(19) (KR)
(12) (A)

(11) 10-2010-0042028
(43) 2010 04 23

(51) Int. Cl.
H04L 27/26 (2006.01)
(21) 10-2008-0101136
(22) 2008 10 15
2008 10 15

(71)

98

(72)

3 880-21
401

320-303

(74)

: 8

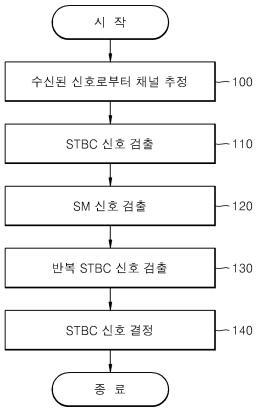
(54)

(57)

MIMO OFDM STBC .

, STBC (Space Time Block Code) SM (Spatial Multiplexing)
STBC , STBC ,
STBC STBC , STBC STBC
(cancellation) SM , STBC
SM (cancellation) STBC STBC
STBC STBC STBC .

- 1



1

STBC (Space Time Block Code) SM (Spatial Multiplexing) STBC
,

(a) STBC ;

(b) STBC STBC ;

(c) STBC STBC (cancellation) SM
;

(d) STBC SM (cancellation) STBC
;

(e) (b) STBC (d) STBC STBC
STBC ; .

2

1 ,

(e) (b) STBC (d) STBC
(d) STBC (b) STBC (c)
, .

3

1 2 ,

(c) ,

(c1) V-BLAST OSIC V-BLAST DFE STBC
;

(c2)
;

(c3) SM ;
, .

4

3 ,

(c2) STBC QPSK 4 ,
16-QAM 16 , .

5

STBC (Space Time Block Code) SM (Spatial Multiplexing) STBC
,

STBC ;

STBC STBC STBC ;

STBC STBC (cancellation) SM
SM ;

STBC SM (cancellation) STBC

STBC ;

STBC STBC STBC STBC
STBC STBC STBC ; .

6

5 ,

STBC STBC STBC STBC
STBC STBC STBC STBC
STBC SM , .

7

5 6 ,

SM ,

V-BLAST OSIC V-BLAST DFE STBC
;

;

SM ; ,
.

8

7 ,

STBC QPSK 4 , 16-QAM
16 , .

[0001] , STBC (Space Time Block Code)
MIMO (Multiple Input Multiple Output) OFDM STBC
.

[0002]

OFDM (Orthogonal
Frequency Division Mulitplexing) .

,

.

(link budget)

. STBC

.

[0003] (multiplexing) Bell Lab BLAST (Bell Lab Layered Space Time)
MIMO (Multiple Input Multiple Output) , (rich scattering)
,

, .

(zero-forcing) MMSE (Minimum Mean Square Error) (nulling) .

[0004] MIMO (coherence bandwidth) BLAST-OFDM . , OFDM BLAST CP . V-BLAST . .

[0005] MIMO OFDM BPSK QPSK, 16-QAM, 64-QAM IFFT/FFT , RF .

[0006] STBC V-BLAST OFDM STBC . .

[0007] STBC STBC STBC . . 2 STBC STBC STBC SM STBC .

[0008] STBC STBC SM V-BLAST OSIC DFE STBC . STBC .

[0009] , , STBC STBC SM STBC .

[0010] , , STBC (Space Time Block Code) SM (Spatial Multiplexing) STBC , (a) STBC ; (b) STBC STBC ; (c) STBC STBC (cancellation) SM ; (d) STBC SM (cancellation) STBC ; (e) (b) STBC (d) STBC STBC STBC ; .

[0011] (e) (b) STBC (d) STBC (d) STBC (b) STBC (c) .

[0012] (c) , (c1) V-BLAST OSIC V-BLAST DFE STBC ; (c2) ; (c3) SM ; .

[0013] , (c2) STBC QPSK 4 , 16-QAM 16 .

