennas. In contrast, multiple replicas of the same signal in multiple antennas yield spatial diversity gain, andit improves link reliability. Thus theperformance of MIMO antenna systems should be designedbased on the multiplexing and diversity tradeoff.Another important broadband wireless transmission technique is orthogonal frequency division multiplexing (OFDM),which can overcome the inter symbol interference (ISI) whentransmitting high-rate data in a frequency selective fadingchannel. Furthermore, OFDM can also provide a degree offreedom in subcarriers for resource allocation. Because MIMOand OFDM can enhance system performance from differentaspects, MIMO-OFDM has become an important research area in the past decade [1], [2].

In the literature survey, many MIMO-OFDM systems have been proposed to achieve the diversity and the multiplexing gains. In [3] a double space time transmit diversity (DSTTD) transmission architecture was proposed for MIMO-OFDM systems, decoded with a pre-whitening filter followed by a minimum-Euclideandistance decoder. Three types of group receivers wereproposed to separate the filtered multiplexing streams, followed by a space-time decoder [4]. Switching between twohybrid MIMO structures was proposed to improve transmission over wireless systems [5]. An algorithm to find the optimalantenna grouping configuration maximizing the throughputof the diversity-multiplexingcombined system was proposed [6]. However, the existing MIMO-OFDM architectures can onlyachieve the integer multiplexing rate [7].

Cyclic delay diversity (CDD) is another popular diversity technique that has been proposed for MIMO-OFDMsystems. With CDD, the same OFDM signal is transmittedover different antennas, each of which experiences differentcyclic shifts. Thus, extra frequency selectivity can be createdat the receiver without changing the receiver structure. For

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combining CDD with the SM-based MIMO can provide both thediversity and multiplexing gains.The combination of CDD and SM-based MIMO systems was adopted without considering thenon-integer multiplexing rates. In our previous work, weproposed a hybrid scheme to obtain non-integer multiplexingrates by combining SCDD and SM-based MIMO-OFDMsystems. However, the systematic code construction and theoutage capacity performance have not yet been reported.

The main objective of this paper is to investigate how a MIMOOFDM system can flexibly exploit the diversity and multiplexing gains to support various data rates and link reliabilityrequirements. The proposed hybrid cyclic delay diversity(HCDD) scheme is designed by combining pure CDD andspatial multiplexing in the OFDM system. The advantage of subcarrier rate assignment in OFDM systems, weproposed HCDD scheme can achieve non-integer multiplexingrates.

2. REVIEW OFCDDANDSCDD

A. Cyclic Delay Diversity

In OFDM systems, the information-bearing symbols s[k] is modulated onto orthogonal subcarriers via Inverse FastFourier Transform (IFFT) operation. The received signals canbe simply represented as$y_k = H_k s_k$ where H_k is the single-input single output (SISO) channel frequency response.

When multiple transmit antennas are available, M_t transmitting antennas, the signal transmitted from the $m-$ th antenna is

$$x_m[n] = \frac{1}{\sqrt{NM_t}} \sum_{k=0}^{N-1} s_k \exp\left\{ \mathrm{j}\frac{2\pi \mathrm{k}((\mathrm{n}-\delta_\mathrm{m}) \bmod \mathrm{N})}{\mathrm{N}} \right\}$$

where N is the number of sub carriers and δ_m is the value of cyclic delay .

The cyclically shifted signal $x_m[n]$ can be

$$x_m[n] = \frac{1}{\sqrt{NM_t}} \sum_{k=0}^{N-1} \left(e^{-j\frac{2\pi\delta_m k}{N}} s_k \right) e^{j\frac{2\pi nk}{N}}$$

