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Efficient Variable Modulation Scheme Based on Codebook in the MIMO-OFDM System

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Abstract—Because current wireless communication requires high reliability in a limited bandwidth environment, this paper proposes the variable modulation scheme based on the codebook. The variable modulation scheme adjusts transmission power using the codebook in accordance with channel state. Also, if the codebook is composed of many bits, the reliability is more improved by the proposed scheme. The simulation results show that the performance of proposed scheme has better reliability than the the performance of conventional scheme.

Keywords—MIMO-OFDM, variable modulation, codebook, channel state.

I. Introduction

CURRENT wireless communication system is required in many fields and the demand for wireless communication services has been increasing. In order to meet the demand, the orthogonal frequency division multiplexing (OFDM) and multiple input multiple output (MIMO) system are required in the wireless communication. The OFDM system has high spectral efficiency compared to the single carrier system [1]-[5]. Also, the MIMO system can achieve proportionally high throughput in accordance with the number of antennas in contrast with single input single output (SISO) system [6]-[10].

As representative MIMO architecture, there is the vertical Bell laboratories layered space time (V-BLAST) that sequentially removes interference from other antennas by unit of spatial stream [11]-[15]. The zero forcing (ZF) is one of the easy detection schemes based on the V-BLAST [16],[17]. The QR decomposition M (QRD-M) has high reliability compared to the ZF [18]-[20]. However, the QRD-M has remarkably high complexity compared to the ZF.

In order to improve reliability of the system, the best method is to assign a lot of transmission power. However, because transmission power is specified on the system, transmission power can not be increased for the reliability of the system. For improvement of reliability, this paper proposes the variable modulation scheme based on channel state.

This paper is composed as follows. Section II shows the system model of the proposed scheme. Section III explains the generation process for the feedback information and the codebook. Section IV shows simulation results of the proposed scheme and the conventional scheme. This paper is concluded in section IV.

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II. System Model

Fig. 1 shows system model of the proposed scheme in MIMO-OFDM system. Transmitter simultaneously sends multiple data streams using multiple antennas in contrast with SISO system. The feedback information is generated based on the codebook in accordance with channel state information (CSI). The transmitting power is reallocated in accordance with feedback information by unit of subcarrier.

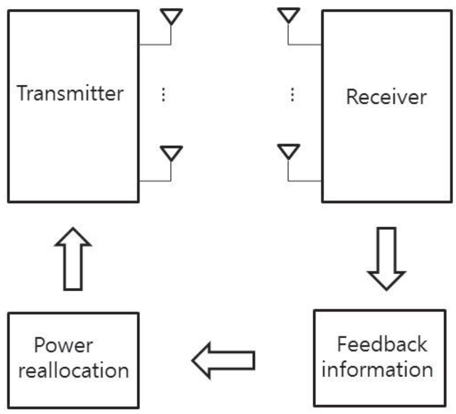

Fig. 1. The system model for proposed scheme using feedback information in MIMO-OFDM system

For generation of feedback information, the transmitter sends training symbol to the receiver. The channel state is estimated by the training symbol at the receiver. The receiver generates feedback information in accordance with estimated CSI and the transmitter sends data stream with adjusted power to the receiver.

The received signal with adjusted power is as follows,

$$Y = \sum_{n=1}^{C_t} W_n X_n H_n + N_n, \tag{1}$$

where C_t is the number of subcarriers, X_n is the symbol on the n-th subcarrier, H_n is the n-th subchannel, and N_n is the Gaussian noise at the n-th subchannel. W_n is the normalization factor for the n-th subcarrier.

III. Proposed Scheme

The proposed scheme is made up of procedure of 3 steps. The first step is procedure for generation of the codebook. The weighting factor of the codebook is amplitude of channel

scope for channel state	weighting factor (w)	bits
1.8750 < x ≤ 2.6000	0.3875	00000
1.2500 < x < 1.8750	0.3985	00001
0.6250 < x < 1.2500	0.4102	00010
0.0000 < x < 0.6250	0.4358	00011

