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(57)

MIMO-OFDM

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,

,

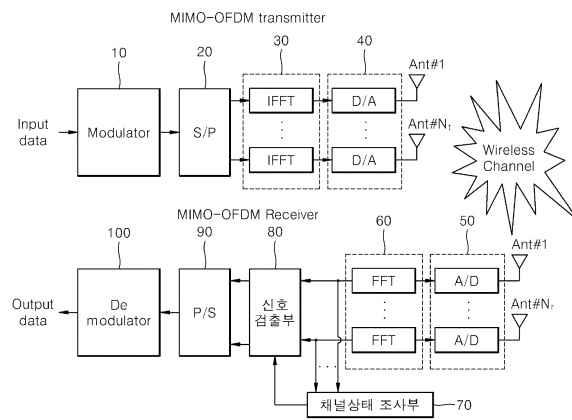
60%

orderde DEF

QRD-M

,

.



1

;

Equalization)

ordered DFE(Decision Feedback

QRD-M

MIMO-OFDM

2

1

(Post SNR)

MIMO-OFDM

3

2

(Post SNR)

MIMO-OFDM

$$\rho_i = \frac{\|X(i)\|^2}{\sigma^2 \|G(i)\|^2}$$

$$\|X(i)\|^2$$

G(i) Moore-Penrose pseudo-inverse

, σ^2

4

1

QRD-M

M

M

MIMO-OFDM

5

;

Equalization)

ordered DFE(Decision Feedback

QRD-M

MIMO-OFDM

6

5

(Post SNR)

MIMO-OFDM

7

6

(Post SNR)

MIMO-OFDM

$$\rho_i = \frac{\|X(i)\|^2}{\sigma^2 \|G(i)\|^2}$$

$\|X(i)\|^2$ i

σ^2

8

G(i) Moore-Penrose pseudo-inverse

5 , QRD-M

M , M

MIMO-OFDM

[0001]

[0002]

OFDM MIMO-OFDM MIMO-

detection (MLD) maximum likelihood

MLD , MLD QRD-M QRD-M

[0003]

Multiple Output Orthogonal Frequency Division Multiplexing : (Multiple Input

' MIMO-OFDM')

[0004]

MIMO-OFDM

;

ordered DFE(Decision Feedback Equalization)

QRD-M

[0005]

MIMO-OFDM

;

ordered DFE(Decision Feedback Equalization)

QRD-M

[0006]

MIMO-OFDM

60%

MIMO-OFDM

[0007] MIMO-OFDM

[0008] 1 MIMO-OFDM

MIMO-OFDM

MIMO-OFDM N_t

MIMO-OFDM MIMO-OFDM

(10), /

(20), IFFT(30) / (40)

FFT(60), / MIMO-OFDM

/ (50),

(90) (100)

MIMO-OFDM

(70)

(80)

[0009] OFDM K X , m

OFDM 1 .

1[0010] $X_m = [X_m^{(0)}, X_m^{(1)}, \dots, X_m^{(K-1)}]$ [0011] OFDM N_t . K

k 2 .

2[0012]
$$Y^k = \sum_{i=1}^{N_r} \sum_{j=1}^{N_t} H_{i,j}^k \cdot X_j^k + N_i^k = H^k \cdot X^k + N^k$$
[0013] j, i , X^k, Y^k, N^k 3 .**3**[0014] $X^k = [X_1, X_2, \dots, X_{N_t}]$ $Y^k = [Y_1, Y_2, \dots, Y_{N_r}]$ $N^k = [N_1, N_2, \dots, N_{N_r}]$ [0015] X^k $N_t \times 1$, Y^k $N_r \times 1$, N^k $N_r \times 1$.[0016] , 2 H^k 4 .