[0014] , , STBC (Space Time Block Code) SM (Spatial Multiplexing) STBC , STBC ; STBC STBC STBC ; STBC STBC (cancellation) SM SM ; STBC SM (cancellation) STBC STBC ; STBC STBC STBC STBC STBC STBC ; .

[0015] , STBC SM . MIMO OFDM .

[0016] .

[0017] 1 , STBC (Space Time Block Code) SM (Spatial Multiplexing) STBC .

[0018] STBC (100). STBC STBC (110), STBC STBC (cancellation) SM (120), STBC SM (cancellation) STBC (130).

[0019] , STBC STBC STBC STBC (140).

[0020] 2 , STBC (Space Time Block Code) SM (Spatial Multiplexing) STBC . 1 .

[0021] STBC (200), (210) (220) .

[0022] (220) , STBC STBC STBC (230), STBC STBC (cancellation) SM SM (240), STBC SM (cancellation) STBC STBC (250) STBC (230) STBC STBC (250) STBC STBC STBC STBC (260) .

[0023] , STBC STBC , SM V- , STBC, SM STBC , .

[0024] STBC 3 . 3 , (300) / (305) , STBC (310) STBC SM STBC 4 (315) , (350) 3 (355) .

[0025] MIMO OFDM STBC (Space Time Block Code), SM (Spatial Multiplexing), STBC, beamforming .

[0026] BLAST

, STBC 3
.

[0027] 3 (300) STBC SM
(350) , (350) STBC (360)
STBC (cancellation) MIMO (365) SM MIMO
. (MIMO (365) (220) , MIMO
)

[0028] 1 4 .

[0029] STBC (Space Time Block Code) SM (Spatial Multiplexing) STBC
(400), , K (405). K
4 415 445 , ,
.

[0030] 4 i=0 , STBC (230) STBC
(410).

[0031] STBC ,
.

[0032] 1 .

1

$$[\mathbf{r}_1\ \mathbf{r}_2] = \mathbf{H}[\mathbf{a}_1\ \mathbf{a}_2] + [\mathbf{n}_1\ \mathbf{n}_2] =$$

$$\begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \\ h_{31} & h_{32} & h_{33} & h_{34} \end{bmatrix} \begin{bmatrix} a_1 & -a_2^* \\ a_2 & a_1^* \\ a_3 & a_5 \\ a_4 & a_6 \end{bmatrix} + \begin{bmatrix} n_{11} & n_{21} \\ n_{12} & n_{22} \\ n_{13} & n_{23} \end{bmatrix}$$

[0033]

[0034] $\mathbf{r}_1$ $\mathbf{r}_2$ 3x1 h_{ij} i.i.d
. i j
. n '0' .

[0035] STBC 4x3
2x2 .

2

$$\mathbf{A} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \qquad \mathbf{B} = \begin{bmatrix} h_{13} & h_{14} \\ h_{23} & h_{24} \end{bmatrix}$$

$$\mathbf{C} = \begin{bmatrix} h_{21} & h_{22} \\ h_{31} & h_{32} \end{bmatrix} \qquad \mathbf{D} = \begin{bmatrix} h_{23} & h_{24} \\ h_{33} & h_{34} \end{bmatrix}$$

[0036]

[0037] .

3

$$\mathbf{s}_{12}=\begin{bmatrix} a_1 & -a_2^* \\ a_2 & a_1^* \end{bmatrix} \qquad \mathbf{s}_{34}=\begin{bmatrix} a_3 & a_5 \\ a_4 & a_6 \end{bmatrix}$$

[0038]

[0039] 4 .

4

$$\tilde{\mathbf{r}}_1=\begin{bmatrix} r_1 & r_4 \\ r_2 & r_5 \end{bmatrix} \qquad \tilde{\mathbf{r}}_2=\begin{bmatrix} r_2 & r_5 \\ r_3 & r_6 \end{bmatrix}$$

[0040]

[0041] .

