Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**An Open-loop MIMO Scheme based on Phase Shift Diversity**
Date Submitted	**2008-05-05**
Source(s)	Moon-il Lee Wookbong Lee Bin-Chul Ihm LG Electronic Inc. LG R&D Complex, 533 Hogye-1dong, Dongan-gu, Anyang, 431-749, Korea Voice: +82-31-450-7903 E-mail: emoon1@lge.com wbong@lge.com bcihm@lge.com
Re:	IEEE 802.16m-08/016r1 Call for Contributions on Project 802.16m System Description Document (SDD). Specific topic : Downlink MIMO schemes
Abstract	This contribution proposes an open-loop MIMO scheme based on phase shift diversity (PSD) which can provide considerable diversity gain with lower receiver complexity.
Purpose	For discussion and approval by TGm
Notice	
Release	
Patent Policy	

An Open-loop MIMO Scheme based on Phase Shift Diversity

Moon-il Lee, Wookbong Lee and Bin-Chul Ihm

LG Electronics

Introduction

For better support of a high-mobility MS, it is necessary to employ an open-loop MIMO scheme that can provide enough diversity gain so that reliable high-data rate transmission can be supported in IEEE 802.16m system. To employ proper open-loop MIMO scheme considering performance and complexity trade-off, the scheme should be evaluated with sophisticated detector such as maximum likelihood (ML) receiver or low complexity ML-like receiver which can provide reliable detection performance with reasonable decoding complexity.

In [1], the double space-time transmit diversity (D-STTD) with cycling (i.e., B matrix) was specified for 4Tx with rank-2 transmission in order to provide full diversity gain. However, it seems hard to employ ML-like receiver for B matrix since four data symbols should be jointly detected at the same time even though the B matrix is rank-2 transmission scheme, thereby requiring excessive decoding complexity. Keeping that in mind, it is preferable to employ rank-2 based transmission scheme which spreads only two data symbols to spatial domain at a time so that only two data symbols need to be jointly detected at the same time. As a candidate of an open-loop transmission scheme that spreads only two data symbols, we introduce an open-loop precoding scheme based on phase-shift-diversity (PSD) which can be employed with ML-like receiver with reasonable performance gain as compared with B matrix.

In this contribution, we compare the performance of proposed scheme and B matrix under high mobility scenario. In addition, we also investigate the decoder complexity between B matrix with MMSE receiver and proposed open-loop scheme with ML-like receiver.

Proposed Scheme

Following figure 1 shows the open-loop transmission scheme based on phase-shift-diversity (PSD) which can be defined irrespective of the number of transmit antennas and rank.

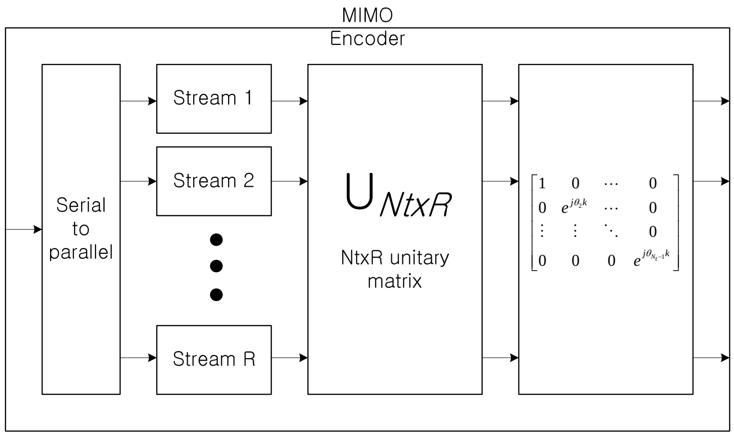

Figure 1. the structure of proposed scheme.

The proposed scheme can be defined by combining phase-shift diagonal matrix (i.e., phase shift diversity matrix) and fixed unitary matrix as shown in the figure 1. Therefore, it can be easily defined by adapting unitary matrix according to the number of transmit antennas and spatial multiplexing rate.

■ Detailed on proposed scheme

Table 1 shows an exemplary of the proposed schemes for 4Tx according to the rank. A large-delay sample is preferable for phase-shift diagonal matrix for high-mobility MS to obtain high frequency diversity gain. In addition, the unitary matrix can be a Fourier matrix or a Walsh Hadamard (WH) matrix and so on. In the table 1, we use 4x4 WH matrix as an example of the proposed scheme.

Table 1. Example of the proposed scheme for 4 Tx according to the rank.