4

$$\begin{pmatrix} H_{1,1} & H_{1,2} & \cdots & H_{1,N_t} \\ H_{2,1} & H_{2,2} & \cdots & H_{2,N_t} \\ \vdots & \vdots & \ddots & \vdots \\ H_{N_r,1} & H_{N_r,2} & \cdots & H_{N_r,N_t} \end{pmatrix}$$

[0017]

$$\mathbf{H}^k \quad N_r \times N_t \quad \cdot \quad H_{i,j} \quad j \quad i$$

$$, \quad H_{i,j} \quad \cdot$$

[0018]

$$, \quad \cdot, \quad \cdot$$

[0019]

$$(70) \quad N_r \quad \cdot$$

$$(80) \quad \cdot, \quad (70) \quad (\text{Post SNR})$$

$$\cdot \text{Post SNR} \quad 5 \quad \cdot$$

5

$$\rho_i = \frac{\|X(i)\|^2}{\sigma^2 \|G(i)\|^2}$$

[0021]

$$, \quad \|X(i)\|^2 \quad i \quad \cdot, \quad G(i) \quad \text{Moore-Penrose pseudo-inverse}$$

$$, \quad \sigma^2 \quad \cdot \text{Moore-Penrose pseudo-inverse} \quad 6$$

$$7 \quad \cdot, \quad 6 \quad \text{zero-forcing} \quad \cdot$$

$$7 \quad \text{minimum mean square error(MMSE)} \quad \cdot$$

[0022]

6

$$\mathbf{G}_{ZF} = (\mathbf{H}^H \mathbf{H})^{-1} \mathbf{H}^H$$

[0023]

7

$$\mathbf{G}_{MMSE} = (\mathbf{H}^H \mathbf{H} + \sigma_n^2 \mathbf{I})^{-1} \mathbf{H}^H$$

[0024]

$$\cdot \text{post SNR} \quad 5 \quad 1 \quad \text{post SNR}$$

$$\cdot \text{post SNR} \quad 6 \quad 7 \quad \text{Moore-Penrose pseudo-inverse}$$

$$\|G\|^2 \quad \cdot \quad \|G\|^2 \quad \cdot, \text{post SNR}$$

$$, \quad \|G\|^2 \quad \text{post SNR} \quad \cdot$$

$$6 \quad 7 \quad \|G\|^2 \quad \cdot \quad \|G\|^2 \quad \cdot$$

$$\cdot \quad 8 \quad \cdot$$

[0025]

8

[0026]

$\boldsymbol{l}=[l_1, l_2, \cdots; l_K]$

[0027]

$l_1 \quad \|\mathbf{G}\|^2 \quad , \quad l_K \quad \|\mathbf{G}\|^2$

[0028]

(80) (70) ,
ordered DEF(ordered Decision Feedback equalization)
QRD-M / (90)
S S
OFDM
64 S 32 8 $l_1 \quad l_{32}$
 $l_{33} \quad l_{64}$

[0029]

ordered DFE 6 7 Moore-Penrose pseudo-inverse

9

[0030]

$P=[P_1, P_2, \ldots, P_{N_t}]$

[0031]

$P_1 \quad P_{N_t}$

[0032]

4 10 , $\overline{\mathbf{H}}$

10

[0033]

$$\begin{pmatrix} H_{1,P_{N_t}} & H_{1,P_{N_t-1}} & \cdots & H_{1,P_1} \\ H_{2,P_{N_t}} & H_{2,P_{N_t-1}} & \cdots & H_{2,P_1} \\ & \vdots & \ddots & \vdots \\ H_{N_r,P_{N_t}} & H_{N_r,P_{N_t-1}} & \cdots & H_{N_r,P_1} \end{pmatrix}$$

[0034]

10 QR

11

[0035]

$\overline{\mathbf{H}} = \mathbf{Q}\mathbf{R}$

[0036]

$\mathbf{Q} \quad \mathbf{Q}^H \mathbf{Q} = \mathbf{I} \quad \mathbf{R}$
11 $\mathbf{Q}^H$ 2

$\mathbf{Q}^H$ $\mathbf{Q}$ conjugate transpose .

12

$$\mathbf{W} = \mathbf{Q}^H \mathbf{Y} = \mathbf{Q}^H \overline{\mathbf{H}} \mathbf{X} + \mathbf{Q}^H \mathbf{N} = \mathbf{R} \mathbf{X} + \overline{\mathbf{N}}$$

$$\begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_{N_t} \end{bmatrix} = \begin{bmatrix} r_{1,1} & r_{1,2} & \cdots & r_{1,N_t} \\ 0 & r_{2,2} & \cdots & r_{2,N_t} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & r_{N_t,N_t} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{N_t} \end{bmatrix} + \begin{bmatrix} \overline{N}_1 \\ \overline{N}_2 \\ \vdots \\ \overline{N}_{N_t} \end{bmatrix}$$

