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An Iterative Channel Estimation and Decoding Algorithm
for CDMA Systems in Uplink Environments

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LDPC   CDMA

.

.   LDPC

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I.   .

Liu

.   ,   .

. Wideband CDMA   .

(W-CDMA) [1], cdma2000 [2]
(CDMA)

.   .

.

Data-aided
[3]-[5].   [3]

,   II   .
.   III

Data-aided   . IV
(LDPC)   V   .

[6]-[9].   II.

[6]   [8][9]
(Factor graph)   . [9]
(Wiener)

(Kalman) SF_P SF_D l

. m k

$r(l,m,k)$.   1-Tap

.   (1)

.

. Liu   [9] $r(l,m,k) = \sqrt{P}\left\{ X(l,m)C_D(k) + \lambda C_P(m,k) \right\} h(l)$

1   AR $+ n(l,m,k),$ (1)

$X(l,m)$ l m
$C_P(m,k)$ $C_D(k)$
.

. P $h(l)$
l
. $r(l,m,k)$ $n(l,m,k)$
0 σ_n^2 .
(1) l
m , $y_D(l,m)$ (2)
.

$$y_D(l,m) = \frac{1}{SF_D}\sum_{k=0}^{SF_D-1} r(l,m,k)C_D(k)$$

$$= \sqrt{P}X(l,m)h(l) + \frac{1}{SF_D}\sum_{k=0}^{SF_D-1} n(l,m,k)C_D(k).$$
(2)

l
.

$$y_P(l,m) = \frac{1}{SF_D}\sum_{k=0}^{SF_D-1} r(l,m,k)C_P(k)$$

$$= h(l) + \frac{1}{SF_D}\sum_{k=0}^{SF_D-1} n(l,m,k)C_P(k)$$

$$= \sqrt{P}\lambda h(l) + n_P(l,m),$$
(3)

$$y_P(l) = \frac{1}{\gamma}\sum_{m=0}^{\gamma-1} y_P(l,m)$$

$$= \sqrt{P}\lambda h(l) + \frac{1}{SF_P}\sum_{m=0}^{\gamma-1}\sum_{k=0}^{SF_D-1} n(l,m,k)C_P(k)$$

$$= \tilde{h}(l) + \tilde{n}(l),$$
(4)

γ

$\tilde{h}(l) = \alpha\lambda h(l)$ $\tilde{n}(l)$
0 $2\sigma_n^2\big/SF_P$.

III. LLR

[8]
.

1
AR

(State-space)

.

.

RAUCH-TUNG-STRIEBEL (Smoother)

1

[10].
1 AR
(5)
'1'
(6) .

$$\tilde{h}(l+1) = \alpha\tilde{h}(l) + w(l),$$
(5)

$$y_P(l) = \tilde{h}(l) + \tilde{n}(l),$$
(6)

α l $l+1$
$J_0(2\pi f_d T_s)$ f_d T_s
.

1 .

Initial Phase : $y_P(l)$
$K(l)$ $\Pi(l)$
. $W(l)$
.

Compensation Phase : $T(l,m)$
$y_D(l,m)$
.

LLR Phase :
$U(l,m)$ (LLR) .

Estimation Phase : C
$U(l,m)$
$T(l,m)$
.

Combining Phase :
$W(l)$
$\Pi(l)$
. Compensation Phase

.

.

.

. q
, $Z^{(q)}(l,m)$.

$$Z_r^{(q)} = y_D(l,m)h_K^*(l)$$
$$= \sqrt{P} X(l,m)h(l)h_K^*(l)$$
$$+ \frac{1}{SF_D}\sum_{k=0}^{SF_D-1} n(l,m,k)C_D(k)h_K^*(l)$$
$$= \frac{X(l,m)}{\lambda}\tilde{h}(l)h_K^*(l)$$
$$+ \frac{1}{SF_D}\sum_{k=0}^{SF_D-1} n(l,m,k)C_D(k)h_K^*(l)$$
$$\approx \frac{X(l,m)}{\lambda}\left|\tilde{h}(l)\right|^2 + h_K^*(l)n_D(l,m)$$
$$+ \frac{1}{\lambda}X(l,m)\tilde{h}(l)e_h^*(l). \tag{7}$$

$e_h(l) = \tilde{h}(l) - h_k(l)$ $\quad h_k(l)$ $\quad l$

$\quad n_D(l,m)$

m

.