4 Transmit Antennas			
Rank 1	Rank 2	Rank 3	Rank 4
$\frac{1}{2}\begin{bmatrix} 1 \\ e^{j\theta_1 k} \\ e^{j\theta_2 k} \\ e^{j\theta_3 k} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} 1 & 1 \\ e^{j\theta_1 k} & -e^{j\theta_1 k} \\ e^{j\theta_2 k} & e^{j\theta_2 k} \\ e^{j\theta_3 k} & -e^{j\theta_3 k} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} 1 & 1 & 1 \\ e^{j\theta_1 k} & -e^{j\theta_1 k} & e^{j\theta_1 k} \\ e^{j\theta_2 k} & e^{j\theta_2 k} & -e^{j\theta_2 k} \\ e^{j\theta_3 k} & -e^{j\theta_3 k} & -e^{j\theta_3 k} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} 1 & 1 & 1 & 1 \\ e^{j\theta_1 k} & -e^{j\theta_1 k} & e^{j\theta_1 k} & -e^{j\theta_1 k} \\ e^{j\theta_2 k} & e^{j\theta_2 k} & -e^{j\theta_2 k} & -e^{j\theta_2 k} \\ e^{j\theta_3 k} & -e^{j\theta_3 k} & -e^{j\theta_3 k} & e^{j\theta_3 k} \end{bmatrix}$

In table 1, k and $\theta_i, i=1,2,3$ denote resource index and phase angles for each transmit antenna, respectively. The phase angle $\theta_i, i=1,2,3$ can be defined according to the delay sample $\tau_i, i=1,2,3$ as $\theta_i = -2\pi / N_{fft} \cdot \tau_i$.

Figure 2 shows the examples for 4Tx according to the rank. As shown in the figure, the smaller rank can be defined by using only the rank number of columns of the unitary matrix.

$$\begin{bmatrix}1&0&0&0\\0&e^{j\theta_1 k}&0&0\\0&0&e^{j\theta_2 k}&0\\0&0&0&e^{j\theta_3 k}\end{bmatrix}\begin{bmatrix}\overbrace{\overbrace{\underbrace{\underbrace{\begin{matrix}1\\1\\1\\1\end{matrix}}_{rank-1}\;\begin{matrix}1\\-1\\1\\-1\end{matrix}}_{rank-2}\;\begin{matrix}1\\1\\-1\\-1\end{matrix}}^{rank-3}\;\begin{matrix}1\\-1\\-1\\1\end{matrix}}^{rank-4}\end{bmatrix}$$

Figure 2. Proposed scheme for 4Tx according to the rank

Performance Evaluation of the Proposed Scheme

In this section, we evaluate the performance of proposed scheme under ITU Vehicular-A channel with 30Km/h MS speed and compare with B matrix. In addition, we also compare the computational complexity between proposed scheme with ML-like receiver and B matrix with MMSE receiver. Note that B matrix needs to calculate 4x4 MMSE weight including an inversion of 4x4 complex equivalent channel matrix, thereby requiring higher decoding complexity over ML-like receiver for proposed scheme.

■ Performance comparison

In this subsection, the performance of proposed scheme under high-mobility scenario will be shown. The simulation assumption is shown in Table 2. In the simulation, we compare the performance between proposed scheme and B matrix defined in [1]. In addition, a packet error rate (PER) was used as a proper performance measure.

Table 2. Simulation assumption

Parameter	Assumption
System Bandwidth	10 MHz
Subframe length	0.617 ms
Resource unit size	18 subcarriers * 6 OFDM symbol
Resource allocation	2RU with distributed mode
Channel Models	ITU Vehicular-A
Mobile Speed (kmph)	30
Modulation schemes and channel coding rates	QPSK (R= 1/2, 3/4)

	16-QAM (R=1/2, 3/4)
Channel Code	Turbo code, Component decoder : max-log-MAP
MIMO structure	Vertical Encoding (SCW)
Delay samples for proposed scheme	64
Antenna configuration	4 transmitter, 2 receiver => [4Tx, 2Rx]
Spatial correlation (Tx, Rx)	(0%, 0%)
MIMO receiver	Linear Minimum Mean Squared Error (MMSE) for B matrix [1] QRM-MLD [2] for proposed scheme
Channel Estimation	Perfect channel estimation

In figure 3, it is seen that the proposed scheme outperforms the B matrix irrespective of channel coding rate and modulation. Furthermore, the gain seems to be more significant as the coding rate becomes higher since the diversity gain of proposed scheme can be fully exploited by ML-like receiver.

