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(12) (A)

(51) 。 Int. Cl.⁷ (11) 10-2004-0101743
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(21) 10-2003-0033456
(22) 2003 05 26

(71) 416

134

(72) 80 701

1 306

134

134

(74) :

(54)

가.

(Forward Error Correction : FEC)

，
.
.

LDPC Normalized-BP , LLR-BP

.

，
，
，
가 가 ，
3 1 2 3
，
，

, (Turbo code) (minimum distance)가 .
 (bit error rate) (error floor)가 .
 가 (codeword) 가 (undetected error probability)
 가 .
 , .
 , 가 가 .
 , (parallel architecture) 가
 가 가 .
 , 가
 (low density parity check code : 'LDPC')가
 (parity check matrix) '1' 가
 LDPC (check node) (variable node), 가 (edge)
 (factor graph) 가 LDPC code
 가 , 가
 '0' 가 , 가
 CRC (overhead) 가 가 .
 LDPC LDPC H
 '0' (linear block code) ,
 0 가 LDPC
 LDPC (Sum-Product algorithm)
 , (soft-decision) . , 0
 .
 LDPC (Log-likelihood ratio: 'LLR')
 LLR-Belief Propagation('LLR-BP') LLR-
 BP LLR
 . LLR-BP 가 (lo
 (Shannon) (tanh) 가 가
 g) .
 Chen Fosser IEEE Trans. Commun., vol. 47, pp. 673-680, May 1999 "Reduced complexity it
 erative decoding of low density parity check codes based on belief propagation,"
 LLR-BP
 Uniformly Most Powerful-Belief Propagation('UMP-BP') Normalized-B
 elief Propagation('Normalized-BP') . UMP-BP LLR-BP
 (log) (tanh)
 가 가
 Normalized-BP UMP-BP 가
 LLR UMP-BP UMP-BP
 LLR-BP LLR-BP
 LDPC 가 1 . 1 LDPC
 가
 LDPC
 (Bit Nodes)(..., 111, 112, 113, 114, ...) . (... , 111, 112, 113, 114, ...)

LLR, (..., 121, 122, 123, 124, 125, ...)
 (..., 121, 122, 123, 124, 125, ...)
 (..., 111, 112, 113, 114, ...) (... , 111, 112, 113, 114, ...)
 (..., 111, 112, 113, 114, ...) (..., 121, 122, 123, 124, 125, ...)

LDPC Normalized-BP 2
 LDPC 200 Normalized-BP
 (z_{mn}) (y_n)
 LDPC (..., 111, 112, 113, 115, ...) 202
 < 1>
 2 (modulo 2 sum)

$$\sigma_{mn} = \begin{cases} 1, & \text{if } z_{mn} > 0 \\ 0, & \text{if } z_{mn} \leq 0 \end{cases}, \quad \sigma_m = \sum_{n \in N(m)} \sigma_{mn} \bmod 2$$

< 1> mn m n, m m
 (..., 111, 112, 113, 115, ...)
 0 LDPC 204
 (..., 111, 112, 113, 115, ...) LLR < 2> <
 2>

$$L_{mn} = (-1)^{\overline{\sigma_m \oplus \sigma_{mn}}} \min_{n' \in N(m) \setminus n} |z_{mn'}| / \alpha$$

< 2>
 Normalized-BP Z_{mn} n < 2> Normalized-BP m 가 n LLR
 Normalized-BP
 LDPC 206
 Z_{mn} < 3>

$$Z_{mn} = y_n + \sum_{m' \in M(n) \setminus m} L_{m'n}$$

< 3> LDPC 208
가 가 . LDPC
208 LDPC 212
, LDPC 210
< 4>

$$Z_n = y_n + \sum_{m \in M(n)} L_{mn} , \quad \begin{cases} \hat{c} = 1 & \text{if } Z_n > 0 \\ \hat{c} = 0 & \text{if } Z_n < 0 \end{cases}$$

< 4> Z_n 가 , 가 214
5> , 가 <

$$H\hat{c} = 0$$

< 5> 가 good , 216
202

Normalized-BP LLR-BP Normaliz
ed-BP 2000 LDPC 3
, LLR-BP Normalized-BP 0.07dB 가 3
Normalized-BP 가 ,

LDPC Normalized-BP
LDPC LLR-BP
LDPC Normalized-BP , LLR-
BP

가 가 3
, 1 , 2 3
3
2 가 1

가 1 , 가 1 가 2 ,
가 1 가 3
.
,
,
,
2 1 가 가
1 , 1 1 가 1
가 가 1 2 , 1 2 가 가 2 3
2 2 , 2 1 2 가 3
3 , 1 2 3
.
.
가 가 , 가
가 .
(特定)
가 .
.
4 LDPC LDPC 4
LDPC 400 . 2
2 mn n < 1>
mod 2 LDPC 404 m 1 가 가
LDPC m 가
1 가 m 1 가 m 2가 가
m 1 가 가 (2n, n=)
LDPC 404 2가 , m 1 가
408 가 , 406 , 406
(2n+1, n=0, 1, 2, 3, ...)
1 1 406
< 6> .