Fig. 2. 2-bit codebook for the proposed scheme

scope for channel state	weighting factor (w)	bits
1.6000 < x ≤ 2.6000	0.2439	000
1.4000 < x < 1.6000	0.6667	001
1.2000 < x < 1.4000	0.7692	010
1.0000 < x < 1.2000	0.9091	011
0.8000 < x < 1.0000	1.1111	100
0.6000 < x < 0.8000	1.4286	101
0.4000 < x < 0.6000	2.0000	110
0.0000 ≤ x < 0.4000	5.0000	111

Fig. 3. 4-bit codebook for the proposed scheme

scope for channel state	weighting factor (w)	bits
1.4500 < x ≤ 2.6000	0.2532	0000
1.3750 < x < 1.4500	0.7080	0001
1.3000 < x < 1.3750	0.7477	0010
1.2250 < x < 1.3000	0.7921	0011
1.1500 < x < 1.2250	0.8421	0100
1.0750 < x < 1.1500	0.8989	0101
1.0000 < x < 1.0750	0.9639	0110
0.9250 < x < 1.0000	1.0390	0111
0.8500 < x < 0.9250	1.1268	1000
0.7750 < x < 0.8500	1.2308	1001
0.7000 < x < 0.7750	1.3559	1010
0.6250 < x < 0.7000	1.5094	1011
0.5500 < x < 0.6250	1.7021	1100
0.4750 < x < 0.5500	1.9512	1101
0.4000 < x < 0.4750	2.2857	1110
0.0000 ≤ x < 0.4000	5.0000	1111

Fig. 4. 4-bit codebook for the proposed scheme

between maximum value and minimum value. The minimum value of the channel is zero. However, the maximum value of the channel is variable. The maximum value is assumed as the statistical value based on cumulative distribution function (CDF). The scope for channel state of the codebook is uniformly divided in accordance with the number of assigned bits. For example, the 2-bit codebook is made up of 4 parts. The 5-bit codebook is made up of 32 parts. The weighing factor of the codebook is specified as the inverse of mean value for scope of the channel state.

The second step is procedure for generation of feedback information. The training symbol is sent by the transmitter to the receiver. The receiver estimates channel state using the training symbol and generates the feedback information in accordance with the codebook. The generated feedback information is sent to the transmitter. The transmitter reallocates transmission power in accordance with the codebook using the received feedback information. If channel state at a specific subcarrier is bad, the transmitter allocates high power in accordance with the codebook. In contrast, if channel state at a specific subcarrier is good, the transmitter allocates low power in accordance with the codebook. The

scope for channel state	weighting factor (w)	bits
2.5450 < x ≤ 2.6000	0.3875	00000
2.4735 < x < 2.5450	0.3985	00001
2.4020 < x < 2.4735	0.4102	00010
2.3305 < x < 2.4020	0.4358	00011
2.2590 < x < 2.3305	0.4498	00100
2.1875 < x < 2.2590	0.4647	00101
2.1160 < x < 2.1875	0.4807	00110
2.0445 < x < 2.1160	0.4978	00111
1.9730 < x < 2.0445	0.5162	01000
1.9015 < x < 1.9730	0.5360	01001
1.8300 < x < 1.9015	0.5573	01010
1.7585 < x < 1.8300	0.5805	01011
1.6870 < x < 1.7585	0.6056	01100
1.6155 < x < 1.6870	0.6330	01101
1.5440 < x < 1.6155	0.6630	01110
1.4725 < x < 1.5440	0.6960	01111
1.4010 < x < 1.4725	0.7325	10000
1.3295 < x < 1.4010	0.7729	10001
1.2580 < x < 1.3295	0.8182	10010
1.1865 < x < 1.2580	0.8690	10100
1.1150 < x < 1.1865	0.9266	10100
1.0435 < x < 1.1150	0.9923	10101
0.9720 < x < 1.0435	1.0681	10110
0.9005 < x < 0.9720	1.1564	10111
0.8290 < x < 0.9005	1.2606	11000
0.7575 < x < 0.8290	1.1564	11001
0.6860 < x < 0.7575	1.3855	11010
0.6145 < x < 0.6860	1.5379	11011
0.5430 < x < 0.6145	1.7279	11100
0.4715 < x < 0.5430	1.9714	11101
0.4000 < x < 0.4715	2.2949	11110
0.0000 ≤ x < 0.4000	5.0000	11111

Fig. 5. 5-bit codebook for the proposed scheme

adjusted data stream by using the variable modulation for power reallocation is sent to the receiver. For demodulation of the received data, the receiver compensates the channel with the weighing factor based on the codebook.