5

$$\tilde{\mathbf{r}}_1=\mathbf{A}\mathbf{s}_{12}+\mathbf{B}\mathbf{s}_{34}+\mathbf{w}_1$$
$$\tilde{\mathbf{r}}_2=\mathbf{C}\mathbf{s}_{12}+\mathbf{D}\mathbf{s}_{34}+\mathbf{w}_2$$

[0042]

[0043] $\mathbf{w}_1$ $\mathbf{w}_2$ $\tilde{\mathbf{r}}_1$ $\tilde{\mathbf{r}}_2$, 2x2 . 5

$\tilde{\mathbf{r}}_1$ $\tilde{\mathbf{r}}_2$. , STBC $\mathbf{s}_{12}$.

$\mathbf{s}_{12}$.

6

$$\mathbf{P}=\mathbf{B}^{-1}\tilde{\mathbf{r}}_1-\mathbf{D}^{-1}\tilde{\mathbf{r}}_2$$
$$=(\mathbf{B}^{-1}\mathbf{A}-\mathbf{D}^{-1}\mathbf{C})\mathbf{s}_{12}+\mathbf{B}^{-1}\mathbf{w}_1-\mathbf{D}^{-1}\mathbf{w}_2$$

[0044]

[0045] 7 .

7

$$\mathbf{P}=\tilde{\mathbf{H}}\mathbf{s}_{12}+\tilde{\mathbf{w}}$$
$$\begin{bmatrix} p_1 & p_3 \\ p_2 & p_4 \end{bmatrix}=\begin{bmatrix} \tilde{h}_{11} & \tilde{h}_{12} \\ \tilde{h}_{21} & \tilde{h}_{22} \end{bmatrix}\begin{bmatrix} a_1 & -a_2^* \\ a_2 & a_1^* \end{bmatrix}+\begin{bmatrix} \tilde{w}_1 & \tilde{w}_3 \\ \tilde{w}_2 & \tilde{w}_4 \end{bmatrix}$$

[0046]

[0047] $\tilde{\mathbf{H}}=\mathbf{B}^{-1}\mathbf{A}-\mathbf{D}^{-1}\mathbf{C},\ \tilde{\mathbf{w}}=\mathbf{B}^{-1}\mathbf{w}_1-\mathbf{D}^{-1}\mathbf{w}_2$. 7 a_1 a_2

p_1 p_4 . 8 STBC , STBC .

8

$$\tilde{a}_1 = \tilde{h}_{11}^* p_1 + \tilde{h}_{21}^* p_2 + \tilde{h}_{12} p_3^* + \tilde{h}_{22} p_4^*$$
$$= \left(|\tilde{h}_{11}| + |\tilde{h}_{12}| + |\tilde{h}_{21}| + |\tilde{h}_{22}|\right)^2 a_1 + W_1$$
$$\tilde{a}_2 = \tilde{h}_{12}^* p_1 + \tilde{h}_{22}^* p_2 - \tilde{h}_{11} p_3^* - \tilde{h}_{21} p_4^*$$
$$= \left(|\tilde{h}_{11}| + |\tilde{h}_{12}| + |\tilde{h}_{21}| + |\tilde{h}_{22}|\right)^2 a_2 + W_2$$

[0048]

$1/\left(|\tilde{h}_{11}| + |\tilde{h}_{12}| + |\tilde{h}_{21}| + |\tilde{h}_{22}|\right)^2$

[0049] STBC STBC . 4x3 2x2 STBC .

[0050] SM (420). K , , 5 415 420 .

[0051] STBC SM 400 STBC (cancellation) .

[0052] SM V-BLAST DFE , V-BLAST . , STBC STBC SM BER V-BLAST SM .

[0053] SM STBC STBC . , SM (cancellation) 9 .