6

$$(-1)^{\overline{\sigma_m \oplus \sigma_{mn}}} \min_{n' \in N(m) \setminus n} |z_{mn'}| / \alpha_2$$

< 6> LLR (tanh) ,
가
가
LDPC 406 < 6> 2 (2)
10 Z_{mn}^m 1 408 Z_{mn} 가 408
412 , Z_{mn} 4
(LLR) 412 3 가
< 7> 3

7

$$(-1)^{\overline{\sigma_m \oplus \sigma_{mn}}} \min_{n' \in N(m) \setminus n} |z_{mn'}| / \alpha_3$$

< 7> Z_{mn} 1 < 2> 가 410
< 8> (1)

8

$$(-1)^{\overline{\sigma_m \oplus \sigma_{mn}}} \min_{n' \in N(m) \setminus n} |z_{mn'}| / \alpha_1$$

< 9> 가

9

$$\alpha_1 < \alpha_2 < \alpha_3$$

가 , < 9> 2 (2) 2 () (2)
)
414 406 410 412 가 LDPC
414 , LLR Z_{mn} < 3>
가 , LDPC 416 가
가 416
418 가 ,

416 LDPC 420 가 , < 4> 420
LDPC 422 424 402 402 422
5 LDPC 5
Normalized-BP (Syndrome) 2 (501, 502)
Normalized-BP (503) (503)
(503) (503)
가 가
(510) (504) (510)
(503) (503)
2 (506) (510) 4 m 1 가 m 1 Z_m
n 1 (505) 3 (507) , Z_{mn}
(504) 3 (505, 506, 507)
06) 2 1 (505) 1 (1) , 3 (507) 3 (5
3) (2) (503) (50
4)
6 20000 LDPC LDPC 6 LLR-BP Normalized-BP
-BP 6 Normalized-BP Modified Normalized
lized-BP 가 Normalized-BP Norma
LLR-BP 0.02dB

(57)

1.

가 가 ,

3

3 1 , 2 3

가 1 1 2 가 1 가

2 , 가 1 3

2.

1 ,

가 1 (1) 2 (2) 3 (3) < 10>

$\alpha_1 < \alpha_2 < \alpha_3$

3.

1 ,

4.

3 , ,

가 , 가 , 1 가

5.

2

1 가 가 1 ,

1 1 가 1 1

1 1 가 가 가 2
,
2 가 2 2
,
2 가 3 3
,
1 2 3
,
.

6.
5 ,
1 (1) 2 (2) 3 (3) < 11>
가 .

11
$$\alpha_1 < \alpha_2 < \alpha_3$$

7.
5 , 1 ,
< 12> .

12
$$(-1)^{\overline{\sigma_m \oplus \sigma_{mn}}} \min_{n' \in N(m) \setminus n} |z_{mn'}| / \alpha_2$$

8.
5 , 2 ,
< 13> .

13
$$(-1)^{\overline{\sigma_m \oplus \sigma_{mn}}} \min_{n' \in N(m) \setminus n} |z_{mn'}| / \alpha_3$$

9.
5 , 3 ,
< 14> .

14

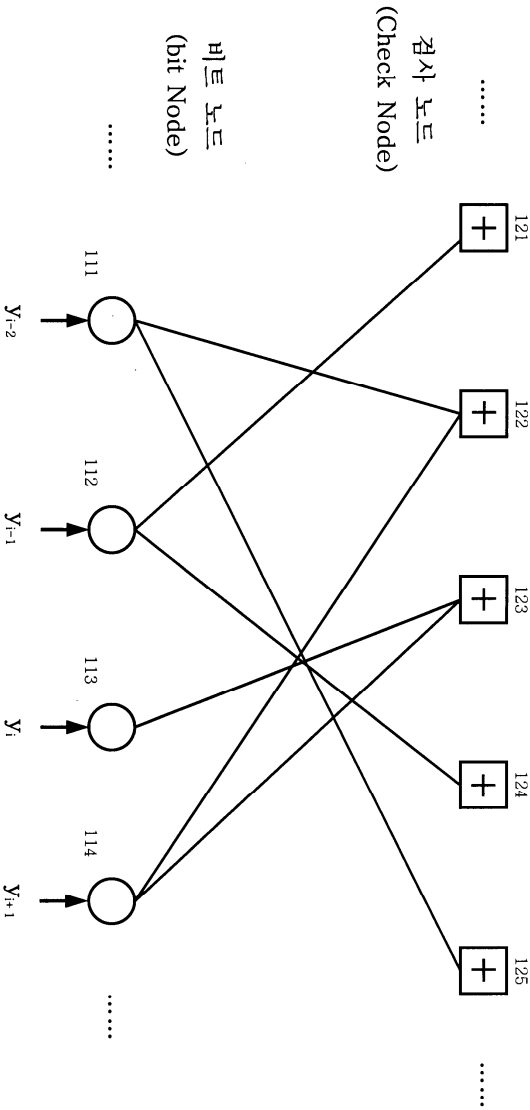
$$(-1)^{\overline{\sigma_m \oplus \sigma_{mn}}} \min_{n' \in N(m) \setminus n} |z_{mn'}| / \alpha_1$$

10.