B. Stacked Cyclic Delay Diversity

The CDD scheme can incorporate spatial multiplexing techniques by stacking multiple groups of CDD antennas, which is referred to as the stacked CDD or the cyclic delayassisted SM-OFDM (CDA-SM-OFDM) [8]. The basic idea of SCDD is to separate data streams into the different groups upon which the CDD scheme is involved. Consider single user MIMO OFDM system with M_t transmitting antennas,$M_r$receiving antennas and N subcarriers. Let r be the number of streams to be transmitted$s_k = [s_k^{(1)}, \dots, s_k^{(r)}]^T$ symbols of each stream at the$k-$th subcarrier after channel coding and quadrature amplitudemodulation (QAM). Mt transmitting antennas are divided to $r$groups, each of which is equipped with $B = M_t/r$ antennas.The received signal at the $k-$ thsubcarrier canbe expressed as

$$y_k^s = \frac{1}{\sqrt{M_t}} \mathrm{H}_k^{(S)} s_k$$

3. PROPOSED SCHEME HYBRID CYCLIC DELAY DIVERSITY

A. Basic Concept

Diversity and multiplexing in the antenna spatial dimension, as exploited by the existing DSTTD and SCDD schemes, we propose a hybrid CDD scheme to explore the subcarrier frequency dimension in OFDM system. Further most existing MIMO-OFDM schemes, in which all subcarriers transmit at the same rate, the proposed HCDD scheme can support different rates at each subcarrier or a group of subcarriers. Let $r_k$be the number of streams assigned to the $k-$thsubcarrier, and$s_k = [s_k^{(1)}, \dots, s_k^{(r)}]^T$. The received signal atthe $k-$th subcarrier can be expressed as

$$\widetilde{y_k} = \frac{1}{\sqrt{M_t}}(H_k D_{M_{t,k}} V_t) s_k + W_k)$$

whereH_k is the MIMO channel frequency response and $D_{M_{t,k}}$ is a diagonal matrix corresponding to the frequency equivalent operation of cyclic delay at each transmitting antenna.

The main advantage of HCDD is that the rate of space-time codes can be adjusted flexibly according to the system requirements by assigning r_k to different sub-carriers. Thenumber of transmitting antennas for the HCDD can also be adjusted flexibly. The minimum number of transmitting antennas required for DSTTD or SCDD is four, while HCDD can be applied to systems with only two transmitting antennas.

B. Construction of HCDD Codes

The general concept of HCDD, $r_k$can be flexibly Assign to each subcarrierand is only limited by the numberof transmitting antennas M_t. However, there are alarge number of subcarriers in contemporary communicationsystems, the decoding process becomes extremely difficult tomanage if$r_k$is arbitrarily assigned without rules. To controlthe complexity of the encoding and decoding process tomaintain the flexibility of HCDD scheme, the followingsystematic construction method is

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proposed. The rate of the HCDD code is determined by

$$r = \frac{\sum_{p=1}^{P} f_p N_p}{N_q}$$

whereN_p is the number of subcarriers with rate equal to f_p. The HCDD encoder chooses one feasible subcarrier number combination $[N_1, N_2, \dots, N_P]$ which isapplied to all the resource blocks and the algorithm shows in figure 2.The proposed construction method has the following twoadvantages. First, since CDD is an open-loop transmittingdiversity technique, no channel state information (CSI) is requiredat the transmitter. It is beneficial to apply $r_k$uniformlyamong all the subcarriers. Secondly, as long as the finitepossible combinations are clearly defined and indexed at boththe transmitter and receiver, the decoder needs only the indexnumber $[N_1, N_2, \dots, N_P]$ to perform decoding, so much lessinformation is needed than other construction methods.

C. *Detection of HCDD*

The decoding process of the proposed HCDD scheme also becomes very easy. If a receiver is informed of the subcarrier combination $[N_1, N_2, \dots, N_P]$ chosen by transmitter, the multiplexing rate at each subcarrier $r_k$is known.Then the decoding process is performed by straightforwardly ona tone-by-tone basis.
For the subcarriers withr_k=1, $\widetilde{H}_k$is a $(M_r$×1)vector,and scalar minimum-mean-square-error (MMSE) detector isgiven as:

$$G_k^{MMSE} = (\widetilde{H}_k^H \widetilde{H}_k + \frac{1}{SNR})^{-1} \widetilde{H}_k$$

The subcarriers with r_k≥2, QR-decomposition (QRD) can be used to obtain successive interference cancellation(SIC). The QRD of $H_k$is given by$H_k = Q_K R_K$, where $Q_K$is the$(M_r \times r_k)$ unitary matrix and $R_K$is the$r_k \times r_k$ upper triangular matrix.