(8)

.

$$LLR(l,m) = -\frac{\left(Z_r^{(q)}(l,m) - \left|h_K(l)\right|^2 / 2\lambda\right)^2}{2\sigma^2}$$
$$+ \frac{\left(Z_r^{(q)}(l,m) + \left|h_K(l)\right|^2 / 2\lambda\right)^2}{2\sigma^2}$$
$$= \frac{2Z_r^{(q)}(l,m)\left|h_K(l)\right|^2 / 2\lambda}{\sigma^2}$$
$$= \frac{\sqrt{2}\left|h_K(l)\right|^2 Z_r^{(q)}(l,m)/\lambda}{\left|h_K(l)\right|^2 \sigma_n^2/SF_D + \left|h_K(l)\right|^2 \sigma_e^2/2\lambda^2}$$
$$= \frac{\sqrt{2}Z_r^{(q)}(l,m)}{\lambda\left(\sigma_n^2/SF_D + \sigma_e^2/2\lambda^2\right)}, \tag{8}$$

(8)

.

(9)

$$y_D(l,m) = \frac{1}{\lambda}X(l,m)\tilde{h}(l) + n_D(l,m). \tag{9}$$

$2\sigma_n^2/SF_D$

. (9)

QPSK 1

$$y_{D,v}(l,m)$$

$y_{D,v}(l,m)$

$h_{D,v}(l,m)$.

$$h_{D,v}(l,m) = y_{D,v}(l,m)\lambda$$
$$= \frac{X(l,m)}{S_v}\tilde{h}(l) + \frac{\lambda}{S_v}n_D(l,m), \tag{10}$$

S_v $\qquad\qquad v$

.

.

.

$h_{D,v}(l,m)$ $\qquad\qquad \overline{h}_D(l,m)$

.

$$\overline{h}_D(l,m) = \sum_{v=0}^3 P_v(l,m)h_{D,v}(l,m). \tag{11}$$

v $\qquad\qquad P_v(l,m)$

LDPC QPSK

(11) .

QPSK $\qquad\qquad , S_v$

$, S_{(v+2)\bmod 4}$

180°

$\pm 90^o$.

180° $\qquad\qquad \pm 90^o$

(12), (13)

$v^+(l,m)$ $\quad v^-(l,m)$

(11)

(15)

.

$$v^+(l,m) = \arg\max_v p_v(l,m), \tag{12}$$
$$v^-(l,m) = \left(v^+(l,m)+1\right)\bmod 4, \tag{13}$$
$$X(l,m) = S_{v^+(l,m)}, \tag{14}$$
$$\overline{h}_D(l,m) = \left(P_{v^+(l,m)} - \overline{P}_{v^+(l,m)}\right)\tilde{h}(l) + \left(P_{v^-(l,m)} - \overline{P}_{v^-(l,m)}\right)j\tilde{h}(l)$$
$$+ n_D(l,m)\lambda\overline{S}^*(l,m), \tag{15}$$

$\overline{S}(l,m)$

$\overline{P}_{v(l,m)}$ $\quad v(l,m)$ $\qquad\qquad 180^o$

.