9

$$[\bar{\mathbf{r}}_1 \ \bar{\mathbf{r}}_2] = \begin{bmatrix} r_1 & r_4 \\ r_2 & r_5 \\ r_3 & r_6 \end{bmatrix} - \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{31} & h_{32} \end{bmatrix} \begin{bmatrix} a_1 & -a_2^* \\ a_2 & a_1^* \end{bmatrix}$$

[0054]

$\overline{\mathbf{r}_1}$ $\overline{\mathbf{r}_2}$

[0055] STBC (cancellation) .

[0056] ordering , G MMSE 10 .

10

$$\mathbf{G} = \left(\mathbf{H}^H \mathbf{H} + \sigma_n^2 \mathbf{I}_M \right)^{-1} \mathbf{H}^H$$

[0057]

[0058] ordering .

11

$$k_i = \arg\min_{j \in \{3,4\}} \left\| (\mathbf{G})_j \right\|^2$$

[0059]

[0060] *i* , SM STBC 3 , 4 . $j \in \{3,4\}$ sorting 2 $i \in \{1,2\}$.

[0061] G .

12

$$\mathbf{H}_{sort} = [\mathbf{H}_{k_1} \ \mathbf{H}_{k_2}]$$

[0062]

[0063] Ordering $\mathbf{H}_{sort}$ QR .

13

$$\mathbf{H}_{sort} = QR$$

[0064]

[0065] , (cancellation) $\mathbf{Q}^{\mathrm{H}}$. 14 .

14

$$\mathbf{z} = \mathbf{Q}^H \bar{\mathbf{r}} = \mathbf{R}\mathbf{a} + \boldsymbol{\eta}$$

$$\begin{bmatrix} z_{1,t} \\ z_{2,t} \end{bmatrix} = \begin{bmatrix} R_{11,t} & R_{12,t} \\ 0 & R_{22,t} \end{bmatrix} \begin{bmatrix} a_{k_2,t} \\ a_{k_1,t} \end{bmatrix} = \begin{bmatrix} \eta_{1,t} \\ \eta_{2,t} \end{bmatrix}$$

[0066]

[0067] t .

[0068] SM .

15

$$a_{k_1,t} = Q(z_{2,t} / R_{22,t})$$

$$a_{k_2,t} = Q((z_{1,t} - (R_{12,t} \cdot a_{k_1,t})) / R_{11,t})$$

[0069]

[0070] Q( ) , SM .

[0071] SM V-BLAST STBC .

[0072] , , SM . V- , V-BLAST . V , V SM .

[0073] . V-BLAST OSIC DFE .

[0074] V , V V .

[0075] , V- .

[0076] V-BLAST OSIC V-BLAST DFE . . V-BLAST OSIC V-BLAST DFE , , .

[0077] , V V . QPSK 4 V 16-QAM 16 V .

[0078] V . . 5 16-QAM V=5 .

[0079] 5 OSIC DFE 1+i . 5 V-1 . .

16

$$\hat{\mathbf{a}}_i = \{\hat{a}_i^{(0)}, \hat{a}_i^{(1)}, \ldots, \hat{a}_i^{(v)}, \hat{a}_i^{(V-1)}\}$$

[0080]

[0081] V=5 , 4 .

$a_{k_1,t}$. 15

$a_{k_1,t}$ $a_{k_2,t}$ SM .

ML OSIC

DFE .

[0082] .

.

17

$$\hat{\mathbf{a}} = \{\hat{\mathbf{a}}^{(0)}, \hat{\mathbf{a}}^{(1)}, \ldots, \hat{\mathbf{a}}^{(v)}, \hat{\mathbf{a}}^{(V-1)}\}$$

[0083]

[0084] 17 .

18

$$\hat{\mathbf{a}}_{final} = \underset{c \in \{0,1,2,\ldots,V-1\}}{\arg\min} \left\| \mathbf{r} - \mathbf{H} \cdot \hat{\mathbf{a}}^{(c)} \right\|$$

[0085]

[0086] SM BER .
, V V
.

[0087] 6 , 3 V-BLAST DFE V- BER
, V BER . V=1
V- V-BLAST DFE . 6 V
. , SM
V .

