UNITED STATES PATENT AND TRADEMARK OFFICE

10/725,779 | I-2-0526.1US:

DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

Application #	Attorney Docket #	Patent #	Status	Filing or 371 (c) date
10/725,779	I-2-0526.1US	7,293,217 Issued - 11/06/2007	Patented Case - 10/17/2007	12/02/2003

Documents & transaction history

Documents

Mail room date	Doc code	Doc description	Pages	Quick download
04/15/2008	COCOUT	Certificate of Correction - Post Issue Communication	2	
12/13/2007	COCIN	Request for Certificate of Correction	9	
10/17/2007	ISSUE.NTF	Issue Notification	1	
09/13/2007	IFEE	Issue Fee Payment (PTO-85B)	3	
06/12/2007	NOA	Notice of Allowance and Fees Due (PTOL-85)	3	
06/12/2007	NOA	Notice of Allowance and Fees Due (PTOL-85)	1	
06/12/2007	1449	List of References cited by applicant and considered by examiner	1	
06/12/2007	IIFW	Issue Information including classification, examiner, name, claim, renumbering, etc.	1	
06/12/2007	SRFW	Search information including classification, databases and other search related notes	1	
06/12/2007	FWCLM	Index of Claims	1	
06/12/2007	BIB	Bibliographic Data Sheet	1	

Mail room date	Doc code	Doc description	Pages	Quick download
05/17/2007	SRNT	Examiner's search strategy and results	3	
03/02/2007	A...	Amendment/Request for Reconsideration-After Non-Final Rejection	2	
03/02/2007	CLM	Claims	17	
03/02/2007	SPEC	Specification	1	
03/02/2007	REM	Applicant Arguments/Remarks Made in an Amendment	3	
03/02/2007	WFEE	Fee Worksheet (SB06)	1	
03/02/2007	FWCLM	Index of Claims	1	
01/19/2007	IDS	Information Disclosure Statement (IDS) Form (SB08)	4	
01/19/2007	FOR	Foreign Reference	62	
01/19/2007	FOR	Foreign Reference	23	
01/19/2007	FOR	Foreign Reference	33	
01/19/2007	FOR	Foreign Reference	28	
01/19/2007	NPL	Non Patent Literature	2	
12/18/2006	CTNF	Non-Final Rejection	8	
12/18/2006	1449	List of References cited by applicant and considered by examiner	1	
12/18/2006	892	List of references cited by examiner	1	
12/18/2006	SRFW	Search information including classification, databases and other search related notes	1	
12/18/2006	FWCLM	Index of Claims	1	
12/18/2006	BIB	Bibliographic Data Sheet	1	
12/07/2006	SRNT	Examiner's search strategy and results	2	
09/23/2005	STATUS.LET	Request for status of Application	2	
04/19/2005	WFEE	Fee Worksheet (SB06)	1	
02/14/2005	A.PE	Preliminary Amendment	1	
02/14/2005	SPEC	Specification	2	

Mail room date	Doc code	Doc description	Pages	Quick download
02/14/2005	CLM	Claims	18	
02/14/2005	REM	Applicant Arguments/Remarks Made in an Amendment	1	
02/14/2005	LET.	Miscellaneous Incoming Letter	18	
02/14/2005	371P	Documents submitted with 371 (National Stage) Applications	17	
02/14/2005	WFEE	Fee Worksheet (SB06)	1	
06/18/2004	IDS	Information Disclosure Statement (IDS) Form (SB08)	4	
06/18/2004	NPL	Non Patent Literature	3	
06/18/2004	NPL	Non Patent Literature	4	
06/18/2004	NPL	Non Patent Literature	80	
06/18/2004	NPL	Non Patent Literature	66	
06/18/2004	NPL	Non Patent Literature	76	
06/04/2004	OATH	Oath or Declaration filed	6	
03/02/2004	PEFN	Pre-Exam Formalities Notice	2	
12/02/2003	SPEC	Specification	38	
12/02/2003	CLM	Claims	14	
12/02/2003	ABST	Abstract	1	
12/02/2003	DRW	Drawings-only black and white line drawings	12	
12/02/2003	ADS	Application Data Sheet	2	
12/02/2003	WFEE	Fee Worksheet (SB06)	1	
12/02/2003	WFEE	Fee Worksheet (SB06)	1	
12/02/2003	TRNA	Transmittal of New Application	2	
12/02/2003	136A	Authorization for Extension of Time all replies	2	

1000 per page ▾ Page 1 of 1 ▾

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,293,217 B2
APPLICATION NO. : 10/725779
DATED : November 6, 2007
INVENTOR(S) : Pietraski et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

IN THE SPECIFICATION

At column 4, line 44, before the word "problematic", delete "avoids" and insert therefor --avoid--.

At column 6, line 9, before the words "in a", delete "deice" and insert therefor --device--.

At column 6, line 32, before the word "includes", delete "**610**" and insert therefor --**605**--.

At column 6, line 47, after the word "stage", delete "**630**" and insert therefor --**610**--.

At column 7, line 42, after the word "combined", delete "in to" and insert therefor --into--.

At column 8, line 7, after the word "number", insert --of--.

At column 8, line 8, before the word "is", delete "bits".

At column 8, line 17, before "(HARQ)", delete "request" and insert therefor --reQuest--.

At column 9, line 20, before the words "in TS", delete "for" and insert therefor --forth--.

At column 12, lines 10 & 11, after the word "point", delete "in to" and insert therefor --into--.

At column 12, line 37, before the words "used to", insert --be--.

At column 16, line 65, after the word "bit,", delete "xk." and insert therefor --x_k--.

At column 16, line 67, after the word "encoder),", delete "zk" and insert therefor --z_k--.

At column 17, line 2, after the word "encoder),", delete "z'k" and insert therefor --z'_k--.

At column 17, line 26, before the word "where", delete "$\Delta N^{\text{ûTTI}} = N_{IR} - N^{TTI}$" and insert therefor --$\Delta N_{il}^{TTI} = N_{IR} - N^{TTI}$--.

At column 18, line 36, after the word "puncturing", delete "maybe" and insert therefor --may be--.

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INVENTOR(S) : Pietraski et al.

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At column 20, delete lines 1 & 2, and insert therefor
--Where $X_{seg1}=42\cdot\lfloor X_i/98\rfloor$, $X_{seg2}=56\cdot\lfloor X_i/98\rfloor$, $X_{seg3}=X_i \bmod 98$--.

At column 21, line 43, before the words "the analysis", delete "when" and insert therefor --When--.

IN THE CLAIMS

At claim 12, column 26, line 9, insert missing copy -- $\hat{N}$ using--.

Signed and Sealed this

Fifteenth Day of April, 2008

JON W. DUDAS
Director of the United States Patent and Trademark Office

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DEC 13 2007
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COFC

PTO/SB/17 (10-07)
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Effective on 12/08/2004.
Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).

FEE TRANSMITTAL
For FY 2008

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT	($)	100

Complete if Known	
Application Number	10/725,779
Filing Date	December 2, 2003
First Named Inventor	Pietraski et al.
Examiner Name	Fritz Alphonse
Art Unit	2112
Attorney Docket No.	I-2-0526.1US

METHOD OF PAYMENT (check all that apply)

☐ Check ☐ Credit Card ☐ Money Order ☐ None ☐ Other (please identify): _____

☑ Deposit Account Deposit Account Number: 09-0435 Deposit Account Name: InterDigital Comm. Corp.

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

☐ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, **except for the filing fee**

☑ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 ☑ Credit any overpayments

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

FEE CALCULATION

1. BASIC FILING, SEARCH, AND EXAMINATION FEES

Application Type	FILING FEES Fee ($)	FILING FEES Small Entity Fee ($)	SEARCH FEES Fee ($)	SEARCH FEES Small Entity Fee ($)	EXAMINATION FEES Fee ($)	EXAMINATION FEES Small Entity Fee ($)	Fees Paid ($)
Utility	310	155	510	255	210	105	
Design	210	105	100	50	130	65	
Plant	210	105	310	155	160	80	
Reissue	310	155	510	255	620	310	
Provisional	210	105	0	0	0	0	

2. EXCESS CLAIM FEES

Fee Description	Fee ($)	Small Entity Fee ($)
Each claim over 20 (including Reissues)	50	25
Each independent claim over 3 (including Reissues)	210	105
Multiple dependent claims	370	185

Total Claims	Extra Claims	Fee ($)	Fee Paid ($)
_____ - 20 or HP =	_____ x	_____ =	0

HP = highest number of total claims paid for, if greater than 20.

Indep. Claims	Extra Claims	Fee ($)	Fee Paid ($)
_____ - 3 or HP =	_____ x	_____ =	0

HP = highest number of independent claims paid for, if greater than 3.

Multiple Dependent Claims Fee ($)	Multiple Dependent Claims Fee Paid ($)
_____	_____

Certificate of Correction DEC 14 2007

3. APPLICATION SIZE FEE

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)), the application size fee due is $260 ($130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets	Extra Sheets	Number of each additional 50 or fraction thereof	Fee ($)	Fee Paid ($)
_____ - 100 =	_____ / 50 =	_____ (round up to a whole number) x	_____ =	

4. OTHER FEE(S)

	Fees Paid ($)
Non-English Specification, $130 fee (no small entity discount)	
Other (e.g., late filing surcharge): Request for Certificate of Correction	100.00

SUBMITTED BY

Signature		Registration No. (Attorney/Agent) 57,204	Telephone 215-568-6400
Name (Print/Type)	Robert D. Leonard		Date 12/11/07

This collection of information is required by 37 CFR 1.136. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Patent Number	7,293,217
Issue Date	November 6, 2007
First Named Inventor	Pietraski et al.
Application Number	10/725,779
Filing Date	December 2, 2003
Attorney Docket Number	I-2-0526.1US

ENCLOSURES *(Check all that apply)*

- [X] Fee Transmittal Form
  - [ ] Fee Attached
- [ ] Amendment/Reply
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
- [ ] Express Abandonment Request
- [ ] Information Disclosure Statement
- [ ] Certified Copy of Priority Document(s)
- [ ] Reply to Missing Parts/ Incomplete Application
  - [ ] Reply to Missing Parts under 37 CFR 1.52 or 1.53
- [ ] Drawing(s)
- [ ] Licensing-related Papers
- [ ] Petition
- [ ] Petition to Convert to a Provisional Application
- [ ] Power of Attorney, Revocation Change of Correspondence Address
- [ ] Terminal Disclaimer
- [ ] Request for Refund
- [ ] CD, Number of CD(s) _____
  - [ ] Landscape Table on CD
- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- [ ] Proprietary Information
- [ ] Status Letter
- [X] Other Enclosure(s) (please Identify below):

Request for Certificate of Correction and Form PTO/SB/44

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	VOLPE AND KOENIG, P.C.		
Signature			
Printed name	Robert D. Leonard		
Date	12/11/07	Reg. No.	57,204

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Certificate of Corrections Branch, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature			
Typed or printed name	Robert D. Leonard	Date	12/11/07

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PATENT & TRADEMARK OFFICE

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the **PATENT** of:	
	Pietraski et al.
Patent No.:	7,293,217
Issued:	November 6, 2007
Appln. No.:	10/725,779
Filed:	December 2, 2003
For: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODE	

Our File: I-2-0526.1US

Date: December 11, 2007

REQUEST FOR CERTIFICATE OF CORRECTION

Certificate of Corrections Branch
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

A Certificate of Correction under 35 U.S.C. §§ 254, 255 and 37 C.F.R. §§1.322, 1.323 is requested for U.S. Patent No. 7,293,217. Correction of the following errors is requested.

IN THE SPECIFICATION

At column 4, line 44, before the word "problematic", delete "avoids" and insert therefor --avoid--.

At column 6, line 9, before the words "in a", delete "deice" and insert therefor --device--.

12/13/2007 MBLANCO 00000007 090435 7293217
01 FC:1811 180.00 DA

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At column 6, line 32, before the word "includes", delete "**610**" and insert therefor --**605**--.

At column 6, line 47, after the word "stage", delete "**630**" and insert therefor --**610**--.

At column 7, line 42, after the word "combined", delete "in to" and insert therefor --into--.

At column 8, line 7, after the word "number", insert --of--.

At column 8, line 8, before the word "is", delete "bits".

At column 8, line 17, before "(HARQ)", delete "request" and insert therefor --reQuest--.

At column 9, line 20, before the words "in TS", delete "for" and insert therefor --forth--.

At column 12, lines 10 & 11, after the word "point", delete "in to" and insert therefor --into--.

At column 12, line 37, before the words "used to", insert --be--.

At column 16, line 65, after the word "bit,", delete "xk." and insert therefor --x_k--.

At column 16, line 67, after the word "encoder),", delete "zk" and insert therefor --z_k--.

At column 17, line 2, after the word "encoder),", delete "z'k" and insert therefor --z'_k--.

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At column 17, line 26, before the word "where", delete "$\Delta N^{ilTTI} = N_{IR}-N^{TTI}$" and insert therefor --$\Delta N_{il}^{TTI} = N_{IR}-N^{TTI}$--.

At column 18, line 36, after the word "puncturing", delete "maybe" and insert therefor --may be--.

At column 20, delete lines 1 & 2, and insert therefor

--Where $X_{seg1}=42\cdot\lfloor X_i/98\rfloor$, $X_{seg2}=56\cdot\lfloor X_i/98\rfloor$, $X_{seg3}=X_i$ mod98--.

At column 21, line 43, before the words "the analysis", delete "when" and insert therefor --When--.

IN THE CLAIMS

At claim 12, column 26, line 9, insert missing copy -- ℕ using--.

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REMARKS

Patentees believe that the above errors are of such a nature as to justify the issuance of a Certificate of Correction. Patentees have enclosed a completed Certificate of Correction Form PTO/SB/44.

Since at least one of the errors was caused by Applicants, please charge the surcharge fee pursuant to C.F.R. §1.20(a) of $100.00 to the Deposit Account of InterDigital Communications Corporation, Deposit Account No. 09-0435.

Patentees respectfully request that the Certificate of Correction be issued.

Respectfully submitted,

Pietraski et al.

By_____
Robert D. Leonard
Registration No. 57,204
(215) 568-6400

Volpe and Koenig, P.C.
United Plaza, Suite 1600
30 South 17th Street
Philadelphia, PA 19103

RDL/dcb

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,293,217

APPLICATION NO.: 10/725,779

ISSUE DATE : November 6, 2007

INVENTOR(S) : Pietraski et al.

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

IN THE SPECIFICATION

At column 4, line 44, before the word "problematic", delete "avoids" and insert therefor --avoid--.

At column 6, line 9, before the words "in a", delete "deice" and insert therefor --device--.

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At column 9, line 20, before the words "in TS", delete "for" and insert therefor --forth--.

MAILING ADDRESS OF SENDER (Please do not use customer number below):
Volpe and Koenig, P.C.
United Plaza, Suite 1600
30 South 17th Street
Philadelphia, PA 19103

This collection of information is required by 37 CFR 1.322, 1.323, and 1.324. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1.0 hour to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Attention Certificate of Corrections Branch, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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At column 12, line 37, before the words "used to", insert --be--.

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CERTIFICATE OF CORRECTION

PATENT NO. : 7,293,217

APPLICATION NO.: 10/725,779

ISSUE DATE : November 6, 2007

INVENTOR(S) : Pietraski et al.

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--Where $X_{seg1}=42\cdot\lfloor X_i/98\rfloor$, $X_{seg2}=56\cdot\lfloor X_i/98\rfloor$, $X_{seg3}=X_i \bmod 98$--.

At column 21, line 43, before the words "the analysis", delete "when" and insert therefor --When--.

IN THE CLAIMS

At claim 12, column 26, line 9, insert missing copy -- $\hat{N}$ using--.

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Philadelphia, PA 19103

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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/725,779	11/06/2007	7293217	I-2-0526.1US	3830

24374 7590 10/17/2007

VOLPE AND KOENIG, P.C.
DEPT. ICC
UNITED PLAZA, SUITE 1600
30 SOUTH 17TH STREET
PHILADELPHIA, PA 19103

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 681 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Philip J. Pietraski, Huntington Station, NY;
Gregory S. Sternberg, Great Neck, NY;

PART B - FEE(S) TRANSMITTAL

SEP 13 2007

Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

24374 7590 06/12/2007

VOLPE AND KOENIG, P.C.
DEPT. ICC
UNITED PLAZA, SUITE 1600
30 SOUTH 17TH STREET
PHILADELPHIA, PA 19103

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

Scott Wolinsky	(Depositor's name)
Scott Wolinsky	(Signature)
September 10, 2007	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/725,779	12/02/2003	Philip J. Pietraski	I-2-0526.1US	3830

TITLE OF INVENTION: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$300	$0	$1700	09/12/2007

EXAMINER	ART UNIT	CLASS-SUBCLASS
ALPHONSE, FRITZ	2112	714-755000

09/14/2007 HVUONG2 00000037 090435 10725779
01 FC:1504 300.00 DA
02 FC:1501 1400.00 DA
03 FC:8001 12.00 DA

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Volpe and Koenig, P.C.
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: InterDigital Technology Corporation

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Wilmington, DE

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
- ☒ Issue Fee
- ☒ Publication Fee (No small entity discount permitted)
- ☒ Advance Order - # of Copies four (4)

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 09-0435 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
- ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature Scott Wolinsky Date September 10, 2007

Typed or printed name Scott Wolinsky Registration No. 46,413

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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OIPE IAP22
SEP 13 2007
PATENT & TRADEMARK OFFICE

PTO/SB/21 (04-07)
Approved for use through 09/30/2007.
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Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number	10/725,779
Filing Date	December 2, 2003
First Named Inventor	Pietraski et al.
Art Unit	2112
Examiner Name	Fritz Alphonse
Attorney Docket Number	I-2-0526.1US

ENCLOSURES *(Check all that apply)*

- [✓] Fee Transmittal Form
  - [ ] Fee Attached
- [ ] Amendment/Reply
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
- [ ] Express Abandonment Request
- [ ] Information Disclosure Statement
- [ ] Certified Copy of Priority Document(s)
- [ ] Reply to Missing Parts/ Incomplete Application
  - [ ] Reply to Missing Parts under 37 CFR 1.52 or 1.53
- [ ] Drawing(s)
- [ ] Licensing-related Papers
- [ ] Petition
- [ ] Petition to Convert to a Provisional Application
- [ ] Power of Attorney, Revocation Change of Correspondence Address
- [ ] Terminal Disclaimer
- [ ] Request for Refund
- [ ] CD, Number of CD(s) _____
  - [ ] Landscape Table on CD
- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- [ ] Proprietary Information
- [ ] Status Letter
- [✓] Other Enclosure(s) (please Identify below):
  Form PTOL-85

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	Volpe and Koenig, P.C.		
Signature	Scott Wolinsky		
Printed name	Scott Wolinsky		
Date	September 10, 2007	Reg. No.	46,413

CERTIFICATE OF TRANSMISSION/MAILING

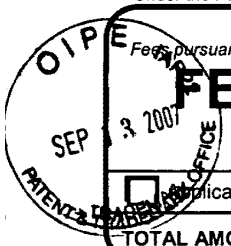
I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Mail Stop Issue Fee, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below.

Signature	Scott Wolinsky		
Typed or printed name	Scott Wolinsky	Date	September 10, 2007

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/SB/17 (05-07)
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Effective on 12/08/2004.
Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).

FEE TRANSMITTAL
For FY 2007

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT	($)	1712

Complete if Known	
Application Number	10/725,779
Filing Date	December 2, 2003
First Named Inventor	Pietraski et al.
Examiner Name	Fritz Alphonse
Art Unit	2112
Attorney Docket No.	I-2-0526.1US

METHOD OF PAYMENT (check all that apply)

☐ Check ☐ Credit Card ☐ Money Order ☐ None ☐ Other (please identify): _____

☒ Deposit Account Deposit Account Number: 09-0435 Deposit Account Name: InterDigital Comm. Corp.

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

☒ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, **except for the filing fee**

☒ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 ☒ Credit any overpayments

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

FEE CALCULATION

1. BASIC FILING, SEARCH, AND EXAMINATION FEES

Application Type	FILING FEES Fee ($)	FILING FEES Small Entity Fee ($)	SEARCH FEES Fee ($)	SEARCH FEES Small Entity Fee ($)	EXAMINATION FEES Fee ($)	EXAMINATION FEES Small Entity Fee ($)	Fees Paid ($)
Utility	300	150	500	250	200	100	
Design	200	100	100	50	130	65	
Plant	200	100	300	150	160	80	
Reissue	300	150	500	250	600	300	
Provisional	200	100	0	0	0	0	

2. EXCESS CLAIM FEES

Fee Description	Fee ($)	Small Entity Fee ($)
Each claim over 20 (including Reissues)	50	25
Each independent claim over 3 (including Reissues)	200	100
Multiple dependent claims	360	180

Total Claims _____ - 20 or HP = _____ Extra Claims x Fee ($) _____ = Fee Paid ($) _____

HP = highest number of total claims paid for, if greater than 20.

Indep. Claims _____ - 3 or HP = _____ Extra Claims x Fee ($) _____ = Fee Paid ($) _____

HP = highest number of independent claims paid for, if greater than 3.

Multiple Dependent Claims Fee ($) _____ Fee Paid ($) _____

3. APPLICATION SIZE FEE

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)), the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets _____ - 100 = _____ Extra Sheets / 50 = _____ Number of each additional 50 or fraction thereof (round **up** to a whole number) x Fee ($) _____ = Fee Paid ($) _____

4. OTHER FEE(S)

	Fees Paid ($)
Non-English Specification, $130 fee (no small entity discount)	
Other (e.g., late filing surcharge): Issue Fee, Publication Fee and Four (4) Advance Soft Copies	1712.00

SUBMITTED BY

Signature	Scott Wolinsky	Registration No. (Attorney/Agent) 46,413	Telephone 215-568-6400
Name (Print/Type)	Scott Wolinsky		Date September 10, 2007

This collection of information is required by 37 CFR 1.136. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

5

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

24374 7590 06/12/2007

VOLPE AND KOENIG, P.C.
DEPT. ICC
UNITED PLAZA, SUITE 1600
30 SOUTH 17TH STREET
PHILADELPHIA, PA 19103

EXAMINER	
ALPHONSE, FRITZ	
ART UNIT	PAPER NUMBER
2112	

DATE MAILED: 06/12/2007

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/725,779	12/02/2003	Philip J. Pietraski	I-2-0526.1US	3830

TITLE OF INVENTION: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$300	$0	$1700	09/12/2007

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 07/06) Approved for use through 06/30/2007.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

24374 7590 06/12/2007

VOLPE AND KOENIG, P.C.
DEPT. ICC
UNITED PLAZA, SUITE 1600
30 SOUTH 17TH STREET
PHILADELPHIA, PA 19103

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/725,779	12/02/2003	Philip J. Pietraski	1-2-0526.1US	3830

TITLE OF INVENTION: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$300	$0	$1700	09/12/2007

EXAMINER	ART UNIT	CLASS-SUBCLASS
ALPHONSE, FRITZ	2112	714-755000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
☐ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/725,779	12/02/2003	Philip J. Pietraski	I-2-0526.1US	3830

24374 7590 06/12/2007

VOLPE AND KOENIG, P.C.
DEPT. ICC
UNITED PLAZA, SUITE 1600
30 SOUTH 17TH STREET
PHILADELPHIA, PA 19103

EXAMINER	
ALPHONSE, FRITZ	
ART UNIT	PAPER NUMBER
2112	

DATE MAILED: 06/12/2007

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 682 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 682 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 07/06) Approved for use through 06/30/2007.

Notice of Allowability	Application No.	Applicant(s)	
	10/725,779	PIETRASKI ET AL.	
	Examiner	Art Unit	
	Fritz Alphonse	2112	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *the amendment filed on 3/02/2007*.

2. ☒ The allowed claim(s) is/are *1,2,4-7,9-11,13-18,25,26,28-31,33-36,38,39,43 and 45-54*.

3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 1/19/07
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

GUY LAMARRE
PRIMARY EXAMINER

OIPE IAP11 JAN 18 2007 PATENT & TRADEMARK OFFICE

FORM PTO-1449 U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Use several sheets if necessary)	ATTY. DOCKET NO. I-2-0526.1US	SERIAL NO. 10/725,779
	APPLICANT Pietraski et al.	
	FILING DATE December 2, 2003	GROUP 2133

U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
FA		6,370,669	04/2002	Eroz et al.			
FA		6,601,214	07/2003	Hammons, Jr.			
FA		6,622,281	09/2003	Yun et al.			
FA		6,665,813	12/2003	Forsman et al.			
FA		7,076,726	07/2006	Yun et al.			
FA		2002/0027956	03/2002	Lee et al.			
FA		2002/0141433	10/2002	Kwon et al.			
FA		2003/0007476	01/2003	Kim et al.			

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO
FA	*	00/11791	03/2000	WO			X[1]	
FA	*	00/41343	07/2000	WO			X[2]	
FA	*	02/33910	04/2002	WO			X[3]	
FA	*	03/069784	08/2003	WO			X[4]	

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc.)

FA		Mo et al., "Analysis of Puncturing Pattern for High Rate Turbo Codes," IEEE International, 0-7803-5538-5/99, 1999, pgs. 547-550.
FA		3GPP TS 25.212 v6.1.0 (2004-03), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Multiplexing and channel coding (FDD) (Release 6).
FA		3GPP TS 25.222 v6.0.0 (2003-12), 3rd Generation Partnership Project, Technical Specification Group Radio Access Network; Multiplexing and channel coding (TDD) (Release 6).
FA		3GPP TS 25.944 v4.1.0 (2001-06), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Channel coding and multiplexing examples (Release 4).

X[1] Equivalent to RU 2190296

X[2] Equivalent to RU 2185025

X[3] Equivalent to RU 2239292

X[4] Equivalent to RU 2004127246

EXAMINER	DATE CONSIDERED
/Fritz Alphonse/	05/17/2007

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Issue Classification	Application/Control No. 10/725,779	Applicant(s)/Patent under Reexamination PIETRASKI ET AL.
	Examiner Fritz Alphonse	Art Unit

ISSUE CLASSIFICATION

ORIGINAL		INTERNATIONAL CLASSIFICATION									
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED				
714	755	H	03	M	13	/00					/
						/					/

CROSS REFERENCES											
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)										
714	786	790									
375	265										

Fritz Alphonse 5/17/2007 (Assistant Examiner) (Date)	GUY LAMARRE PRIMARY EXAMINER (Primary Examiner) (Date) 5/24/07	Total Claims Allowed: 38
(Legal Instruments Examiner) (Date)		O.G. Print Claim(s): 1 / O.G. Print Fig.: 10

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	21	31		61		91		121		151		181
2	2		~~32~~		62		92		122		152		182
	~~3~~	22	33		63		93		123		153		183
3	4	23	34		64		94		124		154		184
4	5	24	35		65		95		125		155		185
5	6	25	36		66		96		126		156		186
6	7		~~37~~		67		97		127		157		187
	~~8~~	26	38		68		98		128		158		188
7	9	27	39		69		99		129		159		189
8	10		~~40~~		70		100		130		160		190
9	11		~~41~~		71		101		131		161		191
	~~12~~		~~42~~		72		102		132		162		192
12	13	28	43		73		103		133		163		193
10	14		~~44~~		74		104		134		164		194
11	15	29	45		75		105		135		165		195
13	16	30	46		76		106		136		166		196
14	17	31	47		77		107		137		167		197
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	~~27~~		57		87		117		147		177		207
18	28		58		88		118		148		178		208
19	29		59		89		119		149		179		209
20	30		60		90		120		150		180		210

Search Notes

Application/Control No.	Applicant(s)/Patent under Reexamination	
10/725,779	PIETRASKI ET AL.	
Examiner	**Art Unit**	
Fritz Alphonse	2112	

SEARCHED			
Class	Subclass	Date	Examiner
714	755	5/17/2007	FA
	786		
	790		
	758		
	800		
375	265		
	146		

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner
US-PGPUB search was conducted for interference.		5/17/2007	FA

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
East Search Updated	2/17/2007 & 5/17/07	FA
INVENTOR Search Updated/ No Double Patenting		

U.S. Patent and Trademark Office

Part of Paper No.

Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
10/725,779	PIETRASKI ET AL.
Examiner	**Art Unit**
Fritz Alphonse	2112

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

Claim		Date								
Final	Original	5/17/07								
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Final	Original	5/17/07								
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Bib Data Sheet

CONFIRMATION NO. 3830

SERIAL NUMBER	FILING OR 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/725,779	12/02/2003 RULE	714	2133	I-2-0526.1US

APPLICANTS

Philip J. Pietraski, Huntington Station, NY;
Gregory S. Sternberg, Great Neck, NY;

**** CONTINUING DATA ***************************

This appln claims benefit of 60/434,232 12/16/2002 and claims benefit of 60/444,068 01/30/2003
and claims benefit of 60/470,921 05/15/2003
and claims benefit of 60/494,404 08/11/2003 yes / F.A.

**** FOREIGN APPLICATIONS ******************** NO / F.A.

IF REQUIRED, FOREIGN FILING LICENSE GRANTED
** 02/27/2004

Foreign Priority claimed	STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
☐ yes ☒ no	NY	12	48	10
35 USC 119 (a-d) conditions met ☐ yes ☒ no ☐ Met after Allowance				
Verified and Acknowledged Examiner's Signature Initials				

ADDRESS
24374

TITLE
Detection, avoidance and/or correction of problematic puncturing patterns in parity bit streams used when implementing turbo codes

FILING FEE RECEIVED	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:
2006	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	83	("6370669" "6601214" "6622281" "6665813" "7076726" "20020027956" "20020141433" "20030007476")	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:25
L2	0	1 and (rate near4 matching same parity adj bit and problematic near4 Turbo adj code)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:26
L3	0	1 and (problematic near4 Turbo adj code)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:27
L4	41	1 and (Turbo adj code)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:27
L5	29	4 and punctur$4 near4 pattern	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:27
L6	3	5 and bit near4 stream same increas$4	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:28
L7	3	6 and rate near5 match$4	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:31
L8	3	7 and output same rate	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:35
L9	0	8 and bias	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:32

EAST Search History

L10	0	1 and bias	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 22:36

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	28	communication same rate adj matching same parity near4 bit	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 19:59
L2	3889	turbo near4 code	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 19:59
L3	26	1 and 2	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 20:00
L4	1	3 and problematic near5 puncturing	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 20:14
L5	1	1 and problematic near4 Turbo	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 20:03
L6	11	problematic near4 Turbo near4 code	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 20:12
L7	1835	(PIETRASKI adj PHILIP or STERNBERG near2 GREGORY or Interdigital adj Technology adj Corporation)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 20:14
L8	3	7 and problematic near5 puncturing	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/05/17 20:15

OIPE MAR 02 2007 PATENT & TRADEMARK OFFICE

IDS

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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number	10/725,779
Filing Date	December 2, 2003
First Named Inventor	Pietraski et al.
Art Unit	2133
Examiner Name	Fritz Alphonse
Attorney Docket Number	I-2-0526.1US

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☒ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
  - ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☐ Other Enclosure(s) (please Identify below):

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	VOLPE AND KOENIG, P.C.		
Signature	Scott Wolinsky		
Printed name	Scott Wolinsky		
Date	February 27, 2007	Reg. No.	46,413

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Mail Stop Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature	Scott Wolinsky		
Typed or printed name	Scott Wolinsky	Date	February 27, 2007

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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MAR 02 2007
PATENT & TRADEMARK OFFICE

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the **PATENT APPLICATION** of:	
Pietraski et al.	
Application No.: 10/725,779	
Confirmation No.: 3830	
Filed: December 2, 2003	Our File: I-2-0526.1US
For: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES	Date: February 27, 2007
Group: 2133	
Examiner: Fritz Alphonse	

REPLY PURSUANT TO 37 C.F.R. §1.111

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Reply is being timely filed in response to the Office Action dated December 18, 2006.

Please amend the application without prejudice or disclaimer as follows:

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (currently amended): In a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) determining whether or not a desired code rate, used to process the parity bit streams, results in a problematic puncturing pattern; ~~and~~

(b) if a problematic puncturing pattern results in step (a), adjusting the number of bits punctured in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams;

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculating the bias

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$$; and

(e) setting $\Delta = 0$ if $\left|\frac{I}{(P/2)} - \frac{7\hat{N}}{2}\right|$ *is not* $< 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

2. (previously amended): The method of claim 1 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits; and

(b2) removing punctured bits from the second group of P2 bits, wherein the puncturing rates of the P1 and P2 bits are biased by adding a number of non-punctured P1 bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

Claim 3 (canceled)

4. (currently amended): The method of claim 2 ~~claim 3~~, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

5. (currently amended): The method of claim 4 wherein the non-puncturing patterns ~~periods~~ will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

6. (currently amended): In a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit

streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) adjusting the number of bits punctured in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams; ~~and~~

(b) adjusting the puncturing rates of each of the parity bit streams while maintaining a constant overall effective coding rate by biasing the puncturing rates;

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculating the bias

$$\Delta = \left\lceil \max\left\{ \left(\frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2} \right), \left(\frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right) \right\} \right\rceil ; \text{ and}$$

(e) setting $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right|$ *is not* $< 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

7. (previously amended): The method of claim 6 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, step (a) further comprises:

(a1) adding punctured bits to the first group of P1 bits; and

(a2) removing punctured bits from the second group of P2 bits; and step (b) further comprises:

(b1) biasing the puncturing rates of the P1 and P2 bits by adding a number of non-punctured P1 bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

Claim 8 (canceled)

9. (currently amended): The method of claim 7 ~~claim 8~~, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

10. (currently amended): The method of claim 9 wherein the non-puncturing patterns ~~periods~~ will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

11. (currently amended): A method of identifying degradations in quality of punctured error correction coded transmissions, the method comprising:

(a) identifying a puncturing pattern which approximates a particular code rate; and

(b) adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate, wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits;

(b2) removing punctured bits from the second group of P2 bits; and

(b3) biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

Claim 12 (canceled)

13. (currently amended): The method of claim 11 ~~claim 12~~ further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculating the bias

$$\Delta = \left\lceil \left| \max\left\{ \left(\frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2} \right), \left(\frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right) \right\} \right| \right\rceil ; \text{ and}$$

(e) setting $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right|$ *is not* $< 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$

~~(c) determining a number of bits~~ $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ ~~wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and~~

~~(d) if~~ $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 + \frac{\hat{N}}{2} - \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, ~~calculate the bias~~

$\Delta = \left| \max\left\{ \left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor, \frac{P}{2}, \frac{P}{2}, \left\lceil \frac{7\hat{N}+1}{2} \right\rceil \right\} \right|$ ~~, otherwise set $\Delta = 0$~~.

14. (original): The method of claim 11 further comprising:

(c) using Turbo code to implement the error correction coded transmissions.

15. (original): The method of claim 14 further comprising:

(d) identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(e) using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

16. (currently amended): A method of identifying degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits, the method comprising:

(a) adding punctured bits to the first group of P1 bits;

(b) removing punctured bits from the second group of P2 bits; ~~and~~

(c) biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group;

(d) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(e) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculating the bias

$$\Delta = \left\lceil \max\left\{ \left(\frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2} \right), \left(\frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right) \right\} \right\rceil ; \text{ and}$$

(f) setting $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right|$ *is not* $< 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

17. (currently amended): The method of claim 16 further comprising:

(g) ~~(d)~~ using Turbo code to implement the error correction coded transmissions.