$\overline{\mathbf{N}}$

13

13

$$\begin{aligned} \widehat{x}_{N_t} &= Q(w_{N_t} / r_{N_t,N_t}), \\ \widehat{x}_{N_t-1} &= Q((w_{N_t-1} - r_{N_t-1,N_t} \cdot \widehat{x}_{N_t}) / r_{N_t-1,N_t-1}), \\ &\vdots \\ \widehat{x}_1 &= Q((w_1 - \sum_{k=2}^{N_t} r_{1,k} \cdot \widehat{x}_k) / r_{1,1}), \end{aligned}$$

$\mathbf{F}$

14

14

$$\widehat{\mathbf{X}} = [\widehat{x}_{p_1}, \widehat{x}_{p_2}, \cdots, \widehat{x}_{p_{N_t}}]$$

QRD-M

12

path metric

. QRD-M

M

, Euclidean distance

path

path metric

path

. QRD-M

15

15

$$\left\| \mathbf{w}_{N_t} - \mathbf{r}_{N_t, N_t} \cdot \hat{\mathbf{x}}_{N_t, candidate} \right\|^2$$

 $\hat{\mathbf{x}}_{N_t, candidate}$

QPSK

4

15
path metric

16

16

$$\left\| \mathbf{w}_{N_t-1} - \left(\mathbf{r}_{N_t-1, N_t-1} \times \hat{\mathbf{x}}_{N_t-1, candidate} + \mathbf{r}_{N_t-1, N_t} \times \hat{\mathbf{x}}_{N_t, retained} \right) \right\|^2$$

 $\hat{\mathbf{x}}_{N_t, retained}$

16

path metric

M*() metric

metric M

17 path metric

17

$$\left\| \mathbf{w}_i - \left(\mathbf{r}_{i,i} \cdot \hat{\mathbf{x}}_{i, candidate} + \sum_{v=i-1}^{N_t} \mathbf{r}_{i,v} \cdot \hat{\mathbf{x}}_{v, retained} \right) \right\|^2$$

metric

2 QRD-M

, 2 QPSK ,

4 , M=2

, MIMO(Multiple-input Multiple-output)

layer survivor path , M

Adaptive QR decomposition

and M-algorithm (: 'Adaptive QRD-M')

M

QRD-M MLD(maximum-likelihood detection)

correct path

M

, M

QRD-M

path metric path metric

path metric (ratio)

M

MLD

, QRD-M

Adaptive QRD-M

QRD-M

8

M

M

8

ordered DFE

9

Adaptive QRD-M

18

18

$$\begin{pmatrix} H_{1,P_1} & H_{1,P_2} & \cdots & H_{1,P_{N_t}} \\ H_{2,P_1} & H_{2,P_2} & \cdots & H_{2,P_{N_t}} \\ \vdots & \vdots & \ddots & \vdots \\ H_{N_r,P_1} & H_{N_r,P_2} & \cdots & H_{N_r,P_{N_t}} \end{pmatrix}$$

[0053]

[0054]

[0055]

3

4

16 QAM

QRD-M

M

16

Adaptive QRD-M

64

S

32

64

32

16,8,4

ordered DFE

adaptive QRD-M

ordered DFE

Adaptive QRD-M

7360+872=8232

2

QRD-M

24832

67%

64

83%

[0056]

[0057]

[0058]

[0059]

4

QRD-M

adaptive QRD-M

10⁻⁵

1 [dB]

5

S

/2

adaptive QRD-M

M

16,8,4

83%

10⁻⁵

0.5 [dB]

6

S

/2

adaptive QRD-M

M

16,8,4

83%

10⁻⁵

0.5 [dB]

[0060]

[0061]

[0062]

[0063]

MIMO-OFDM

MIMO-OFDM

(200).

(Post SNR)

(Post SNR)

5

Post SNR

6

7

Moore-Penrose pseudo-inverse

||G||²

6

7

||G||²

||G||²

[0064]

200

Feedback Equalization)