[0088] STBC . STBC SM
STBC .

[0089] SM (cancellation) (430), STBC
(435).

[0090] (435) STBC 410 STBC (445),
STBC STBC STBC (450).
STBC STBC 410 STBC
(440), STBC 415 SM (420 425
). SM STBC (435),
STBC . , STBC STBC
.

[0091] STBC STBC STBC ,
.

[0092] 4 405 K 415 445
, 4
, .

[0093] STBC
.

[0094] 7 9 MIMO OFDM 1/2
. 7 Rayleigh .

[0095] 7 , (proposed detection) STBC (general detection)
, 3
4 , 3 . 7 STBC SM

V- BER 10^{-4} 2 dB

.

[0096] 8 STBC (proposed detector) 7 (general detection) STBC . 8 V- .

[0097] 9 STBC *V* . ZF V-BLAST V V- V . STBC SM , V- . V V=1 V- V- .

[0098] , STBC MIMO OFDM , .

[0099] . . ROM, RAM, CD_ROM, , , , . , .

[0100] . , , . . , .

[0101] , MIMO OFDM .

[0102] 1 STBC .

[0103] 2 STBC .

[0104] 3 , 4 3 .

[0105] 4 1 , .

[0106] 5 V- 16-QAM .

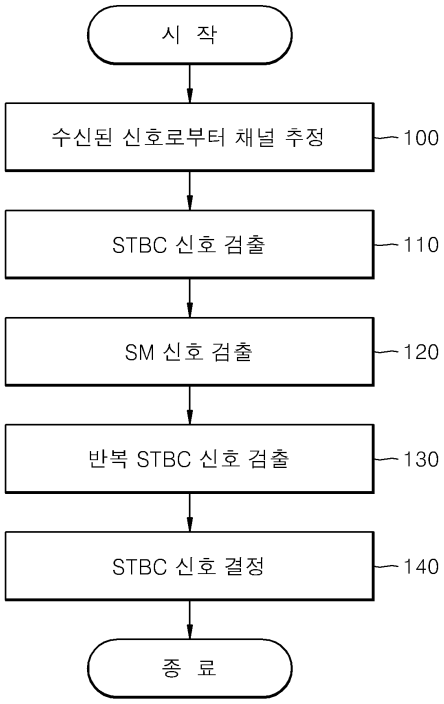
[0107] 6 3 , 3 V-BLAST V V- .

[0108] 7 MIMO OFDM STBC STBC .

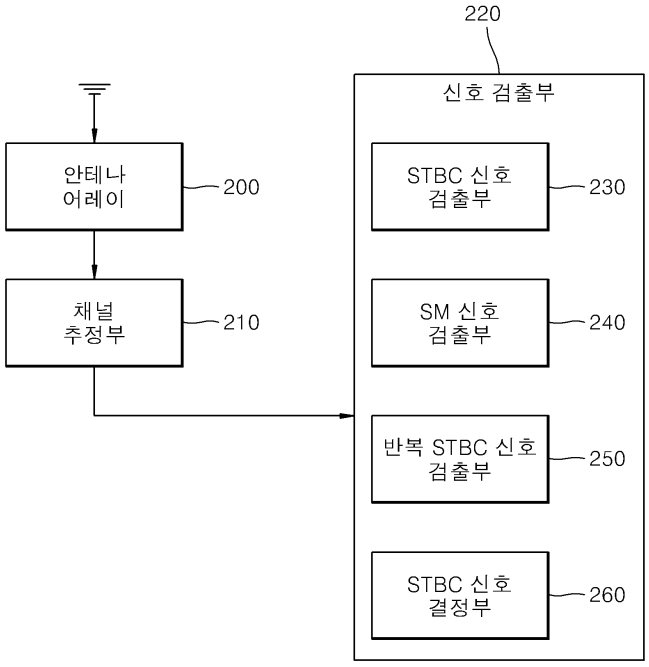
[0109] 8 MIMO OFDM STBC STBC STBC . 9 MIMO OFDM STBC

V .