18. (currently amended): The method of claim 17 further comprising:

(h) ~~(e)~~ identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(i) ~~(f)~~ using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

Claims 19-24 (canceled)

25. (currently amended): A communications system for avoiding problematic Turbo code puncturing patterns, the system comprising:

(a) a plurality of rate matching stages for processing a plurality of individual parity bit streams;

(b) means for adjusting the number of bits punctured in each stage of rate matching; ~~and~~

(c) means for adjusting the number of bits punctured in each of the plurality of parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams, and biasing the puncturing rate of a problematic puncturing pattern;

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \left\lfloor \frac{I}{\left\lceil \frac{7\hat{N}-1}{2} \right\rceil} - \frac{P}{2} \right\rfloor, \frac{P}{2} - \left\lceil \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\rceil \right\} \right\rceil$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(f) means for setting bias $\Delta = 0$ if $\left|\frac{I}{(P/2)} - \frac{7\hat{N}}{2}\right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

26. (previously amended): The system of claim 25 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means for adjusting the number of bits punctured in each of the plurality of parity bit streams further comprising:

(c1) means for adding punctured bits to the first group of P1 bits;

(c2) means for removing punctured bits from the second group of P2 bits; and

(c3) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

Claim 27 (canceled)

28. (currently amended): The system of claim 26 ~~claim 27~~, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

29. (currently amended): The system of claim 28 wherein the non-puncturing patterns ~~periods~~ will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

30. (currently amended): A communications system for avoiding problematic Turbo code puncturing patterns, the system comprising:

(a) a plurality of rate matching stages for processing a plurality of individual parity bit streams;

(b) means for adjusting the number of punctured bits in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams; ~~and~~

(c) means for biasing the puncturing rates of each of the individual parity bit streams while maintaining a constant overall effective coding rate;

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(f) means for setting bias $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

31. (previously amended): The system of claim 30 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, wherein the means for adjusting the number of punctured bits comprises:

(b1) means for adding punctured bits to the first group of P1 bits; and

(b2) means for removing punctured bits from the second group of P2 bits; and the means for biasing the puncturing rates comprises:

(c1) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

Claim 32 (canceled)

33. (currently amended): The system of claim 31 ~~claim 32~~, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

34. (currently amended): The system of claim 33 wherein the non-puncturing patterns ~~periods~~ will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

35. (currently amended): A communications system for identifying degradations in quality of punctured error correction coded transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; ~~and~~

(b) means for adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the puncturing rate of a problematic puncturing pattern;

(c) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(d) means for calculating the bias $\Delta = \left\lceil \max\left\{ \left\lfloor \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} \right\rfloor - \frac{P}{2}, \frac{P}{2} - \left\lfloor \frac{I}{\left\lfloor \frac{7\hat{N}+1}{2} \right\rfloor} \right\rfloor \right\} \right\rceil$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(e) means for setting bias $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

36. (previously amended): The system of claim 35 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means for adjusting a value for anticipated degradation further comprising:

(b1) means for adding punctured bits to the first group of P1 bits;

(b2) means for removing punctured bits from the second group of P2 bits;

and

(b3) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

Claim 37 (canceled)

38. (currently amended): The system of claim 35 further comprising:

(f) ~~(e)~~ means for using Turbo code to implement the error correction coded transmissions.

39. (currently amended): The system of claim 38 further comprising:

(g) ~~(d)~~ means for identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(h) ~~(e)~~ means for using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

Claims 40-42 (canceled)

43. (currently amended): A communications system for reducing degradations in quality of punctured error corrected code transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; ~~and~~

(b) means for adjusting the parameters of the transmissions sufficiently to cause a mismatch in the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate;

(c) means for determining a capacity of a wireless transmit and receive unit (WTRU), including buffer sizes that are supported by the WTRU;

(d) means for using puncturing to remove sufficient bits to fit into the buffer; and

(e) means for adjusting an overall code rate so as to provide sufficient error correction capability, thereby providing a first rate in a first stage of puncturing and providing a second rate in a second stage of puncturing.

Claim 44 (canceled)

45. (currently amended): The system of claim 43 ~~claim 44,~~ further comprising:

(f) means for increasing non-punctured bits in one of the first stage and second stage of puncturing, and decreasing non-punctured bits in another of the first stage and second stage of puncturing, thereby adding additional puncturing to one stage and removing it from the other stage.

46. (currently amended): The system of claim 43 ~~claim 44~~ further comprising:

(f) means for increasing non-punctured bits in the first stage and decreasing non-punctured bits in the second stage.

47. (currently amended): The system of claim 43 ~~claim 44~~ further comprising:

(f) means for decreasing non-punctured bits in the first stage and increasing non-punctured bits in the second stage.

48. (currently amended): The system of claim 43 ~~claim 44~~ further comprising:

(f) means for interleaving parity bits before rate matching occurs; and

(g) means for subsequently de-interleaving the parity bits, thereby avoiding a need to periodically sample the parity bits when performing periodic sampling in rate matching, thereby mitigating the effect of the periodicity of the puncturing pattern.

49. (new): In a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and the puncturing rates of the P1 and P2 bits are biased by adding a number of non-punctured P1 bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group, the method including:

(a) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(b) if $\left|\frac{I}{(P/2)}-\frac{7\hat{N}}{2}\right|<1-\frac{\hat{N}}{2}+\left\lfloor\frac{\hat{N}}{2}\right\rfloor$, calculating the bias

$$\Delta=\left\lceil\max\left\{\frac{I}{\left\lfloor\frac{7\hat{N}-1}{2}\right\rfloor}-\frac{P}{2},\frac{P}{2}-\frac{I}{\left\lceil\frac{7\hat{N}+1}{2}\right\rceil}\right\}\right\rceil$$; and

(c) setting $\Delta=0$ if $\left|\frac{I}{(P/2)}-\frac{7\hat{N}}{2}\right|$ *is not* $<1-\frac{\hat{N}}{2}+\left\lfloor\frac{\hat{N}}{2}\right\rfloor$.

50. (new): The method of claim 49 wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

51. (new): The method of claim 50 wherein the non-puncturing patterns will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

52. (new): A wireless communication system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and the puncturing rates of the P1 and P2 bits are biased by adding a number of non-punctured P1 bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group, the system including:

(a) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(b) means for calculating the bias

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil \text{ if } \left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor \text{; and}$$

(c) means for setting $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right|$ *is not* $< 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

53. (new): The system of claim 52 wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

54. (new): The system of claim 53 wherein the non-puncturing patterns will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

Amendments to the Specification:

Please replace paragraph [0055] with the following amended paragraph:

[0055] When non-puncturing patterns with period $7\hat{N}/2$ ($\hat{N}$ = 1, 2, 3...) are used, degradation in performance results. These non-puncturing patterns ~~periods~~ will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

REMARKS

After the foregoing Amendment, claims 1, 2, 4-7, 9-11, 13-18, 25, 26, 28-31, 33-36, 38, 39, 43 and 45-54 are pending in this application. Claims 1, 6, 11, 16, 25, 30, 35 and 43 have been amended and new claims 49-54 have been added to incorporate subject matter deemed allowable by the Examiner into independent claim form, and to more distinctly claim subject matter which the Applicants regard as the invention. Claims 3, 8, 12, 19-24, 27, 32, 37, 40-42 and 44 have been canceled without prejudice. Paragraph [0055] of the specification has been amended to correct a typographical error. The Applicants submit that no new matter has been added by the Amendment.

The Examiner is thanked for indicating that claims 3-5, 8-10, 12, 13, 27-29, 32-34, 37 and 44-48 include allowable subject matter.

Claim 1 has been amended to incorporate the allowable subject matter of claim 3. Thus, the Applicants submit that claim 1, and dependent claims 2, 4 and 5, are allowable over the prior art of record.

Claim 6 has been amended to incorporate the allowable subject matter of claim 8. Thus, the Applicants submit that claim 6, and dependent claims 7, 9 and 10, are allowable over the prior art of record.

Claim 11 has been amended to incorporate the allowable subject matter of claim 12. Thus, the Applicants submit that claim 11, and dependent claims 13-15, are allowable over the prior art of record.

Claim 16 has also been amended to incorporate the allowable subject matter of claim 8. Thus, the Applicants submit that claim 16, and dependent claims 17 and 18, are allowable over the prior art of record.

Claim 25 has also been amended to incorporate the allowable subject matter of claim 27. Thus, the Applicants submit that claim 25, and dependent claims 26, 28 and 29, are allowable over the prior art of record.

Claim 30 has also been amended to incorporate the allowable subject matter of claim 32. Thus, the Applicants submit that claim 30, and dependent claims 31, 33 and 34, are allowable over the prior art of record.

Claim 35 has also been amended to incorporate the allowable subject matter of claim 37. Thus, the Applicants submit that claim 35, and dependent claims 36, 38 and 39, are allowable over the prior art of record.

Claim 43 has also been amended to incorporate the allowable subject matter of claim 44. Thus, the Applicants submit that claim 43, and dependent claims 45-48, are allowable over the prior art of record.

New claims 49-54 also include subject matter which the Examiner indicated as being allowable.

Conclusion

If the Examiner believes that any additional minor formal matters need to be addressed in order to place this application in condition for allowance, or that a telephone interview will help to materially advance the prosecution of this application, the Examiner is invited to contact the undersigned by telephone at the Examiner's convenience.

In view of the foregoing amendment and remarks, Applicants respectfully submit that the present application, including claims 1, 2, 4-7, 9-11, 13-18, 25, 26, 28-31, 33-36, 38, 39, 43 and 45-54, is in condition for allowance and a notice to that effect is respectfully requested.

Respectfully submitted,

Pietraski et al.

By Scott Wolinsky
Scott Wolinsky
Registration No. 46,413

Volpe and Koenig, P.C.
United Plaza, Suite 1600
30 South 17th Street
Philadelphia, PA 19103
Telephone: (215) 568-6400
Facsimile: (215) 568-6499

SW/bbf

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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 10/725,779

CLAIMS AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE	SMALL ENTITY FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY FEE
BASIC FEE (37 CFR 1.16(a))	48			$395.00	OR		$790.00
TOTAL CLAIMS (37 CFR 1.16(c))	48 minus 20 =	* 28	x $25 =		OR	x $50 =	1400.00
INDEPENDENT CLAIMS (37 CFR 1.16(b))	10 minus 3 =	* 7	x $100 =		OR	x $200 =	1400.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(d))			+ $ =		OR	+ $ =	
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL		OR	TOTAL	3570.00

CLAIMS AS AMENDED – PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE	SMALL ENTITY ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY ADDITIONAL FEE
Total (37 CFR 1.16(c))	* 48	Minus	** 48	* 0	x $25 =		OR	x $50 =	0
Independent (37 CFR 1.16(b))	* 10	Minus	*** 10	* 0	x $100 =		OR	x $200 =	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(d))					+ $ =		OR	+ $ =	
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0

AMENDMENT B — 3/2/07

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE	SMALL ENTITY ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY ADDITIONAL FEE
Total (37 CFR 1.16(c))	* 38	Minus	** 48	*	x $25 =		OR	x $50 =	
Independent (37 CFR 1.16(b))	* 10	Minus	*** 10	*	x $100 =		OR	x $200 =	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(d))					+ $ =		OR	+ $ =	
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT C

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE	SMALL ENTITY ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY ADDITIONAL FEE
Total (37 CFR 1.16(c))	*	Minus	**	*	x $25 =		OR	x $50 =	
Independent (37 CFR 1.16(b))	*	Minus	***	*	x $100 =		OR	x $200 =	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(d))					+ $ =		OR	+ $ =	
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

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Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
10/725,779	PIETRASKI ET AL.
Examiner	**Art Unit**
Fritz Alphonse	2133

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Claim Final	Claim Original	Date 12/7/06	Claim Final	Claim Original	Date	Claim Final	Claim Original	Date
	1	V		51			101	
	2	V		52			102	
	3	O		53			103	
	4	O		54			104	
	5	O		55			105	
	6	V		56			106	
	7	V		57			107	
	8	O		58			108	
	9	O		59			109	
	10	O		60			110	
	11	V		61			111	
	12	O		62			112	
	13	O		63			113	
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	18	V		68			118	
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	22	V		72			122	
	23	V		73			123	
	24	V		74			124	
	25	V		75			125	
	26	V		76			126	
	27	O		77			127	
	28	O		78			128	
	29	O		79			129	
	30	V		80			130	
	31	V		81			131	
	32	O		82			132	
	33	O		83			133	
	34	O		84			134	
	35	V		85			135	
	36	V		86			136	
	37	O		87			137	
	38	V		88			138	
	39	V		89			139	
	40	V		90			140	
	41	V		91			141	
	42	V		92			142	
	43	V		93			143	
	44	O		94			144	
	45	O		95			145	
	46	O		96			146	
	47	O		97			147	
	48	O		98			148	
	49			99			149	
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ENCLOSURES *(Check all that apply)*

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Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	VOLPE AND KOENIG, P.C.		
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Printed name	Scott Wolinsky		
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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the **PATENT APPLICATION** of:

Pietraski et al.

Application No.: 10/725,779

Confirmation No.: 3830

Filed: December 2, 2003

For: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

Group: 2133

Examiner: Fritz Alphonse

Our File: I-2-0526.1US

Date: January 16, 2007

INFORMATION DISCLOSURE STATEMENT

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Sir:

Further to Applicants' Duty of Disclosure pursuant to 37 C.F.R. §1.56, Applicants wish to bring to the Examiner's attention the material cited on the enclosed PTO-1449 form. Newly cited documents are indicated by an asterisk (*). Copies of the cited documents are enclosed.

Pursuant to 37 C.F.R. § 1.97(e)(1), the undersigned certifies that each new item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart application, copy enclosed, and that this communication was not received by any individual designated in §1.56(c) more than three (3) months prior to the filing of this Information Disclosure Statement.

The source of the newly identified items of information is the enclosed communication from a foreign patent office in a counterpart application, dated November 10, 2006.

It is respectfully requested that the Examiner consider these documents and return an initialed copy of the PTO-1449 form indicating his consideration of the cited materials.

Respectfully submitted,

Pietraski et al.

By Scott Wolinsky
Scott Wolinsky
Registration No. 46,413
(215) 568-6400

Volpe and Koenig, P.C.
United Plaza, Suite 1600
30 South 17th Street
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FORM PTO-1449 U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Use several sheets if necessary)	ATTY. DOCKET NO. I-2-0526.1US	SERIAL NO. 10/725,779
	APPLICANT Pietraski et al.	
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U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
		6,370,669	04/2002	Eroz et al.			
		6,601,214	07/2003	Hammons, Jr.			
		6,622,281	09/2003	Yun et al.			
		6,665,813	12/2003	Forsman et al.			
		7,076,726	07/2006	Yun et al.			
		2002/0027956	03/2002	Lee et al.			
		2002/0141433	10/2002	Kwon et al.			
		2003/0007476	01/2003	Kim et al.			

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO
	*	00/11791	03/2000	WO			X[1]	
	*	00/41343	07/2000	WO			X[2]	
	*	02/33910	04/2002	WO			X[3]	
	*	03/069784	08/2003	WO			X[4]	

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc.)

		Mo et al., "Analysis of Puncturing Pattern for High Rate Turbo Codes," IEEE International, 0-7803-5538-5/99, 1999, pgs. 547-550.
		3GPP TS 25.212 v6.1.0 (2004-03), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Multiplexing and channel coding (FDD) (Release 6).
		3GPP TS 25.222 v6.0.0 (2003-12), 3rd Generation Partnership Project, Technical Specification Group Radio Access Network; Multiplexing and channel coding (TDD) (Release 6).
		3GPP TS 25.944 v4.1.0 (2001-06), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Channel coding and multiplexing examples (Release 4).

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X[2] Equivalent to RU 2185025

X[3] Equivalent to RU 2239292

X[4] Equivalent to RU 2004127246

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(71) Applicant: SAMSUNG ELECTRONICS CO., LTD. [KR/KR]; 416, Maetan-dong, Paldal-gu, Suwon-shi, Kyungki-do 442-370 (KR).

(72) Inventors: KIM, Jae-Yoel; Sanpon 9-danji, Baekdu Apt. #960-1401, Sanpon 2-dong, Kunpo-shi, Kyonggi-do 435-042 (KR). PARK, Chang-Soo; 72-2, Munjong-dong, Songpa-gu, Seoul 138-200 (KR).

(74) Agent: LEE, Keon-Joo; Mihwa Building, 110-2, Myon-gryun-dong 4-ga, Chongro-gu, Seoul 110-524 (KR).

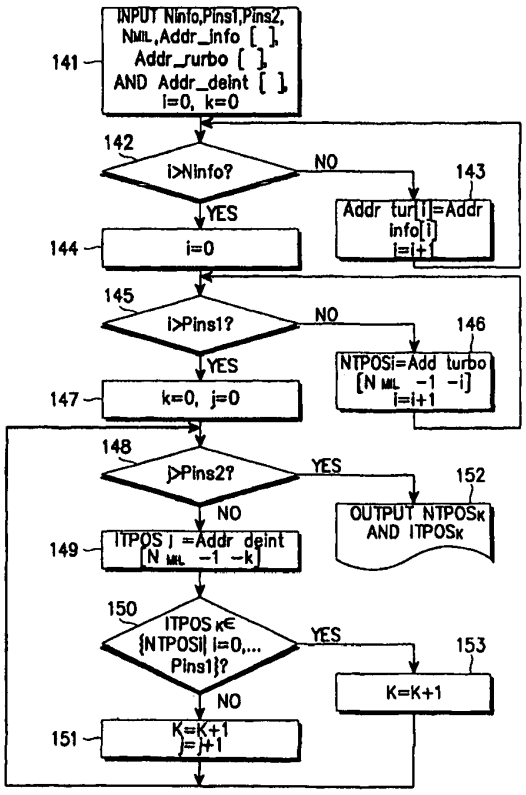
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(54) Title: DEVICE AND METHOD FOR INSERTING PREVIOUSLY KNOWN BITS IN INPUT STAGE OF CHANNEL ENCODER

(57) Abstract

A turbo coding device includes a bit inserter for inserting at least one specific bit at a last position of a data bit stream being input to a first constituent encoder, and inserting at least one specific bit at a last position of an interleaved data bit stream being input to a second constituent encoder; the first constituent encoder for encoding the specific bit-inserted data bits to generate first parity symbols; an interleaver for interleaving the specific bit-inserted data bits; the second constituent encoder for encoding the interleaved data bits to generate second parity symbols; and a multiplexer for multiplexing outputs of the bit inserter, the first constituent encoder and the second constituent encoder.



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DEVICE AND METHOD FOR INSERTING PREVIOUSLY KNOWN BITS IN INPUT STAGE OF CHANNEL ENCODER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a channel encoding device and method for a communication system, and in particular, to a device and a method for inserting previously known bits in an input stage of a channel encoding device.

2. Description of the Related Art

In communication systems for processing voice, character, image and video signals, data is generally transmitted on a frame unit basis. A frame is defined as a basic timing interval in the system. Further, in a system for communicating such frame data, a channel encoder for error correction should also encode data on the frame unit basis. In this case, the channel encoder performs zero tail biting to indicate the termination of each frame so that a decoder can efficiently decode the frames using that information. Encoder tail bits represent a fixed sequence of bits added to the end of a data frame to reset the convolutional encoder to a known state. An IS-95 system typically uses a non-recursive systemic convolutional encoder, which adds a sequence of zero (0) bits to the end of each frame equal to the number of delays, to implement frame

termination. However, in contrast to the non-recursive systemic convolutional encoder, a recursive systemic encoder cannot add the zero bits to the end of the frame to implement the frame termination, because input bits are fed back to the delays.

FIG. 1 illustrates a block diagram of a conventional parallel turbo encoder, which is disclosed in U.S. Pat. No. 5,446,747 issued to Berrou. The encoder of FIG. 1 is one type of conventional recursive systemic encoder. The turbo encoder encodes an N-bit input frame into parity symbols using two simple constituent encoders, and can be configured to have either a parallel or serial structure. In addition, the turbo encoder of FIG. 1 uses recursive systemic convolutional codes as constituent codes.

The turbo encoder of FIG. 1 includes an interleaver 120 interposed between a first constituent encoder 110 and a second constituent encoder 130. The interleaver 120 has the same size as a frame length, N, of input data bits and re-arranges the order of the data bits input to the second constituent encoder 130 to reduce the correlation between the outputs of the first and second encoders.

The first constituent encoder 110 encodes the input data bits and the interleaver 120 interleaves (or randomizes) the bits in the input data stream according to a specified rule so that burst errors introduced by the channel can be converted to random errors. The second constituent encoder 130 encodes the

output of the interleaver 120.

FIG. 2 is a diagram illustrating a termination scheme in the recursive systemic convolutional encoder of FIG. 1. For more detailed information, see D. Divsalar and F. Pollara, On the Design of Turbo Dodes , TDA Progress Report 42-123, Nov. 15, 1995. Here, frame data input to the first and second constituent encoders 110 and 130 is assumed to be 20-bit data. In FIG. 2, D1-D4 denotes delays and XOR1-XOR6 exclusive OR gates.

Referring to FIG. 2, the operative steps to perform encoding are as follows. A switch SW1 is maintained in the ON position and a switch SW2 is maintained in the OFF position. Then, the 20-bit input frame data is applied in sequence to the delays D1-D4 and exclusively ORed by the exclusive OR gates XOR1-XOR6, thus outputting encoded bits at the output of exclusive OR gate XOR6. When the 20 data bits are all encoded in this manner, the switch SW1 is switched OFF and the switch SW2 is switched ON, for frame termination. Then, the XOR gates XOR1-XOR4 exclusively OR the output data bits of the delays and the corresponding fed-back data bits, respectively, thereby outputting zero bits. The resulting zero bits are again input to the delays D1-D4 and stored therein. These zero bits input to the delays D1-D4 become tail bits, which are applied to a multiplexer.

The multiplexer multiplexes the encoded data bits and the tail bits output

from the constituent encoder. The number of generated tail bits depends on the number of delays included in the constituent encoders 110 and 130. The termination scheme of FIG. 2 generates 4 tail bits per frame plus additional encoded bits generated for each of the respective tail bits, undesirably increasing the overall final encoded bit count, which leads to a decrease in the bit rate. That is, when the bit rate is defined as;

Bit Rate = (the Number of Input Data Bits)/(the Number of Output Data Bits),

a constituent encoder having the structure of FIG. 2 has a bit rate of

Bit Rate = (the Number of Input Data Bits)/{(the Number of Encoded Data Bits)+(the Number of Tail Bits)+(the Number of Encoded Bits for the Tail Bits)}.

Accordingly, in FIG. 2, since the frame data is composed of 20 bits and the number of delays equals 4, the bit rate becomes 20/28.

It is therefore apparent that the recursive systemic convolutional encoder s performance depends upon the tailing method, because it is difficult to perfectly tail the turbo codes.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a device and method for inserting bits in each channel frame at positions having a higher error occur range probability having a specific value at a last position of frame data bits, wherein the last position has a high error occurrence probability during decoding in a turbo coding device.

It is another object of the present invention to provide a device and method for inserting specific bits at the tail positions of data bit streams being respectively input to a first constituent encoder and a second constituent encoder in a turbo coding device.

It is a further object of the present invention to provide a device and method for inserting specific bits at the tail positions of data bit streams being respectively input to a first constituent encoder and a second constituent encoder in a turbo coding device, wherein a position of the specific bit inserted in the second constituent encoder is shifted forward when the positions of the specific bits inserted in the first and second constituent encoders overlap each other.

To achieve the above objects, a turbo coding device according to the present invention includes a bit inserter for inserting one or more specific bits at tail positions of a data bit stream being input to a first constituent encoder, and inserting at least one specific bit at a last position of an interleaved data bit stream being input to a second constituent encoder; the first constituent encoder for

encoding the specific bit-inserted data bits to generate first parity symbols; an interleaver for interleaving the specific bit-inserted data bits; the second constituent encoder for encoding the interleaved data bits to generate second parity symbols; and a multiplexer for multiplexing outputs of the bit inserter, the first constituent encoder and the second constituent encoder.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which like reference numerals indicate like parts. In the drawings:

FIG. 1 is a block diagram illustrating a prior art channel encoder for use in a wireless communication system;

FIG. 2 is a detailed block diagram illustrating a prior art constituent encoder of FIG. 1;

FIG. 3 is a diagram illustrating a channel encoder according to a first embodiment of the present invention;

FIG. 4 is a detailed diagram illustrating a bit inserter of FIG. 3;

FIG. 5 is a detailed diagram illustrating a constituent encoder of FIG. 3;

FIG. 6 is a diagram illustrating a bit processing procedure according to the first embodiment of the present invention;

FIG. 7 is a diagram illustrating a channel encoder according to a second

embodiment of the present invention;

FIG. 8 is a detailed diagram illustrating a multiplexer of FIG. 7;

FIG. 9 is a diagram illustrating a bit processing procedure according to a second embodiment of the present invention;

FIG. 10 is a diagram illustrating a channel encoder according to a third embodiment of the present invention;

FIG. 11 is a detailed diagram illustrating a constituent encoder of FIG. 10;

FIG. 12 is a detailed diagram illustrating a multiplexer of FIG. 10;

FIG. 13 is a diagram illustrating a bit processing procedure according to a third embodiment of the present invention; and

FIG. 14 is a diagram illustrating a procedure for inserting previously known bits in an input stage of a channel encoder according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described herein below with reference to the accompanying drawings. In the following description, well known functions or constructions are not described in detail since they would obscure the invention in unnecessary detail. The term "data bit" as used herein refers to data which is not encoded, and the term "parity bit" refers to data which is encoded by a constituent encoder.

Generally, in a communication system, a transmitter encodes transmission data using a channel encoder and transmits the encoded data; a receiver then demodulates the data received from the transmitter to convert the received data into the original data. The channel encoder encodes the transmission data on a frame unit basis and generates tail bits, which are added to each frame to indicate a termination of the frame. The present invention discloses a frame structure having a termination effect in the channel encoder.

The frame structure having the termination effect can be implemented in accordance with several embodiments as described below:

First Embodiment: A number of specific bits are inserted in each channel frame at positions having a higher error occurrence probability, where the number of bits to be inserted is defined by the number of tail bits. Because the recursive systemic constituent encoders are not configured to generate tail bits, the error occurrence probability is determined by way of experiment, and the insert positions should be known to both the channel encoder and a channel decoder. The specific bits to be inserted should preferably be insignificant bits which have little or no impact on communication performance, whether they are transmitted or not. Also, they can be encoded bits or data bits predetermined with a receiver. Herein, they are assumed to be zero bits.

Second Embodiment: A number of bits are inserted in each channel

frame at positions having a higher error occurrence probability, where the number of bits to be inserted is determined by the number of tail bits. The specific bits are inserted to exceed a predefined frame length. The bit-inserted data bits are encoded using the constituent encoders. Then, when outputting the channel encoded data, the bits exceeding the frame length of the channel encoded data are punctured at the bit-inserted positions of the input data. Here, the recursive systemic encoder does not generate tail bits and the channel decoder should have prior knowledge of the bit-inserted positions.

Third Embodiment: A number of specific bits are inserted in each channel frame at positions having a higher error occurrence probability, where the number of bits to be inserted is determined by the number of tail bits. The constituent encoder generates tail bits for termination and associated encoded data for the tail bits and thereafter, punctures the data bits at specific insert positions in each channel frame to insert the tail bits and the encoded data for the tail bits in the punctured positions selected for bit insertion.

First Embodiment

An encoder according to a first embodiment of the present invention does not generate tail bits, but rather, inserts specific bits at predetermined positions to perform the termination function. In this embodiment, one 24-bit frame includes 16 data bits, and 8 specific bits, where each of the 8 specific bits

are zero bits inserted in the frame at bit positions having a higher error probability. Here, the bit insert positions are determined by experimentally detecting the positions where most errors occur while decoding the encoded data. Further, each constituent encoder uses a 1/3 coding rate.

In this embodiment, the positions having the higher error probability during decoding are experimentally determined, when the 24-bit frame data (i.e., 16 frame data bits plus the 8 specific bits) is encoded using a turbo encoder having a 1/3 coding rate. Eight bit positions having the relatively higher error probability are determined, and the specific bits are inserted at the determined positions. Here, the decoder knows the bit-inserted positions, when decoding the encoded frame data in which the specific codes are inserted.

In practice, all "0" bits are actually transmitted as "-1". When the inserted specific bits are zero bits, the zero bits at the insert positions are changed to a large negative value (e.g., -5) before decoding, in order to increase reliability. This is to improve decoding performance due to variations which can occur during transmission in a radio environment. However, since the decoder previously knows the position of the specific bit to be received, the decoder inserts a higher value other than -1 for the specific bit in the actual decoding process. In this case, the decoder can improve decoding performance by virtue of the inserted specific value. This decoding operation will be described in detail with reference to FIG. 14. In this manner, the decoder decoding the bits, knows

at least 8 bits of the 24 by virtue of them being transmitted as a large negative value, thereby increasing decoding performance. In this embodiment, decoding performance increases as the frame becomes shorter.

FIG. 3 is a diagram illustrating a turbo encoder having a bit inserter for inserting the specific bits according to the first embodiment of the present invention. A bit inserter 310 includes a bit generator for generating specific bits by processing input data bits, and generates data bits in the frame unit by inserting the specific bits generated by the bit generator in the received data bit stream at predefined bit insert positions. In the embodiment, it is assumed that a position where the bit inserter 310 inserts a specific bit is the latter portion of the data bit stream. Insertion of the specific bits are determined by an undepicted controller. A first constituent encoder 320 encodes the data bits output from the bit inserter 310. An interleaver 330 interleaves the data bits in the frame unit, output from the bit inserter 310, according to a predetermined rule so as to re-arrange the sequence of the data bits. In the exemplary embodiment, a diagonal interleaver is used for the interleaver 330.

A second constituent encoder 340 encodes the interleaved data bits in the frame unit, output from the interleaver 330. Recursive systemic convolutional encoders can be used for the first and second constituent encoders 320 and 340. A multiplexer 350 multiplexes outputs of the bit inserter 310, the first constituent encoder 320 and the second constituent encoder 340, under the control of the

undepicted controller. Here, the bit inserter 310 outputs the data bits I_k. The first constituent encoder 320 outputs the first parity bits $P1_k$, and the second constituent encoder 340 outputs the second parity bits $P2_k$.

FIG. 4 is a detailed block diagram illustrating the bit inserter 310 in the turbo encoder of FIG. 3. Referring to FIG. 4, a bit generator 430 generates specific bits to be inserted amongst the data bits. Here, the specific bits are assumed to be zero bits. Delays 412-426, which may be embodied as memory elements such as flip-flops, may have a serial shift register structure for shifting an input data bit according to a bit clock.

A switch 432 is switched to select the outputs of the delays 412-426, under the control of the undepicted controller. Also, the switch 432 is switched to an output of a next delay at the positions where a specific bit output from the bit generator 430 is inserted in the data bits, under the control of the undepicted controller. That is, the switch 432 selects a data bit being delayed by one bit, when the selected specific bit is inserted in the data bits. The switch 432 can be implemented by a multiplexer. A switch 434 is switched to outputs of the bit generator 430 and the switch 432 to generate data bits I_k, under the control of the undepicted controller. The switch 434 selects either the specific bits or the data bits for insertion at the predefined positions, under the control of the controller.

Referring to FIG. 4, a description will be made directed to the operation

of inserting the specific bits. The input data bits are delayed by the delays 412-426 according to the bit clock. Initially, the switch 432 selects the input data bits (i.e., Pole 1) and the switch 434 is initially connected to the switch 432 (i.e., Pole B). Then, the input data bits are output via the switches 432 and 434. In the meantime, when a bit insert position is determined, the switch 432 is connected to the output of the delay 412 (i.e., Pole 2) and the switch 434 is connected to the output of the bit generator 430 (i.e., Pole A), under the control of the controller. As a result, a path for the data bits is cut off and the zero bit output from the bit generator 430 is inserted in the corresponding bit position. In the case where the data bits are continuously output after insertion of the zero bit, the switch 434 is again connected to the switch 432 by the controller. That is, since the one bit-delayed data bit is selected after insertion of the zero bit, the zero bit can be inserted at the predefined position without loss of the data bit.

The zero bits are inserted in the data bits for one frame by repeating this process. Upon reception of data bits for the next frame after insertion of the zero bits, the switch 432 is again connected to an input bit node (Pole 1) and the above process is repeated again. In the case where data bits are encoded for communication, an error probability is statistically relatively higher at the rear portion of the data bit stream input to the respective constituent encoders. Accordingly, the positions where the zero bits output from the bit generator 430 are inserted, can be mostly located at the rear portion of the data bit stream as shown in Table 1, by way of example.

TABLE 1

I1 I2 I3 I4 I5 I6 I7 I8 I9 I10 I11 **Ib1** I12 I13 I14 **Ib2** I15 I16 **Ib3** **Ib4** **Ib5** **Ib6** **Ib7** **Ib8**

where Ix denotes data bits and Ibx inserted bits.

The data bits of Table 1, output from the bit inserter 310, are applied to both the first constituent encoder 320 and the interleaver 330 in parallel. The interleaved data bits in the frame unit, output from the interleaver 330, are encoded by the second constituent encoder 340. FIG. 5 illustrates a structure of the first and second constituent encoders 320 and 340 of FIG. 3 in accordance with the first embodiment. As illustrated, the first and second constituent encoders 320 and 340 are recursive systemic convolutional encoders. In addition, the constituent encoders 320 and 340 are configured not to generate tail bits, as shown in FIG. 5.

The first constituent encoder 320 encodes the data bits of Table 1, output from the bit inserter 310. The encoded data bits output from the first constituent encoder 320 are shown in Table 2.

TABLE 2

C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 **Cb1** C12 C13 C14 **Cb2** C15 C16 **Cb3** **Cb4** **Cb5** **Cb6** **Cb7** **Cb8**

where Cx denotes symbols output from the first constituent encoder 320, and Cbx denotes symbols of the inserted bits, output from the first constituent encoder 320. Here, in the case where the first constituent encoder 320 has the 1/3 coding rate, each symbol C becomes three symbols. Note, however, that Table 1 does not show the redundant symbols.

In the meantime, the interleaver 330 interleaves the data bits output from the bit inserter 310 and the second constituent encoder 340 encodes the interleaved data bits output from the interleaver 330. The encoded data bits output from the second constituent encoder 340 are shown in Table 3.

TABLE 3

D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 Db1 D12 D13 D14 Db2 D15 D16 Db3 Db4 Db5 Db6 Db7 Db8

where Dx denotes symbols output from the second constituent encoder 340 and Dbx symbols of the inserted bits, output from the second constituent encoder 340. Here, in the case where the second constituent encoder 340 has the 1/3 coding rate, each symbol D becomes three symbols. Although the sequence of the data bits was actually rearranged by interleaving, the sequence remains unchanged in Table 3, for the convenience of explanation.

The multiplexer 350 then multiplexes the outputs of the bit inserter 310, the first constituent encoder 320 and the second constituent encoder 340, under

the control of the undepicted controller. Shown in Table 4 are the specific bit inserted-data bits and outputs of the first and second constituent encoders 320 and 340. The multiplexer 350 can multiplex input symbols in the sequence of the data symbol, the first parity symbol and the second parity symbol either on a frame unit basis as shown in Table 4, or on a symbol unit basis.

TABLE 4

I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	Ib1	I12	I13	I14	Ib2	I15	I16	Ib3	Ib4	Ib5	Ib6	Ib7	Ib8
C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	Cb1	C12	C13	C14	Cb2	C15	C16	Cb3	Cb4	Cb5	Cb6	Cb7	Cb8
D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	Db1	D12	D13	D14	Db2	D15	D16	Db3	Db4	Db5	Db6	Db7	Db8

FIG. 6 is a timing diagram of the turbo encoder of FIG. 3 according to the first embodiment of the present invention. Referring to FIG. 6, in an interval T1, the bit inserter 310 inserts the zero bits in the frame at the predefined bit positions to generate a bit inserted data bit stream I_k where the inserted bits are zero valued of Table 1 (see 611). In an interval T2, the zero valued bit-inserted data bits I_k are simultaneously applied to the multiplexer 350, the first constituent encoder 320 and the interleaver 330. Then, in the T2 interval, the first constituent encoder 320 encodes the zero valued bit-inserted data bits I_k to generate first encoded data bits C_k which are the first parity bits (see 612), and in the same T2 interval, the interleaver 330 interleaves the zero bit-inserted data bits I_k according to the predefined rule (see 613).

Thereafter, in an interval T3, the multiplexer 350 delays the data bits I_k

output from the bit inserter 310 by one frame period, the first constituent encoder 320 inputs the first encoded data bits C_k to the multiplexer 350 and the second constituent encoder 340 encodes the interleaved data bits I_k output from the interleaver 330 to generate second encoded data bits D_k which are the second parity bits. Upon completion of generating the second parity bits D_k by the second constituent encoder 340, the multiplexer 350 multiplexes the data bits I_k, the first parity bits C_k and the second parity bits D_k, in an interval T4.

Although FIG. 6 shows an example of parallel processing the data bits I_k, the first parity bits C_k and the second parity bits D_k, it is also possible to serially output the outputs of the bit inserter 310, the first constituent encoder 320 and the second constituent encoder 340 in the order of bit generation.

As can be appreciated from the foregoing descriptions, in the recursive systemic turbo encoder according to the first embodiment, the respective constituent encoders do not generate tail bits for termination, but instead, insert some number of specific bits (i.e., zero bits) at bit positions having a determined higher error probability.

Second Embodiment

Like the first embodiment, a channel encoder according to a second embodiment of the present invention inserts specific bits at bit positions having a

higher error occurrence probability. However, the second embodiment may be differentiated from the first embodiment in that the number of the inserted bits is set to exceed the frame size (or length). In this exemplary embodiment, each frame is assumed to include 16 input data bits I_k and 12 inserted bits. This embodiment adds four additional inserted bits. Since the output data bits I_k, parity bits C_k and D_k should equal 24 bits and 28 bits are generated in total, the surplus parity bits C_k and D_k are punctured from the data bits I_k at the bit-inserted positions.