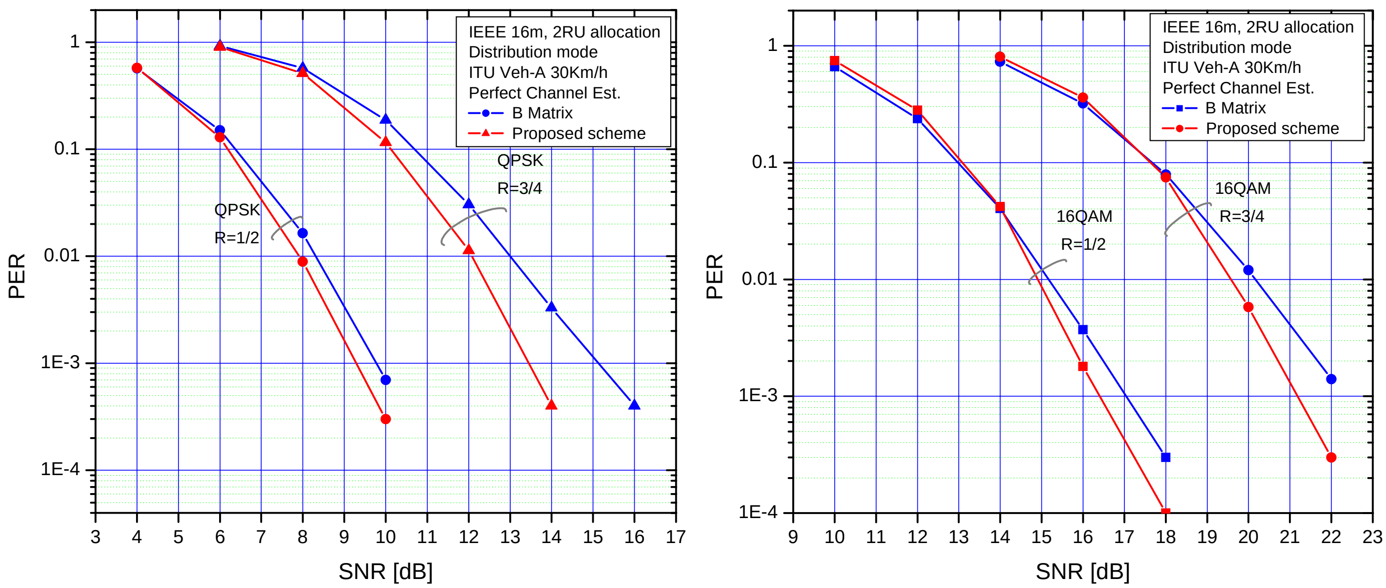

Figure 3. Performance comparison between proposed scheme and B matrix under ITU Veh-A channel.

■ Complexity comparison

In table 3, we show the computational complexity of full ML receiver and ML-like receiver for proposed scheme and MMSE receiver for B matrix. In addition, number of real multiplications assuming rank-2 and one RU case for instance. As shown in the table, ML-like receiver (i.e., QRM-MLD [2]) has much less computational complexity as compared with MMSE receiver for B matrix since the B matrix needs to decouple four data symbols with one MMSE filtering so that higher order MMSE weight calculation is required in rank-2 transmission. In addition, the complexity reduction seems more considerable as the modulation order gets lower.

Table 3. Number of real multiplications per resource block [2]. (4Tx, 2Rx, Rank(R)=2)