The final step is the normalization procedure for transmission power. The amount of used transmission power by the proposed scheme is same as the conventional scheme. The normalization factor W_k for the k-th subcarrier is as follows,

$$\mathrm{W_k} = \frac{\text{The number of the subcarriers} \times P(C_k)}{P(C_t)} \times w_k, \qquad (2)$$

where $P(C_k)$ is the transmission power on the k-th subcarrier and $P(C_t)$ is the total used transmission power on the all subcarriers. w_k is the weighting factor for the k-th subcarrier.

IV. Simulation Results

In this section, the improved performance is verified by bit error rate (BER) for the proposed scheme and the conventional scheme. The simulation results show the difference of the performance in accordance with the number of assigned bit at the codebook. The 2-bit codebook and the 5-bit codebook are used for simulation. The parameters for the proposed scheme are as follows: the number of antennas is 2x2, the fast Fourier transform (FFT) size is 256, the cyclic prefix size is 64 and the modulation scheme is 16 quadrature amplitude modulation (QAM). The assumed channel is a Rayleigh fading with 7 path and the detection scheme is assumed as the ZF.

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scope for channel state	weighting factor (w)	bits
$2.5777 < x \le 2.6000$	0.3853	000000
$2.5420 < x < 2.5777$	0.3906	000001
$2.5063 < x < 2.5420$	0.3962	000010
$2.4706 < x < 2.5063$	0.4019	000011
$2.4349 < x < 2.4706$	0.4137	000100
$2.3992 < x < 2.4349$	0.4199	000101
$2.3635 < x < 2.3992$	0.4263	000110
$2.3278 < x < 2.3635$	0.4329	000111
$2.2921 < x < 2.3278$	0.4397	001000
$2.2564 < x < 2.2921$	0.4467	001001
$2.2207 < x < 2.2564$	0.4540	001011
$2.1850 < x < 2.2207$	0.4614	001100
$2.1493 < x < 2.1850$	0.4692	001101
$2.1136 < x < 2.1493$	0.4772	001110
$2.0779 < x < 2.1136$	0.4854	001111
$2.0422 < x < 2.0779$	0.4940	010000
$2.0065 < x < 2.0422$	0.5029	010001
$1.9708 < x < 2.0065$	0.5120	010010
$1.1865 < x < 1.9708$	0.5216	010100
$1.9351 < x < 1.1865$	0.5315	010111
$1.8994 < x < 1.9351$	0.5418	011000
$1.8637 < x < 1.8994$	0.5524	011001
$1.8280 < x < 1.8637$	0.5636	011010
$1.7923 < x < 1.8280$	0.5751	011000
$1.7566 < x < 1.7923$	0.5872	011001
$1.7209 < x < 1.7566$	0.5998	011010
$1.6852 < x < 1.7209$	0.6129	011011
$1.6495 < x < 1.6852$	0.6266	011100
$1.6138 < x < 1.6495$	0.6409	011101
$1.5781 < x < 1.6138$	0.6559	011110
$1.5424 < x < 1.5781$	0.6882	011111
$1.5067 < x < 1.5424$	0.7055	100000
$1.4710 < x < 1.5067$	0.7237	100001
$1.4353 < x < 1.4710$	0.7429	100010
$1.3996 < x < 1.4353$	0.7632	100011
$1.3639 < x < 1.3996$	0.7845	100100
$1.3282 < x < 1.3639$	0.8071	100101
$1.2925 < x < 1.3282$	0.8311	100110
$1.2568 < x < 1.2925$	0.8565	100111
$1.2211 < x < 1.2568$	0.8835	101000
$1.1854 < x < 1.2211$	0.9123	101001
$1.1497 < x < 1.1854$	0.9758	101010
$1.1140 < x < 1.1497$	1.0111	101011
$1.0783 < x < 1.1140$	1.0489	101100
$1.0426 < x < 1.0783$	1.0897	101101
$1.0069 < x < 1.0426$	1.1339	101110
$0.9712 < x < 1.0069$	1.1817	101111
$0.9355 < x < 0.9712$	1.2337	110000
$0.8998 < x < 0.9355$	1.2906	110001
$0.8641 < x < 0.8998$	1.3529	110010
$0.8284 < x < 0.8641$	1.4216	110011
$0.7570 < x < 0.8284$	1.4976	110100
$0.7213 < x < 0.7570$	1.5822	110101
$0.6856 < x < 0.7213$	1.6769	110110
$0.6499 < x < 0.6856$	1.7836	110111
$0.6142 < x < 0.6499$	1.9049	111000
$0.5785 < x < 0.6142$	2.0439	111001
$0.5428 < x < 0.5785$	2.2048	111010
$0.5071 < x < 0.5428$	2.3932	111011
$0.4714 < x < 0.5071$	2.3962	111100
$0.4357 < x < 0.4714$	2.4992	111101
$0.4000 < x < 0.4357$	2.6022	111110
$0.0000 \le x < 0.4000$	5.0000	111111