FIG. 7 is a diagram illustrating the channel encoder according to the second embodiment of the present invention. A bit inserter 710 includes a bit generator for generating specific bits by processing input data bits, and generates data bits exceeding the frame size by inserting the specific bits generated by the bit generator at predefined bit positions. A first constituent encoder 720 encodes the data bits output from the bit inserter 710 to generate first parity bits C_k. An interleaver 730 interleaves the data bits in the frame unit, output from the bit inserter 710, according to a predetermined rule so as to change the arrangement (or sequence) of the data bits. In the exemplary embodiment, a diagonal interleaver is used for the interleaver 730.

A second constituent encoder 740 encodes the interleaved data bits in the frame unit, output from the interleaver 730, to generate second parity bits D_k. A recursive systemic convolutional encoder can be used for the first and second

constituent encoders 720 and 740. A multiplexer 750 multiplexes outputs of the bit inserter 710, the first constituent encoder 720 and the second constituent encoder 740 to generate a data frame of a predefined length, under the control of a undepicted controller. Here, the bit inserter 710 outputs the data bits I_k, the first constituent encoder 720 outputs the first parity bits $P1_k$ and the second constituent encoder 740 outputs the second parity bits $P2_k$.

In operation, upon receipt of the 16 input data bits I_k, the bit inserter 710 operates in the same manner as the bit inserter 310 of the first embodiment. The bit inserter 710 has a structure similar to that of FIG. 4 except that it is composed of 12 delays instead of 8. Therefore, the bit inserter 710 inserts 12 zero bits in the frame at 12 bit positions having the higher error probability by controlling the internal switches under the control of the undepicted controller. Accordingly, in this embodiment, the bit inserter 710 outputs the 28 data bits I_k (i.e., 16 data bits and 12 zero bits), which are simultaneously applied to the multiplexer 750, the first constituent encoder 720 and the interleaver 730. Further, the interleaved data bits I_k output from the interleaver 730 are applied to the second constituent encoder 740. Here, the first and second constituent encoders 720 and 740 have the structure of FIG. 5, which does not generate the tail bits for termination.

The first constituent encoder 720 then encodes the 28 data bits I_k output from the bit inserter 710 with the 12 zero bits inserted therein, and outputs 28 first parity bits C_k to the multiplexer 750. The interleaver 730 interleaves the 28

data bits I_k output from the bit inserter 710, and the second constituent encoder 740 encodes the interleaved data bits in the same manner as the first constituent encoder 720 to generate 28 second parity bits D_k, which are applied to the multiplexer 750. The multiplexer 750 punctures the data bits I_k to insert the four first parity bits C_k and the four second parity bits D_k in the punctured positions and then, outputs the remaining 24 first parity bits C_k and the remaining 24 second parity bits D_k.

Referring to FIG. 8, the multiplexer 750 first receives the 28 data bits I_k output from the bit inserter 710. Then, a switch 812 in the multiplexer 750 is connected to a delay 822 until the first 24 data bits out of the 28 data bits I_k are received from the bit inserter 710. The delay 822 delays the first 24 received data bits I_k. Thereafter, the switch 812 is connected to a delay 824 until the remaining 4 data bits out of the 28 data bits I_k are received from the bit inserter 710. The delay 824 delays the remaining 4 data bits.

In the same manner, the multiplexer 750 receives the 28 first parity bits C_k output from the first constituent encoder 720. Then, a switch 814 in the multiplexer 750 is connected to a delay 826 until the first 24 data bits out of the 28 first parity bits C_k are received from the first constituent encoder 720, and the delay 826 delays the received first parity bits C_k. Thereafter, the switch 814 is connected to a delay 828 until the remaining 4 first parity bits out of the 28 first parity bits C_k are received from the first constituent encoder 720, and the delay

828 delays the received remaining 4 first parity bits.

Thereafter, the multiplexer 750 receives the 28 second parity bits D_k output from the second constituent encoder 740. Then, a switch 816 in the multiplexer 750 is connected to a delay 830 until the first 24 data bits out of the 28 second parity bits D_k are received from the second constituent encoder 740, and the delay 830 delays the received second parity bits D_k. Thereafter, the switch 816 is connected to a delay 832 until the remaining 4 second parity bits out of the 28 second parity bits D_k are received from the second constituent encoder 740, and the delay 832 delays the received remaining 4 second parity bits.

As described above, the multiplexer 750 sequentially receives the 28 data bits I_k, the 28 first parity bits C_k and the 28 second parity bits D_k, and separately stores the first 24 bits and the remaining 4 bits out of the respective bits in the corresponding delays. The switches 812-816 are controlled by the undepicted controller. Further, the delays 822-832 each are composed of cascaded memory elements and store the input bits until the corresponding delay process is completed.

Upon completion of the delay process, the switch 844 is connected to a switch 842 and the switch 842 is connected to the delay 822. Therefore, an output of the delay 822 is output via the switches 842 and 844. When one data bit

stored in the delay 822 is output, the switch 842 is connected to the delay 824, maintaining connection with the switch 844. Then, one of the remaining data bits stored in the delay 824 is output via the switches 842 and 844. That is, the data bit stored in the delay 822 is punctured and the data bit stored in the delay 824 is output in its place. Thereafter, the switch 842 is connected to the delay 822, continuously maintaining connection with the switch 844. By repeating the above process 4 times, the data bits stored in the delay 822 are punctured and the four data bits stored in the delay 824 are inserted in the four punctured positions.

Subsequently, the switch 842 is connected to the delay 822, maintaining connection with the switch 844. Then, the output of the delay 822 is output via the switches 842 and 844. When one data bit stored in the delay 822 is output, the switch 842 is connected to the delay 828, maintaining connection with the switch 844. Then, one of the remaining four first parity bits stored in the delay 828 is output via the switches 842 and 844. Thereafter, the switch 842 is connected again to the delay 822, continuously maintaining connection with the switch 844. By repeating the above process 4 times, the data bits stored in the delay 822 are punctured and the four first parity bits stored in the delay 828 are inserted in the punctured positions.

In this manner, the data bits and the remaining four first parity bits are alternately output. Next, the switch 842 is connected to the delay 822, maintaining connection with the switch 844. Then, the output of the delay 822 is

output via the switches 842 and 844. When one data bit stored in the delay 822 is output, the switch 842 is connected to the delay 832, maintaining connection with the switch 844. Then, one of the remaining four second parity bits stored in the delay 832 is output via the switches 842 and 844. Thereafter, the switch 842 is connected again to the delay 822, continuously maintaining connection with the switch 844. By repeating the above process 4 times, the data bits stored in the delay 822 are punctured and then, the remaining four second parity bits stored in the delay 832 are inserted in the punctured positions.

By way of the foregoing procedure, the 24 data bits stored in the delay 822 are punctured and then, the 4 data bits stored in the delay 824, the 4 first parity bits stored in the delay 828 and the 4 second parity bits stored in the delay 832 are inserted in the punctured positions. Accordingly, the multiplexer 750 punctures the data bits I_k output from the bit inserter 710 and inserts the 8 parity bits in the punctured insert positions, thereby outputting 24 data bits.

Upon completion of the above process, the switch 844 is connected to the delay 826. Then, the 24 first parity bits C_k stored in the delay 826 are output. Thereafter, the switch 844 is connected to the delay 830 to output the 24 second parity bits D_k stored in the delay 830.

Referring to FIG. 9, in the encoder of FIG. 7 according to the second embodiment, the bit inserter 710 inserts 12 bits in the 16 input data bits to

generate the 28 data bits I_k. The first and second constituent encoders 720 and 740 generate the 28 first parity bits C_k and the 28 second parity bits D_k, respectively. The multiplexer 750 punctures the 28 data bits I_k at 12 insert positions and then, inserts therein the surplus data bits, i.e., 4 surplus data bits, 4 surplus first parity bits and surplus 4 second parity bits. Thereafter, the multiplexer 750 sequentially outputs the data bits I_k, the first parity bits C_k and the second parity bits D_k.

In the decoding process, the output values of the multiplexer 750 are demultiplexed into a data bit portion, a first parity bit portion and a second parity bit portion, wherein the data bit portion is punctured with a value of -5 at the bit inserting portion. Such processed data bits are decoded by an existing decoder. (See Claude Berrou, Alain Glavieux and Punya Thitmajshima Near Shannon Limit Error-Correction Coding and Decoding: Turbo-Codes (1) .)

Third Embodiment

An encoder according to a third embodiment of the present invention inserts data bits having a specific logic among the data bits at bit positions having a higher than normal error occurrence probability, wherein the constituent encoders encode the specific bit-inserted data bits and generate tail bits to be added to encoded data bits. That is, the encoder according to the third embodiment performs the termination function by both bit insertion and tail bit

adding.

FIG. 10 is a diagram illustrating the encoder according to the third embodiment of the present invention. Referring to FIG. 10, a bit inserter 1010 receives 16 input bits and has the same structure as the bit inserter 310 according to the first embodiment. The bit inserter 1010 inserts 8 zero bits in each frame at 8 data bit positions having a higher than normal error probability, under the control of a undepicted controller. Accordingly, in this exemplary embodiment, the bit inserter 1010 outputs 24 data bits I_k, which are applied in common to a multiplexer 1050, a first constituent encoder 1020 and an interleaver 1030.

Further, the interleaved data bits I_k output from the interleaver 1030 are applied to a second constituent encoder 1040. The first constituent encoder 1020 is a recursive systemic constituent encoder shown in FIG. 11, having a structure for generating tail bits to be added to the encoded data bits. In addition, the first constituent encoder 1020 has a structure which does not generate the tail bits for termination, as that in FIG. 5 of the first embodiment.

Referring to FIG. 11, operation of the first constituent encoder 1020 will be described. For encoding, a switch 1111 connects an input node to an exclusive OR gate 1131, a switch 1113 maintains an OFF state, and a switch 1115 is connected to an exclusive OR gate 1135. Then, the 24 data bits I_k are sequentially applied to delays 1121-1127 via the switch 1111, the exclusive OR

gate 1131, and the exclusive OR gate 1135 outputs encoded data bits. When the data bits I_k are all encoded by the delays 1121-1127 and the exclusive OR gate 1135 in this manner, the switch 1111 is connected to exclusive OR gates 1133 and 1131, the switch 1113 is ON, and the switch 1115 is connected to the switch 1113. Then, zero bits are generated by exclusive ORing the outputs being fed back, stored in the delays 1121-1127 and output via the switch 1115. Here, the zero values stored in the delays 1121-1127 become the tail bits and are output through the switch 1115. The number of tail bits generated corresponds to the number of delays in the constituent encoder 1020. In FIG. 11, the constituent encoder 1020 generates 4 tail bits per frame and also generates encoded bits for the respective tail bits.

Accordingly, the first constituent encoder 1020 generates 24 first parity bits C_k and, upon processing the last data bit (i.e., the 24^{th} data bit), switch 1111 connected to the exclusive OR gate 1133, the switch 1113 is connected to the switch 1111 and the switch 1115 is connected to the switch 1113; the same process is repeated four times to generate 4 tail bits. Through this procedure, the 28 first parity bits C_k and the 4 tail bits are output to the multiplexer 1050.

In addition, the interleaver 1030 interleaves the 24 data bits I_k output from the bit inserter 1010 and provides the interleaved data bits to the second constituent encoder 1040. The second constituent encoder 1040 then encodes the interleaved data bits in the same manner as the first constituent encoder 1020 to

generate 24 second parity bits D_k, which are applied to the multiplexer 1050.

The interleaved data bits in the frame unit, output from the interleaver 1030, are encoded by the second constituent encoder 1040 which has the same structure as that shown in FIG. 5. The second constituent encoder 1040 is a recursive systemic convolutional encoder, as shown in FIG. 5. In addition, the second constituent encoder 1040 has a structure which does not generate the tail bits.

The multiplexer 1050 then punctures the data bits I_k, and inserts the 4 first parity bits C_k in the punctured positions, and selectively outputs the remaining 24 first parity bits C_k and the 24 second parity bits D_k.

FIG. 12 is a diagram illustrating the multiplexer 1050. Referring to FIG. 12, the multiplexer 1050 first receives the 24 data bits I_k output from the bit inserter 1010. A delay 1222 in the multiplexer 1050 then stores the received 24 data bits I_k.

Thereafter, the multiplexer 1050 receives the 28 first parity bits C_k output from the first constituent encoder 1020. A switch 1212 in the multiplexer 1050 then is connected to a delay 1224 until the first 24 bits out of the first parity bits C_k are received from the first constituent encoder 1020, and the delay 1224 stores the received first parity bits C_k. Subsequently, the switch 1212 is

connected to a delay 1226 until the remaining 8 bits out of the 32 first parity bits C_k are received from the first constituent encoder 1020, and the delay 1226 stores the remaining 8 bits of the first parity bits C_k.

Next, the multiplexer 1050 receives the 24 second parity bits D_k output from the second constituent encoder 1040. A delay 1228 in the multiplexer 1050 then stores the received 24 second parity bits D_k.

Such sequentially generated 24 data bits I_k, 28 first parity bits C_k and 24 second parity bits D_k are applied to the multiplexer 1050. The multiplexer 1050 then stores the sequentially received data bits I_k, first parity bits C_k and second parity bits D_k in corresponding delays in the order of reception, wherein the first 24 bits and the remaining 4 bits out of the 28 first parity bits C_k are separately stored in the corresponding delays. The delays 1222-1228 each are composed of cascaded memory elements and store the corresponding input bits until the above delay process is completed.

After the above delay process, a switch 1236 is connected to a switch 1234, and the switch 1234 is connected to delay 1222. Thus, an output of the delay 1222 is output via the switches 1234 and 1236. After a data bit at a pre-specified position is stored in the delay 1222 is output, the switch 1234 is connected to the delay 1226, maintaining connection with the switch 1236. Then, one of the surplus first parity bits stored in the delay 1226 is output via the

switches 1234 and 1236. That is, the data bit stored in the delay 1222 is punctured and the first parity bit stored in the delay 1226 is inserted in the punctured position. Thereafter, the switch 1234 is connected again to the delay 1222, maintaining connection with the switch 1236. The above operation is repeated 8 times to puncture eight data bits stored in the delay 1222 and insert in the punctured positions the surplus 8 first parity bits stored in the delay 1226. As a result, the 24 data bits I_k are punctured to insert the 8 first parity bits in the punctured positions (i.e., bit insert positions), thereby outputting 24 bits.

Thereafter, the switch 1236 is connected to an output of the delay 1224. Then, the 24 first parity bits C_k stored in the delay 1224 are output via the switch 1236. Next, the switch 1236 is switched to the delay 1228 to output the 24 second parity bits D_k stored in the delay 1228.

Referring to FIG. 13, in the encoder of FIG. 10 according to the third embodiment, the bit inserter 1010 inserts 8 bits in the 16 input data bits to generate the 24 data bits I_k. A recursive systemic constituent encoder which generates the tail bits, is used for the constituent encoder. In this case, the constituent encoder generates 32 data bits in total, composed of 24 encoded data bits, 4 tail bits and encoded data of the 4 tail bits. When outputting the 24 encoded data bits, the input data bits I_k are first punctured to insert the remaining 8 first parity bits (i.e., 4 tail bits and encoded data of 4 tail bits) in the bit punctured positions.

The channel coded specific bit-inserted symbols are transmitted through a channel, and a receiver then receives and decodes the channel coded symbols. In the decoding process, the output values of the multiplexer 1050 are demultiplexed into a data symbol portion, a first parity symbol portion and a second parity symbol portion, wherein the data symbol portion is punctured to insert therein a specific value of, for example, -5 at the bit inserting portion. Such processed data bits are decoded by an existing decoder. (See Claude Berrou, Alain Glavieux and Punya Thitmajshima Near Shannon Limit Error-Correction Coding and Decoding: Turbo-Codes (1) .)

In the respective embodiments stated above, it is assumed that the encoder inserts the specific bits at the latter portion of the data bit stream. That is, the encoder inserts the specific bits at an end portion of a frame data to be transmitted. Since the data bits input to the second constituent encoder of the channel encoder are interleaved by the interleaver prior to being applied to the second constituent encoder, the last position of the data bit input to the first constituent encoder may not coincide with the last position of the data bit input to the second constituent encoder. In addition, since the insert positions of the specific bits being input to the second constituent encoder depend on the size and type of the interleaver, there is a demand for a method which can determine the last portion of the data bit stream to be input to the first and second constituent encoders in the channel encoder.

The present invention provides a method for determining an insert position of a specific bit, which depends on the interleaver of the channel encoder. FIG. 14 illustrates a procedure for determining an insert position of the specific bit in the channel encoder. The flowchart of FIG. 14 describes a program to be performed by the channel encoder of FIG. 3. In the following description, a first constituent encoder corresponds to the first constituent encoder 320, a second constituent encoder corresponds to the second constituent encoder 340, and an interleaver corresponds to the interleaver 330. Further, the flowchart of FIG. 14 controls operation of the bit inserter 310 to insert the specific bits. When the bit inserter 310 has the structure of FIG. 4, the flowchart of FIG. 14 can be performed by a undepicted controller which controls the operation of the switch 434 in the bit inserter 310. That is, the program of FIG. 14 controls the switch 434 to designate an insert position of a specific bit such that the specific bit output from the bit generator 430 should be located at the last portion of the data bit stream.

Referring to FIG. 14, in step 141, the following are provided as input: a data bit number Ninfo, an MIL interleaver's size N_{MIL}, the number of specific bits to be inserted at the last position of the data bit input to the first constituent encoder (Pins1), the number of specific bits to be inserted at the last position of the data bit input to the second constituent encoder (Pins2), arrays Addrinfo[], and Addrdeint[] for storing data bit positions of deinterleaved data bits and variables, array Addrturbo[] for storing positions of the data bits, and variables i

and k initialized to "0". Thereafter, in step 142, it is determined whether the variable i is higher than the data bit number Ninfo. When i > Ninfo, the program proceeds to step 144; otherwise, the program goes to step 143. Step 143 is repeated as many times as the data bit number Ninfo. In step 143, the deinterleaved data bit positions Addrinfo[] are stored in the array Addrturbo[]. Step 143 is repeated as many times as the data bit number Ninfo to store all the data bit positions Addrinfo[] in the variables Addrturbo[] for storing positions of the data bits, and thereafter, the program proceeds to step 144 to initialize the variable i to "0".

After initialization of the variable i, it is determined in step 145 whether the variable i is higher than Pins1 the number of bits to be inserted at the last position of the data bit stream input to the first constituent encoder. Step 146 is repeated as many times as the number, Pins1, of bits to be inserted at the last position of the data bit stream. When i ≤ Pins1, the program proceeds to step 146 where the last position of the data bit stream input to the first constituent encoder is designated as an insert position of a specific bit and is then stored in a variable NTPOSi. When the above operation is repeated as many times as Pins1, the number of specific bits to be inserted at the last position of the data bit stream being input to the first constituent encoder, the process continues to step 147 where the position of the specific bit to be inserted at the last position of Pins1=4 data bits being input to the first constituent encoder is stored and thereafter, the variables k and j are initialized to zero.

After initialization of the variables k and j, it is determined in step 148 whether the variable k is higher than Pins2, the number of the specific bits to be inserted at the last position of the data bit stream being input to the second constituent encoder. Steps 149, 150 and 151 are repeated as many times as the number, Pins2, of specific bits to be inserted at the last position of the data bit stream. When $j \leq$ Pins2, the process continues to step 149 where the positions of the bits located at the last portion of the data bit stream being input to the second constituent encoder are selected as insert positions of the specific bits and stored in a variable ITPOSj. Thereafter, in step 150, it is determined whether the position values stored in the variable ITPOSj overlap the position values stored in the variable NTPSOi. That is, the variable ITPOSj stores the positional information of the specific bits to be inserted at the last position of the data bits being input to the second constituent encoder, and the variable NTPOSi stores the positional information of the specific bits to be inserted at the last position of the data bits being input to the first constituent encoder. Therefore, when the information stored in ITPOSj overlaps the information stored in the NTPOSi, it means that the same specific bits are overlappedly inserted at the last portion of the data bits being input to the firs and second constituent encoders.

Therefore, in step 150, it is judged whether the positions, stored in ITPOSj, of the bits to be inserted at the last position of the data bits being input to the second constituent encoder overlaps with the positions which were selected and stored in NTPOSi at step 146. When ITPOSj overlaps with NTPOSi, the

variable k is increased by one in step 153. After increment of the variable k, the program returns to step 148. Therefore, when the positions of the specific bits to inserted at the last positions of the data bits being input to the first and second constituent encoders overlap each other, insert positions of other specific bits to be inserted at the last position of the data bits being input to the second encoder are stored in ITPOSj and then, the step 150 is performed again to determine whether the bit positions stored in ITPOSj overlap with the bit positions stored in NTPOSi. When the bit positions stored in ITPOSj do not overlap with the bit positions stored in NTPOSi, the variables k and j are increased by one in step 151, respectively. Thereafter, the program returns to step 148. The steps 148 to 153 are repeated as many times as Pins2. After repetition of the above steps as many times as Pins2 (i.e., when $j > Pins2$), the step 148 proceeds to step 152 where are output the variables ITPOSk and NTPOSk in which the insert positions of the specific bits are stored.

Therefore, in steps 148 and 152, when the bit positions stored in ITPOSj overlap with the insert positions of the specific bits stored in NTPOSi, the position of a specific bit to be inserted at the last portion of the data bit stream being input to the second constituent encoder is shifted to be designated to the other position. However, when they do not overlap each other, the designated position located at the last position of the data bit stream being input to the second constituent encoder is maintained, as it is. In the embodiment, when the bit positions stored in ITPOSj overlap with the insert positions of the specific bits,

stored in NTPOSi, the specific bit insert position of the data bit stream being input to the second constituent encoder is changed. However, it is also possible to change the specific bit insert position of the data bit stream being input to the first constituent encoder.

For a better understanding of the program shown in FIG. 14, a detailed description will now be made as to how the program actually determines the insert position of the specific bit according to the interleaver.

First, if it is assumed that the input data bit stream has a length of 16 bits and the number of the specific bits to be inserted is 8, the size of the interleaver in use becomes (the length of data bit stream) + (the number of the specific bits to be inserted) =16+8=24 bits. Therefore, it will be assumed herein that the interleaver has a length of 24 bits, as shown in Table 5.

TABLE 5

0 6 12 18 1 7 13 19 2 8 14 20 3 9 15 21 4 10 16 22 5 11 17 23

Table 5 shows the positions of the bits arranged in the order they are output from the interleaver. That is, "0" appearing at the first bit position means that a 0-th input bit is first output; "6" appearing at the second bit position means that a sixth input bit is output next; and "12" appearing at the third bit position means that a twelfth input bit is output next.

With reference to FIG. 14, a description will be made regarding a method for determining the insert positions for the interleaver. In step 141, the length of the data bit stream is input as Ninfo=16, an MIL interleaver's size N_{MIL}=24, the number of specific bits to be inserted at the end of the data bit stream input to the first constituent encoder (Pins1=4), the number of specific bits to be inserted at the end of the data bit stream input to the second constituent encoder (Pins2=4), data bit positions Addrinfo[24], positions of deinterleaved data bits, and variables Addrdeinst[24], Addrturbo[24] for storing positions of the data bits, and variables i and k are initialized to "0".

Thereafter, in step 142, it is determined whether the variable i is higher than the data bit number Ninfo=16. When i > Ninfo(=16), the program proceeds to step 144; otherwise, the program goes to step 143. At this point, step 143 is repeated 16 times which correspond to the data bit number Ninfo=16, and the 16 data bit positions Addrinfo[16] are sequentially stored in the array Addrturbo[16]. Thereafter, the program proceeds to step 144 to initialize the variable i to "0".

After initialization of the variable i, it is determined in step 145 whether the variable i is higher than the number of bits to be inserted at the end of the data bit stream input to the first constituent encoder (Pins1=4). Step 146 is repeated as many times as the number (Pins1=4) of bits to be inserted at the end of the data bit stream. When i ≤ Pins1(=4), the program proceeds to step 146

where the last position of the data bit stream input to the first constituent encoder is designated as an insert position of a specific bit and is then stored in variables NTPOSi. That is, the positions of the last 4 bits prior to interleaving are stored in the variables NTPOSi. When the above operation is repeated as many times as the number, Pins1=4, of specific bits to be inserted at the last position of the data bit stream being input to the first constituent encoder, the process ocntinues to step 147 where the position of the specific bit to be inserted at the last position of Pins1=4 data bits being input to the first constituent encoder is stored and thereafter, the variables k and j are initialized to zero. Shown in Table 6 are positions of the 4 bits inserted at the last position of the data bit frame prior to interleaving (i.e., 20, 21, 22 and 23).

TABLE 6

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 **20 21 22 23**

Next, it is determined in step 148 whether the variable k is higher than the number, Pins2=4, of specific bits to be inserted at the last position of the data bit stream being input to the second constituent encoder. Steps 149, 150 and 151 are repeated four times which correspond to the number of the specific bits to be inserted at the last position of the data bit stream (Pins2=4). When $j \leq$ Pins2(=4), the process continues to step 149 where the positions of the last 4 bits located at the last portion of the data bit stream being input to the second

constituent encoder are selected as insert positions of the specific bits and stored in variables ITPOSj. Table 7 shows the insert positions of the last 4 bits, shown in Table 6, determined for the first constituent encoder prior to interleaving, together with the insert positions of the last 4 bits determined for the second constituent encoder after interleaving.

TABLE 7

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Here, the insert positions of the last 4 bits prior to interleaving, determined for the first constituent encoder, are {20, 21, 22, 23}, and the insert positions of the last 4 bits after interleaving, determined for the second constituent encoder, are {5, 11, 17, 23}. It is noted that an insert position "23" out of the determined insert positions are only insert position "23" is overlapped. Therefore, the total number of the determined insert positions is not 8 but 7. Accordingly, in order to determine one more bit, it is determined in step 150 whether the positions, stored in the variable ITPOSj, of the bits to be inserted at the last position of the data bit stream being input to the second constituent encoder overlap the positions which are selected in step 146 and stored in the variable NTPSOi. Here, since the 23rd position is overlapped in Tables 6 and 7, the program proceeds to step 148 through step 151. Then, the process continues to step 149 where another insert position of a bit to be inserted at the last position

of the data bit stream being input to the second constituent encoder is stored in ITPOSj to determine a 19th bit position as an insert position. Thereafter, in step 150, it is determined again whether the bit positions stored in ITPOSj overlaps with the bit positions stored in NTPOSi. Here, since the 19th bit position is not overlapped, this selected position is constantly stored. Thereafter, the steps 148, 149, 150, 151 and 153 are repeated as many times as Pins2. After repetition of the above steps, the variables ITPOSk and NTPOSk are output, which store the stored insert positions, in step 152. Table 8 shows the 8 insert positions output from the variables ITPOSk and NTPOSk.

TABLE 8

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Here, the program of FIG. 14 can be expressed as:

```
<Step1>
Store input (information) bits
  i = 0
  do while i < Ninfo
    Addrturbo[i] = Addrinfo[i]
    i = i + 1
  end do
```

```
<Step2>
  i = 0
  do while i < Pins1
    NTPOSi = Addrturbo[NMIL- 1 - i] ; insertion positions for end part of
RSC1 input
    insert zero bits to the Addrturbo[NTPOSi]  ; insert known (e.g., 0) bits to
the
    i = i + 1
  end do                          ; pre-determined positions

<Step3>
  k = 0
  j = 0
  do while j < Pins2
    ITPOSj = Addrdeint[NMIL- 1 - k]  ; insertion positions for end part of
RSC2 input
    if (ITPOSj = ((NTPOSi) || {ITPOS0, ITPOS1, ... , ITPOSk-1})) ;exclude
overlapping
      ITPOSj = ITPOSk + m                ; for the pre-processed positions
      k = k + 1
    else                              ; m is certain integer value
      insert zero bit to the Addrturbo[ITPOSk]
      k = k + 1
```

```
        j = j + 1
    end do
```

Legend:

| | : or

As described above, the novel channel encoder including the recursive systemic constituent encoders can perform a channel coding function using a frame structure having the termination effect.

While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

CLAIMS :

1. A turbo coding device comprising:

a bit inserter for inserting at least one specific data bit at a last position of a data bit stream being input to a first constituent encoder, and inserting at least one specific data bit at a last position of an interleaved data bit stream being input to a second constituent encoder;

the first constituent encoder for encoding the bit-inserted data bit stream to generate first parity symbols;

an interleaver for interleaving the bit-inserted data bit stream;

the second constituent encoder for encoding the interleaved data bit stream to generate second parity symbols; and

a multiplexer for multiplexing outputs of the bit inserter, the first constituent encoder and the second constituent encoder.

2. The turbo coding device as claimed in claim 1, wherein the bit inserter inserts at least two specific data bits, wherein half of the specific data bits are inserted at the end of the data bit stream being input to the first constituent encoder and a remaining half of the specific data bits are inserted at the end of the data bit stream being input to the second constituent encoder.

3. The turbo coding device as claimed in claim 2, wherein the bit inserter shifts forward a position of a specific bit to be inserted in the second

constituent encoder, when a position of a specific bit to be inserted in the first constituent encoder overlaps with a position of a specific bit to be inserted in the second constituent encoder.

4. A method for inserting a specific bit in a turbo coder having a first constituent encoder for encoding received data bits to generate first parity symbols, an interleaver for interleaving the specific bit-inserted data bits, and a second constituent encoder for encoding the interleaved data bits to generate second parity symbols, the method comprising the steps of:

storing positions of the data bits having the same size as a size of a received frame;

inserting a predetermined number of specific bits at a last position of data bits being input to the first constituent encoder; and

determining a last position of data bits being input to the second constituent encoder after interleaving, and inserting the predetermined number of specific bits at the determined last position.

5. The method as claimed in claim 4, wherein the number of the specific bits inserted in the first constituent encoder is identical to the number of the specific bits inserted in the second constituent encoder.

6. The method as claimed in claim 4, wherein a position of a

specific bit to be inserted in the second constituent encoder is shifted forward, when a position of a specific bit to be inserted in the first constituent encoder overlaps with a position of a specific bit to be inserted in the second constituent encoder.