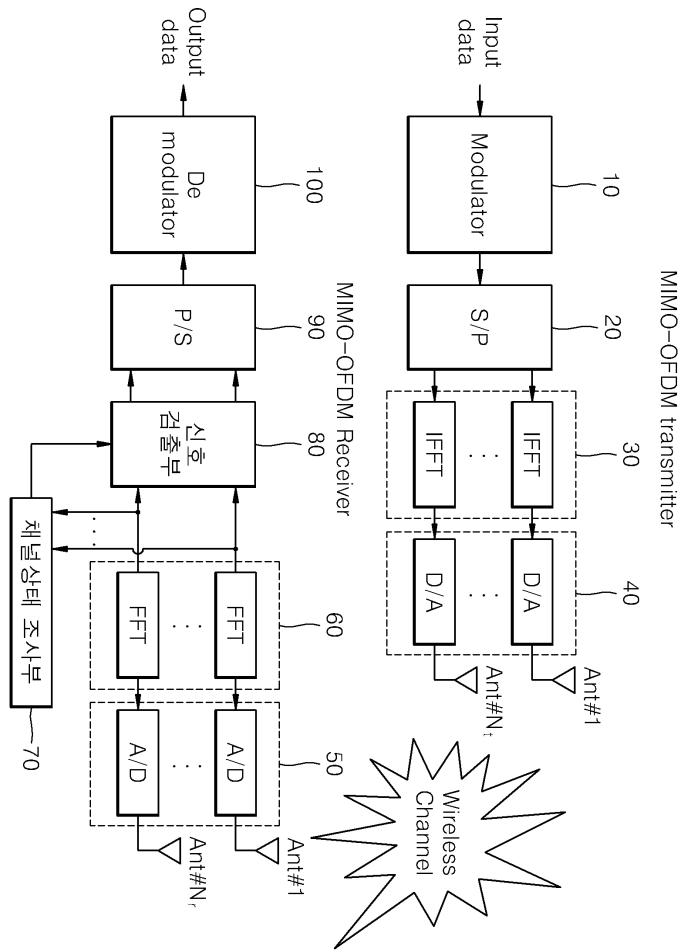
ordered DFE(Decision

QRD-M

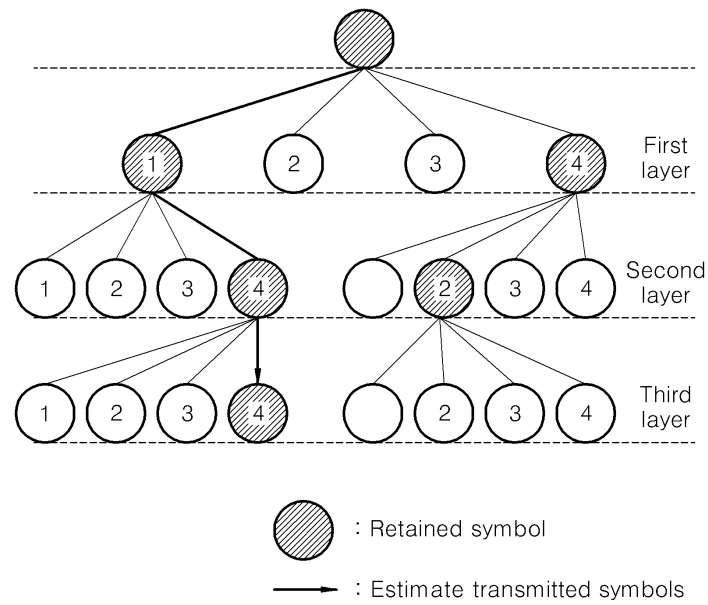
(202). , M , , S , S
M .
, OFDM 64 S 32 8
l₁ l₃₂ ,
l₃₃ l₆₄ ,
ordered DFE(Decision Feedback Equalization) , QRD-M Adaptive QRD-M
,
[0065] , MIMO-OFDM /
(instructions)/
/ /
(, , (, , ,) ,
(, ,) (, ,)
, () ,
, (segment)
,

- [0066] MIMO-OFDM
, , ,
[0067] 1 MIMO-OFDM MIMO-OFDM .
[0068] 2 QRD-M .
[0069] 3 .
[0070] 4 QRD-M Adaptive QRD-M .
[0071] 5 S QRD-M .
[0072] 6 S /2 Adaptive QRD-M M .
[0073] 7 MIMO-OFDM .