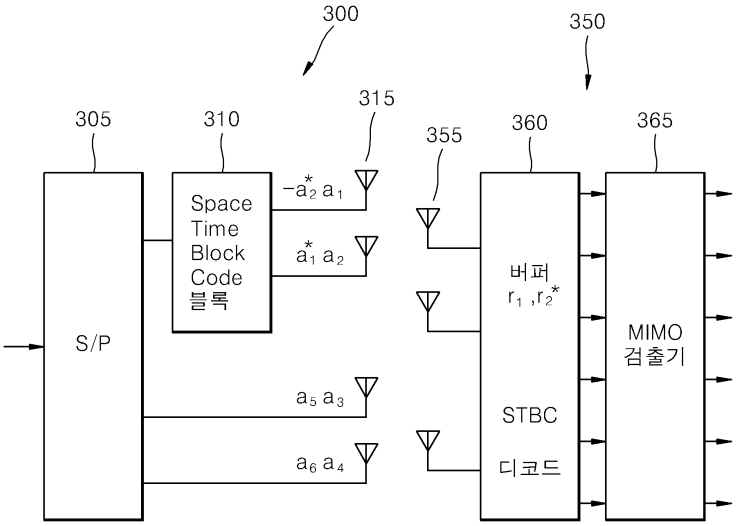
1


시 작
수신된 신호로부터 채널 추정
100
STBC 신호 검출
110
SM 신호 검출
120
반복 STBC 신호 검출
130
STBC 신호 결정
140
종 료

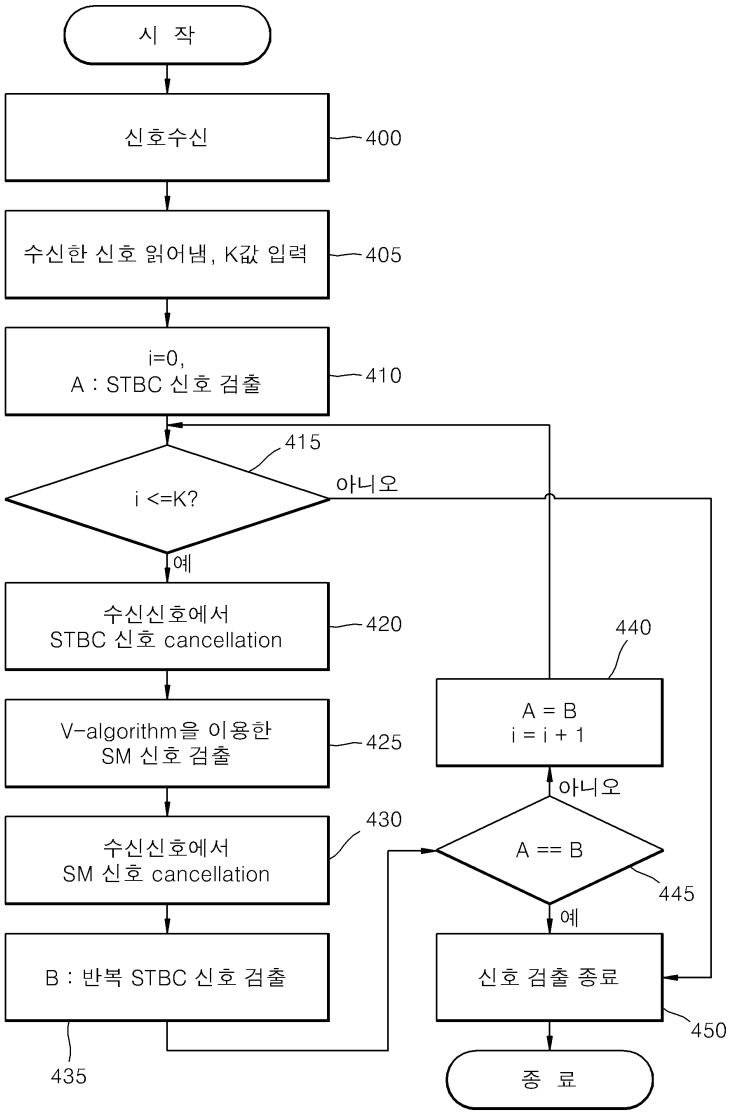
2


220
신호 검출부
안테나 어레이
200
채널 추정부
210
STBC 신호 검출부
230
SM 신호 검출부
240
반복 STBC 신호 검출부
250
STBC 신호 결정부
260