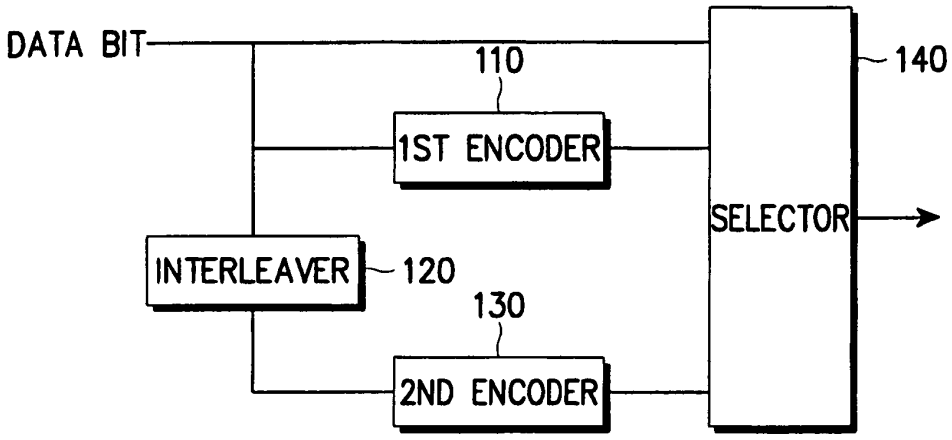

DATA BIT
110
1ST ENCODER
140
SELECTOR
INTERLEAVER
120
130
2ND ENCODER

FIG. 1

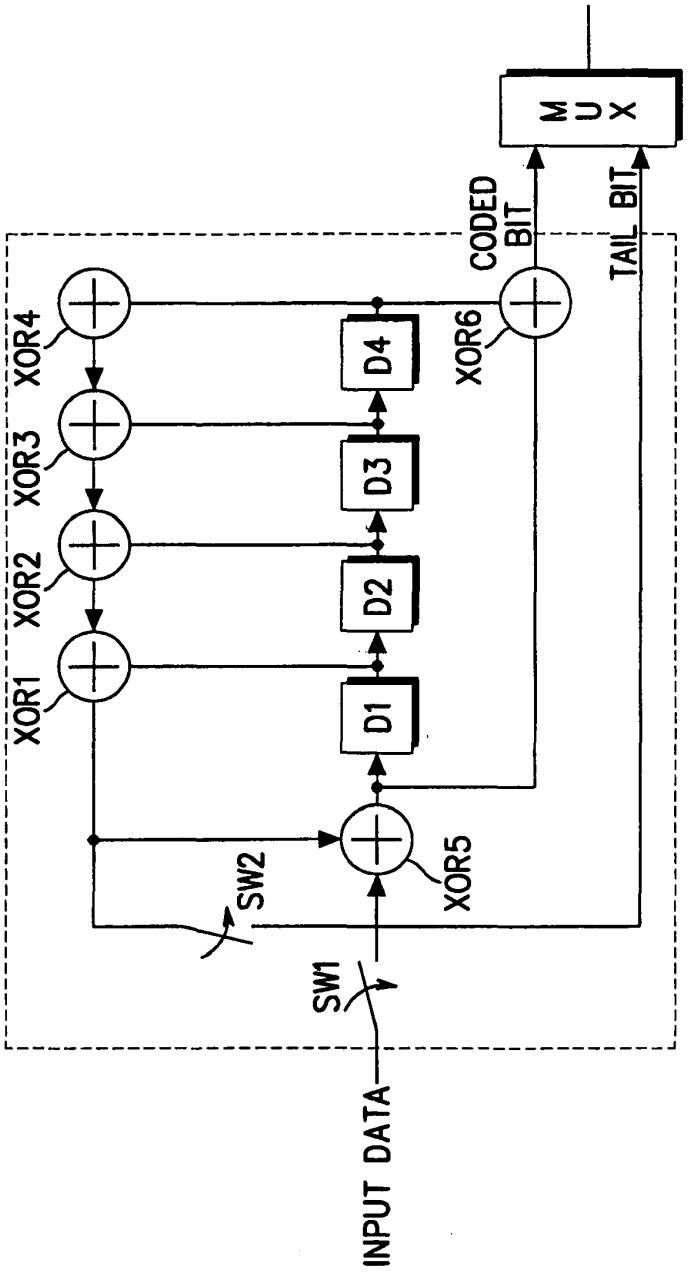

MUX
CODED BIT
TAIL BIT
XOR4
XOR3
XOR2
XOR1
XOR6
XOR5
D4
D3
D2
D1
SW2
SW1
INPUT DATA

FIG. 2

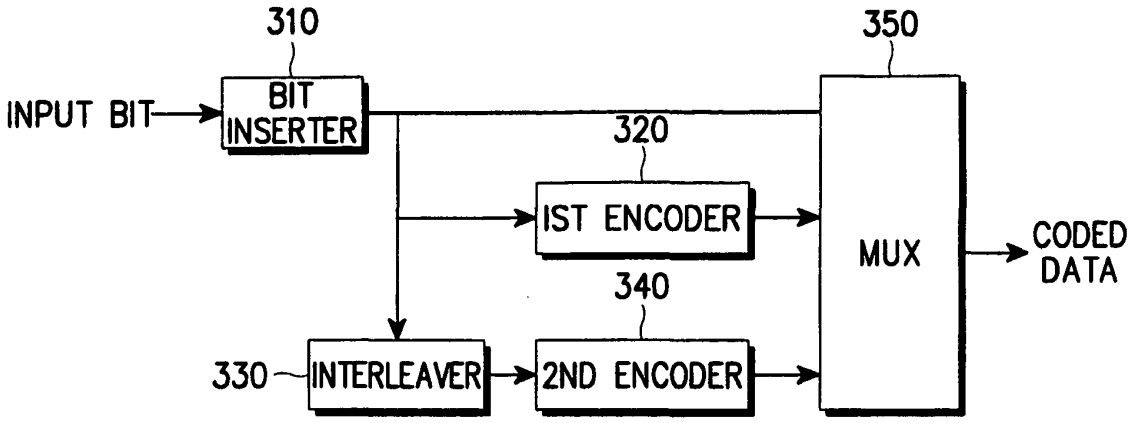

310
350
INPUT BIT
BIT INSERTER
320
IST ENCODER
MUX
CODED DATA
340
330
INTERLEAVER
2ND ENCODER

FIG. 3

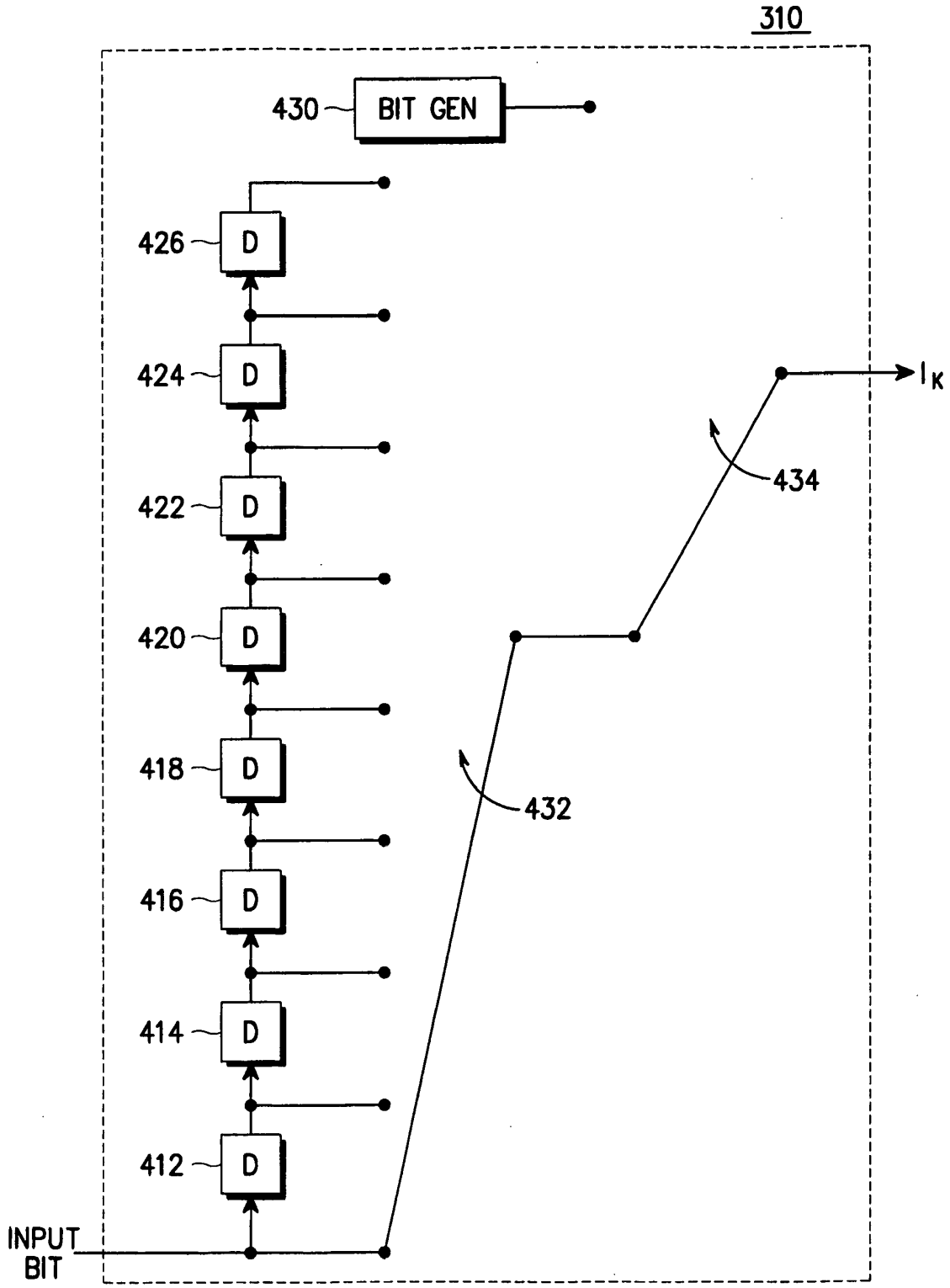

310
430
BIT GEN
426
424
422
420
418
416
414
412
D
I_K
434
432
INPUT BIT

FIG. 4

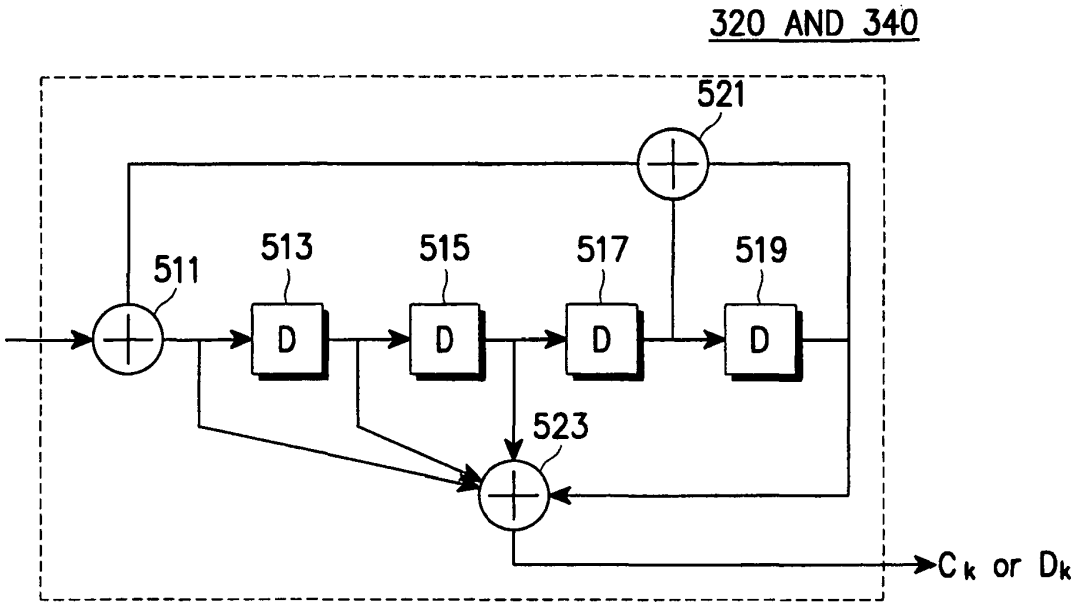


FIG. 5

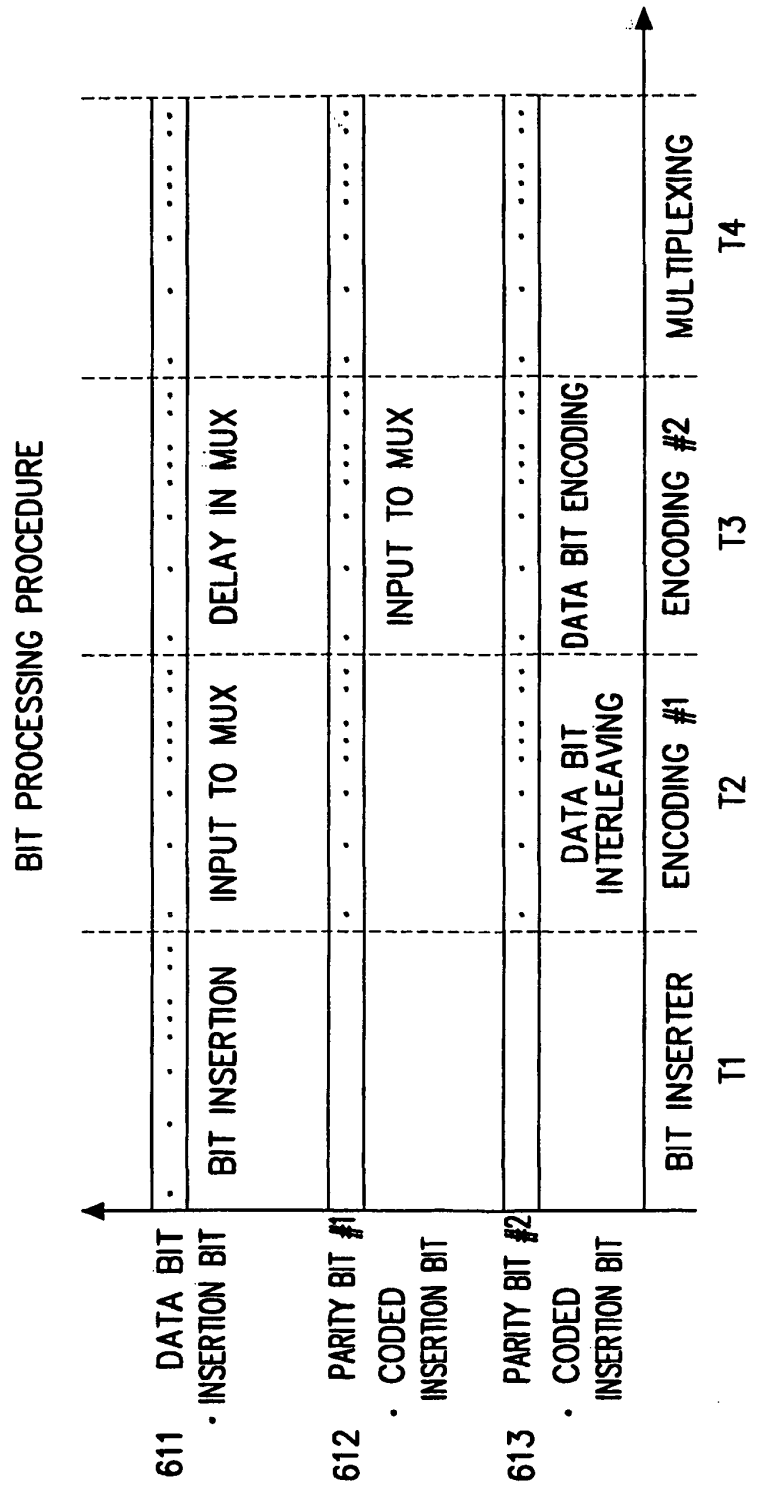

BIT PROCESSING PROCEDURE
611 DATA BIT
• INSERTION BIT
612 PARITY BIT #1
• CODED
INSERTION BIT
613 PARITY BIT #2
• CODED
INSERTION BIT
BIT INSERTION
INPUT TO MUX
DELAY IN MUX
INPUT TO MUX
DATA BIT
INTERLEAVING
ENCODING #1
DATA BIT ENCODING
ENCODING #2
MULTIPLEXING
BIT INSERTER
T1
T2
T3
T4

FIG. 6

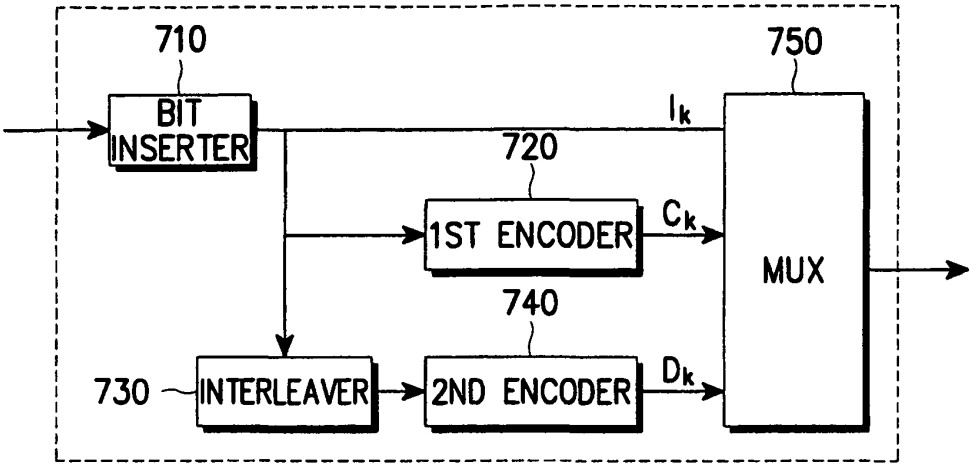

710
BIT INSERTER
750
I_k
720
1ST ENCODER
C_k
MUX
740
730
INTERLEAVER
2ND ENCODER
D_k

FIG. 7

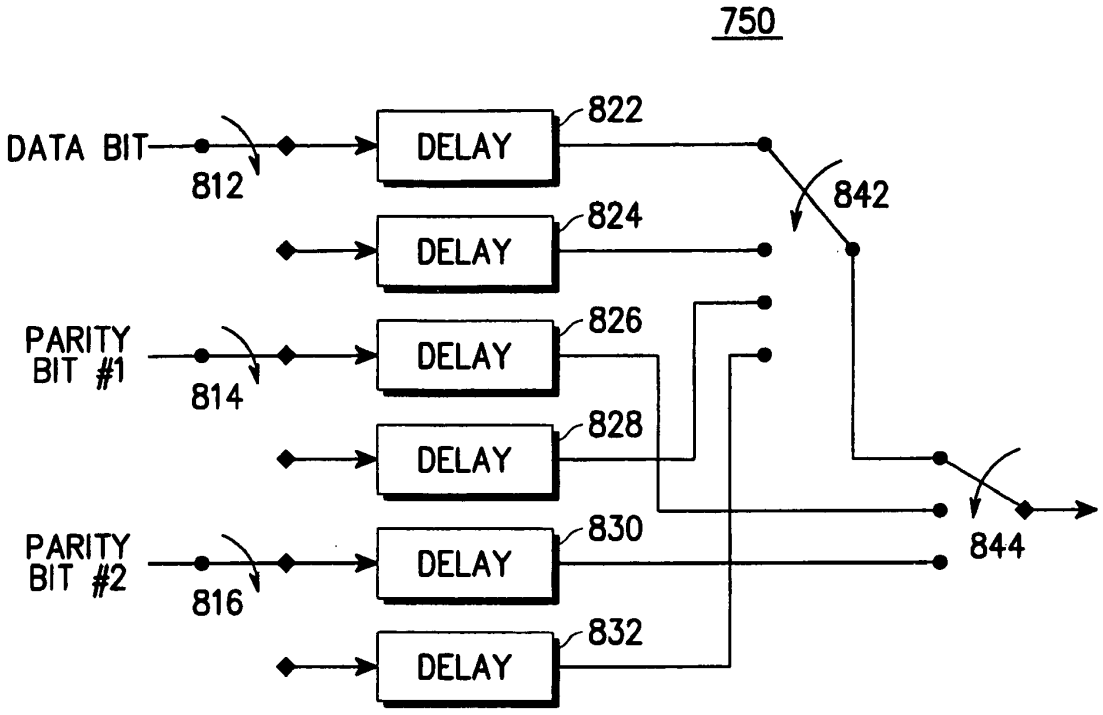

750
DATA BIT
812
DELAY
822
DELAY
824
842
PARITY BIT #1
814
DELAY
826
DELAY
828
PARITY BIT #2
816
DELAY
830
DELAY
832
844

FIG. 8

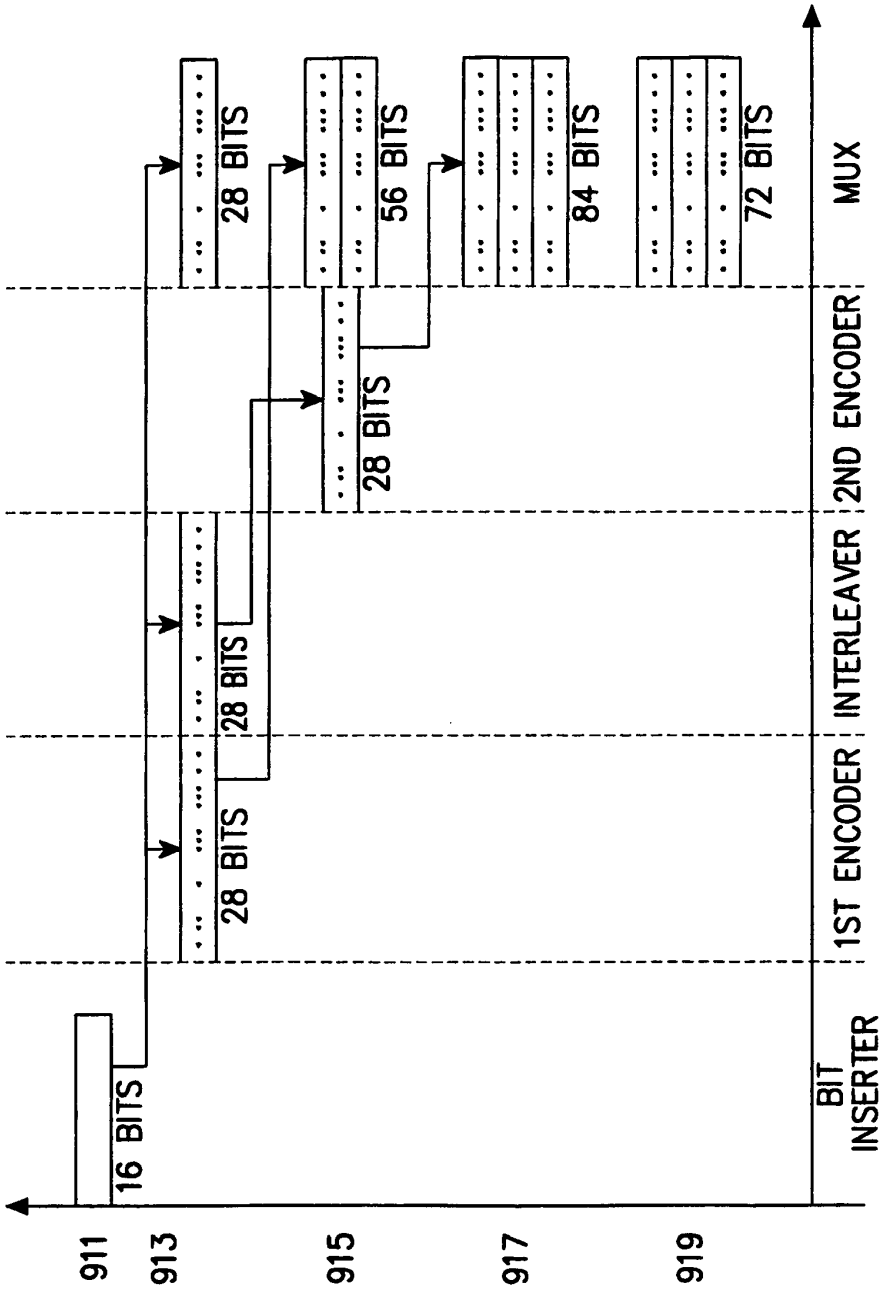

911
913
915
917
919
16 BITS
28 BITS
28 BITS
28 BITS
28 BITS
56 BITS
84 BITS
72 BITS
BIT INSERTER
1ST ENCODER
INTERLEAVER
2ND ENCODER
MUX

FIG. 9

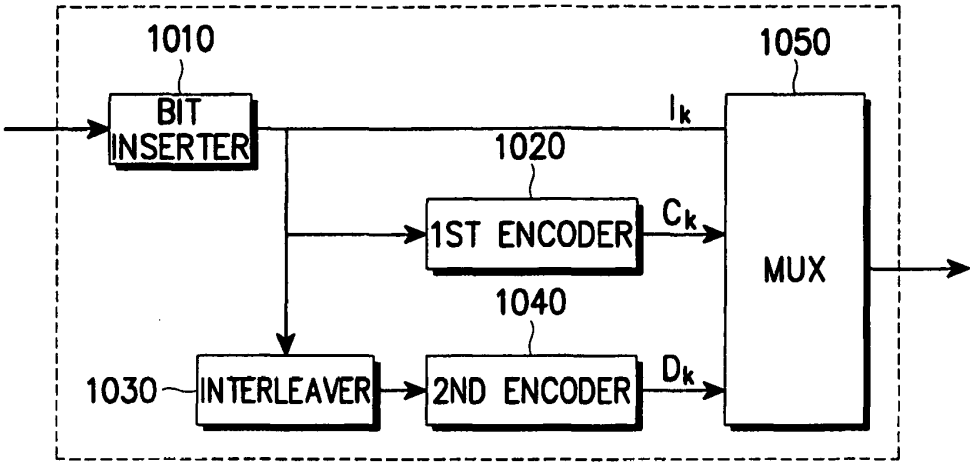

1010
BIT INSERTER
1050
I_k
1020
1ST ENCODER
C_k
MUX
1040
1030
INTERLEAVER
2ND ENCODER
D_k

FIG. 10

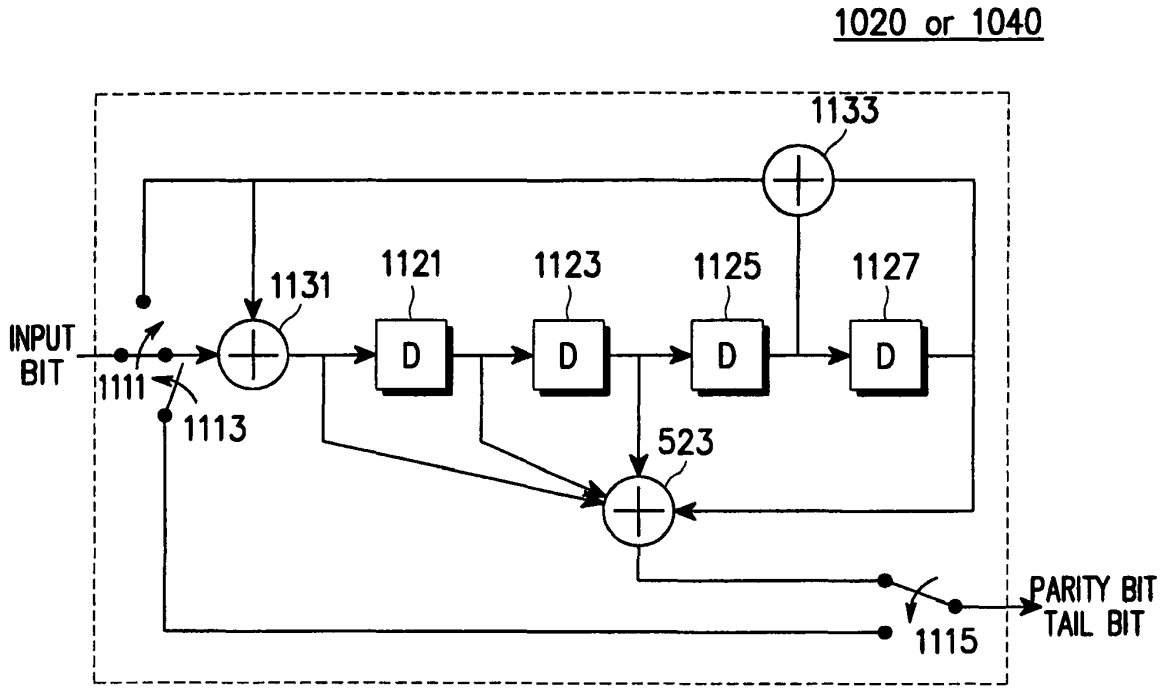

1020 or 1040
1133
1131
1121
1123
1125
1127
INPUT BIT
1111
1113
D
D
D
D
523
PARITY BIT TAIL BIT
1115

FIG. 11

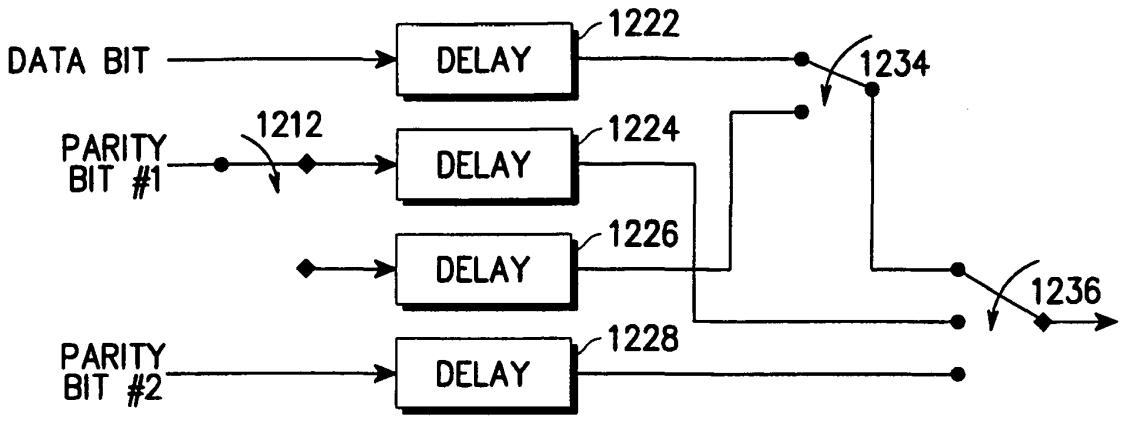

DATA BIT
DELAY
1222
1234
PARITY BIT #1
1212
DELAY
1224
DELAY
1226
1236
PARITY BIT #2
DELAY
1228

FIG. 12

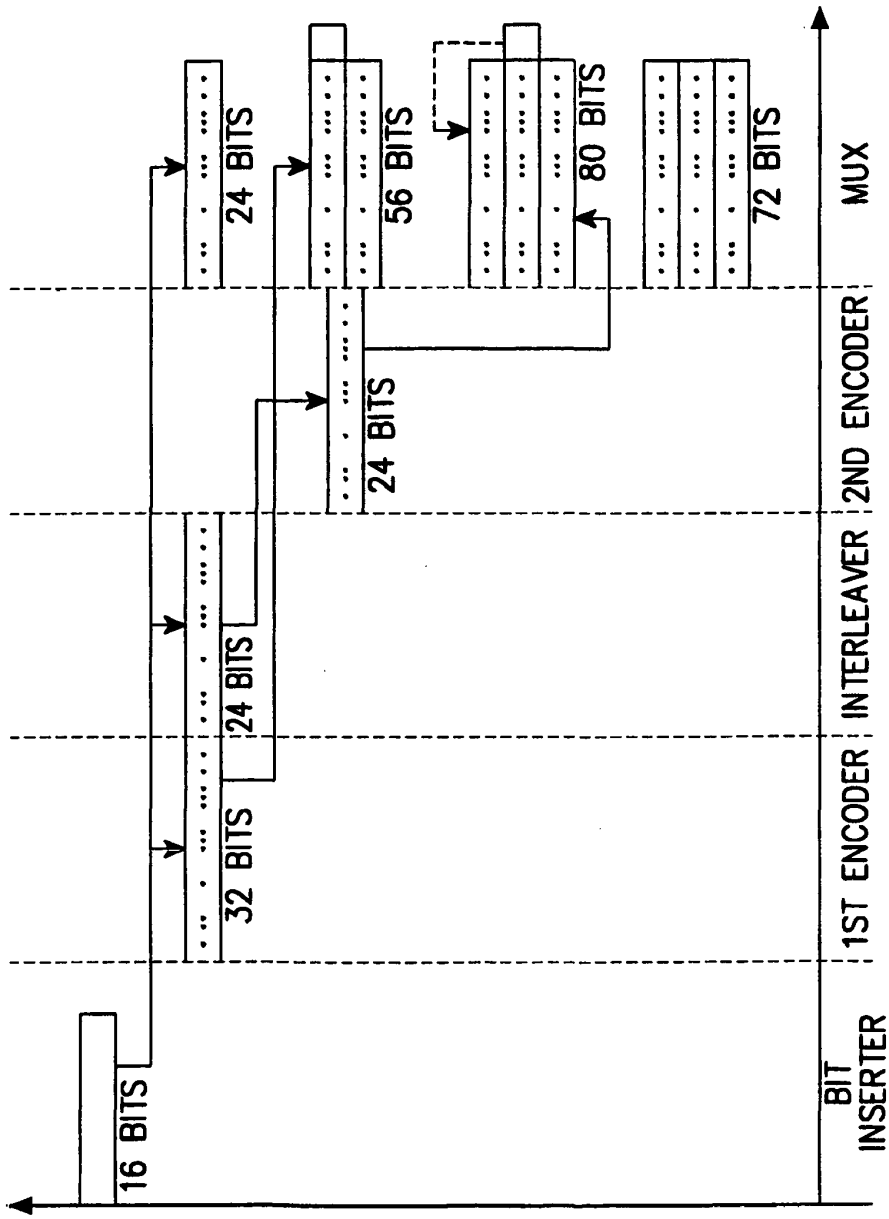

16 BITS
32 BITS
24 BITS
24 BITS
56 BITS
80 BITS
72 BITS
BIT INSERTER
1ST ENCODER
INTERLEAVER
2ND ENCODER
MUX

FIG. 13

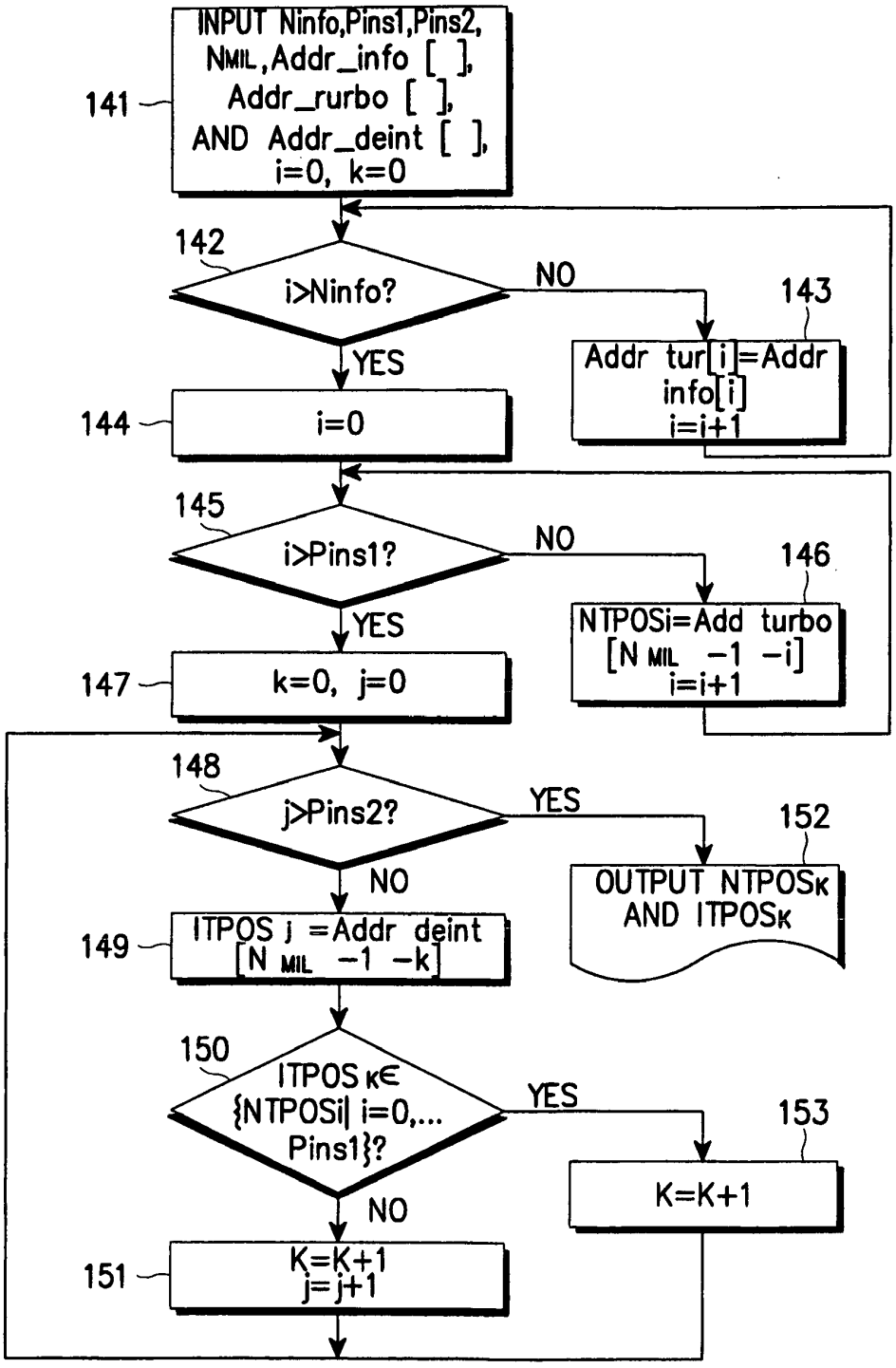

INPUT Ninfo,Pins1,Pins2, NMIL,Addr_info [ ], Addr_rurbo [ ], AND Addr_deint [ ], i=0, k=0
141
142
i>Ninfo?
NO
143
Addr tur[i]=Addr info[i] i=i+1
YES
144
i=0
145
i>Pins1?
NO
146
NTPOSi=Add turbo [N MIL -1 -i] i=i+1
YES
147
k=0, j=0
148
j>Pins2?
YES
152
OUTPUT NTPOSK AND ITPOSK
NO
149
ITPOS j =Addr deint [N MIL -1 -k]
150
ITPOS K∈ {NTPOSi| i=0,... Pins1}?
YES
153
K=K+1
NO
151
K=K+1 j=j+1

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR 99/00472

A. CLASSIFICATION OF SUBJECT MATTER

IPC[7]: H 03 M 13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC[7]: H 03 M 13/00, 13/12, 13/22; G 06 F 11/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
T	EP 0952673 A1 (NTT MOBILE COMMUNICATIONS NETWORK) 27 October 1999 (27.10.99) description.	1-6
A,P	GB 2330501 A (SAMSUNG ELECTRONICS) 21 April 1999 (21.04.99) description, fig. 4.	1-6
A	US 5446747 A (C. BERROU) 29 August 1995 (29.08.95) description.	1-6

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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„Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
„&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 October 1999 (29.10.99)	13 December 1999 (13.12.99)

Name and mailing adress of the ISA/AT	Authorized officer
Austrian Patent Office Kohlmarkt 8-10; A-1014 Vienna Facsimile No. 1/53424/200	Zugarek Telephone No. 1/53424/383

Form PCT/ISA/210 (second sheet) (July 1998)

Information on patent family members

International application No.
PCT/KR 99/00472

Im Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
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GB A 2330501		CN A 1213232 GB A0 9816552 GB A1 2330501 GB B2 2330501 JP A2 11145936	07-04-1999 30-09-1998 21-04-1999 10-11-1999 28-05-1999
US A 5446747	29-08-1995	DE C0 69215743 DE T2 69215743 EP A1 511141 EP A2 735696 EP B1 511141 EP A3 735696 FR A1 2675971 FR B1 2675971 HK A1 1007841	23-01-1997 10-07-1997 28-10-1992 02-10-1996 11-12-1996 13-01-1999 30-10-1992 06-08-1993 23-04-1999

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

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(30) Priority Data:
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(71) Applicant: SAMSUNG ELECTRONICS CO., LTD. [KR/KR]; 416, Maetan-dong, Paldal-gu, Suwon-shi, Kyungki-do 442-370 (KR).

(72) Inventors: LEE, Young-Hwan; 237-7, Chongja-dong, Puntang-gu, Songnam-shi, Kyonggi-do 463-010 (KR). KIM, Min-Goo; 973-3, Youngtong-dong, Paltal-gu, Suwon-shi, Kyonggi-do 442-470 (KR). KIM, Beong-Jo; 201, Kumi-dong, Puntang-gu, Songnam-shi, Kyonggi-do 463-500 (KR).

(74) Agent: LEE, Keon-Joo; Mihwa Building, 110-2, Myon-gryun-dong 4-ga, Chongro-gu Seoul 110-524 (KR).

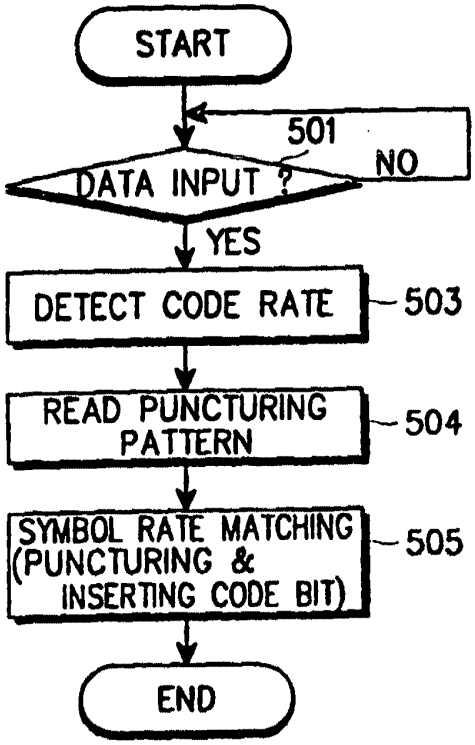
(81) Designated States: BR, CA, CN, IN, JP, RU, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: PUNCTURING DEVICE AND METHOD FOR TURBO ENCODER IN MOBILE COMMUNICATION SYSTEM

(57) Abstract

A puncturing device for a turbo encoder in a mobile communication system having a turbo encoder which turbo encodes input source data into a plurality of information frames and tail symbols at a given code rate is disclosed. The puncturing device comprises a frame generator for generating a transmission frame by performing puncturing and adding invalid symbols; and a controller for performing puncturing on the information frames according to the code rate, puncturing the tail symbols only when the number of punctured information frames and tail symbols exceeds a bit number according to a symbol rate, and otherwise, controlling the frame generator by reading a puncturing pattern according to the code rate and information about the number of invalid symbols.