Decoding Method	Operation	Required number of multiplications per frame	Examples $(R=2,\ N_{sub}=108(i.e.,1RU))$
Full MLD for proposed scheme	Generation of symbol replica candidates	$4\cdot R^2\cdot C\cdot N_{sub}$	■ 4QAM (*C*=4) : 13824 ■ 16QAM (*C*=16) : 138240 ■ 64QAM (*C*=64) : 1880064
	Calculation of squared Euclidian distance	$2\cdot R\cdot C^R\cdot N_{sub}$	
MMSE for B Matrix	MMSE weight generation	$4(2\cdot(2R)^3+((2R)^3-2R)/3)\cdot N_{sub}$	■ 4QAM (*C*=4) : 74304 ■ 16QAM (*C*=16) : 84672 ■ 64QAM (*C*=64) : 126144
	Signal separation using MMSE weight	$4\cdot(2\cdot R)^2\cdot N_{sub}$	
	Calculation of squared Euclidian distances	$4\cdot R\cdot C\cdot N_{sub}$	
QRM-MLD for proposed scheme	QR decomposition of channel matrix $\mathbf{H}$	$4\cdot R^3\cdot N_{sub}$	■ 4QAM (*C*=4) : 12960 ✓ $S_1=4,\ S_2=8$ ■ 16QAM (*C*=16) : 43200 ✓ $S_1=16,\ S_2=64$ ■ 64QAM (*C*=64) : 129600 ✓ $S_1=64,\ S_2=128$
	Multiplication of $\mathbf{Q^H}$ to received signal vector	$4\cdot R^2\cdot N_{sub}$	
	Generation of symbol replica candidates	$4\cdot(R\cdot(R+1)/2)\cdot C\cdot N_{sub}$	
	Calculation of squared Euclidian distances	$2\cdot(\sum_{m=1}^{R}S_m)\cdot N_{sub}$	

Conclusions

In this contribution, we introduced the PSD based scheme as a candidate of an open-loop MIMO transmission scheme in order for better support of high mobility MS with high geometry so that the system can provide proper high quality services irrespective of the mobile speed. From the above investigation, we can conclude as follows:

- ✓ Proposed scheme can provide significant performance gain over B matrix with less decoding complexity
  - ■ ML-like receiver can provide full performance gain with less complexity when two data symbol joint detection is capable.
- ✓ The performance difference between two schemes including proposed scheme with ML-type receiver and B matrix with MMSE receiver could be more significant if we take channel estimation loss into account since the MMSE receiver is more sensitive to channel estimation incorrectness due to inter-layer interference increment.

Therefore, we strongly recommend the use of proposed scheme for IEEE 802.16m downlink open-loop MIMO scheme since it can obtain full frequency diversity gain in combination with ML-type receiver with lower decoding complexity.

Text Proposal

-- Text Start --

11.x Multiple antenna transmission

11.x.1 MIMO structure

11.x.2 Downlink

11.x.2.1 Open-loop MIMO

Open loop MIMO (OL-MIMO) scheme requires only CQI. OL-MIMO is suitable for high speed user, control channel or limited uplink feedback situation.

To reduce options or complexity, a single or limited number of transmit diversity (TxD) scheme which can be extended to any number of transmit antennas and any number of streams is preferred. To implement simpler receiver, the number of simultaneously transmit symbols is same as transmit rank. Only SU-MIMO mode shall be used for OL-MIMO transmission.

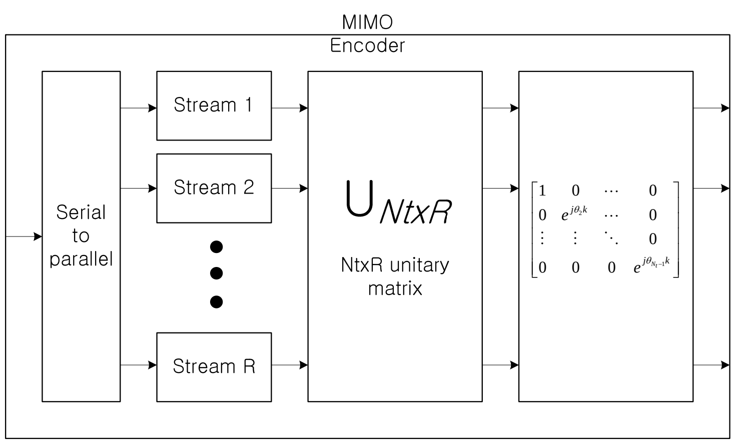

Figure x. the structure of open-loop MIMO scheme.

Where k and $\theta_i, i=1,2,\ldots,N_t-1$ denote resource index and phase angles for each transmit antenna, respectively. The phase angle $\theta_i, i=1,2,\ldots,N_t-1$ can be defined according to the delay sample $\tau_i, i=1,2,\ldots,N_t-1$ as $\theta_i = {-2\pi}/{N_{fft}} \cdot \tau_i$. Transmit rank R can be defined by the number of columns of the unitary matrix U.

11.x.2.2 Closed-loop MIMO

11.x.2.3 Collaborative MIMO

-- Text End --

References

[1] IEEE 802.16Rev2/D4, April 2008

[2] Kenichi Higuchi et. al. '*Adaptive selection of surviving symbol replica candidates based on maximum reliability in QRM-MLD for OFCDM MIMO multiplexing*,' Globecom 2004