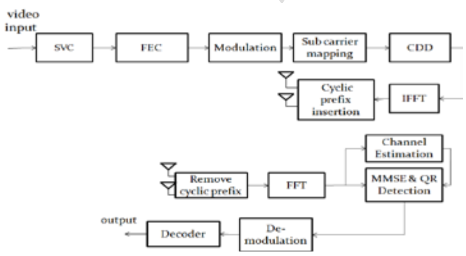

Figure.1. Proposed HCDD - SVB transmitter and receiver.

D. *HCDD Transceiver Architecture and its Application in SVB*

In mobile communication systems, the video streaming applications have been increase rapidly and thus expecting more bandwidth. Therefore, it becomes important to develop bandwidth-efficient video transmission techniques. By broadcasting and multicasting, multiple mobile terminals can be served with common data and radio resources.

Scalable video coding (SVC) is an extension of H.264/AVC video compression standard [9]. SVC can separate a high-quality video stream into several distinct streams called the basic layer and advanced layer(s). As long as the basic layer can be decoded correctly, the terminal can at least display a low resolution video. The display quality can be enhanced if the next layer is decoded correctly. When all the layers are decoded successfully, the original high-quality video is recovered. The signal processing of an HCDD based SVB is illustrated in fig 1.

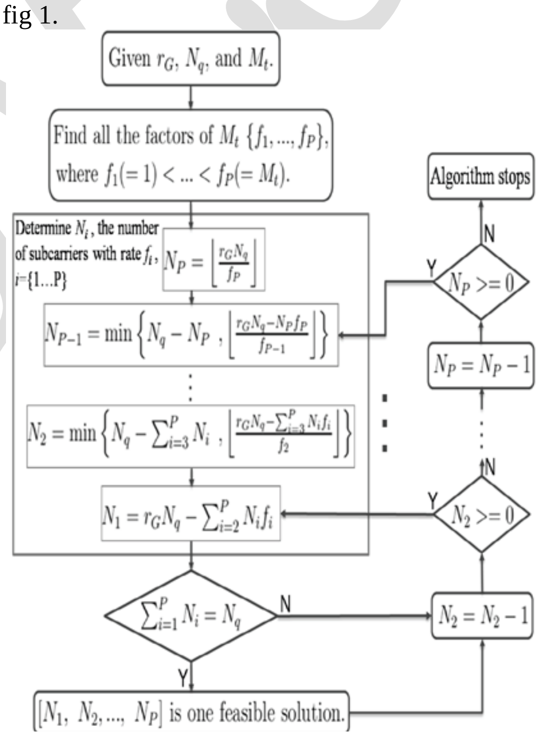

Figure.2. Algorithm for HCDD code construction.

For the receivers, with HCDD-based SVB, the smallerterminals with single antenna only need to access the subcarrierscarrying the basic layer with highest reliability (r_k= 1).In practice, because a small handheld terminal has a smalldisplay, low resolution

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video is sufficient. Moreover, small terminals are more sensitive to manufacturing costand power consumption, single antenna/RF chain and lowercomplexity are preferred. On the other side, bigger terminalswith two or more antennas can access the subcarriers carryingadvanced layers with$r_k \geq$ 2. More advanced signal processingtechniques are also applicable to enhance the service quality. This is reasonable since a bigger terminal with the larger display is more likely to have multiple RF chains and higher complexity. As a result, a finer video can beachieved when more receiving antennas and channel ranksare available and basic video is always available for allterminals. Furthermore, small terminals can be made moresimply and better energy efficient thanconventional SCFDM-based SVB receivers.