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PUNCTURING DEVICE AND METHOD FOR TURBO ENCODER IN MOBILE COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a puncturing device and method for a turbo encoder in a mobile communication system, and in particular, to a puncturing device and method for minimizing puncturing of tail symbols.

2. Description of the Related Art

In mobile communication systems such as satellite, ISDN (Integrated Services Digital Network), digital cellular, W-CDMA (Wideband Code Division Multiple Access) and IMT-2000 communication systems, a channel codec punctures encoded data in order to match symbol rates during transmission of data having different data rates. In particular, the IMT-2000 system can use either a convolutional encoder or a turbo encoder. However, in either case, the rates of the output symbols should be identical to one another because an interleaver typically follows the encoder and has the same memory capacity for storing the symbols.

Generally, the number of output nodes of the convolutional encoder is equal to a code rate. However, in the turbo specific encoder, the number of output nodes is not equal to the code rate and therefore puncturing should be performed to match the code rate. At this point, the tail symbols output from the turbo encoder are also punctured according to the same puncturing pattern as that used for the parity part of the code symbol.

In the convolutional encoder and the turbo encoder, the number of tail symbols required for termination varies depending on the code rate. For example, a constraint length K=9 convolutional encoder requires (8×(1/code rate)) tail symbols, Column A of Table 1, and a K=4 turbo encoder requires 3×6=18 tail symbols regardless of the code rate (when using two component encoders and

separate termination), Column B of Table 1. Therefore, turbo encoder has extra symbols (or reserved symbols, Column C of Table 1) except for the case of the code rate 1/2, as compared with the convolutional encoder. The extra symbols correspond to the difference between Columns A and B and are equal to 0 if negative. When using the turbo encoder, for symbol rate matching, invalid information ('0' or '1' which is known to the receiving side) is added to the reserved symbols to create a frame. Herein, the invalid information added for symbol rate matching will be referred to as invalid symbols. Column Cof Table 1 below shows the invalid number of symbols.

[Table 1]

Code Rate	Tail Symbols for Convolutional Code (A)	Tail Symbols for Turbo Code (B)	Reserved Symbol Number (C)
R=1/2	16(= 8 × 2)	18(= 3 × 6)	0 bit
R=1/3	24(= 8 × 3)	18(= 3 × 6)	6 bits
R=1/4	32(= 8 × 4)	18(= 3 × 6)	14 bits

FIG. 1 shows a conceptional block diagram of a common turbo encoder. A description will be made of an operation of puncturing a turbo code, with reference to FIG. 1.

The turbo encoder comprises a first encoder 110, an interleaver 130 and a second encoder 120, and receives an L-bit information frame X. The first encoder 110 encodes the L-bit one information frame X, which is source data, into a first systematic symbol L, a first L-bit parity symbol Y0, a second L-bit parity symbol Y1, and m bit tail symbols for each of the parity signals Y0, Y1 and m tail symbols for first systematic symbol X. The m tail symbols for first systematic symbol L are a tail bit itself, generated by first encoder terminating memory of the encoder. The m tail symbols are generated when the first encoder receives the last three bits of the tail bit, thereby to reset a shift register in the first encoder 110. Further, the information frame X is output, as it is, without coding, and only the m tail symbols for the information frame X are created by the first encoder 110. The interleaver 130 interleaves the input one frame data X and outputs

interleaved source data X'. The second encoder 120 encodes the interleaved source data X' into a third parity symbol Y'0, a fourth parity symbol Y'1, and m tail symbols for each of the parity symbol Y'0, Y'1 and m tail symbols for second systematic symbol L'. The m tail symbols for second systematic symbol L' are a tail bit itself, generated by second encoder terminating memory of the encoder. The second encoder can output second systematic symbol X', but all of the second systematic symbol X' is punctured at all of the code rate. Therefore, it is equal to do not output the second systematic symbol X'. In this specification, we describe the turbo encoder outputs several coded symbol frames X, Y0, Y1, Y'0 and Y'1 in response to an input frame, and excluding the interleaved information frame X', and m tail symbols for each of the signals X, Y0, Y1, Y'0, Y'1 and X'. Commonly, there are provided 3 tail symbols for each of the coded symbol frame. However, it is also possible to output the interleaved frame X', as it is, and then delete it in the following stage by puncturing.

Such a turbo encoder internally creates the five coded symbol frames and six set of tail symbols using one input information frame. The five coded symbol frames and six set of tail symbols should undergo the same puncturing pattern during creation of a transmission frame, for transmission at a previously defined code rate.

For code rate matching, the proposed IMT-2000 system performs select (inversely say puncturing) as shown in Table 2.

[Table 2]

	R=1/2	R=1/3	R=1/4
X(t) & X(t) (Tail Bit)	t=m+1	t=m+1	t=m+1
Y0(t)	None	None	t=m+2
Y1(t)	Alternate at t=m+2	t=m+2	Alternate at t=m+3
X'(t) (Info Frame)	None	None	None
X'(t) (Tail Bit)	t=m+3 (when tail bit X'(t) selection)	t=m+4	t=m+5
Y'0(t)	None	None	t=m+4
Y'1(t)	Alternate at t=m+2	t=m+3	Alternate at t=m+3

In Table 2, 'm' denotes a given time point, and 'i' in m+i (i=1,2,3,4,5,..)

denotes the order of selection at the time m. For example, for a code rate R=1/2, at the time m, the systematic frame X is first selected, the encoded information frame Y0 is punctured all, and one of the encoded symbols Y1 and Y'1 is selected and the non selected one (Y1 OR Y'1) is punctured. Further, after the tail symbols for the systematic frame X are selected, one of the tail symbols for the encoded parity symbol frames Y1 and Y'1 are selected and the non selected one (Y1 OR Y'1) is punctured and thereafter, the tail symbols for the interleaved frame X' are selected. After puncturing in this manner, multiplexing is performed to transmit the frame.

FIGS. 2A to 2C show puncturing methods according to Table 2, for R=1/2, 1/3 and 1/4, respectively. In the drawings, the hatched boxes denote the tail symbols, and the 'X'-marked boxes denote the punctured bits. The boxes corresponding to X'(t) are surrounded by a dashed line as they are not output. This can be expressed with the factors output from the turbo encoder as follows, wherein the underlined factors denote the punctured factors (i.e. not selected).

1) For the case of R =1/2:

X(0),Y0(0),Y1(0),Y'0(0),Y'1(0), X(1),Y0(1),Y1(1)Y'0(1),Y'1(1),....,
X(L-1),Y0(L-1),Y1(L-1),Y'0(L-1),Y'1(L-1),
T1(0),TP11(0),TP12(0),T2(0),TP21(0),TP22(0),
T1(1),TP11(1),TP12(1),T2(1),TP21(1),T22(1)...
T1(m-1),TP11(m-1),TP12(m-1),T2(m-1),TP21(m-1),T22(m-1)

where T1 is tail symbol for systematic symbol, TP11 is tail parity for parity Y0 , TP12 IS tail parity for parity Y1, TP21 is tail parity for Y'0, TP22 is tail parity for Y'1.

2) For the case of R=1/3:

X(0),Y0(0),Y1(0),Y'0(0),Y'1(0), X(1),Y0(1),Y1(1),Y'0(1),Y'1(1), ..,
X(L-1),Y0(L-1),Y1(L-1),Y'0(L-1),Y'1(L-1),
T1(0),TP11(0),TP12(0),T2(0),TP21(0),T22(0),...
T1(m-1),TP11(m-1),TP12(m-1),T2(m-1),TP21(m-1),T22(m-1),
RVB(0),RVB(1).....,RVB(h).

where RVB() means reserved bits.

3) For the case of R=1/4:

X(0),Y0(0),Y1(0)Y'0(0),Y'1(0), X(1),Y0(1),Y1(1),Y'0(1),Y'1(1), ... ,

X(L-2),Y0(L-2),Y1(L-2),Y'0(L-2),Y'1(L-2),
X(L-1),Y0(L-1),Y1(L-1),Y'0(L-1),Y'1(L-1),
T1(0),TP11(0),TP12(0),T2(0),TP21(0),T22(0),
T1(1),TP11(1),TP12(1),T2(1),TP21(1),T22(1)...
T1(m-1),TP11(m-1),TP12(m-1),T2(m-1),TP21(m-1),T22(m-1),
RVB(0),RVB(1).....,RVB(h).

Table 1 has shown the number of the reserved symbols at every code rate, and Table 2 has shown the puncturing methods. As shown in Tables 1 and 2, even when the tail symbols of the turbo code are punctured, the reserved symbols are generated except for the case of R=1/2. When the tail symbols are punctured, 6 invalid symbols are inserted for R=1/3 as shown in FIG. 2B, and the 3 tail symbols are punctured, 14 invalid symbols are inserted for R=1/4 as shown in FIG. 2C and Table 1.

As described above, even though there remain the reserved symbols, a method for puncturing the encoded information frame is equally applied to the tail symbols in order to match a rate of the symbols added to increase a decoding accuracy, thereby decreasing the decoding capability of the receiver.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a puncturing device and method for a turbo encoder, which minimizes or avoids puncturing of tail symbols using reserved symbols generated while performing turbo encoding.

It is another object of the present invention to provide a selection(puncturing) device and method for a turbo encoder, witch selection(puncturing) rule is different at the coded symbol frame period and tail symbol selection period for minimize puncturing of tail symbol.

To achieve the above object, there is provided a puncturing device for a turbo encoder in a mobile communication system having a turbo encoder which turbo encodes input source data into a plurality of coded symbol frames and tail symbols at a given code rate. The puncturing device comprises a frame generator for generating a transmission frame by performing puncturing and adding invalid

symbols; and a controller for performing puncturing on the symbol frames according to the code rate, puncturing the tail symbols only when the number of selected symbol frames and tail symbols exceeds a bit number according to a symbol rate.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a block diagram illustrating a common turbo encoder according to the prior art;

FIG. 2A is a diagram illustrating a puncturing method of a general R=1/2 turbo encoder according to the prior art;

FIG. 2B is a diagram illustrating a puncturing method of a general R=1/3 turbo encoder according to the prior art;

FIG. 2C is a diagram illustrating a puncturing method of a general R=1/4 turbo encoder according to the prior art;

FIG. 3 is a block diagram illustrating a puncturing device for a turbo encoder according to an embodiment of the present invention;

FIG. 4A is a diagram illustrating a puncturing method of an R=1/2 turbo encoder according to an embodiment of the present invention;

FIG. 4B is a diagram illustrating a puncturing method of an R=1/3 turbo encoder according to an embodiment of the present invention;

FIG. 4C is a diagram illustrating a puncturing method of an R=1/4 turbo encoder according to an embodiment of the present invention; and

FIG. 5 is a flow chart illustrating a puncturing method for a turbo encoder according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described herein below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the invention in unnecessary detail.

FIG. 3 shows a block diagram of a puncturing device for a turbo encoder according to an embodiment of the present invention. Referring to FIG. 3, upon receiving 5 symbol frames and 6 tail symbols part encoded by the turbo encoder of FIG. 1, a frame generator 133 performs puncturing for code rate matching and symbol rate matching on the received encoded symbols to output a frame of the symbol rate. However, since the total encoded symbols number is larger than the transmission symbol number according to the predetermined code rate, it is necessary to match the code rate and symbol rate by puncturing some of the encoded symbols. At this point, the frame generator 133 according to the present invention is controlled to perform puncturing for code rate matching on the symbol frame and perform puncturing for symbol rate matching on the tail symbols. Further, the frame generator 133 adds invalid symbols to the reserved symbols to generate a frame according to the symbol rate. A memory 137 has information about a puncturing pattern for the code rate and information about the number of the added invalid symbols. A controller 135, which may previously know the code rate of the turbo encoder, controls the frame generator 133 according to the information about the puncturing pattern and the number of the added invalid symbols, thereby performing puncturing for code rate matching, puncturing for symbol rate matching, and invalid symbol inserting.

FIGS. 4A to 4C show puncturing methods of the puncturing device for a turbo encoder according to an embodiment of the present invention. More specifically, FIG. 4A shows a puncturing method of an R=1/2 turbo encoder according to an embodiment of the present invention; FIG. 4B shows a puncturing method of an R=1/3 turbo encoder according to an embodiment of the present invention; and FIG. 4C shows a puncturing method of an R=1/4 turbo encoder according to an embodiment of the present invention.

In FIG. 4A, puncturing for code rate matching is performed on the coded symbols frame corresponding to the input information frame, and then two symbols are punctured from 18 coded tail symbols for the tail bits to output 16 tail symbols that the convolutional code can transmit. That is, there are no reserved symbols. However, in FIG. 4B, puncturing for code rate matching is performed on the coded frame symbols corresponding to the input information frame, and then 6 invalid symbols are inserted without puncturing the tail symbols, because there remain 6 reserved symbols when the 18 tail symbols for

the turbo code are smaller than the 24 tail symbols for the convolutional code can transmit. Further, in FIG. 4C, when compared with the convolutional code, the turbo code has 14 reserved symbols. Therefore, 14 invalid symbols are inserted without puncturing the tail symbols. That is, puncturing the tail symbols is minimized to increase the decoding accuracy. Generally, the tail symbol is more important than parity symbol at decoding. Therefore, it is preferable to repeat the tail symbols, rather than insert the invalid symbols.

This can be expressed with the factors output from the turbo encoder as follows:

1) For the case of R=1/2:

X(0),Y0(0),Y1(0),Y'0(0),Y'1(0), X(1),Y0(1),Y1(1)Y'0(1),Y'1(1), ..., X(L-1),Y0(L-1),Y1(L-1),Y'0(L-1),Y'1(L-1),
T1(0),TP11(0),TP12(0),T2(0),TP21(0),TP22(0),
T1(1),TP11(1),TP12(1),T2(1),TP21(1),T22(1)...
T1(m-1),TP11(m-1),TP12(m-1),T2(m-1),TP21(m-1),T22(m-1)

2) For the case of R=1/3:

X(0),Y0(0),Y1(0),Y'0(0),Y'1(0), X(1),Y0(1),Y1(1),Y'0(1),Y'1(1), ..., X(L-1),Y0(L-1),Y1(L-1),Y'0(L-1),Y'1(L-1),
T1(0),TP11(0),TP12(0),T2(0),TP21(0),T22(0),...
T1(m-1),TP11(m-1),TP12(m-1),T2(m-1),TP21(m-1),T22(m-1),
RVB(0),RVB(1),RVB(2).....,RVB(h).

3) For the case of R=1/4:

X(0),Y0(0),Y1(0)Y'0(0),Y'1(0), X(1),Y0(1),Y1(1)Y'0(1),Y'1(1), ..., X(L-2),Y0(L-2),Y1(L-2),Y'0(L-2),Y'1(L-2),
X(L-1),Y0(L-1),Y1(L-1),Y'0(L-1),Y'1(L-1),
T1(0),TP11(0),TP12(0),T2(0),TP21(0),T22(0),
T1(1),TP11(1),TP12(1),T2(1),TP21(1),T22(1)...
T1(m-1),TP11(m-1),TP12(m-1),T2(m-1),TP21(m-1),T22(m-1),
RVB(0),RVB(1),RVB(2).....,RVB(h).

FIG. 5 shows a puncturing method of a turbo encoder according to an embodiment of the present invention. Referring to FIG. 5, the controller 135

examines in step 501 whether data is input from the turbo encoder. The controller 135 may either previously know a code rate of the turbo encoder, or detect the code rate of the data. Upon receipt of data from the turbo encoder, the controller 135 detect a code rate of the received data in step 503 using the above methods. After detecting the code rate, the controller 135 reads a puncturing pattern for the detected code rate in step 504. For example, when the detected code rate is 1/3, the controller 135 reads the puncturing pattern of FIG. 4B. After reading the puncturing pattern, the controller 135 controls puncturing on the parity symbols according to the read puncturing pattern and inserts invalid symbols in the reserved symbols, if any, in step 505. For example, when the detected code rate is 1/2, the controller 135 controls the frame generator 133 to puncture on the parity symbols for code rate matching and on the tail parity symbol for symbol rate matching. For the symbool rate matching two of the tail symbols for the parity signals are punctured.. When the code rate matching is 1/4, the controller 135 controls the frame generator 133 to puncture the parity symbol for code rate matching. There is no puncturing on the tail symbol but insert reserved bits.

As described above, the novel puncturing device can minimize or avoid puncturing of tail symbols according to the code rate, thereby increasing the decoding capability of the receiver. And this invention provide different puncturing pattern on one frame period for minimizing or avoid puncturing of tail symbol.

While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

CLAIMS:

1. A puncturing device for a turbo encoder in a mobile communication system which encodes an input frame data into an encoded symbols, a plurality of symbol frames including a systematic symbol frame and a parity symbol frames and tail symbols at a given code rate, the device comprising:

a frame generator for generating a transmission frame by puncturing the encoded symbol; and

a controller for controlling said frame generator by controlling said puncturing of the symbol frames according to the code rate, and puncturing the tail symbols only when the number of selected symbol out of the symbol frames and tail symbols exceeds a bit number according to a symbol rate.

2. The puncturing device as claimed in claim 1, wherein said frame generator, under the control of said controller, punctures two symbols out of the tail symbols, the parity symbol frames according to the code rate when the code rate is ½, said tail symbols corresponding to the coded symbol frames.

3. The puncturing device as claimed in claim 1, wherein systematic symbol is not punctured.

4. The puncturing device as claimed in claim 1, wherein said controller further controls said frame generator by reading a puncturing pattern according to the code rate and information about the number of invalid symbols.

5. A puncturing method in a mobile communication system including an encoder for turbo encoding input source data into a plurality of symbol frames and tail symbols at a given code rate, the method comprising the steps of:

detecting the code rate of the turbo encoder;

reading from a memory information about the puncturing pattern for the detected code rate and information about the number of invalid symbols to be added; and

performing puncturing according to the information read.

6. The puncturing method as claimed in claim 5, wherein two bits out of the tail symbols of parity signals and the three of symbol of symbol frames at a puncturing time are punctured, when the code rate is 1/2.

7. The puncturing method as claimed in claim 5, wherein only bits of the symbol frames are punctured, when the code rate is lower than 1/2.

8. A puncturing device in a communication system, comprising:
a turbo encoder for encoding an input information frame comprised of L serial information bits and generating n encoded parallel symbols frames to output n(L+M) encoded symbols comprised of nL encoded symbols and nM encoded tail coded symbols; and
a frame generator having a code rate R, for puncturing (n(L+M)) (1/R)(L+M') symbols from nL encoded symbols if n(L+M)≥ (1/R)(L+M') to generate a transmission frame comprised of transmission information symbol ((1/R)*L) and transmission tail coded symbols (1/R)*M'.

9. The puncturing device as claimed in claim 8, wherein for a code rate R=1/2, two of the tail coded symbols of parity signals are punctured.

10. The puncturing device as claimed in claim 8, wherein for a code rate R=1/3, only bits of the symbol frames are punctured and (1/R)*M – nM invalid symbols are inserted.

11. The puncturing device as claimed in claim 8, wherein for a code rate R=1/4, only bits of the symbol frames are punctured and(1/R)*M – nM invalid symbols are inserted.

12. The puncturing device as claimed in claim 10, wherein M=3.

13. The puncturing device as claimed in claim 10, wherein M'=8.

14. A puncturing method in a communication system, comprising:
a turbo encoder for encoding an input information frame comprised of L serial information bits and generation n encoded parallel symbols frames to output

n(L+M) encoded symbols comprised of nL encoded symbols and nM encoded tail coded symbols; and

puncturing (n(L+M))-(1/R)(L+M') symbols from nL encoded symbols if the number of coded symbol n(L+M) is more than the number of transmission symbol (1/R)(L+M') to generate a transmission frame comprised of transmission information symbol ((1/R)L) and transmission tail coded symbols (1/R)M'

15. The puncturing device as claimed in claim 14, wherein for a code rate R=1/2, two of the tail coded symbols of parity signals are punctured.

16.The puncturing method as claimed in claim 14, wherein for a code rate R=1/3, only bits of the symbol frames are punctured and (1/R)*M – nM invalid symbols are inserted.

17. The puncturing method as claimed in claim 14, wherein for a code rate R=1/4, only bits of the symbol frames are punctured and (1/R)*M – nM invalid symbols are inserted.

18. The puncturing device as claimed in claim 17, wherein M=3.

19. The puncturing device as claimed in claim 17, wherein M'=8.

20. A puncturing device for a turbo encoder in a mobile communication system which encodes a input frame data into a systematic code symbol frame, plurality of parity symbol frames and plurality sets of tail coded symbol at a given code rate, the device comprising;

a frame generator for generating a transmission frame by puncturing at least one of said symbols and;

a controller for controlling said frame generator to puncture said parity symbol frames with the first puncturing pattern and said sets of tail coded symbol with the second puncturing pattern, wherein, said number of punctured symbols in the second puncturing pattern is less than that of the first puncturing pattern..

21. The puncturing device as claimed in claim 20, wherein first puncturing pattern is for code rate matching.

22. The puncturing device as claimed in claim 20, wherein second puncturing pattern is for symbol rate matching.

23. A puncturing device for a turbo encoder in a mobile communication system which encodes a input frame data into a systematic code symbol frame, plurality of parity symbol frames and plurality sets of tail coded symbol at a given code rate, the device comprising;

a frame generator for generating a transmission frame by code rate matching and symbol rate matching and;

a controller for controlling said frame generator to puncture only said parity symbol frames for code rate matching and to repeat said tail coded symbols according to number of excess bit.

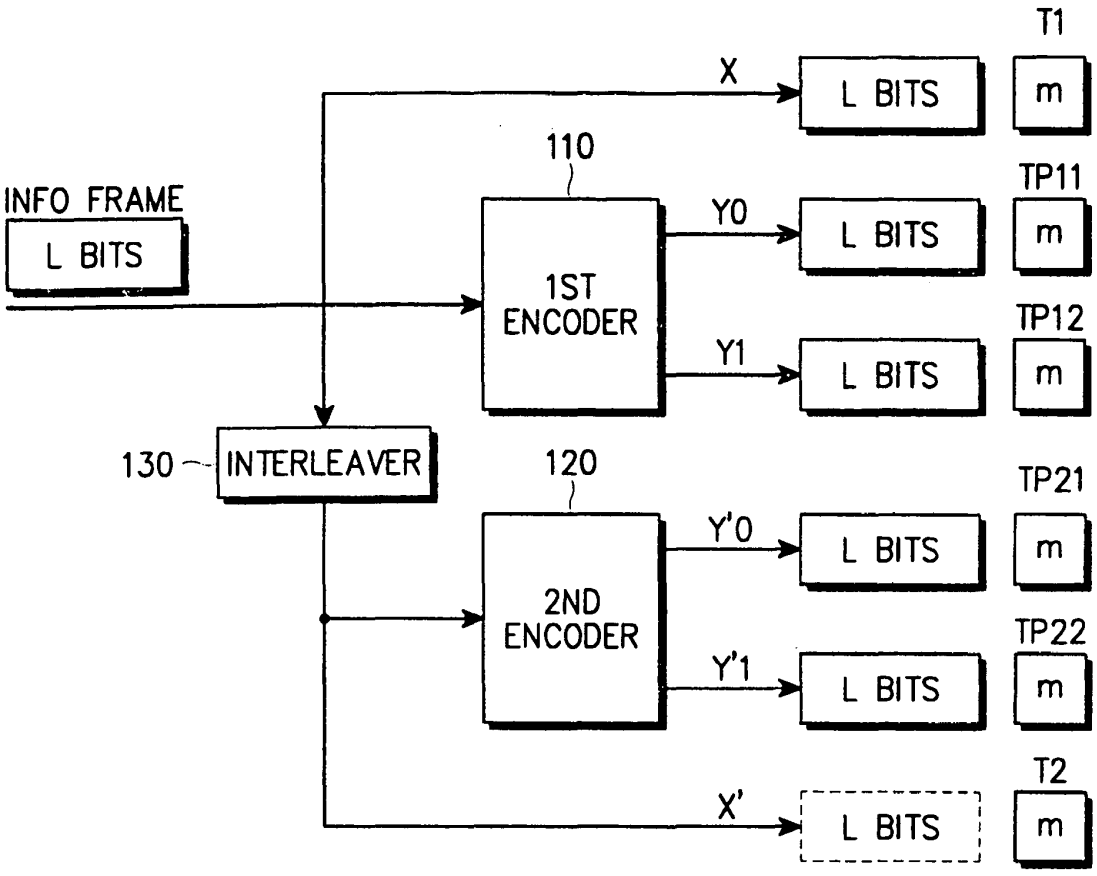

T1
X
L BITS
m
110
TP11
INFO FRAME
L BITS
Y0
L BITS
m
1ST
ENCODER
TP12
Y1
L BITS
m
130
INTERLEAVER
120
TP21
Y'0
L BITS
m
2ND
ENCODER
TP22
Y'1
L BITS
m
T2
X'
L BITS
m

FIG.1

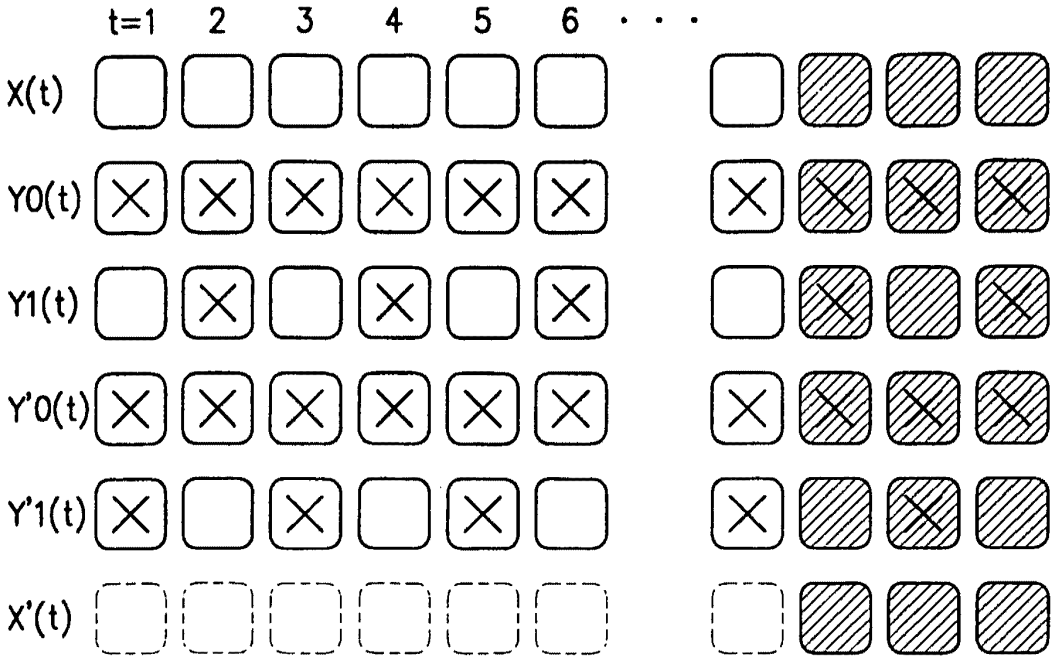


FIG.2A

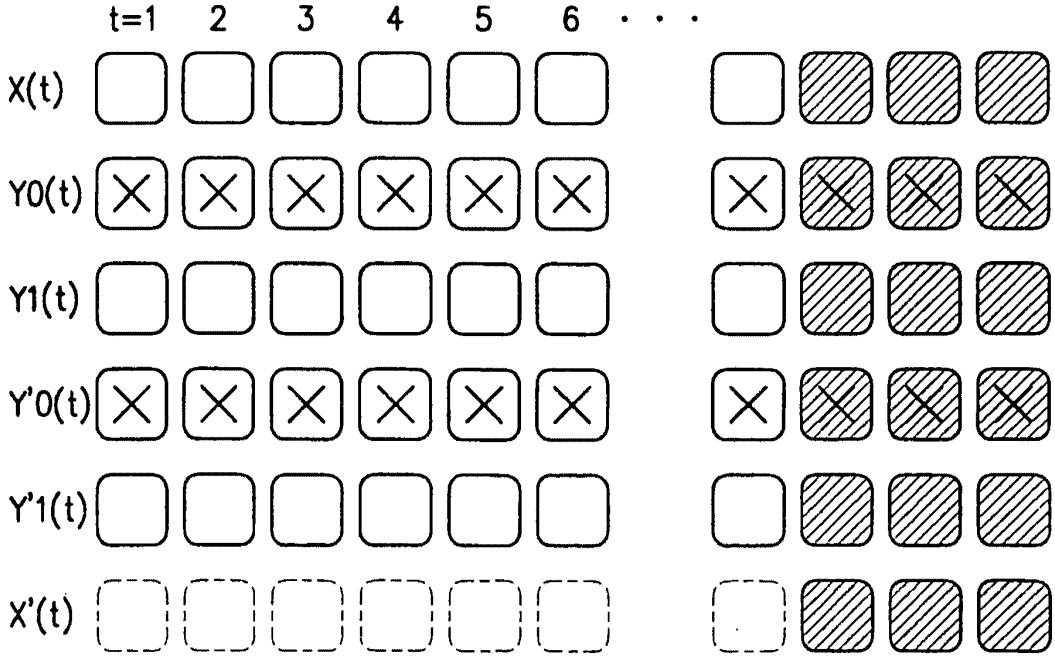


FIG.2B

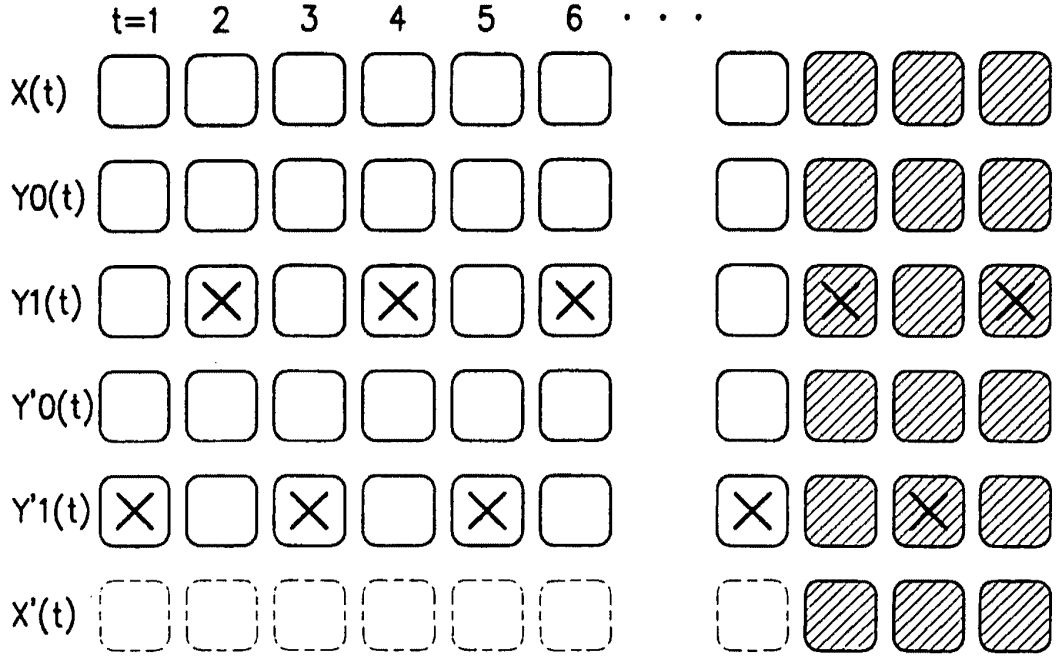


FIG.2C

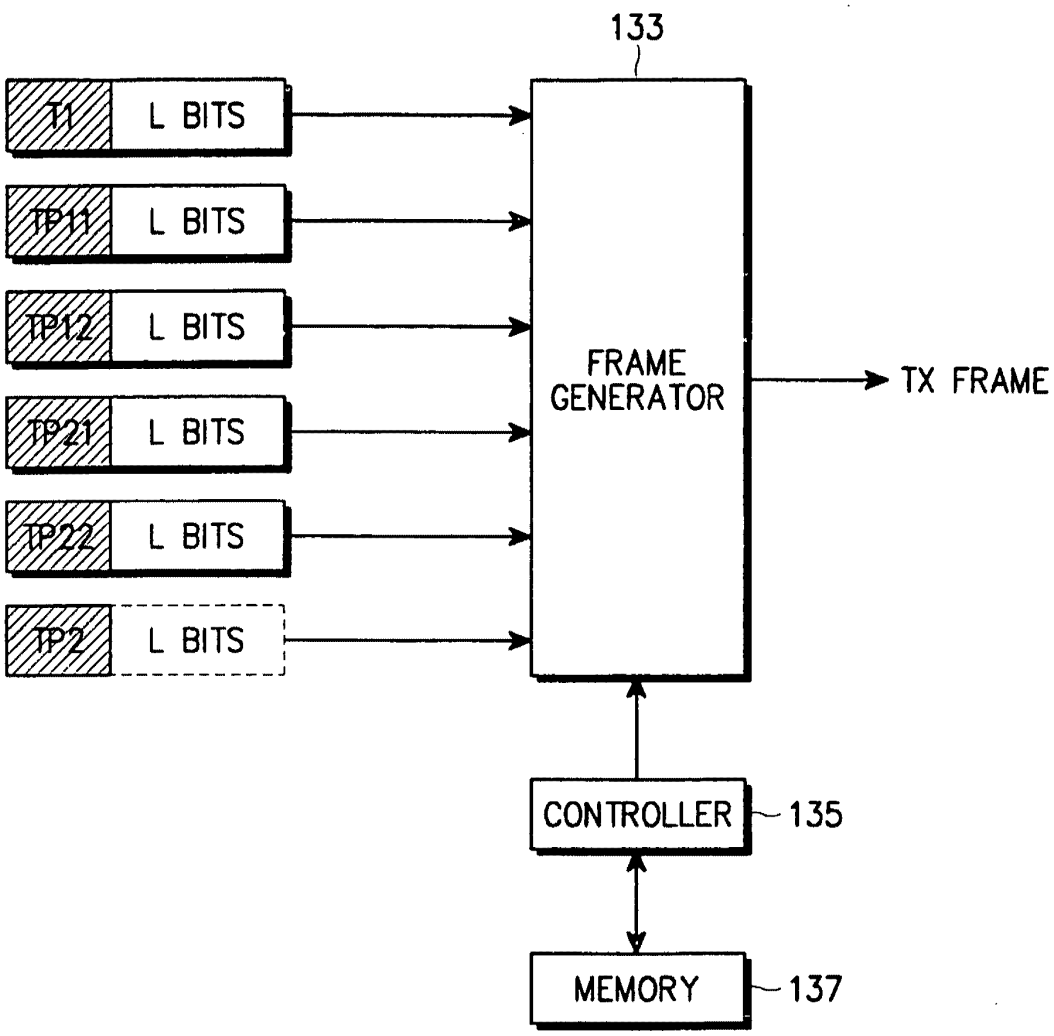

133
T1
L BITS
TP11
L BITS
TP12
L BITS
TP21
L BITS
TP22
L BITS
TP2
L BITS
FRAME GENERATOR
TX FRAME
CONTROLLER
135
MEMORY
137