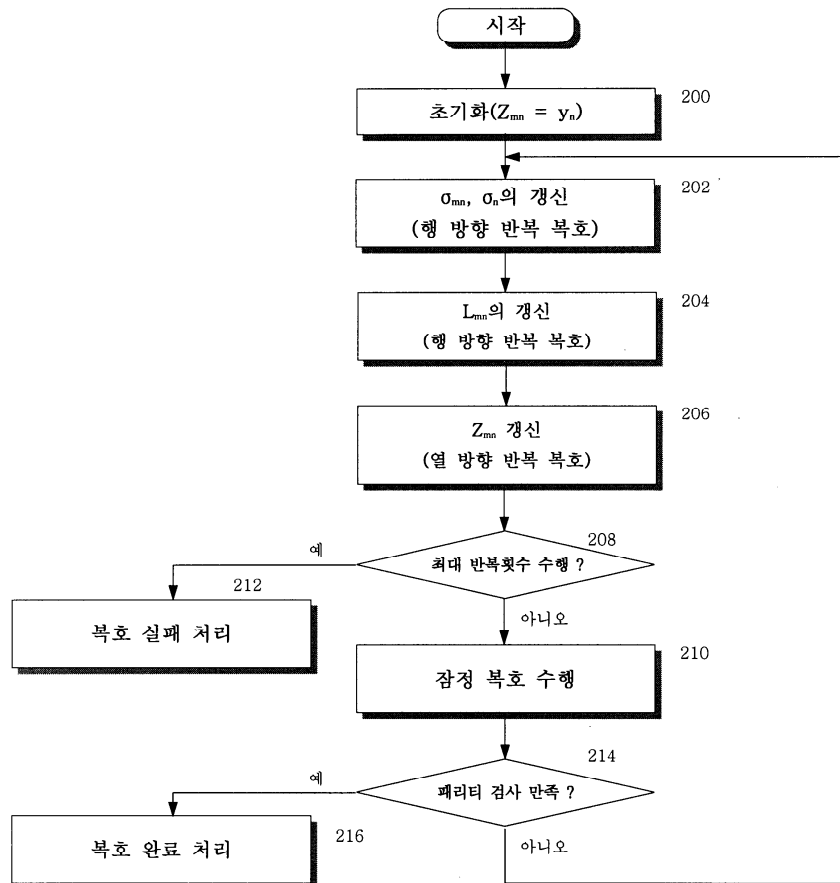
5 ,

가

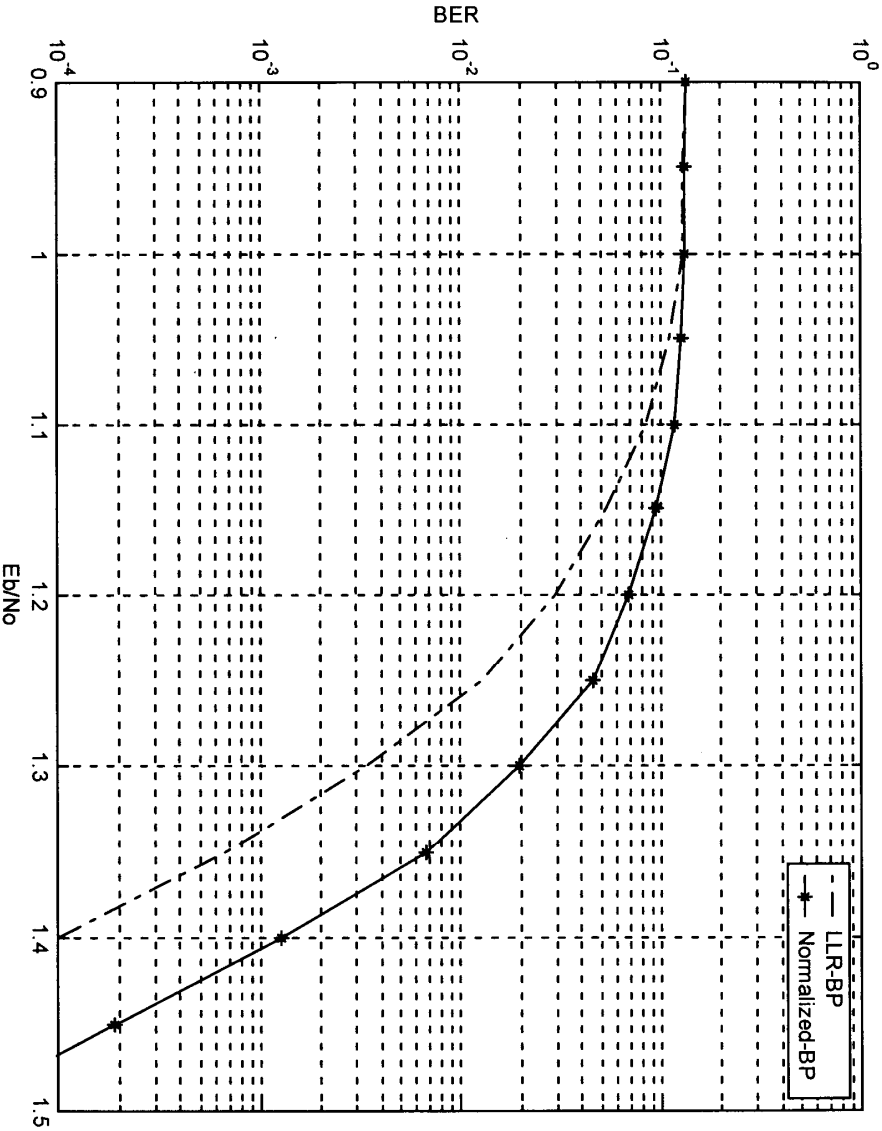