4. NUMERICAL RESULTS

The performance of the proposed HCDD scheme with current CDD, SCDD and spatial multiplexing schemes. As mentioned above, the major advantage of the HCDD scheme is its flexibility to achieve non-integer diversity – multiplexing - tradeoff requirements. The proposing HCDD will be shown in terms of the outage capacity and bit error rate (BER).

Without using CSI at the transmitter, the per-tone channel capacity for MIMO-OFDM systems is written as [10]

$$C_k = \log_2\left[\det\left(\mathrm{I}_{M_r} + \frac{E_s}{M_t}\mathrm{H}_k\mathrm{H}_k^H\right)\right]$$

$$= \sum_{i=1}^{R_k} \log_2\left(1 + \frac{E_s}{M_t N_0}\lambda_i\right)$$

whereR_K is the rank and λ_i $(i = 1,2,\ldots,R_K)$are the positive values of $\mathrm{H}_k\mathrm{H}_k^H$. Thus the channel capacityaveraged over all subcarriers is given by

$$C = \frac{1}{N}\sum_{k=1}^{N} C_k$$

The per-tone channel capacities for the HCDD and SCDD schemes are obtained by channel matrix H_k and H_k^H.The *q* % outage capacity is called as the channel capacity that (100-*q*) % independent realizations can achieve.

A.***Outage Capacity Performance***

The 1% outage capacity of the SM, CDD,HCDDschemes in 2×2 MIMO-OFDM systems, where the multiplexing rates are shown in fig 3. The SM and CDD schemes are twoand one respectively. In contrast, the multiplexing rate ofthe HCDD scheme can be flexibly chosen as any non integernumber between one and two. The HCDDwith r_G= 1.5 is located exactly between the other twoschemes. Suppose that 10 bps/Hz is required to guarantee 99%of all channels when E_b/N_0reaches 25 dB. Then the proposedHCDD scheme r_G= 1.5 can satisfy this particularrequirement.

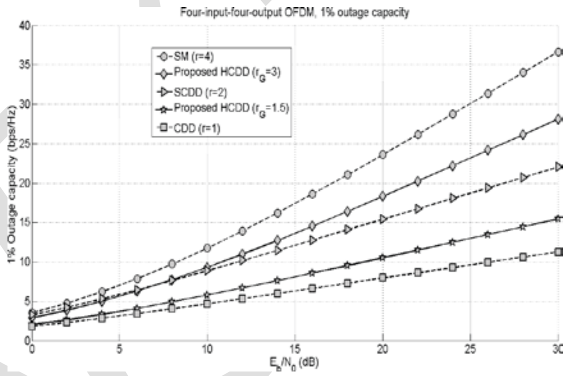

Figure.3. The 1%outage capacity performance of different transmission scheme in the 4×4 MIMO – OFDM systems.

The non-integer multiplexing rates for the HCDD scheme are achieved by assigning $[N_1 N_2 N_3]$ (number of subcarriers with r_k= 1,r_k= 2, and r_k= 4in each 10-subcarrier resource block). In this example, thevalues of [7 2 1] and [2 2 6] result in the multiplexing rates r_G= 1.5 and r_G= 3, respectively.

B. Impact of Antenna Correlation

The correlation amongtransmitting antennas is kept as small as 0.1. The correlatedchannel can be described as

$$\mathrm{H}_k = \mathrm{H}_k^{(w)}\mathrm{R}^{\frac{1}{2}}$$

where$\mathrm{H}_k^{(w)}$is the uncorrelated channel matrix; Ris theexponential correlation matrix ; $\mathrm{R}_{i,j} = \rho^{|i-j|}$and ρis thecorrelation coefficient between consecutive antennas.The antenna correlation increases from 0.1 to 0.9, the capacity of the proposed HCDD decreases by 32% and 26% when the rate is 12 and 5 respectively, which are between the SM and CDD scheme.