FIG.3

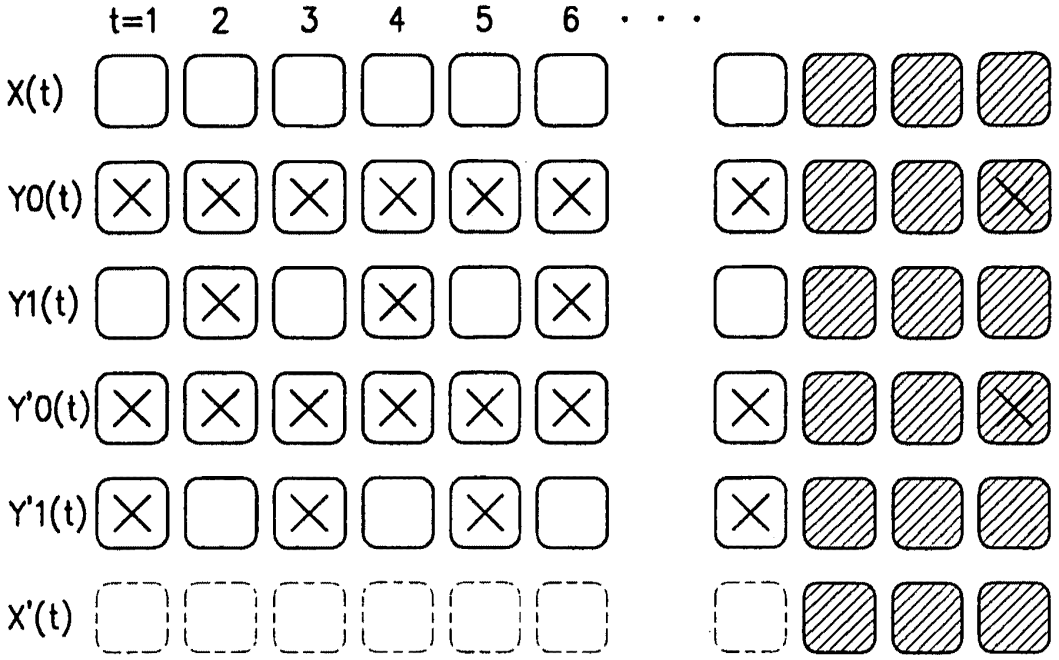


FIG.4A

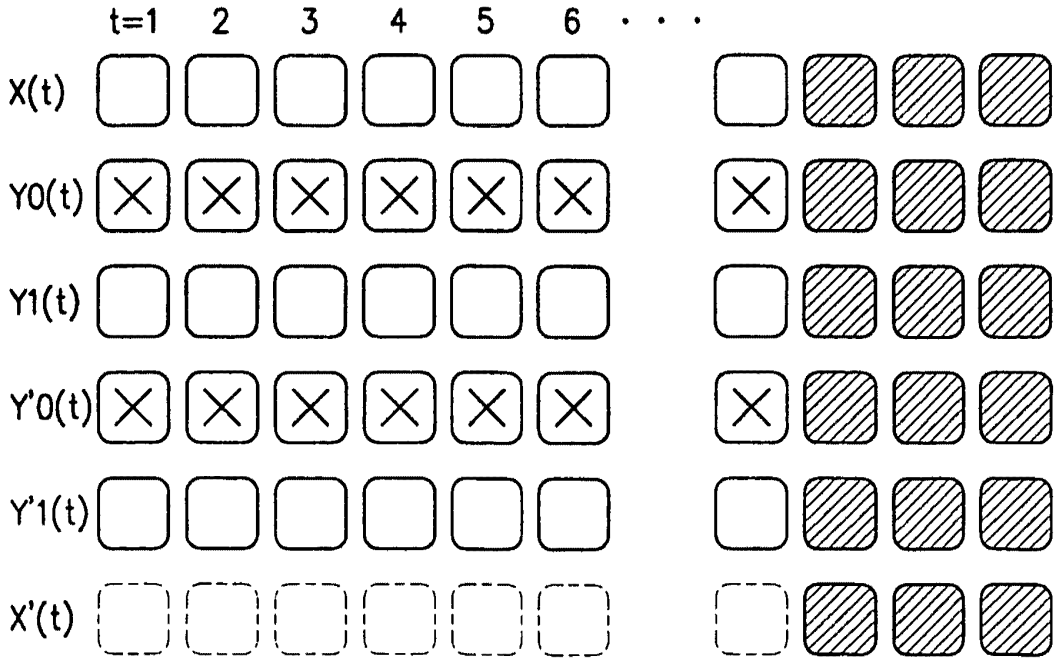


FIG.4B

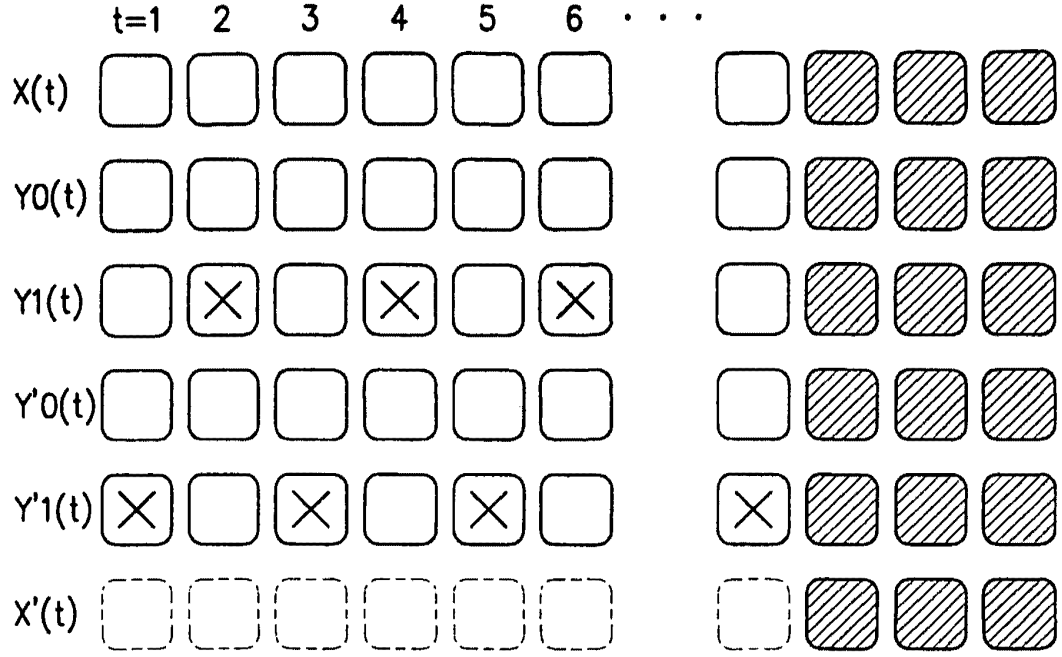


FIG.4C

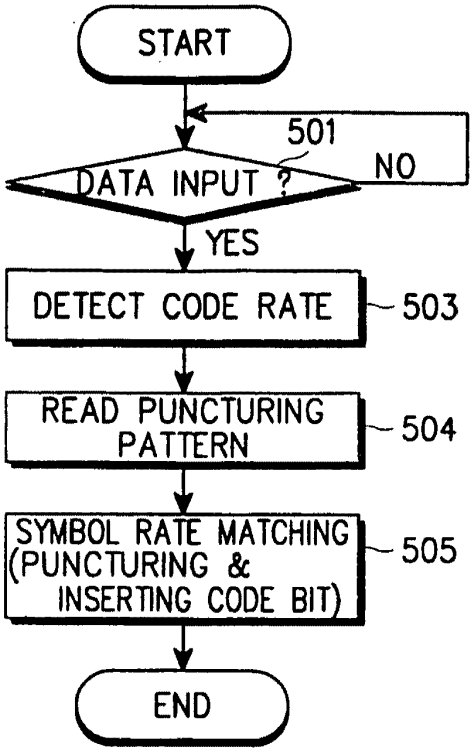

START
501
DATA INPUT ?
NO
YES
DETECT CODE RATE
503
READ PUNCTURING PATTERN
504
SYMBOL RATE MATCHING (PUNCTURING & INSERTING CODE BIT)
505
END

FIG.5

INTERNATIONAL SEARCH REPORT

international application No.
PCT/KR99/00851

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H04B 7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)

IPC7 H04B 7/26, H03M 13/00, H03M 13/12, H03M 13/29

Documentation searched other than minimun documentation to the extent that such documents are included in the fileds searched

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search trerms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE, 19521327(SIEMENS AG) 19 DEC 1995 Abstract	1 ~ 23
P, A	US, A, 5983384(GEN ELECTRIC) 9 NOV 1999 column 1, line 29 ~ column 1, line 50	1 ~ 7, 20 ~ 23
E, A	WO, 00/13323(HUGHES ELECTRONICS CO) 9 MARCH 2000 page 2, line 17 ~ page 3, line 12	1 ~ 7, 20 ~ 23

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevence
"E" earlier application or patent but published on or after the international filing date
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 APRIL 2000 (12.04.2000)	14 APRIL 2000 (14.04.2000)

Name and mailing address of the ISA/KR	Authorized officer
Korean Industrial Property Office Government Complex-Taejon, Dunsan-dong, So-ku, Taejon Metropolitan City 302-701, Republic of Korea	KANG, Heum Jung
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(71) Applicant: SAMSUNG ELECTRONICS CO., LTD [KR/KR]; 416, Maetan-dong, Paldal-gu, Suwon-shi, Kyungki-do 442-370 (KR).

(72) Inventors: KIM, Min-Koo; 973, Youngtong-dong, Paltal-gu, Suwon-shi, Kyonggi-do 442-470 (KR). JANG, Jae-Sung; 1102-203, Chungang-dong, Kwachon-shi, Kyonggi-do 427-010 (KR).

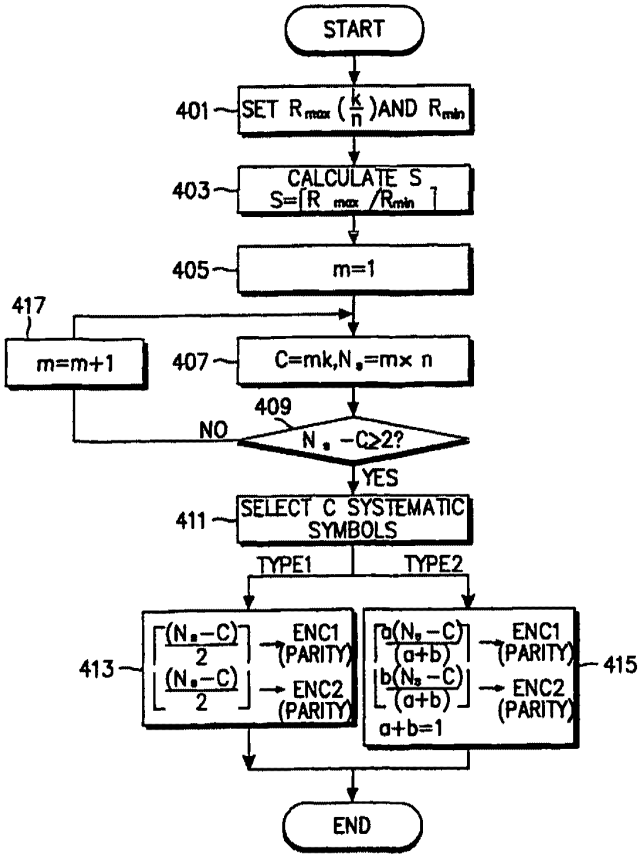
(74) Agent: LEE, Keon-Joo; Mihwa Building 110-2, Myongryun-dong 4-ga, Chongro-gu, Seoul 110-524 (KR).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: GENERATING CODES IN A COMMUNICATION SYSTEM



(57) Abstract: There are provided an apparatus and method for generating an initial puncturing matrix from which a first sub-code is produced in a communication system having a turbo encoder for generating information symbols, first parity symbols, and second parity symbols for the input of an information bit stream and a sub-code generator for generating sub-codes from the information symbols, the first parity symbols, and the second parity symbols using puncturing matrices, a number of the sub-codes being identical to a number of the puncturing matrices, comprising the steps of selecting as many information symbols as a number of columns in the initial puncturing matrix from the information symbols output from the turbo encoder.

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GENERATING CODES IN A COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to an apparatus and method for generating codes in a data communications system, and in particular, to an apparatus and method for generating complementary codes with use of turbo codes in a communications system employing a retransmission scheme.

2. Description of the Related Art

In general, a system using a retransmission scheme (e.g., hybrid ARQ[Automatic Repeat Request]) performs soft combining to improve transmission throughput. The soft combining techniques are divided into packet diversity combining and packet code combining. These two combining schemes are usually called soft packet combining. Although the packet diversity combining scheme is sub-optimal in performance relative to the packet code combining scheme, it is favorable due to easy implementation when performance loss is low.

A packet transmission system uses the packet code combining scheme to improve transmission throughput. That is, a transmitter transmits a code with a different code rate at each packet transmission. If an error is detected from the received packet, a receiver requests a retransmission and performs soft combining between the original packet and a retransmitted packet. The retransmitted packet may have a different code from the previous packet. The packet code combining scheme is a process of combining received N packets with a code rate R to a code with an effective code rate of R/N prior to decoding, to thereby obtain a coding gain.

With regard to the packet diversity combining scheme, on the other hand, the transmitter transmits a code with the same code rate R at each packet transmission. If an error is detected from the received packet, the receiver requests a retransmission and performs soft combining between the original packet and the retransmitted packet. The retransmitted packet has an identical code to that in the previous packet. In this sense, the packet diversity

combining scheme can be considered symbol averaging on a random channel. The packet diversity combining scheme reduces noise power by averaging the soft outputs of received symbols and achieves such a diversity gain as offered by a multipath channel because the same code is repeatedly transmitted on a fading channel. However, the packet diversity combining scheme does not provide such an additional coding gain as obtained according to a code structure in the packet code combining scheme.

Due to implementation simplicity, most packet communication systems have used the packet diversity combining scheme, which is under study for application to the synchronous IS-2000 system and the asynchronous UMTS system. The reason is that the existing packet communication systems have used convolutional codes and even packet code combining does not offer a great gain when convolutional codes with a low code rate are used. If a system with R=1/3 supports retransmission, there is not a wide difference in performance between the packet code combining scheme and the packet diversity combining scheme. Thus, the packet diversity combining scheme is selected considering implementation complexity. However, the use of turbo codes as forward error correction codes (FEC) requires a different packet combining mechanism because the turbo codes are designed as error correction codes to have performance characteristics very close to the "Shannon Channel Capacity Limit" by iterative decoding and their performance varies obviously with the coding rates unlike convolutional codes. Therefore, it can be concluded that packet code combining is feasible for a packet communication system using turbo codes in a retransmission scheme to achieve the goal of optimum performance.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide an apparatus and method for generating sub-codes for optimal code combination in a retransmission system using turbo codes.

It is another object of the present invention to provide an apparatus and method for generating complementary codes using turbo codes in a communications system.

The above and other objects can be achieved by providing an apparatus and method for generating sub-codes from turbo codes in a communications

system. In the sub-code generating apparatus, a turbo encoder generates information symbols, first parity symbols, and second parity symbols for the input of an information bit stream and a sub-code generator generates sub-codes from the information symbols, the first parity symbols, and the second parity symbols using puncturing matrixes. Here, the number of the sub-codes is identical to the number of the puncturing matrixes. To generate an initial puncturing matrix for the first sub-code, the sub-code generator selects as many information symbols as the number of columns in the initial puncturing matrix from the information symbols from the turbo encoder, if the difference between the number Ns of selected symbols in the initial puncturing matrix and the number of the columns in the initial puncturing matrix is equal to or greater than the number of component encoders in the turbo encoder. Then, the sub-code generator selects as many first and second parity symbols as the difference in such a way that the number of the selected first parity symbols is equal to or greater than the number of the selected second parity symbols.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a graph showing the performance difference between packet code combining and packet diversity combining in a packet data system using turbo codes;

FIG. 2 is a block diagram of a sub-code generating apparatus according to an embodiment of the present invention;

FIG. 3 is a graph showing the performances of a retransmission scheme without using sub-codes, a retransmission scheme implementing diversity combining with sub-codes, and a retransmission scheme implementing code

the embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described hereinbelow with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the invention in unnecessary detail.

The present invention proposes a method of generating sub-codes for optimal packet combining in a retransmission system using turbo codes and a system that selectively employs a packet code combining scheme and a packet diversity combining scheme according to the data rates. The advantages and performance gain of the proposed system will be described.

First, there will be given a description of the operation of the system that selectively uses the packet code combining scheme and the packet diversity scheme combining according to the data rates.

In a system using R=1/5 turbo codes, for example, packet code combining is applied until the overall code rate of codes produced by soft-combining of retransmitted packets reaches 1/5. For the subsequent retransmitted packets, packet diversity combining and then packet code combining are performed. If the first packet is transmitted at a data rate of 1/3, the required redundancy symbols are provided at a retransmission request to make the overall code rate 1/5. Thus, when a receiver receives both packets, the overall code rate becomes 1/5. Each of the following packets is repeated prior to transmission and the receiver performs packet diversity combining and then packet code combining on the retransmitted packets at the code rate 1/5.

FIG. 1 is a graph showing the performance difference between packet code combining and packet diversity combining in the case of turbo codes. As shown in FIG. 1, a turbo code with a low data rate of 1/6 exhibits a greater performance gain than a turbo code with a high code rate of 1/3 with the same symbol energy Es and obtains a performance gain of 3dB from the packet code combining. Consequently, generation of R=1/3 turbo codes by packet code combining of R=1/6 sub-codes produces a gain that turbo codes with a code rate lower than 1/3 exhibits and a gain that code combining of different codes

offers, contemporaneously.

More specifically, for the same code symbol energy Es and the same given code rate, turbo codes provide performance close to the "Shannon Channel Capacity Limit" according to the code rates only if iteration decoding is fully implemented, unlike convolutional codes. It is known that a turbo code with a low code rate offers a greater performance gain than a turbo code with a high code rate with the same code symbol energy Es. For example, when R=1/3 is reduced to R=1/6, the performance difference can be estimated by analyzing a change in the "Shannon Channel Capacity Limit". The reason for assuming the same symbol energy irrespective of R=1/3 or 1/6 for the curves of FIG. 1 is that the same symbol energy Es is used for each retransmission in a hybrid ARQ system.

If an R=1/3 code is repeated once and the two codes are packet-diversity-combined on an AWGN (Additive White Gaussian Noise) channel, a maximum gain of 3dB is obtained in terms of a symbol energy-to-noise ratio (Es/No). The same is the case with an R=1/6 code. Thus, a performance curve for the R=1/3 turbo code shifts to the left in parallel by a +3dB scale due to a packet diversity combining gain and a performance curve for the R=1/6 turbo code also shifts to the left in parallel by a +3dB scale when the same symbol energy is given. Here, the performance curves are derived with respect to the energy-to-noise ratio (Eb/No) which is measured to compare code performances according to the code rates. As a consequence, the difference between the turbo code performance curves is equivalent to the performance difference between the packet diversity combining and the packet code combining. The performance difference according to the code rates can be estimated from the "Shannon Channel Capacity Limit" and a minimum performance difference can be obtained using a minimum required signal-to-noise ratio (SNR).

In a system using turbo codes with a code rate R and a very large encoder block size L, a minimum Eb/No required to provide an error-free channel is expressed as

$$Eb/No \rangle (4^R - 1)/2R \quad \ldots\ldots (1)$$

According to the above equation, the minimum required Eb/No in AWGN at each code rate for the turbo codes is listed in Table 1 below. In Table 1, a typical Eb/No indicates a required Eb/No for a bit error rate (BER) below 0.00001 when the encoding block size L of the turbo codes is 1024.

(Table 1)

Code rates	Required Eb/No (dB)	Typical Eb/No (dB) for BER=10^{-5}
3/4	0.86	3.310
2/3	0.57	2.625
1/2	0.00	1.682
3/8	−0.414	1.202
1/3	−0.55	0.975
1/4	−0.82	0.756
1/5	−0.975	0.626
1/6	−1.084	0.525
0	−1.62	NA

As shown in Table 1, required Eb/No are 0.86, 0.57, 0.0, −0.414, −0.55, −0.82, −0.975, and −1.084dB respectively, for the code rates of 3/4, 2/3, 1/2, 3/8, 1/3, 1/4, 1/5, and 1/6. An at least 0.53dB performance difference exists between a system using R=1/3 code and a system using R=1/6 code. This is a minimum performance difference based on the "Shannon Channel Capacity Limit". Considering implementation of a real decoder and system environment, the difference becomes wider. From a simulation, approximately 1.12dB performance difference was observed between a system using packet code combining for R=2/3 codes and a system using packet diversity combining for the R=2/3 codes.

Table 2 shows the performance difference between packet code combining and packet diversity combining after one retransmission in a system with a sub-code code rate of 2/3. As shown in Table 2, a minimum performance difference is 1.12dB and the packet code combining scheme produces a higher performance gain in the system using turbo code. (Table 2)

Items	Packet combining	Code combining
Mother code rate R_m	1/3	1/3

	(X, Y0, Y'0) in FIG. 2	(X, Y0, Y'0) in FIG. 2
Block size (L)	496	496
Maximum number of iterations	8	8
Number of transmissions	2	2
Actual Tx code rate Re for each transmission	2/3 (by puncturing)	2/3 (by puncturing)
Redundancy selection	Identical pattern for all transmissions.	Different pattern for all transmissions.
Soft combining	Packet diversity combining	Packet code combining
Gain through retransmissions	Symbol repetition gain	Coding gain for low rate codes
Minimum required Eb/No in Table 1	+0.57 (dB)	R–2/3 +0.57 (dB) R–2/6 –0.55 (dB)
Required Eb/No at 2nd retransmissions	+0.57–3.0 (dB)	–0.55–3.0 (dB)
Relative performance gain	0	1.12 (=0.57+0.55) dB
Simulated relative gain (@ BER = 10^{-5})	0	2.5 (dB)

As described above, the packet code combining scheme shows excellent performance in the retransmission system using turbo code. Therefore, the present invention provides a sub-code generating method for optimal packet code combining in the retransmission system using turbo code . Generation of sub-codes for packet code combining according to a predetermined rule produces the aforementioned code combining gain and maximizes the performance of a system requesting sub-codes of the same size for each retransmission.

FIG. 2 is a block diagram of a sub-code generating apparatus using turbo codes according to an embodiment of the present invention. As shown in FIG. 2, the sub-code generating apparatus includes a turbo encoder, a sub-code generator 204, and a controller 205.

First, with regard to the turbo encoder, a first component encoder (or a first constituent encoder) 201 encodes an input information bit stream and

outputs first code symbols, i.e., information symbols X and first parity symbols Y0 and Y1. An interleaver 202 interleaves the input information bit stream according to a predetermined rule. A second component encoder (or a second constituent encoder) 203 encodes the interleaved information bit stream and outputs second code symbols, i.e., information symbols X' and second parity symbols Y'0 and Y'1. Thus, the output symbols of the turbo encoder are the first and second code symbols. Since the information symbols X' generated from the second component encoder 203 are not transmitted in reality, the code rate of the turbo encoder is 1/5.

The sub-code generator 204 generates sub-codes from the first and second code symbols received from the first and second component encoders 201 and 203 by puncturing and repetition under the control of the controller 205. The controller 205 stores puncturing (and repetition) matrixes generated from algorithms shown in FIGs. 4, 5 and 6 and outputs symbol selection signals for the puncturing matrixes to the sub-code generator 204. Then, the sub-code generator 204 selects a predetermined number of code symbols within a predetermined puncturing range according to the symbol selection signals.

The reference characters as used here, X, Y0, Y1, Y'0, and Y'1 are defined as follows.

X: systematic code symbol or information symbol

Y0: redundancy symbol from the upper component encoder of the turbo encoder

Y1: redundancy symbol from the upper component encoder of the turbo encoder

Y'0: redundancy symbol from the lower component encoder of the turbo encoder

Y'1: redundancy symbol from the lower component encoder of the turbo encoder

FIGs. 4, 5 and 6 are flowcharts illustrating sub-code (or puncturing matrix) generating procedures according to the embodiment of the present invention. Specifically, FIG. 4 illustrates a procedure of generating the first sub-code C_0 in a sub-code set, FIG. 5 illustrates a procedure of generating middle sub-codes C_1 to C_{s-2} in the sub-code set, and FIG. 6 illustrates a procedure of generating the last sub-code C_{s-1} in the sub-code set.

Hereinbelow, ENC1 (referred to as first code symbols) indicate the information symbols X and the first parity symbols Y0 and Y1 output from the first component encoder 201 and ENC2 (referred to as second code symbols) indicate the second parity symbols Y'0 and Y'1 output from the second component encoder 203.

Referring to FIG. 4, a maximum code rate (Rmax) available to a transmitter is set in step 401. This value is mostly given according to the data rate used in the system. A minimum code rate (Rmin) is set to be an integer-multiple of Rmax (=k/n). Here, k is the number of input symbols and n is the number of output symbols. Although Rmin can be determined arbitrarily, it is usually 1/6, 1/7 or lower Because a coding gain is saturated due to the decrease of code rates at or below R=1/7 in turbo codes. In addition, the real code rate, i.e., mother code rate (R) of a decoder in a receiver, is determined. R is set to be greater than Rmin.

In real system implementation, Rmax and Rmin are preset. In some sense, Rmax is the code rate of the sub-codes to be generated and Rmin is a target code rate after code combining of the sub-codes. In general, Rmin is the code rate of an encoder in the transmitter.

In step 403, the number of sub-codes (S) is calculated by the following equation using Rmax and Rmin. Here, the number of the sub-codes or the number of puncturing matrixes is a minimum integer exceeding the ratio of Rmax to Rmin.

$$S = \lceil R_{max} / R_{min} \rceil \quad \ldots\ldots (2)$$

where $\lceil * \rceil$ represents a minimum integer equal to or larger than *.

A variable m is set to an initial value of 1 in step 405 and C (= m× k) is determined in step 407. C is the number of the columns of each puncturing matrix, determined by Rmax. For example, for Rmax = 3/4, C can be 3, 6, 9, . . . and is set to a minimum available value for the first sub-code to be transmitted. Here, C is set to 3 for Rmax=3/4.

In step 407, the number of symbols to be selected from the puncturing matrix ,Ns, is calculated by multiplying the variable m by the code length i.e.,

the number of code symbols n from Rmax=k/n. Ns is the number of selected symbols or the number of selected positions in each puncturing matrix and calculated by C/Rmax.

In step 409, (Ns–C) is compared with the number of the component encoders of the turbo encoder in the transmitter. The present turbo encoder is generally provided with two component encoders. Thus, it is supposed that two component encoders are used. It is determined whether (Ns–C) is 2 or greater in step 409 because the turbo encoder has two component encoders connected in parallel with the interleaver interposed as shown in FIG. 2 unlike conventional encoders using other single codes. In other words, at least one parity symbol from each component encoder must be transmitted after the information symbols are all transmitted in order to preserve the characteristics inherent in the turbo encoder.

If (Ns–C) is less than 2, only one symbol is selected from either the first parity symbol set or the second parity symbol set. From the perspective of turbo codes, either case may face problems. In the first case, sub-codes generated without second parity symbols are not turbo codes but convolutional codes with constraint length K=4 from an encoder having only the first component encoder and offers no interleaver gain that is available in the turbo encoder. On the other hand, in the second case , transmission of only systematic symbols without parity symbols from the first component encoder results in sub-codes with a code rate of 1. This is equivalent to an uncoded system without any coding gain. Accordingly, (Ns–C) must be equal to or greater than 2 to provide turbo encoder performance.

If (Ns–C) is equal to or greater than 2 in step 409, C systematic information symbols are selected from the puncturing matrix in step 411 and the other symbols are selected according to a predetermined type . For type 1, the other symbols are selected from the first and second parity symbols by Eq. (3) in step 413. The number of selected first parity symbols is equal to or greater than that of selected second parity symbols. For example, if the number of the other symbols , (Ns–C), is 3, first and second parity symbols are selected by Eq. (3) and then one more symbol is selected from the first parity symbols.

$$\lceil (Ns-C)/2 \rceil \; ENC1(parity)$$
$$\lfloor (Ns-C)/2 \rfloor \; ENC2(parity)$$

..... (3)

where $\lfloor * \rfloor$ represents a maximum integer equal to or less than *.

For type 2, the other symbols are selected from the first and second parity symbols by Eq. (4) in step 415. If a and b are given as symbol distribution rates for the first parity symbols and the second parity symbols, respectively, as many symbols as a minimum integer equal to or larger than the ratio of a(Ns–C) to (a+b) are selected from the first parity symbols and as many symbols as a maximum integer equal to or less than the ratio of b(Ns–C) to (a+b) are selected from the second parity symbols.

$$\begin{matrix} \lceil a(Ns-C)/(a+b) \rceil & ENC1(parity) \\ \lfloor b(Ns-C)/(a+b) \rfloor & ENC2(parity) \end{matrix}$$

..... (4)

where a+b =1 and a and b indicate the symbol distribution ratios for ENC1 and ENC2, respectively.

If the condition given in step 409 is not satisfied, that is, (Ns–C) is less than 2, the variable m is incremented by 1 in step 417 and the procedure returns to step 407. The purpose of step 409 is to determine whether sub-codes capable of preserving the nature of turbo codes can be generated within the present puncturing range (the size of the puncturing matrix). If the nature of the turbo codes cannot be preserved, the puncturing range is enlarged in step 417.

As described above, the initial puncturing matrix is so constructed that all information symbols are selected and at least one symbol is selected from each of the first and second parity symbol sets in the turbo encoder.

Now there will be given a description of a middle puncturing matrix generation method referring to FIG. 5. By repeating the procedure of FIG. 5, puncturing matrices C_1 to C_{s-2} are generated.

Referring to FIG. 5, step 501 or 503 is performed according to a predetermined type. For type 1, Ns symbols are selected from the first and second parity symbol sets by Eq. (5) in step 501. Ns is the product of m and n given from Rmax (=k/n). The number of selected first parity symbols is equal to or greater than that of selected second parity symbols. Here, unselected symbols from the previous puncturing matrices are selected.

$$\begin{matrix} \lceil Ns/2 \rceil & ENC1(parity) \\ \lfloor Ns/2 \rfloor & ENC2(parity) \end{matrix} \quad \ldots\ldots (5)$$

For type 2, Ns symbols are selected from the first and second parity symbol sets according to predetermined ratios by Eq. (6) in step 503. If a and b are given as symbol distribution ratios for the first parity symbols and the second parity symbols, respectively, as many symbols as a minimum integer equal to or greater than the ratio of a(Ns) to (a+b) are selected from the first parity symbols and as many symbols as a maximum integer equal to or less than the ratio of b(Ns) to (a+b) are selected from the second parity symbols. Here, unselected symbols from the previous puncturing .matrices are selected.

$$\begin{matrix} \lceil a(Ns)/(a+b) \rceil & ENC1(parity) \\ \lfloor b(Ns)/(a+b) \rfloor & ENC2(parity) \end{matrix} \quad \ldots\ldots (6)$$

A last puncturing matrix C_{s-1} generating method will be described below referring to FIG. 6.

Referring to FIG. 6, the remaining unselected symbols from the previous puncturing matrices are all selected in step 601. The number of the selected symbols is defined as Ns2. In step 603, a new Ns is defined by (Ns–Ns2). Since symbols at all positions are selected from the puncturing matrices in the process of the operations shown in FIGs. 4, 5 and 6, the new Ns is the number of symbols to be repeatedly selected. In step 605, it is determined whether the new Ns is greater than 0. If the new Ns is 0, the procedure ends. If it is greater than 0, as many symbols as the new Ns are selected repeatedly from the information symbols. In other words, the selected symbols are transmitted repeatedly ..

The above-described sub-code generation method according to the present invention will be made clear below with specific numerical citations.

For Rmax=3/4 and R=1/5, Rmin=1/6 and S=6/(4/3)=4.5→5. Thus, five puncturing matrices are produced.

$\{C_0, C_1, C_2, C_3, C_4\}$: Rmax=3/4.

Since the code rate of sub-codes is 3/4 and the number of sub-codes is 5, the sub-codes have a code rate 3/20 ((1/S)×Rmax=(1/5)×(3/4)=3/20) after code combining. This implies that for 3 information bits, a receiver receives 20 code symbols. However, since 15 symbols are generated from S×n=5×4=20 and S×k=5×3=15, 5 symbols among the 15 symbols are repeatedly transmitted. The repeated symbols are preferably information symbols. In the above example, if an information symbol X is repeated once in each sub-code, a decoder receives turbo codes with R=1/5 in which information symbols occur twice for each of S sub-codes when S sub-codes are all received.

The resulting sub-codes from the procedures shown in FIGs. 4, 5 and 6 are a kind of complementary codes, but they are not in a strict sense of the term because repeated symbols exist and each sub-code exhibits a different characteristic. In view of the sub-codes being produced from turbo codes, they will be called quasi-complementary turbo codes (QCTCs). A hybrid ARQ system using QCTCs employs the following retransmission scheme

The hybrid ARQ system is the major example using packet code combining. Packet code combining is available to the present hybrid ARQ systems, HARQ type I, Type II, and Type III. In these systems, a retransmission technique can be implemented using QCTCs. If a transport unit (TU) is defined as an information bit block being a basic unit for packet transmission, one sub-code C_i is selected for each TU transmission in the hybrid systems.

A retransmission unit and an initial transmission TU can be the same or different in size. For an initial transmission and each retransmission, the following QCTC set is used.

From a QCTC C_q having a code set size S, a mother code C can be reconstructed, or a new code Cq with a lower code rate than the mother code rate Rm can be generated by combining (or code-combining) sub-codes C_i (i = 0, 1, 2, . . . ,S−1). Here, the mother code has a minimum code rate available in the encoder. Then, the QCTC is defined as

Original code C with code rate R=Rm or code C with code rate R<Rm

$$= \bigcup_{i=0}^{S-1} C_i$$

. . . . . (7)

where S is the number of sub-codes with a code rate of Ri and Rm is the mother code rate.

The operation of a system transmitting TUs of the same size for an initial transmission and each retransmission using a QCTC will be described. Needless to say, the transmission scheme using different TUs can also be supported in the present invention. Here, the number of sub-codes S is 4 and the mother code rate R is 1/5.

(Step 1) Transmission is performed on a TU basis and a sub-code C_i of the QCTC is transmitted at the initial transmission and each retransmission.

(Step 2) When the overall code rate of codes produced by soft combining of the initially transmitted and retransmitted packets is greater than 1/5, each sub-code C_i of the QCTC is transmitted in the order of C_0, C_1, C_2, . . ., C_{S-1} at each retransmission request. This is packet code combining.

(Step 3) When the overall code rate of codes produced by soft combining of the initially transmitted and retransmitted packets is less than or equal to 1/5, each sub-code C_i of the QCTC is repeatedly transmitted in the order of C_0, C_1, C_2, . . ., C_{S-1} at each retransmission request. This is packet diversity combining.

(Step 4) The QCTC set size can be an arbitrary value, determined by the mother code rate. For R=1/5 and a sub-code code rate of 2/3 for retransmission, up to four sub-codes can be used.

Table 3 below lists QCTC sets for forward traffic channel packet data rates that are expected to be available in the present IS-2000 1XEVDV system. Here, a mother code rate R=1/5 and a sub-code code rate R=2/3, 1/3, or 1/6.

(Table 3)

Set size S	Code set	Sub-code rate set	Data rates
1	$\{C_0\}$	C_0: R_0=1/6	307.2kbps 153.6kbps 76.8kbps 38.4kbps

			19.2kbps
2	$\{C_0, C_1\}$	C_0: R_0=1/3 C_1: R_1=1/3	1228.8kbps 921.6kbps 614.4kbps 307.2kbps
4	$\{C_0, C_1, C_2, C_3\}$	C_0: R_0=2/3 C_1: R_1=2/3 C_2: R_2=2/3 C_3: R_3=2/3	2457.6kbps 1843.2kbps 1228.8kbps

As shown in Table 3, for a sub-code code rate of 1/6 less than the mother code rate 1/5, the same code C_0 is used at each transmission. For a sub-code code rate of 1/3, greater than the mother code rate 1/5, different code C_0 and C_1 are used at each transmission. In this case, the code set size S is 2. For a sub-code code rate of 2/3, greater than the mother code rate 1/5, different code C_0, C_1, C_2, C_3 are used at each transmission. The code set size S is 4. When S sub-codes are all transmitted, the receiver can recover the mother code rate R and obtain the maximum coding gain offered by the encoder.

Table 4 below illustrates examples of puncturing matrices for each sub-code code rate.

(Table 4)

Code rates	C_0	C_1	C_2	C_3
R=1/6	$\begin{vmatrix} X \\ Y0 \\ Y1 \\ Y'0 \\ Y'1 \end{vmatrix} = \begin{vmatrix} 2 \\ 1 \\ 1 \\ 1 \\ 1 \end{vmatrix}$	NA	NA	NA
R=1/3	$\begin{vmatrix} 1 \\ 1 \\ 0 \\ 1 \\ 0 \end{vmatrix}$	$\begin{vmatrix} 1 \\ 1 \\ 0 \\ 1 \\ 0 \end{vmatrix}$	NA	NA

R=2/3	0 1 1 0 0 0 0 1 0 0	1 0 0 1 0 0 1 0 0 0	0 1 0 0 1 0 0 0 0 1	1 0 0 0 0 1 0 0 1 0
R=2/3	1 1 1 1 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0	0 0 0 0 0 1 1 1 0 0 0 0 1 1 0 1 0 0 0 0	0 0 0 0 0 0 0 0 1 1 0 1 0 0 0 0 0 1 1 1	1 1 1 1 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0

As shown in Table 4, when a rate 1/5 turbo code is used as a mother code and a rate 2/3 sub-code is generated with code symbols output for 4 information bits, 20 code symbols are generated from the 4 information bits. The rate 2/3 sub-code is generated by puncturing 14 symbols among the 20 symbols. For packet diversity combining of such sub-codes, C_0 produced from the above puncturing matrices is repeatedly transmitted at each retransmission request. On the other hand, for packet code combining, a different code symbol is transmitted at each retransmission request. After transmitting all sub-codes C_0, C_1, C_2, C_3 in the set, the packet diversity combining is executed. For HARQ Type III using packet code combining, full code symbols of the mother code are decoded after four transmissions occur.