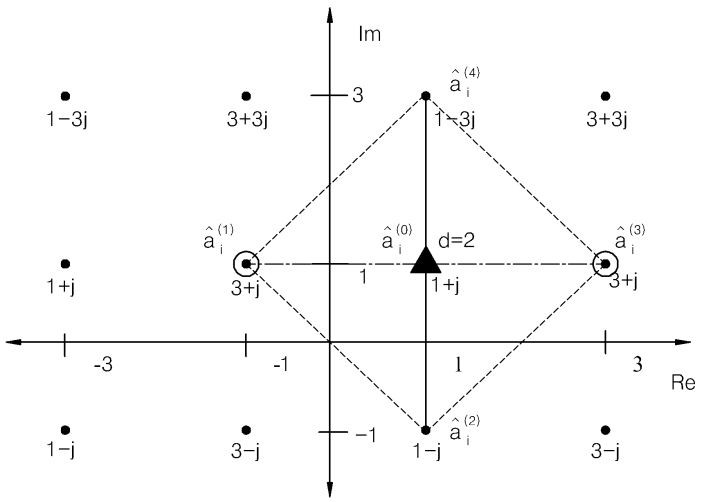
3


300
350
305
310
315
355
360
365
S/P
Space
Time
Block
Code
블록
$-a_2^* a_1$
$a_1^* a_2$
$a_5 a_3$
$a_6 a_4$
버퍼
r_1, r_2^*
STBC
디코드
MIMO
검출기

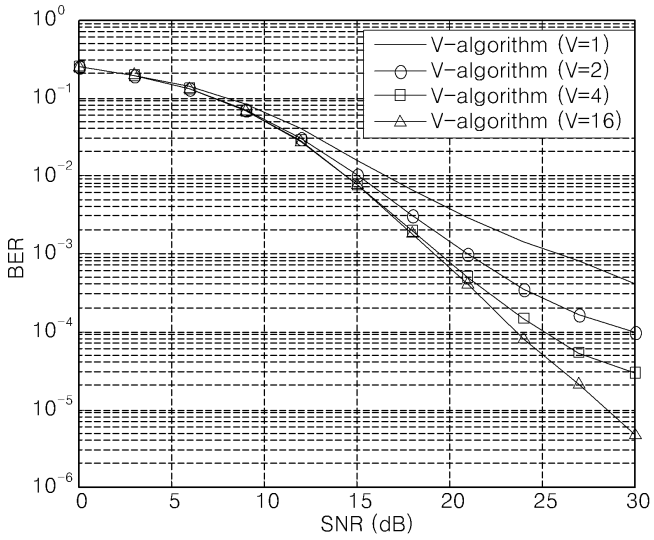
4


시 작
신호수신
400
수신한 신호 읽어냄, K값 입력
405
i=0,
A : STBC 신호 검출
410
415
i <=K?
아니오
예
수신신호에서
STBC 신호 cancellation
420
V-algorithm을 이용한
SM 신호 검출
425
수신신호에서
SM 신호 cancellation
430
B : 반복 STBC 신호 검출
435
440
A = B
i = i + 1
아니오
A == B
445
예
신호 검출 종료
450
종 료