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C. Bit Error Rate

Here we obtain the bit error rate performance of different antenna and multiplexing schemes in MIMO-OFDM systems.Table I shows the system parameters used in our simulations.Figure 4 shows the bit error rate (BER) performance of the HCDD scheme with the multiplexing rate r_G= 1.25 and r_G = 1.33.

For comparison, the BER performances of the MIMO-OFDM systems with SM and CDD are shown. It is well known that the diversity gain can be estimated from the slope of the BER curve against E_b / N_0.The SM MIMO systems and CDD MIMO systems can be viewed as the extreme cases of the HCDD scheme.

Table I. Bit Error Rate Simulation Parameters

Parameter	Description
Number of subcarriers (N)	128
Carrier bandwidth	10 MHZ
Cyclic prefix length	N/4
Channel Model	Flat-fading channel
Channel Code	Convolutional encoder, Vitervi decoder
Constraint Length	7, [133 171]
Modulation	BPSK
MIMO Receiver	Linear MMSE
Channel Estimation	Ideal Channel Estimation

The multiplexing rates of the HCDD scheme are 0.8, 1.5 and 4.0 and can be any non-integer between 1 and 4 for providing more flexibility in system [11].For the 0.01 BER requirement the proposed scheme can achieve multiplexing rates from 2 up to 4 by adjusting the values of $[N_1 N_2 N_3]$.

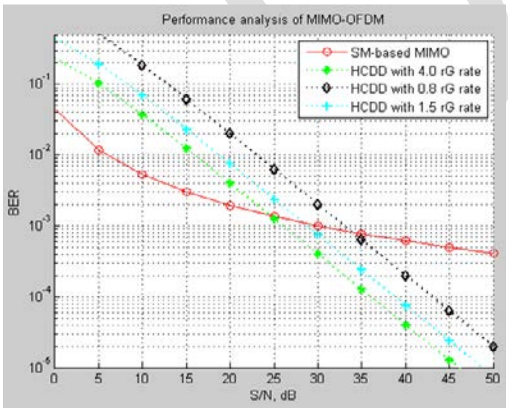

Figure.4. Comparison of the bit error rate performance of HCDD and SM antenna transmission in4 × 4 MIMO-OFDM systems.

The SNR vs. BER for HCDD and SM, etc., we obtain BER at the *y*-axis for a fixed E_b / N_0at *x*-axis. As shown in the figure, one can see that the proposed HCDD fills the gap of the CDD/SCDD and SM for the case4 ×4 MIMO-OFDM at E_b / N_0= 10 dB.

D. *SVB using HCDD*

Three layers are transmitted by a four-antenna BS. For each OFDM symbol, the data bit of each layer is 160, 160, and 240 bits, respectively. Layer 1 is the basic layer and the other two layers are represented as advanced layers. Layer 2 can be decoded only if layer 1 is decoded successfully. Layer 3 can be decoded only if layer 1 and 2 are both decoded successfully.All layers can be detected, and HCDD is slightly superior to SCFDM in all layer coverage. In addition to the comparable coverage performance, HCDD receivers still have the advantage of less complexity than SCFDM receivers.

5. CONCLUSION

This paper proposes a novel HCDD architecture to achieveflexible diversity-multiplexing tradeoff in MIMO OFDM systems.Unlike the existing transmitting antenna diversityscheme, which is suitable only for integer multiplexing rates,the proposed HCDD MIMO-OFDM systems can achieve non-integermultiplexing rates by taking advantage of the rateassignment in the degree of freedom subcarrier. Our simulation results show that the proposed HCDD can successfully fill the performance gap between the existing MIMO schemes, which can only provide the integer value multiplexing rates. The idea of utilizing the dimension subcarrier of OFDM to achieve the non-integer multiplexing rates can achieve the diversity and multiplexing tradeoff with more flexibility and can provide important insights into the design of future MIMO-OFDM systems. The combination of HCDD with SVB provides flexible diversity gains to different layers, and the overall receiver complexity is lower than conventional scheme.

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