Meanwhile, "1"s in the puncturing matrices of Table 4 indicate that the symbols at the positions are selected or transmitted and "0"s indicate that the symbols at the positions are punctured. A "2" indicates that the symbol at the position occurs twice. The puncturing (and repetition) matrices are designed to satisfy the following conditions.

(Condition 1) An information symbol X is repeated in a sub-code of a QCTC when repetition is used.

(Condition 2) If the information symbol X is repeated in a sub-code of the QCTC using repetition, the repeating period is set to be a minimal constant in the QCTC having all sub-codes in combination.

(Condition 3) If puncturing is used, redundancy symbols except the

information symbol X are punctured if possible in the sub-codes of the QCTC.

(Condition 4) If puncturing is used, redundancy symbols except the information symbol X are uniformly punctured if possible in the sub-codes of the QCTC.

A puncturing and repetition matrix with R=1/6 satisfying the above conditions will be described. Decoding is carried out after the symbols X that occur twice are soft-combined and so the real code rate for the decoder is 1/5. The rate 1/5 code, having the energy of the information symbol X increased, has an improved performance, as compared to a rate 1/5 code having a uniform symbol energy across the symbols. In other words, the most appropriate symbol to be repeated is an information symbol. It can be said that the puncturing and repetition matrices shown in Table 4 are constructed in such a way that information symbol energy is increased through uniform repetition of the information symbols.

In Table 4, for R=1/6, the sequence of transmission code symbols is given as

C_0: X, X, Y0, Y1, Y'0, Y'1, X, X, Y0, Y1, Y'0, Y'1, . . .

Because six code symbols are generated for the input of one information symbol, the code rate of the sub-code is 1/6.

For R=1/3, the sequences of transmission code symbols are given as

C_0: X, Y0, Y'0, X, Y0, Y'0, X, Y0, Y'0, X, Y0, Y'0, . . .

C_1: X, Y1, Y'1, X, Y1, Y'1, X, Y1, Y'1, X, Y1, Y'1, . . .

Because three code symbols are generated for the input of one information symbol, the code rate of the sub-code is 1/3. A different code is transmitted at each transmission due to the use of a different puncturing matrix. After soft combining of C_0 and C_1, X occurs twice and each of Y0, Y1, Y'0 and Y'1 occurs once. Thus, the decoder with a code rate 1/5 can be used in this case and the puncturing matrices satisfy the above-described conditions, ensuring performance.

In the first case with R=2/3 of Table 4, the sequence of transmission code symbols are given as

C_0: Y0, X, Y'0, Y0, X, Y'0, Y0, X, Y'0, Y0, X, Y'0, . . .
C_1: X, Y'0, Y0, X, Y'0, Y0, X, Y'0, Y0, X, Y'0, Y0, . . .
C_2: Y1, X, Y'1, Y1, X, Y'1, Y1, X, Y'1, Y1, X, Y'1, . . .
C_3: X, Y'1, Y1, X, Y'1, Y1, X, Y'1, Y1, X, Y'1, Y1, . . .

Because three code symbols are generated for the input of two information symbols, the code rate of the sub-code is 2/3. A different code is transmitted at each transmission due to the use of a different puncturing matrix. After soft combining of C_0, C_1, C_2, C_3, X occurs twice and each of Y0, Y1, Y'0 and Y'1 occurs once. Thus, the decoder with a code rate 1/5 can be used also in this case as for R=1/6 and the puncturing matrices satisfy the above-described conditions, ensuring performance.

In the second case with R=2/3 of Table 4, the sequence of transmission code symbols are given as

C_0: X, Y0, X, X, Y'0, X, X, Y0, X, X, Y'0, X, X, Y0, X, X, Y'0, X, . . .
C_1: Y'0, Y0, Y'0, Y0, Y0, Y'0, Y'0, Y0, Y'0, Y0, Y0, Y'0, . . .
C_2: Y1, Y1, Y'1, Y'1, Y1, Y'1, Y1, Y1, Y'1, Y'1, Y1, Y'1, . . .
C_3: X, Y'1, X, X, Y'1, X, X, Y'1, X, X, Y'1, X, . . .

Because six code symbols are generated for the input of four information symbols, the code rate of the sub-code is 2/3. A different code is transmitted at each transmission due to the use of a different puncturing matrix. After soft combining of C_0, C_1, C_2, C_3, X occurs twice and each of Y0, Y1, Y'0 and Y'1 occurs once. Thus, the decoder with a code rate 1/5 can be used also in this case as for R=1/6 and the puncturing matrices satisfy the above-described conditions, ensuring performance.

FIG. 3 is a graph showing a comparison between the performance of HARQ using packet code combining and the performance of HARQ using packet diversity combining in terms of data throughput for a QCTC with R=2/3 and S=4 according to the present invention. As shown in FIG. 3, an HARQ 301 using packet code combining for the QCTC and an HARQ 302 using packet diversity combining for the QCTC show better performance than an HARQ 303 without the QCTC. For the same real time data throughput (e. g., 0.25), about −4dB of Es/No is required in the HARQ 301, about −1.3dB in the HARQ 302, and about 1dB in the HARQ 303. Consequently, the use of the QCTC

according to the present invention ensures a higher data throughput with less symbol energy.

As described above, sub-codes generated for optimum packet code combining according to a predetermined rule remarkably improves transmission throughput in a packet retransmission system using turbo codes according to the present invention.

While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A method of generating an initial puncturing matrix from which a first sub-code is produced in a communication system having a turbo encoder for generating information symbols, first parity symbols, and second parity symbols for the input of an information bit stream and a sub-code generator for generating sub-codes from the information symbols, the first parity symbols, and the second parity symbols using puncturing matrices , a number of the sub-codes being identical to a number of the puncturing matrices, comprising the steps of:

selecting as many information symbols as a number of columns in the initial puncturing matrix from the information symbols output from the turbo encoder, if a difference between a number Ns of selected symbols in the initial puncturing matrix and the number of the columns in the initial puncturing matrix is equal to or greater than a number of component encoders in the turbo encoder; and

selecting as many first and second parity symbols as the difference, a number of the selected first parity symbols being equal to or greater than a number of the selected second parity symbols.

2. The method of claim 1, further comprising the step of increasing the number of the columns in the puncturing matrix by an integer multiple if the difference is less than the number of the component encoders.

3. The method of claim 1, further comprising the step of selecting the Ns symbols from unselected first and second parity symbols in the initial puncturing matrix in generating a second puncturing matrix, wherein the number of the selected first parity symbols is equal to or greater than the number of the selected second parity symbols.

4. The method of claim 3, further comprising the step of selecting remaining unselected first and second parity symbols in the other puncturing matrices except for a last puncturing matrix and repeating (Ns–Ns2) information symbols, Ns2 being a number of the other unselected parity symbols in the other puncturing matrices.

5. The method of claim 1, wherein the communication system uses the sub-code to hybrid ARQ (Automatic Repeat Request).

6. The method of claim 1, wherein the number Ns of selected symbols is determined by C/Rmax, C being the number of the columns and Rmax being a code rate of the sub-code.

7. A method of generating a first sub-code to be transmitted by selecting a predetermined number of symbols from information symbols and first and second parity symbols within a predetermined puncturing range in a communication system having a turbo encoder for generating information symbols, first parity symbols, and second parity symbols for the input of an information bit stream, the predetermined number of symbols being Ns symbols, comprising the steps of:

selecting all the information symbols within the puncturing range, if a difference between Ns and a number of the information symbols is equal to or greater than a number of component encoders in the turbo encoder; and

selecting as many first and second parity symbols as the difference, anumber of the selected first parity symbols being equal to or greater than a number of the selected second parity symbols.

8. The method of claim 7, further comprising the step of increasing the puncturing range by an integer multiple if the difference is less than the number of the component encoders.

9. The method of claim 7, further comprising the step of selecting the Ns symbols from unselected first and second parity symbols in the first sub-code in generating a second sub-code, wherein the number of the selected first parity symbols is equal to or greater than the number of the selected second parity symbols.

10. The method of claim 9, further comprising the step of selecting remaining unselected first and second parity symbols in the other sub-codes except for a last sub-code and repeating (Ns–Ns2) information symbols, Ns2 being a number of the other unselected parity symbols in generating the last sub-code.

11. The method of claim 7, wherein the communication system uses the sub-codes to hybrid ARQ (Automatic Repeat Request).

12. The method of claim 7, wherein the number Ns of selected

symbols is determined by C/Rmax, C being a number of columns in a puncturing matrix and Rmax being a code rate of the sub-code.

13. A method of generating puncturing matrices by which information symbols and first and second parity symbols are punctured in a communication system having a turbo encoder for generating information symbols, first parity symbols, and second parity symbols for the input of an information bit stream, and a sub-code generator for generating sub-codes from the information symbols, the first parity symbols, and the second parity symbols by puncturing, comprising the steps of:

determining a number S of the puncturing matrices by calculating a minimum integer equal to or greater than a ratio of Rmax to Rmin, Rmax being a given maximum code rate and Rmin being a given minimum code rate for the turbo encoder;

determining a number Ns of symbols to be selected from each puncturing matrix by C/Rmax, C being a number of columns of the puncturing matrix; and

generating a first puncturing matrix for which C information symbols are selected, as many first parity symbols as a minimum integer equal to or greater than a ratio of a(Ns–C) to (a+b) are selected, and as many second parity symbols as a maximum integer equal to or less than a ratio of b(Ns–C) to (a+b) are selected, if a difference between Ns and C, (Ns–C), is equal to or greater than a number of component encoders in the turbo encoder, a and b being symbol distribution ratios for the first and second parity symbols.

14. The method of claim 13, further comprising the step of increasing the number of the columns in the puncturing matrix by an integer multiple if the difference is less than the number of the component encoders.

15. The method of claim 13, further comprising the step of generating middle puncturing matrices except for the first and a last puncturing matrices by selecting as many first parity symbols as a minimum integer equal to or greater than a ratio of aNs to (a+b) and as many second parity symbols as a maximum integer equal to or less than a ratio of bNs to (a+b) without selecting any information symbols, so that the first and second parity symbols differ in the first and other puncturing matrices.

16. The method of claim 15, further comprising the step of generating the last puncturing matrix by selecting remaining unselected first and second parity symbols in the other puncturing matrices except for the last puncturing matrix and repeating (Ns–Ns2) information symbols, Ns2 being a number of the other unselected parity symbols in the other puncturing matrices.

17. The method of claim 13, wherein the communication system uses the sub-codes to hybrid ARQ (Automatic Repeat Request).

18. An apparatus for generating a sub-code in a communication system, comprising:

a turbo encoder for encoding an input information bit stream with a given code rate and generating information symbols, first parity symbols, and second parity symbols; and

a sub-code generator for generating a first sub-code to be transmitted by selecting all information symbols within a predetermined puncturing range and selecting as many first and second parity symbols as a difference between a predetermined number Ns of symbols to be selected and a number of the information symbols within the predetermined puncturing range, a number of the selected first parity symbols being equal to or greater than a number of the selected second parity symbols, if the difference is equal to or greater than a number of component encoders in the turbo encoder.

19. The apparatus of claim 18, wherein the sub-code generator generates a second sub-code by selecting Ns symbols from the first and second parity symbols without selecting information symbols, the number of the selected first parity symbols being equal to or greater than the number of the selected second parity symbols.

20. The apparatus of claim 19, wherein the sub-code generator generates a last sub-code by selecting remaining unselected first and second parity symbols in the other sub-codes except for the last sub-code and repeating (Ns–Ns2) information symbols, Ns2 being a number of the other unselected parity symbols in the other sub-codes.

21. The apparatus of claim 18, wherein the sub-code generator generates the sub-codes by increasing the puncturing range by an integer multiple if the difference is less than the number of the component encoders.

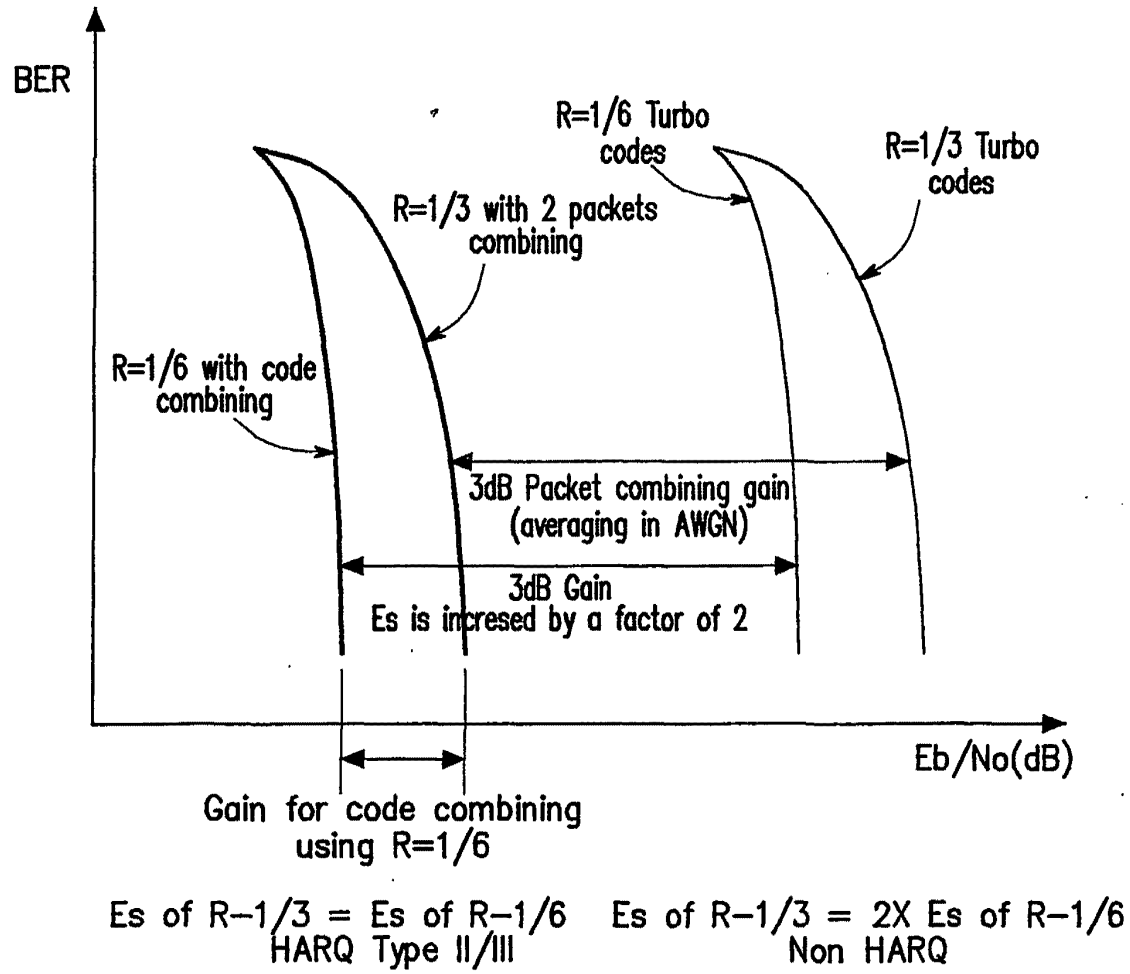

BER
R=1/6 Turbo codes
R=1/3 Turbo codes
R=1/3 with 2 packets combining
R=1/6 with code combining
3dB Packet combining gain (averaging in AWGN)
3dB Gain
Es is incresed by a factor of 2
Eb/No(dB)
Gain for code combining using R=1/6
Es of R-1/3 = Es of R-1/6
HARQ Type II/III
Es of R-1/3 = 2X Es of R-1/6
Non HARQ

FIG. 1

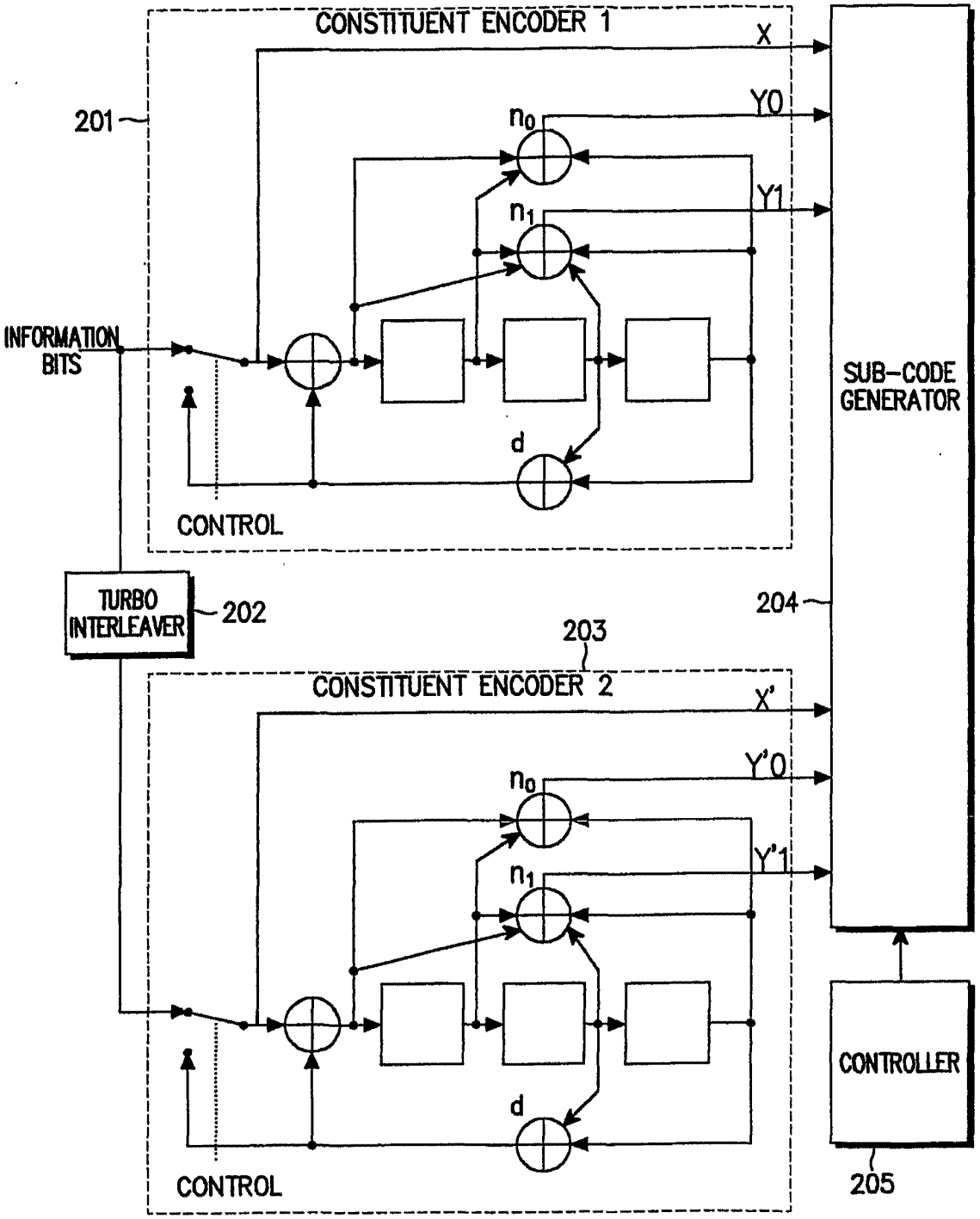

CONSTITUENT ENCODER 1
X
Y0
Y1
201
n_0
n_1
INFORMATION BITS
d
CONTROL
SUB-CODE GENERATOR
TURBO INTERLEAVER
202
203
204
CONSTITUENT ENCODER 2
X'
Y'0
Y'1
n_0
n_1
d
CONTROL
CONTROLLER
205

FIG. 2

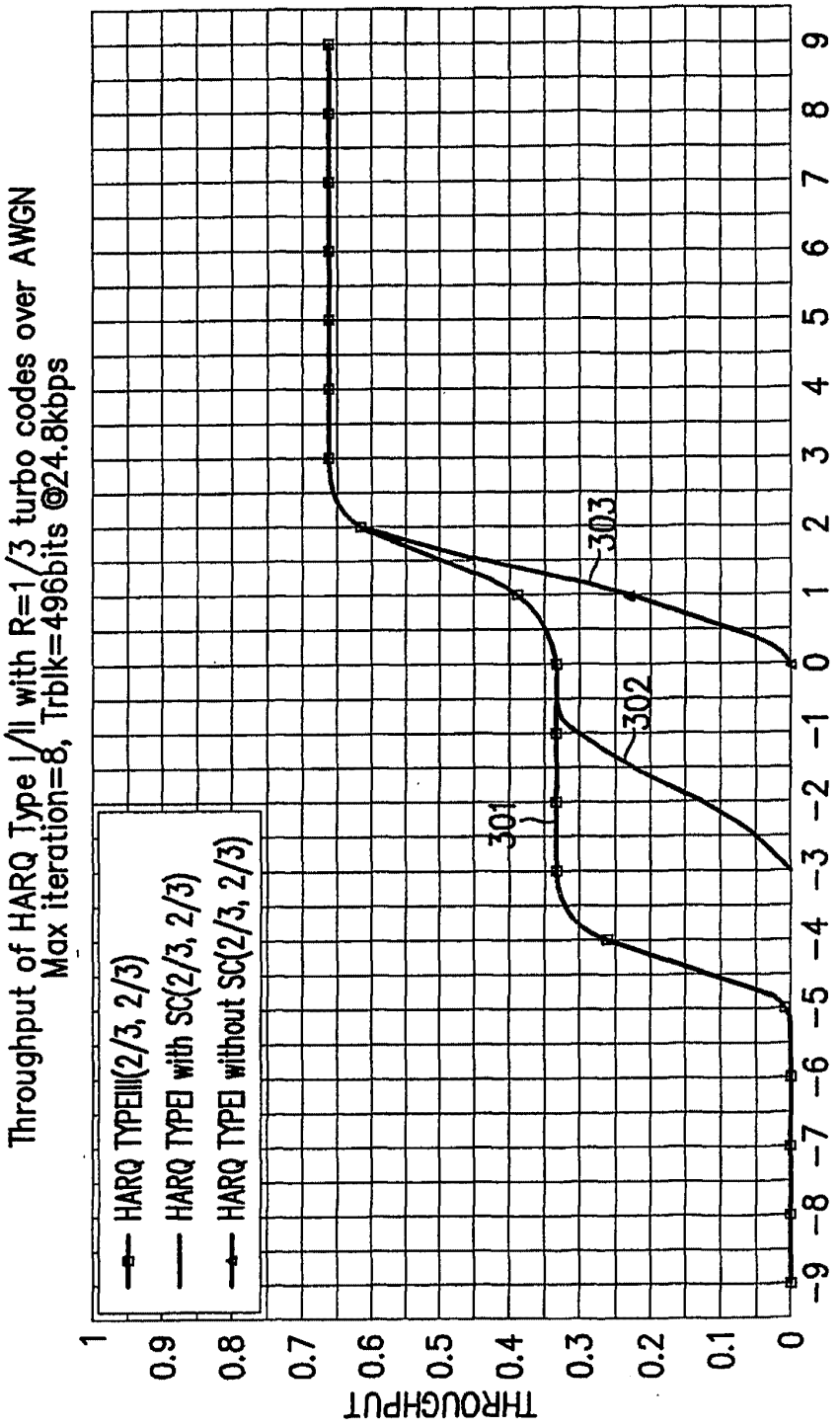

Throughput of HARQ Type I/II with R=1/3 turbo codes over AWGN
Max iteration=8, Trblk=496bits @24.8kbps
HARQ TYPEIII(2/3, 2/3)
HARQ TYPEI with SC(2/3, 2/3)
HARQ TYPEI without SC(2/3, 2/3)
THROUGHPUT
Es/No (dB)
301
302
303

FIG. 3

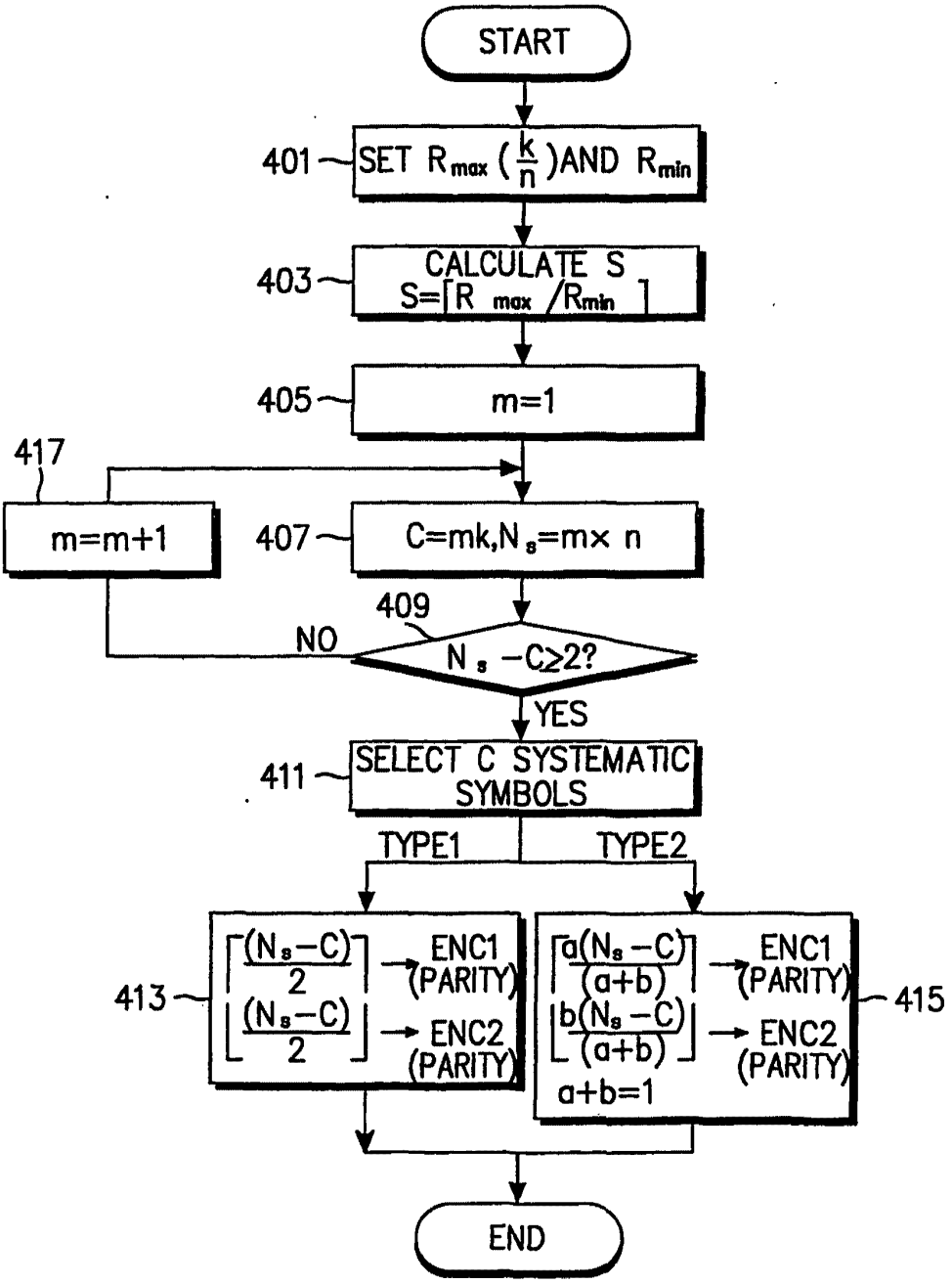

START
401
SET $R_{max}(\frac{k}{n})$ AND R_{min}
403
CALCULATE S
$S=\lceil R_{max}/R_{min} \rceil$
405
m=1
417
m=m+1
407
C=mk, N_s=m× n
409
NO
$N_s - C \geq 2$?
YES
411
SELECT C SYSTEMATIC SYMBOLS
TYPE1
TYPE2
413
$\lceil \frac{(N_s-C)}{2} \rceil$ → ENC1 (PARITY)
$\lceil \frac{(N_s-C)}{2} \rceil$ → ENC2 (PARITY)
$\lceil \frac{a(N_s-C)}{(a+b)} \rceil$ → ENC1 (PARITY)
$\lceil \frac{b(N_s-C)}{(a+b)} \rceil$ → ENC2 (PARITY)
a+b=1
415
END

FIG. 4

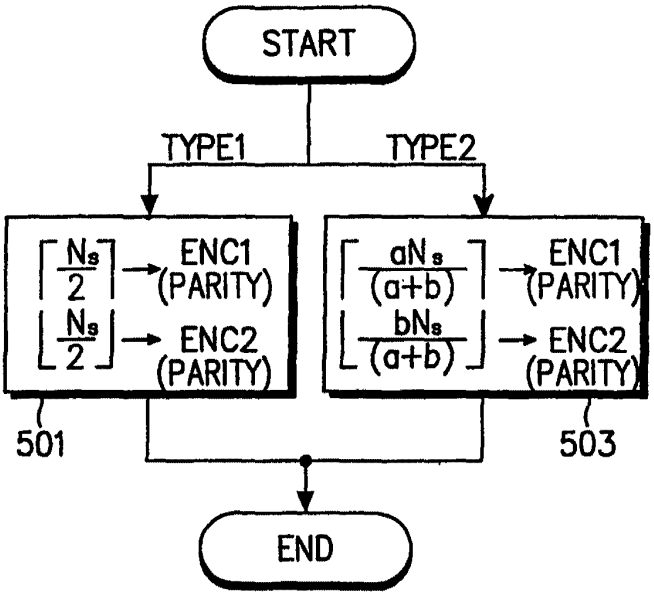

START
TYPE1
TYPE2
⌈Ns/2⌉ → ENC1 (PARITY)
⌊Ns/2⌋ → ENC2 (PARITY)
⌈aNs/(a+b)⌉ → ENC1 (PARITY)
⌊bNs/(a+b)⌋ → ENC2 (PARITY)
501
503
END

FIG. 5

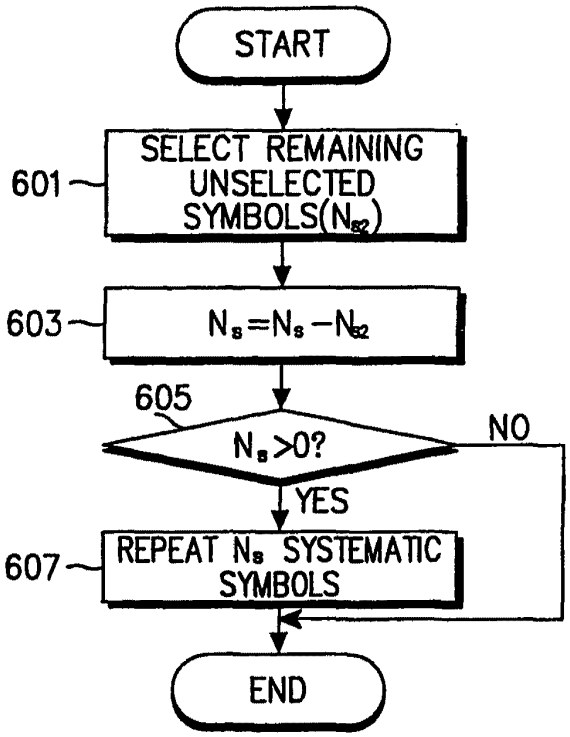

START
601
SELECT REMAINING UNSELECTED SYMBOLS(N_{s2})
603
$N_s = N_s - N_{s2}$
605
$N_s > 0$?
NO
YES
607
REPEAT N_s SYSTEMATIC SYMBOLS
END

FIG. 6

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H04L 12/56

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)

IPC7 H04L 12/56

Documentation searched other than minimun documentation to the extent that such documents are included in the fileds searched

Korean patents and applications for inventions since 1975
Korean utility models and applications for utility models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search trerms used)

http://ep.sepacenet.com(Worldwide search in the European Patent Offfice), "packet code combine"
IEEE/IEE Electronic library(since 1988), "packet and code and symbol and combine and diversity"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Iterative space-time detection of TCM for broadband wireless channels Koca, M.; Levy, B.C. Wireless Communications, 2001.(SPAWC'01). 2001 IEEE Third Workshop on Signal Processing Advances in Published: 2001, Page(s): 122-125	1-21
A	Joint coding and decision feedback qualization for broadband wireless channels Ariyavisitakul, S.; Ye Li Vehicular Technology Conference, 1998. VTC 98. 48th IEEE Published: 1998 Volume:3, Page(s):2256-2261 vol.3	1-21
A	A Performance Analysis for Adaptive Rate, Trellis Coded Hybrid-ARQ Protocols Rasmudden, L. K.; Wicker, S.B. Information Theory, 1993. Proceedings, 1993 IEEE International Symposium on, Page(s):384-384	1-21

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevence
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevence; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 DECEMBER 2001 (17.12.2001)	19 DECEMBER 2001 (19.12.2001)
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon, Dunsan-dong, Seo-gu, Daejeon Metropolitan City 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer KIM, Beom Yong Telephone No. 82-42-481-5684

Form PCT/ISA/210 (second sheet) (July 1998)

International application No.
PCT/KR01/01780

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Joint coding and decision feedback equalization for broadband wireless channels Ariyavisitakul, S.L.; Ye Li Selected Areas in Communications, IEEE Journal on Published: Dec. 1998 Volume: 169, Page(s): 1670-1678	1-21
A	US 5,983,382 A (LUCENT TECHNOLOGIES, INC.) 9 November 1999(09.11.99) the whole document	1-21
A	US 5,410,546 A (STORAGE TECHNOLOGY CORP.) 25 April 1995(25.04.95) the whole document	1-21
A	KR 2001-80224 A (LUCENT TECHNOLOGIES, INC.) 18 April 2001(18.04.2001) the whole document	1-21

PCT/KR01/01780

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
KR 2001-80224	18.04.2001	WO 2000/24153	27.04.2000

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
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(71) Applicant: **MOTOROLA, INC.** [US/US]; 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

(72) Inventors: **BUCKLEY, Michael, E.**; 5242 Louis Court, Gurnee, IL 60031 (US). **BACHU, Raja, S.**; 1022 Lake Hurst Drive, Waukegan, IL 60085 (US). **GHOSH, Amitava**; 3240 Indian Creek Drive, Buffalo Grove, IL 60089 (US). **RATASUK, Rapeepat**; 141 Green Bay Road, Wilmette, IL 60091 (US). **STEWART, Kenneth, A.**; 1571 Amos Bennett Street, Grayslake, IL 60030 (US). **VILLION, Mathieu**; 11, rue Gambetta, F-31000 Toulouse (FR).

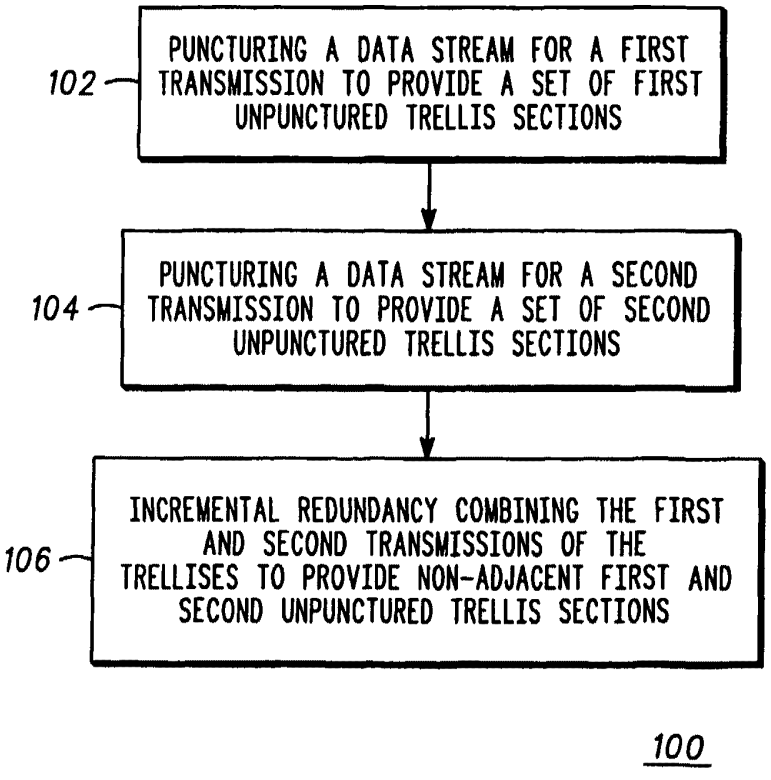
(74) Agents: **MANCINI, Brian, M.** et al.; Motorola, Inc., Intellectual Property Dept., 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

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(54) Title: IMPROVED TURBO CODE BASED INCREMENTAL REDUNDANCY



(57) Abstract: An improved turbo code based incremental redundancy includes a first step (102) of puncturing a data stream for a first transmission to provide a set of first unpunctured trellis sections. A next step (104) includes puncturing a data stream for a second transmission to provide a set of second unpunctured trellis sections. A next step (106) includes incremental redundancy combining the first and second transmissions of the trellises to provide non-adjacent first and second unpunctured trellis sections. The above arrangement results in a uniform distribution of punctured and unpunctured bits to provide lower errors.