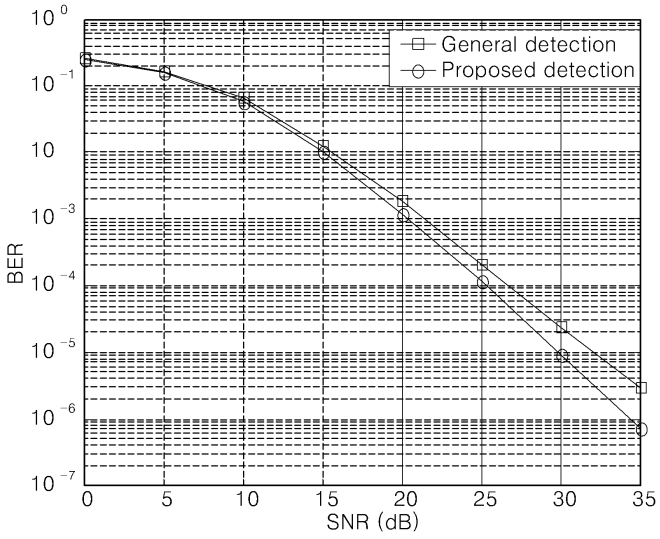
5


Im
Re
3
1
-1
-3
1-3j
3+3j
1+j
3+j
1-j
3-j
d=2

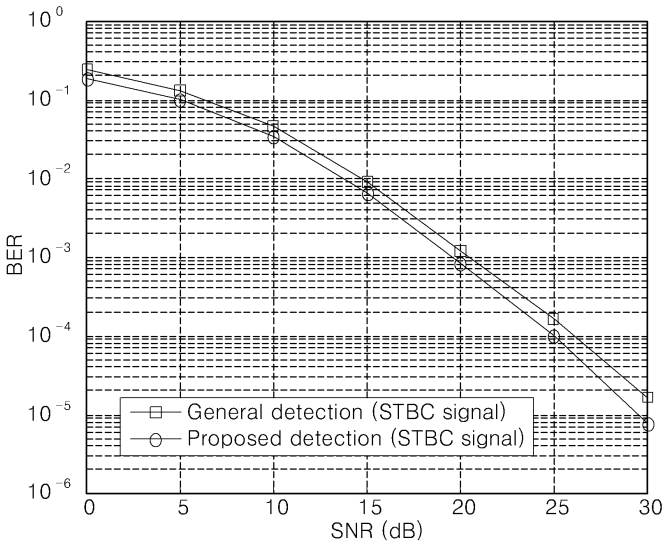
6


V-algorithm (V=1)
V-algorithm (V=2)
V-algorithm (V=4)
V-algorithm (V=16)
BER
SNR (dB)

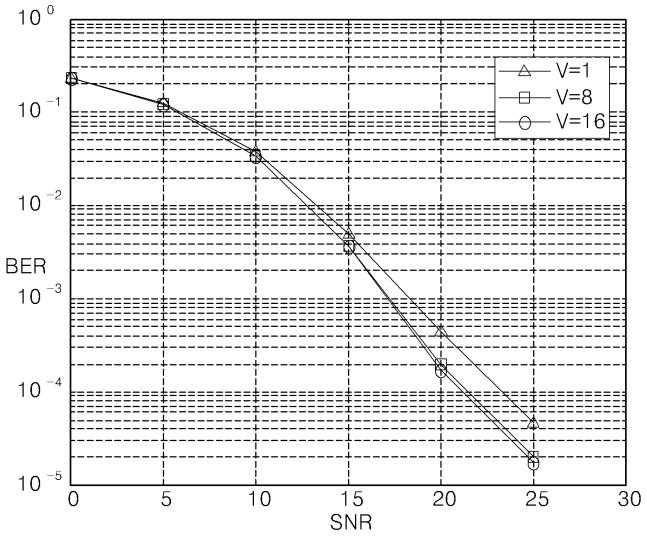
7


General detection
Proposed detection
BER
SNR (dB)

8


BER
SNR (dB)
General detection (STBC signal)
Proposed detection (STBC signal)

9


BER
SNR
V=1
V=8
V=16