$\tilde{h}(l)$.

$$\tilde{h}_D(l,m) = \frac{1}{P(l,m)}\overline{h}_D(l,m)$$
$$= \tilde{h}(l) + \frac{P^\perp(l,m)}{P(l,m)}j\tilde{h}(l) + \frac{\lambda_{D,P}}{P(l,m)}\overline{S}^*(l,m)n_D(l,m), \tag{16}$$
$$P(l,m) = P_{v^*(l,m)} - \overline{P}_{v^*(l,m)}, \quad P^\perp(l,m) = P_{v^-(l,m)} - \overline{P}_{v^-(l,m)}$$

$\tilde{h}_D(l,m)$

$\tilde{h}(l)$ $\qquad\qquad q_D(l,m)$

.

$$q_D(l,m) \triangleq E\left\{\left|\tilde{h}_D(l,m) - \tilde{h}(l)\right|^2\right\}$$
$$= \left[\frac{P^\perp(l,m)}{P(l,m)}\right]^2\left|\tilde{h}(l)\right|^2 + \frac{\lambda^2\left|\overline{S}(l,m)\right|^2}{P^2(l,m)}\frac{\sigma_n^2}{SF_D}$$
$$\approx \left[\frac{P^\perp(l,m)}{P(l,m)}\right]^2\left|h_K(l)\right|^2 + \frac{\lambda^2\left|\overline{S}(l,m)\right|^2}{P^2(l,m)}\frac{\sigma_n^2}{SF_D} \tag{17}$$

(4)

$q_P(l)$ $\qquad\qquad$ (4) $\qquad$ (16)

(18)

.

$$\overline{y}_c(l) = \left(\frac{y_P(l)}{q_P(l)} + \sum_{m=0}^{\gamma-1} \frac{\tilde{h}_D(l,m)}{q_D(l,m)} \right) \Bigg/ \left(\frac{1}{q_P(l)} + \sum_{m=0}^{\gamma-1} \frac{1}{q_D(l,m)} \right) \quad (18)$$

$$= \tilde{h}(l) + \overline{n}_c(l)$$

$$Var\{\overline{y}_c(l)\} = \left(\frac{1}{q_P(l)} + \sum_{m=0}^{\gamma-1} \frac{1}{q_D(l,m)} \right)^{-1} \quad (19)$$

$$\overline{y}_c(l) \quad (19)$$

$$\overline{y}_c(l)$$

.

(7) $\qquad h_K(l)$ $\overline{y}_c(l)$

.

IV.

.

762   0.5 .

4 .

.

2 60km/h

3 200km/h
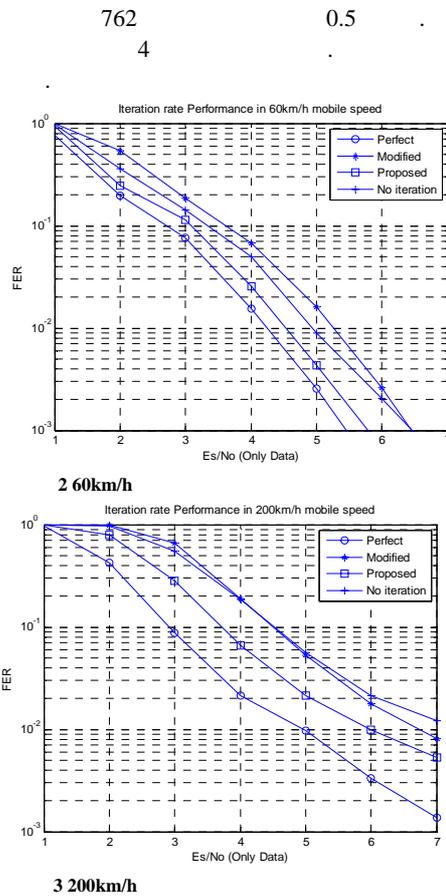
'Perfec'

'Modified reference' Liu [9]

'Proposed'

'No Iteration'

LDPC

. 2, 3

[9]

[9]

SNR

4 .

SNR

(200km/h)   SNR

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V.

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QPSK

QPSK

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QUALCOMM YONSEI CDMA Research Lab.

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VI.

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