1



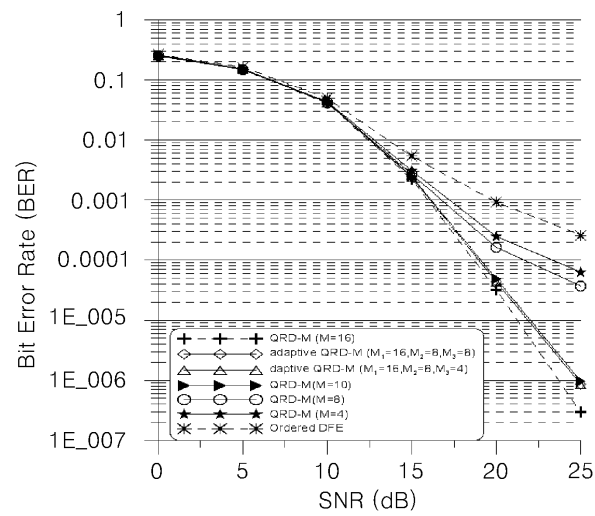
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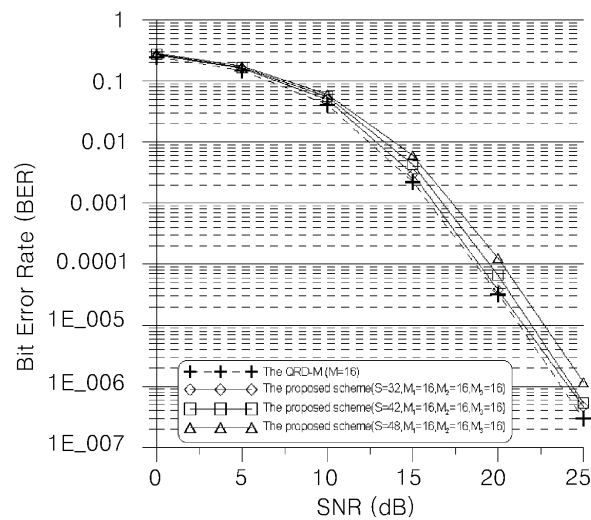
3

Detection scheme	Operation	Required of multiplication per subcarrier	$S = \frac{\text{all subcarriers}}{2}$ $M=16, M_1=16$ $M_2=8, M_3=4$	Sum of computational complexity per subcarrier
QRD-M	Generation of symbol replica	$4 \cdot C + \sum_{i=2}^T 4 \cdot C \cdot M$	9280	12416
	Calculation of Euclidian distance	$4 \cdot C + (T-1)(4 \cdot M \cdot C)$	3136	
Ordered DFE	Generation of symbol replica	$\sum_{i=1}^T 4 \cdot i$	40	872
	Calculation of Moore-Penrose pseudo inverse matrix(G)	$\begin{cases} HH^H : 4 \cdot R \cdot T \cdot T \\ \text{inverse} : 4 \cdot T^3 \end{cases}$	$512+256=768$	
	Calculation of G matrix power	$4 \cdot T \cdot R$	64	
Adaptive QRD-M	generation of symbol replica	$4 \cdot C + \sum_{i=2}^T 4 \cdot M_{i-1} \cdot C$	4672	7360
	Calculation of Euclidian distance	$4 \cdot C + \sum_{i=2}^T 4 \cdot M_{i-1} \cdot C$	1856	
	Calculation of Moore-Penrose pseudo inverse matrix(G)	$\begin{cases} HH^H : 4 \cdot R \cdot T \cdot T \\ \text{inverse} : 4 \cdot T^3 \end{cases}$	$512+256=768$	
	Calculation of G matrix power	$4 \cdot T \cdot R$	64	

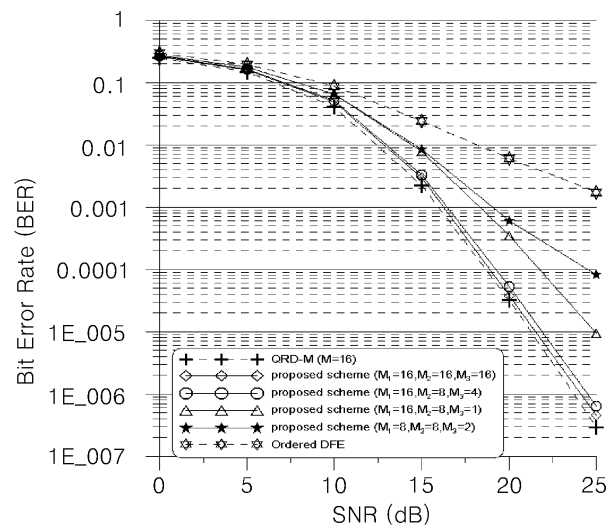
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5



6



7