1



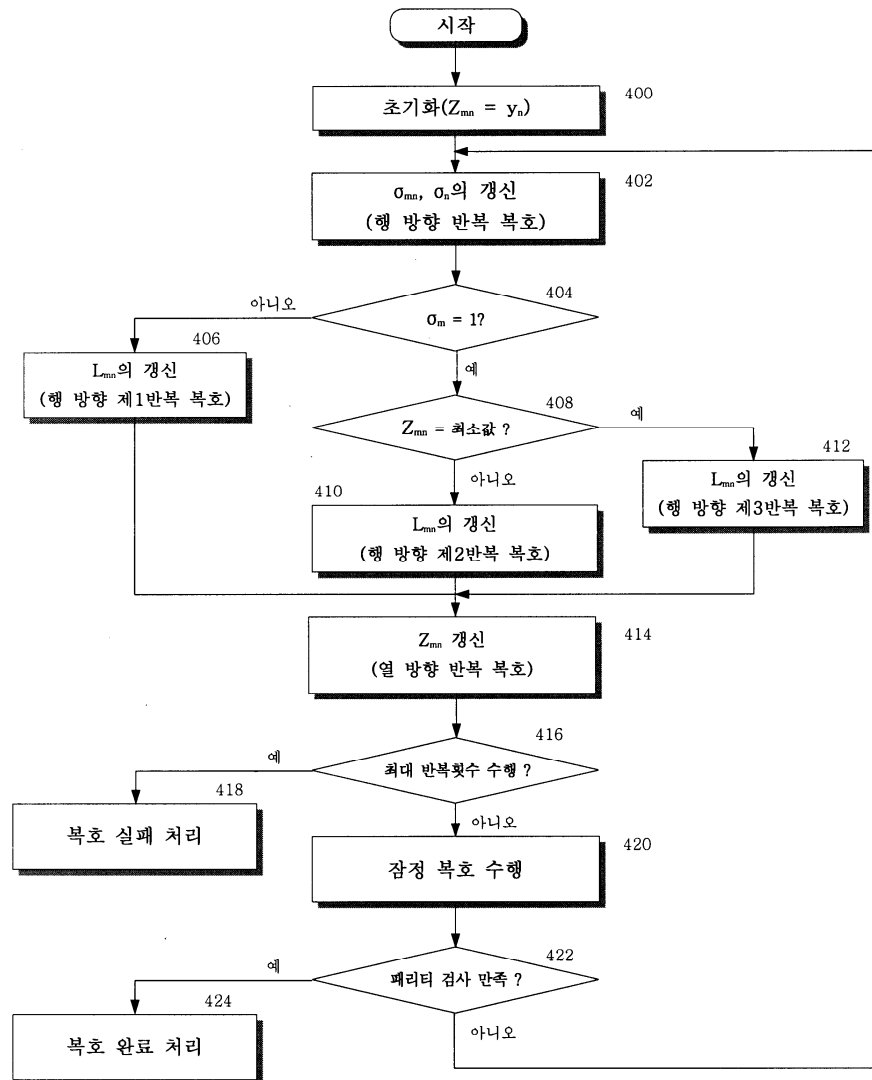
2



3



4



5