Fig. 6. 6-bit codebook for the proposed scheme

Fig. 2 shows BER performance in the 2x2 MIMO-OFDM system. Because of the large range for each scope of the codebook, the 2-bit codebook is difficult to assign the correct weighting factor in accordance with the channel state. From simulation result, BER performance of the proposed scheme using the 2-bit codebook is similar to the conventional scheme.

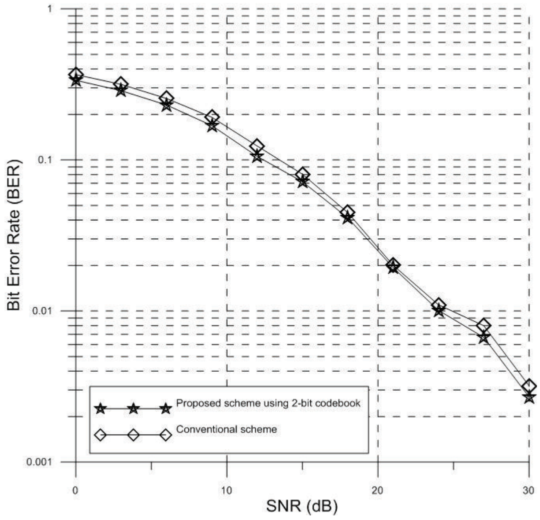

Fig. 7. BER performance of proposed scheme for 2-bit codebook and conventional scheme

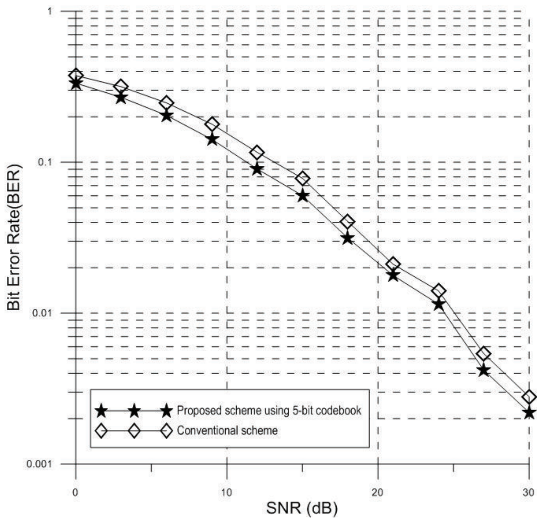

Fig. 8. BER performance of proposed scheme for 5-bit codebook and conventional scheme

Fig. 3 shows BER performance in the 2x2 MIMO-OFDM system. The simulation for Fig. 3 uses the 5-bit codebook. Because of the small range for each scope of the codebook, the 5-bit codebook can assign the correct weighting factor compared to the 2-bit codebook. From simulation result, the proposed scheme using the 5-bit codebook has about 1.5dB signal to noise ratio (SNR) gain compared to the conventional scheme. As a result, if the number of assigned bit for the codebook is increased, it is verified that the reliability is increased by the proposed scheme in the MIMO-OFDM system.

V. Conclusion

This paper proposes the efficient variable modulation scheme based on the codebook for enhanced reliability in the MIMO-OFDM system. The proposed scheme adjusts transmission power by unit of subcarrier in accordance with channel state. The simulation results show that the proposed scheme has more better BER performance than the conventional scheme. Also, if the codebook is composed of many bits, the reliability is more improved by the proposed scheme.

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