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IMPROVED TURBO CODE BASED INCREMENTAL REDUNDANCY

FIELD OF THE INVENTION

This invention relates generally to communication systems, and more particularly to coding in a turbo coded communication system.

BACKGROUND OF THE INVENTION

Convolutional codes are often used in digital communication systems to protect transmitted information from error. Such communication systems include the Direct Sequence Code Division Multiple Access (DS-CDMA) standard IS-95, the Global System for Mobile Communications (GSM), and next generation wideband communication systems. Typically in these systems, a signal is convolutionally coded into an outgoing code vector that is transmitted. At a receiver, a decoder, such as a Viterbi decoder as is known in the art, uses a trellis structure to perform an optimum search for the transmitted signal bits based on maximum likelihood criterion.

More recently, turbo codes have been developed that outperform conventional coding techniques. Turbo codes are generally composed of two or more recursive systematic convolutional codes and turbo interleavers. Correspondingly, turbo decoding is iterative and uses a soft output decoder to decode the individual convolutional codes. The soft outputs of the decoders are used in the decoding procedure to iteratively approach the converged final results.

FIG. 1 shows an overview of typical turbo encoder that is constructed with one interleaver and two constituent codes, which are recursive systematic convolutional (RSC) codes, but can be block codes, also. A turbo encoder is shown which is a parallel concatenation of two RSCs with an interleaver, π, between them. The output of the turbo encoder is generated by multiplexing (concatenating) the systematic information bits, x_s, and parity bits, p_1 and p_2, from the two encoders. Typically, the parity bits are punctured in some manner for the first transmission and combined to increase code rate. The puncturing mechanism occurs in the Rate Matching block. In

the case subsequent transmissions are allowed and transmissions with different puncturings can be combined at the receiver, puncturing may also be preformed on the systematic bits.

Typically, the encoded data is transmitted to a receiver, which uses error correction typically provided by the turbo code, followed by error detection typically provided by a CRC code. If an error is detected, the receiver can request that the transmitter, such as a base station for example, retransmit the data using an Automatic Repeat Request (ARQ). In other words, if a receiver is not able to resolve the data bits in time, the radio can request the transmitter to resend either an identical transmission as the first, or one punctured different from the first transmission but encoded based on same message (i.e. based on the same information bit sequence input to the turbo encoder). Since this process is a hybrid form of error correction coupled with error detection feedback through the ARQ mechanism it is commonly referred to as Hybrid Automatic Repeat Request (HARQ).

Two known forms of HARQ are Chase combining and Incremental Redundancy (IR). In addition, the IR scheme can be full or partial. Chase combining is a simplified form of HARQ wherein the receiver simply requests retransmission of the original codeword again. IR is more complicated in that it provides for a retransmission of the code word using more or different parity bits (than were present during the previous transmission), lowering the overall combined code rate. A repetition or puncturing pattern in the parity bits can be defined using a classical code puncturing matrix, as is known in the art, or a rate matching algorithm to maintain the code rate of the physical channel. However, previous rate matching algorithms do not maintain a homogenous puncturing pattern after incremental redundancy even if orthogonality is retained (i.e. even if each transmission contains unique bits not contained in other transmissions), thereby presenting a higher than necessary frame error rate (FER). In particular, existing rate matching algorithms provide differing error degradations depending on the redundancy version being used. Moreover, there is no method for determining redundancy parameters for HARQ.

What is needed is an improved turbo coder that utilizes a unified puncturing scheme, which provides an improved frame error rate using an incremental

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redundancy technique whereby orthogonal redundancy versions are available for transmission, the combination of which result in an uniform puncturing pattern throughout the decoder trellis. It would also be advantageous to provide this improvement using any of the available redundancy versions. It would also be of benefit, to provide a technique for determining redundancy parameters to provide a turbo coder with minimized computational complexity.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention, which are believed to be novel, are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in conjunction with the accompanying drawings, in the several figures of which like reference numerals identify like elements, and in which:

FIG. 1 shows a simplified block diagram for a turbo encoder as is known in the prior art;

FIG. 2 shows a simplified flow chart for a prior art coding structure;

FIG. 3 shows a simplified flow chart for a coding apparatus, in accordance with the present invention;

FIG. 4 shows a simplified block diagram for the rate matching of FIG. 3;

FIG. 5 shows simplified graphic representation for prior art puncturing;

FIG. 6 shows simplified graphic representation for puncturing, in accordance with the present invention;

FIG. 7 shows a graphical representation of the improvement provided by the present invention;

FIG. 8 shows a chart for bit priority mapping, in accordance with the present invention;

FIG. 9 shows a chart for block interleaver management, in accordance with the present invention;

FIG. 10 shows a simplified flow chart of a method, in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention provides a method and apparatus for a turbo coder that supports Chase and incremental redundancy (IR) as a form of ARQ combining, using a single, unified puncturing scheme. In particular, the present invention uses an improved rate-matching technique for puncturing. The nature of the rate matching ensures a regular puncturing distributed throughout the encoded trellis ensuring good code performance. The puncturing approach of the present invention has the advantage of ease of implementation as well as retaining the orthogonality in adapting to any selected redundancy version without an increase in frame errors.

In application, The High Speed Downlink Packet Access (HSDPA) feature of the Third Generation Partnership Project (3GPP) UTRA (UMTS Terrestrial Radio Access) or Wideband Code Division Multiple Access (WCDMA) system features adaptive modulation and coding and details a hybrid-ARQ scheme based on Incremental Redundancy (IR) methods applied to a rate-1/3 turbo-code. The present invention defines the High Speed Downlink Shared Channel (HS-DSCH) coding modulation using incremental redundancy in user equipment (UE), such as a cellular radio communication device. The present invention describes a specific method for applying IR to HSDPA.

IR methods are known in the art, and have been applied before to systems such as Enhanced Data for GSM Evaluation (EDGE). However, the HSDPA problem is novel, in that, all possible coding rates must be supported and only under certain conditions such as in some cases, retransmissions of equal size, is there the potential for orthogonal transmissions. Moreover, the present invention allows for a change in the final coding rate according to the available coded symbol memory or Soft Metric Locations (SMLs) available to the HARQ process. Also, unlike the present invention, prior systems, such as EDGE, utilized convolutional codes rather than turbo codes, and supported a different number of redundancy versions.

The present invention provides a flexible IR puncturing scheme specifically applicable to HSDPA. In particular, the puncturing scheme of the present invention supports a variable set of possible redundancy versions using a novel implementation

of a rate-matching puncturing technique. Prior art implementations for rate-matching, while providing orthogonal puncturing patterns in the individual parity bit streams, do not result in a uniformly patterned (and orthogonal) puncturing scheme in the composite of the parity transmissions. This results in increased FER for the different redundancy version used. The present invention accounts for these problems by retaining orthogonality between redundancy versions and provides uniform spacing (i.e. equally spaced unpunctured trellis sections) throughout the composite IR combined trellis. This can include puncturing of parity and systematic bits. Moreover, the present invention provides a method of selecting redundancy parameters as will be described below.

FIG. 2 shows the existing reference channel coding model for High Speed Downlink Packet Access (HSDPA) in accordance with the 3GPP specification protocols of section 4.2, "Technical Specification Group Radio Access Network; Multiplexing and Channel Coding (FDD) (Release 1999)", TS 25.212 v3.5.0 (2000-12), which is hereby incorporated by reference. Data is input from a single transport block. To this stream, cyclic redundancy check (CRC) is added 202, and then the stream is segmented 204 to produce N_{CB} code blocks 206. The detailed functionality of these blocks 200-206 is presented in TS 25.212. At this point, each of the code blocks are individually subjected to channel coding 208 and rate matching 210 according to the puncturing and incremental redundancy used. The blocks are then subject to physical channel segmentation 212, interleaving 214, and physical channel mapping 216, where physical channels 1 through K are output.

FIG. 3 shows a channel coding model for the HSDPA turbo coder in accordance with the present invention. The first four operations (transport block concatenation 200, CRC attachment 202, code block segmentation 204, and channel coding 208) proceed according to the 3GPP protocols previously described. Preferably, channel coding 208 proceeds according to a channel coder operable to code an input data stream into systematic bits and parity bits at a rate-1/3 turbo encoding function. In addition, the last three stages (physical channel segmentation 312, (symbol) interleaver 314, and physical channel mapping 316) also proceed similarly to the 3GPP protocols with the exception of operation on symbols instead of

bits. The present invention occurs in the redundancy version selector 309, rate matching/incremental redundancy block 310, and the optional bit priority mapper/interleaver 311, as detailed in FIG. 4.

The functionality of HARQ uses two rate-matching stages. The matching block 310 matches the number of bits at the output of the channel coder 208 to the total number of bits of the HS-DSCH physical channels through puncturing or repeating incoming systematic, parity 1 and parity 2 bits, and is controlled by the redundancy version (RV). The rate matching algorithm is applied differently to different set of systematic and parity inputs bits, depending on the parameters of the redundancy version. The rate matching block 310 punctures a data stream (that can include parity and systematic bits) for a first transmission to provide a set of first unpunctured trellis sections and punctures a data stream. A redundancy version selector 309 is coupled to the rate matching block 310 and provides rate-matching parameters thereto. The rate matching block 310 provides incremental redundancy to combine the first and second transmissions of the data stream trellises to provide non-adjacent first and second unpunctured trellis sections.

The first rate-matching stage 316 matches the number of input bits to the number of soft bits available at the user equipment. If the number of soft bits available at the user equipment is greater than or equal to the number of bits output from the channel encoder 208 then all the bits can be stored and the first rate-matching stage is transparent. However, if the number of soft bits available at the user equipment is less than the number of bits output from the channel encoder 208, as is typical, then puncturing occurs so that the number of encoder output bits matches the available soft-buffering capability of the user equipment, represented by buffer stage 317.

The second rate-matching stage 318 matches the number of bits output from the first rate-matching stage 316 to the number of bits available in the HS-DSCH physical channel. The same basic technique is used as for the first rate-matching stage. However, compared to first stage rate matching, the rate-matching algorithm may use different values for the rate-matching parameters, depending on the RV parameters: s, which can take the value 0 or 1 to distinguish self-decodable (1) and

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non self-decodable (0) transmissions, and the RV parameter r (range 0 to r_{max}, which is the maximum number of redundancy versions supported by the communication system) which changes the initial error variable e_{ini}.

For example, the number of bits before second rate matching can be denoted as N_{sys} for the systematic bits, N_{p1} for the parity 1 bits, and N_{p2} for the parity 2 bits, respectively. The number of available physical channel bits per transmit time interval (TTI) is N_{data}. Bit separation is used and the rate matching parameters are determined as follows. For $N_{data} \le N_{sys} + N_{p1} + N_{p2}$, puncturing is performed in the second rate matching stage 318. The number of transmitted systematic bits in a retransmission is

$$N_{t,sys} = \min\{N_{sys}, N_{data}\}$$

for a transmission of self-decodable type ($s = 1$) and

$$N_{t,sys} = \max\{N_{data} - (N_{p1} + N_{p2}), 0\}$$

in the non self-decodable case, i.e., $s = 0$.

For $N_{data} > N_{sys} + N_{p1} + N_{p2}$ repetition is performed in the second rate matching stage. A similar repetition rate in all bit streams is achieved by setting the number of transmitted systematic bits to

$$N_{t,sys} = N_{sys} + \left\lceil \frac{N_{data} - (N_{sys} + N_{p1} + N_{p2})}{3} \right\rceil .$$

The available room for parity bits in a transmission is:

$$N_{t,p1} = \left\lfloor \frac{N_{data} - N_{t,sys}}{2} \right\rfloor \quad \text{and} \quad N_{t,p2} = \left\lceil \frac{N_{data} - N_{t,sys}}{2} \right\rceil$$

for the parity 1 and parity 2 bits, respectively.

Table 1 summarizes the resulting parameter choice for the second rate matching stage 318. The parameter a in Table 1 is chosen such that $a = 2$ for parity 1 and $a = 1$ for parity 2.

Table 1
Parameters for Second Rate Matching Stage

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	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys} - N_{t,sys} \rvert$
Parity 1 RM P1_2	N_{p1}	$a \cdot N_{p1}$	$a \cdot \lvert N_{p1} - N_{t,p1} \rvert$
Parity 2 RM P2_2	N_{p2}	$a \cdot N_{p2}$	$a \cdot \lvert N_{p2} - N_{t,p2} \rvert$

where N_{sys} is the number of systematic bits, N_{p1} is the number of parity 1 bits, N_{p2} is the number of parity 2 bits, $N_{t,sys}$ is the number of transmitted systematic bits, $N_{t,p1}$ is the number of transmitted parity 1 bits, and $N_{t,p2}$ is the number of transmitted parity 2 bits.

In the prior art, the rate matching parameter e_{ini} is calculated for each bit stream according to the e_{ini} variation parameter r, $r \in \{0,1\}$ using

$$e_{ini}(r) = \{[X_i - r \cdot e_{minus} - 1] \bmod e_{plus}\} + 1$$

in the case of puncturing , i.e., $N_{data} \le N_{sys} + N_{p1} + N_{p2}$, and

$$e_{ini}(r) = \{[X_i - (2 \cdot s + r) \cdot e_{minus} - 1] \bmod e_{plus}\} + 1$$

for repetition, i.e., $N_{data} > N_{sys} + N_{p1} + N_{p2}$. While varying r does result in mutually orthogonal puncturing patterns, their composite does not result in a uniformly patterned puncturing scheme as shown in the example of FIG. 5. In the scenario shown in FIG. 5, both transmissions are self-decodable with the Parity 1 codeword bits of the first transmission consisting of the 4^{th}, 10^{th}, 16^{th}, ... trellis sections and those of the second transmission consisting of the 3^{rd}, 9^{th}, 15^{th}, ... sections. The IR combined trellis based on the first two transmissions is therefore concerned with the 3^{rd}, 4^{th}, 9^{th}, 10^{th}, 15^{th}, 16^{th}, ... stages in the trellis. In practice, this non-uniform grouping of punctured and unpunctured bits results in a higher FER.

In contrast, in the present invention, e_{ini} is calculated for each bit stream according to the e_{ini} variation parameter r, $r \in \{0,1\}$, using

$$e_{ini}(r) = \left\{\left[X_i - \left(r \cdot e_{plus}/2\right) - 1\right] \bmod e_{plus}\right\} + 1$$

in the case of puncturing , i.e., $N_{data} \le N_{sys} + N_{p1} + N_{p2}$, and

$$e_{ini}(r)=\left\{\left[X_t-\left((s+2\cdot r)\cdot e_{plus}/4\right)-1\right]\bmod e_{plus}\right\}+1$$

for repetition, i.e., $N_{data} > N_{sys}+N_{p1}+N_{p2}$.

In its more general form where $r \in \{0,\cdots,r_{\max}-1\}$ and $r_{\max}$ is the total number of redundancy versions allowed by varying r, then e_{ini} is calculated for each bit stream according to the e_{ini} variation parameter r, $r \in \{0,\cdots,r_{\max}-1\}$, using

$$e_{ini}(r)=\left\{\left[X_t-\left(r\cdot e_{plus}/r_{\max}\right)-1\right]\bmod e_{plus}\right\}+1$$

in the case of puncturing and/or repetition, and

$$e_{ini}(r)=\left\{\left[X_t-\left((s+2\cdot r)\cdot e_{plus}/(2\cdot r_{\max})\right)-1\right]\bmod e_{plus}\right\}+1$$

also in the case of puncturing and/or repetition. In other words, the rate matching equations can be chooses such that either one of the equations is used to rate match for both the case of puncturing (i.e., $N_{data} \le N_{sys}+N_{p1}+N_{p2}$) and the case of repetition (i.e., $N_{data} > N_{sys}+N_{p1}+N_{p2}$), or one of the equations is chosen to rate match for puncturing and the other equation to rate matching for repetition.

The resulting puncturing pattern both retains orthogonality between redundancy versions of the same *s* value, but is now uniformly spaced throughout the composite IR combined trellis as shown in the example of parity trellises of FIG. 6, which results in improved FER over that of the trellis of FIG. 5. The invention is applicable to both parity bits and systematic bits.

FIG. 7 shows the improvement provided improved puncturing technique of the present invention. Both the prior art and proposed rate-matching e_{ini} variation schemes were simulated, using known techniques, over an additive white Gaussian noise (AWGN) channel using BPSK modulation with a codeword length of 960 and Ninfo = 720, and using two transmission. Curves 60 and 62 represent the FER for the prior art puncturing method after first and second transmissions, respectively. Curves 64 and 66 represent the FER for the puncturing method of the present invention after first and second transmissions, respectively. As can be seen from the simulation results, there is about a 0.2-0.3dB improvement in FER performance of the present

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invention over the prior art after two transmissions. In view of the above, the present invention provides a useful improvement over the prior art with no increase in complexity.

In a preferred embodiment, the present invention also provides a method and apparatus to select optimized s and r parameters based on the redundancy scheme chosen (Chase, Partial IR, or Full IR), referring back to redundancy version selector 309 of FIG. 3. The selection of the redundancy version depends on the redundancy scheme being utilized. Currently, three schemes are expected to be support in HSDPA: Chase, Partial Incremental Redundancy (IR) and Full IR. For each redundancy scheme the following methods are used for calculating $s, s \in \{0,1\}$ and $r, r \in \{0,1,2,\ldots,r_{\max}-1\}$.

If the Chase redundancy scheme is used, $s = 1$ and $r = 1$ for all transmissions.

If a Partial IR redundancy scheme is used, a first step includes calculating the possible number of unique redundancy versions as

$$r_N = \left\lceil \frac{\sum_{i=1}^{P} N_{p\_i}}{\sum_{i=1}^{P} N_{t\_p\_i}} \right\rceil$$

where N_{p_i} represents the number of parity bits at the output of the turbo encoder from the i^{th} parity stream, $N_{t\_p\_i}$ represents the number of parity bits to be transmitted from the i^{th} parity stream, and P is the number of parity streams. Also, if $r_N > r_{max}$ then $r_N = r_{max}$. In a next step, for transmission index, n, from $1,2,\ldots,r_N$, set $s = 1$ and $r = n\text{-}1$. If $n > r_N$, reset n to 1 and repeat the previous step.

If a Full IR redundancy scheme is used, a first step includes calculating the possible number of unique redundancy versions as

$$r_N = \min_k \left[\frac{1}{R} \times k = \frac{1}{BR} \times i \right]$$

where BR is the base code rate, R is the transmit code rate, and k and i are positive integers. Note that k and i are chosen such that exactly k transmissions will equal i

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output blocks (systematic and parity) from the turbo encoder. Also, if $r_N > r_{max}$ then $r_N = r_{max}$. In a next parameter setting step, for transmission index $n = 1$, set $s = 1$, $r = 0$, and $N_t = N_{trans}$, or for transmission index n from $2,\ldots,r_N$, repeat the remaining substeps of: a) a first substep sets $N_t = N_t + N_{trans}$, b) in a next substep, if $(N_t \geq \frac{1}{BR} \times N_{sys})$ then set $flag = 1$ and $(N_t = N_t - \frac{1}{BR} \times N_{sys})$ where N_{sys} is the number of systematic bits generated by the turbo encoder. Otherwise set $flag = 0$, c) in a next substep, if $((N_t \geq N_{sys}) \,\&\, (flag = 1))$ then set $s = 1$. Otherwise set $s = 0$, d) in a next sub step set $r = r + 1$, e) in a next substep, if $n > r_N$, reset n to 1 and repeat parameter setting step.

The above schemes automatically select the self-decodable parameter (s) and the redundancy version (r) for the Incremental Redundancy scheme adopted by 3GPP. The values are chosen based on the pre-selected redundancy scheme, which includes Chase, Partial IR, and Full IR, and can be used in conjunction with any adaptive modulation and coding scheme (AMCS) assuming synchronization between the Node B and UE. Otherwise the (s) and (r) parameters can be transmitted to the UE using one of the following two schemes, a) explicitly specifying the value of "s" and "r" and transmitting these values using the High Speed Shared Control Channel (HS-SCCH) or (b) setting up a table of "s" and "r" values and communicating the table at call initiation to UE through higher level signaling. The specific entry in the table is then signaled over the HS-SCCH at each transmission.

In a separate embodiment, where r_{max} is not necessarily known then e_{ini} can be defined as follows

$$e_{ini}(r) = \left\{\left[X_t - \left(f(r) \cdot e_{plus}\right) - 1\right] \bmod e_{plus}\right\} + 1$$

where

$$f(r) = \text{bin2dec(fliplr(dec2bin(r-1)))}/2^{\lceil \log_2(r) \rceil}$$

where "bin2dec" denotes binary to decimal conversion, "dec2bin" denotes decimal to binary conversion, and "fliplr" denotes bit order reversion of the binary sequence.

In a preferred embodiment, the present invention provides a bit priority mapper (311 referring back to FIG. 3) coupled to the rate matching block. The bit

priority mapper is for mapping to systematic bits to position of higher reliability in the modulation constellation, which further improves the performance of IR. Bit priority mapping (BPM) is based on utilizing the differing bit reliability offered by higher order constellations (16-QAM or higher). It is well known that systematic portions of a turbo codeword are of greater importance to decoder performance than the parity portions. It naturally follows that system performance can be further improved by placing systematic bits in positions of high reliability if a higher order constellation is used. To achieve this a simple interleaver (reference 311 in FIG. 3) of size $N_{row} \times N_{col}$ is used. The numbers of rows and columns are determined from:

$$N_{row} = \log_2(M)$$
$$N_{col} = N_{trans} / N_{row}$$

where M is the modulation size (constellation order) and N_{trans} is the number of coded and rate-matched bits to be transmitted. For example, $N_{row} = \log_2(16) = 4$ in the case of 16-QAM. In the general turbo encoder case a codeword is separated into a systematic stream and parity streams denoted by $x_{S,k}$, $p_{1,k}$, $p_{2,k}$ where $k \in \{1, ..., N_{trans}\}$, or in the preferred case a systematic stream and combined parity stream denoted by $x_{S,k}$ and $x_{P,k}$ (see FIG. 1). Data is read into the interleaver row by row, and out of the interleaver column by column. To perform priority mapping, the whole stream of systematic bits from the turbo encoder is read in first (code block-wise and then from left-to-right), followed by combined alternating bits from the two parity streams. Systematic codeword bits 700 are read code block-wise and then from left-to-right into the BPM array. Once all systematic codeword bits have been read in, the combined alternating bits from the two parity streams are read in, continuing from where the systematic codeword bits left off, again code block-wise and then from left-to-right. In the case of full IR where no systematic bits form part of the transmission codeword, only parity codeword bits fill up the array. The BPM array is a sequence of QAM symbols or bit vectors (a vector of four bits in the case of 16-QAM and a vector of two bits in the case of QPSK) given by the columns of the BPM array, read in sequence from left-to-right. Advantageously, this results in systematic bits being mapped into the first rows of the bit mapper followed by subsequent mapping of parity bits.

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Interleaving is determined in the same manner as the turbo code internal interleavers, such as is described in section 4.2.3.2.3.1 of "Technical Specification Group Radio Access Network; Multiplexing and Channel Coding (FDD) (Release 1999)", TS 25.212 v3.5.0 (2000-12), which is hereby incorporated by reference.

The symbol mapping is dependent on the type of modulation and the number of systematic and parity bits used in transmission. As an example, if an effective code rate of 3/4 and 16-QAM modulation is used, each QAM symbol comprises of three systematic bits and one parity bit, while if the same version is used with a code rate of 1/2 and 16-QAM modulation, each QAM symbol then comprises of two systematic and two parity bits. FIG. 8 illustrates the bit distribution process for 16-QAM and rate 1/2, where S represents systematic bits and P represents parity bits.

In practice, the interleaver of the present invention is a symbol block interleaver of size 16x30. The interleaving operation proceeds by reading the input symbol sequence $\{y_{p,i}\}$ into the interleaver row by row starting with column 0 of row 0 and continuing on to column 30 of row 16, as shown in FIG. 9. The next step includes performing inter-column permutation using the following permutation pattern {0, 20, 10, 5, 15, 25, 3, 13, 23, 8, 18, 28, 1, 11, 21, 6, 16, 26, 4, 14, 24, 19, 9, 29, 12, 2, 7, 22, 27, 17}, which provides a more homogenous and therefore desirable distribution. In permuting the columns, it is ensured that no sub-block section of the trellis is neglected when only a portion of a row is read out to form the transmitted codeword. The last step is reading the output symbols, column by column.

Referring back to FIG. 3, the physical channel segmentation 312 proceeds according to the 3GPP protocol of section 4.2.10 of TS 25.212, incorporated by reference, but with a modification. Instead of applying the algorithm on bits as in section 4.2.10, it is applied on the QAM symbols/bit vectors output from the BPM described above.

Following channel segmentation 312, (second) interleaving 314, as described in section 4.2.11 in TS 25.212 is applied, again with a modification. In this case, instead of applying the interleaver on the bits comprising each physical channel, it is applied on the QAM symbols values or symbol indices of each of the physical channel which are output from the physical channel segmentation 312.

Finally and similarly, the physical channel mapping 314 described in section 4.2.12 of TS 25.212 is applied, again with substitution of QAM data symbols for bits.

FIG. 10 shows a flow chart summarizing the method 100 of improved puncturing for turbo code based incremental redundancy, in accordance with the present invention. A first step 102 of the method includes puncturing a data stream for a first transmission to provide a set of first unpunctured trellis sections. A next step 104 includes puncturing a data stream for a second transmission to provide a set of second unpunctured trellis sections. This can be applied to parity and systematic bits. A next step 106 includes incremental redundancy combining the first and second transmissions of the trellises to provide non-adjacent first and second unpunctured trellis sections. Preferably, this provides uniformly patterned punctured and unpunctured trellis sections in the combined trellis. A next step includes outputting the transmissions of the turbo code, for decoding in a turbo decoder, to obtain the information contained within the turbo code, and providing the information to a user over a user interface such as a speaker, display, and the like, or for storage in a data storage device.

Although the invention has been described and illustrated in the above description and drawings, it is understood that this description is by way of example only and that numerous changes and modifications can me made by those skilled in the art without departing from the broad scope of the invention. Although the present invention finds particular use in portable cellular radiotelephones, the invention could be applied to any two-way wireless communication device, including pagers, electronic organizers, and computers. Applicants' invention should be limited only by the following claims.

CLAIMS

What is claimed is:

1. A method for improving turbo code based incremental redundancy, the method comprising the steps of:

puncturing a data stream for a first transmission to provide a set of first unpunctured trellis sections;

puncturing a data stream for a second transmission to provide a set of second unpunctured trellis sections; and

incremental redundancy combining the first and second transmissions of the trellises to provide non-adjacent first and second unpunctured trellis sections.

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2. The method of claim 1, wherein the combining step provides a composite puncturing pattern that is uniformly patterned with unpunctured trellis sections.

3. The method of claim 1, wherein the puncturing steps each provide a set of respective first and second orthogonal unpunctured trellis sections.

4. The method of claim 1, wherein the puncturing steps each include a substep of rate matching each bit stream using a rate matching parameter defined by the equations

$$e_{ini}(r) = \left\{\left[X_i - \left(r \cdot e_{plus} / r_{\max}\right) - 1\right] \bmod e_{plus}\right\} + 1$$

and

$$e_{ini}(r) = \left\{\left[X_i - \left((s+2\cdot r)\cdot e_{plus} / (2\cdot r_{\max})\right) - 1\right] \bmod e_{plus}\right\} + 1$$

where $r \in \{0, \cdots, r_{\max} - 1\}$ and $r_{\max}$ is the total number of redundancy versions allowed by varying r, wherein e_{ini} is calculated for each bit stream according to the e_{ini} variation parameter r, s is 0 or 1 depending on whether the transmission is non-self-decodable or self-decodable, respectively, e_{plus}, and e_{minus} are chosen according to the table

	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys} - N_{t,sys}\rvert$
Parity 1 RM P1_2	N_{p1}	$a \cdot N_{p1}$	$a \cdot \lvert N_{p1} - N_{t,p1}\rvert$
Parity 2 RM P2_2	N_{p2}	$a \cdot N_{p2}$	$a \cdot \lvert N_{p2} - N_{t,p2}\rvert$

where $a = 2$ for parity 1 and $a = 1$ for parity 2, N_{sys} is the number of systematic bits, N_{p1} is the number of parity 1 bits, N_{p2} is the number of parity 2 bits, $N_{t,sys}$ is the number of transmitted systematic bits, $N_{t,p1}$ is the number of transmitted parity 1 bits, and $N_{t,p2}$ is the number of transmitted parity 2 bits, and wherein rate matching equations are selected from one of the group consisting of: choosing either one of the equations to rate match for both the case of puncturing (i.e., $N_{data} \le N_{sys} + N_{p1} + N_{p2}$) and the case of repetition (i.e., $N_{data} > N_{sys} + N_{p1} + N_{p2}$), and choosing one of the equations to rate match for puncturing and the other equation to rate matching for repetition.

IPR2023-01272 Page 195

5. The method of claim 1, wherein the puncturing steps each include a substep of rate matching each bit stream using a rate matching parameter defined by the equations

$$e_{ini}(r)=\left\{\left[X_i-\left(r\cdot e_{plus}/2\right)-1\right]\bmod e_{plus}\right\}+1$$

in the case of puncturing , i.e., $N_{data} \le N_{sys}+N_{p1}+N_{p2}$, and

$$e_{ini}(r)=\left\{\left[X_i-\left((2\cdot s+r)\cdot e_{plus}/4\right)-1\right]\bmod e_{plus}\right\}+1$$

for repetition, i.e., $N_{data} > N_{sys}+N_{p1}+N_{p2}$, where r is the e_{ini} variation parameter, s is 0 or 1 depending on whether the transmission is non-self-decodable or self-decodable, respectively, and r ranges from 0 to r_{max} to vary the initial error variable e_{ini}, and X_i , e_{plus}, and e_{minus} are chosen according to the table

	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys}-N_{t,sys}\rvert$
Parity 1 RM P1_2	N_{p1}	$a\cdot N_{p1}$	$a\cdot\lvert N_{p1}-N_{t,p1}\rvert$
Parity 2 RM P2_2	N_{p2}	$a\cdot N_{p2}$	$a\cdot\lvert N_{p2}-N_{t,p2}\rvert$

where $a = 2$ for parity 1 and $a = 1$ for parity 2, N_{sys} is the number of systematic bits, N_{p1} is the number of parity 1 bits, N_{p2} is the number of parity 2 bits, $N_{t,sys}$ is the number of transmitted systematic bits, $N_{t,p1}$ is the number of transmitted parity 1 bits, and $N_{t,p2}$ is the number of transmitted parity 2 bits.

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6. The method of claim 5, further comprising a step of selecting a redundancy scheme, wherein:

if Chase redundancy is chosen, setting $s = 1$ and $r = 1$ for all transmissions;
if a partial IR redundancy is chosen, performing the substeps of:
calculating the possible number of unique redundancy versions as

$$r_N = \left\lceil \frac{\sum_{i=1}^{P} N_{p\_i}}{\sum_{i=1}^{P} N_{t\_p\_i}} \right\rceil$$

where N_{p_i} represents the number of parity bits at the output of the turbo encoder from the i^{th} parity stream, $N_{t\_p\_i}$ represents the number of parity bits to be transmitted from the i^{th} parity stream, and P is the number of parity streams, wherein if $r_N > r_{max}$ then $r_N = r_{max}$; and
for transmission index n, from 1,2,...,r_N , setting $s = 1$ and $r = n$-1, and
wherein if $n > r_N$, resetting n to 1 and repeating this substep; and
if a full IR redundancy is chosen, performing the substeps of:
a) calculating the possible number of unique redundancy versions as

$$r_N = \min_k \left[\frac{1}{R} \times k = \frac{1}{BR} \times i \right]$$

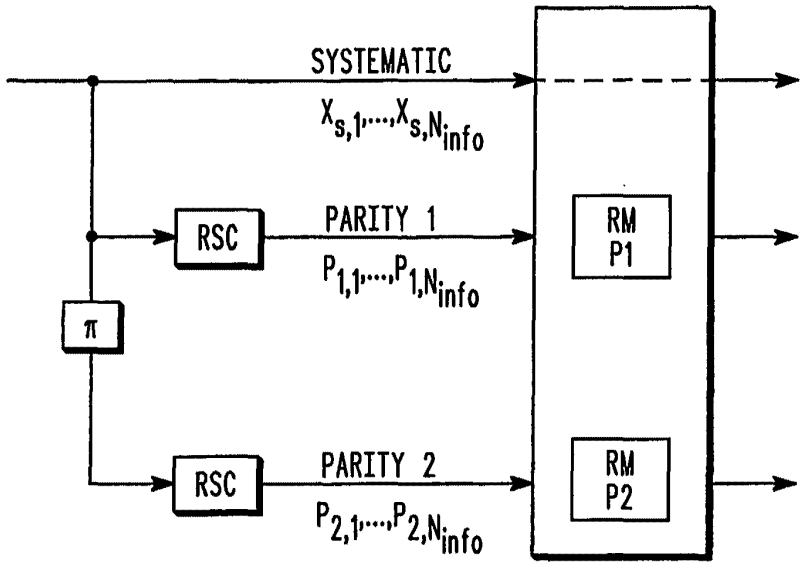
where BR is the base code rate, R is the transmit code rate, and k and i are positive integers chosen such that exactly k transmissions equal i systematic and parity output blocks, wherein if $r_N > r_{max}$ then $r_N = r_{max}$;
b) for transmission index $n = 1$, setting $s = 1$, $r = 0$, and $N_t = N_{trans}$, and
c) for transmission index n from 2,...,r_N , repeating the substeps of:
setting $N_t = N_t + N_{trans}$;
setting $flag = 0$;
if $(N_t \geq \frac{1}{BR} \times N_{sys})$ then setting $flag = 1$ and $(N_t = N_t - \frac{1}{BR} \times N_{sys})$ where N_{sys} is the number of systematic bits generated by the turbo encoder;
setting $s = 0$;
if $((N_t \geq N_{sys}) \,\&\, (flag = 1))$ then setting $s = 1$;
setting $r = r + 1$; and
if $n > r_N$, resetting n to 1 and repeating step b).

7. The method of claim 1, further comprising the step of bit priority mapping of systematic bits to position of higher reliability in a modulation constellation.

8. The method of claim 7, wherein the mapping step includes providing an interleaver of size $N_{row} \times N_{col}$, where $N_{row}=log_2(M)$ and $N_{col}=N_{trans}/N_{row}$, where M is the modulation size and N_{trans} is the number of coded and rate-matched bits to be transmitted and the upper rows of the array have a higher priority than the lower rows of the array, and wherein data is read into the interleaver row by row starting in the topmost row, filling the interleaver with all the systematic bits first, followed by the parity bits, and reading data out of the interleaver column by column.

9. The method of claim 8, wherein the interleaver is of size 16x30, and wherein the mapping step includes performing inter-column permutation using the following permutation pattern {0, 20, 10, 5, 15, 25, 3, 13, 23, 8, 18, 28, 1, 11, 21, 6, 16, 26, 4, 14, 24, 19, 9, 29, 12, 2, 7, 22, 27, 17}.

10. The method of claim 1, further comprising the step of transmitting a set of parameters governing a selected incremental redundancy version sequence operable in the puncturing steps, the transmitting step including one of the group consisting of: explicitly specifying the redundancy version parameters and transmitting these parameters using a control channel, and initially transmitting a table of redundancy version parameters and then selecting a table entry as a means of identifying the redundancy version parameters.



— PRIOR ART —

FIG.1

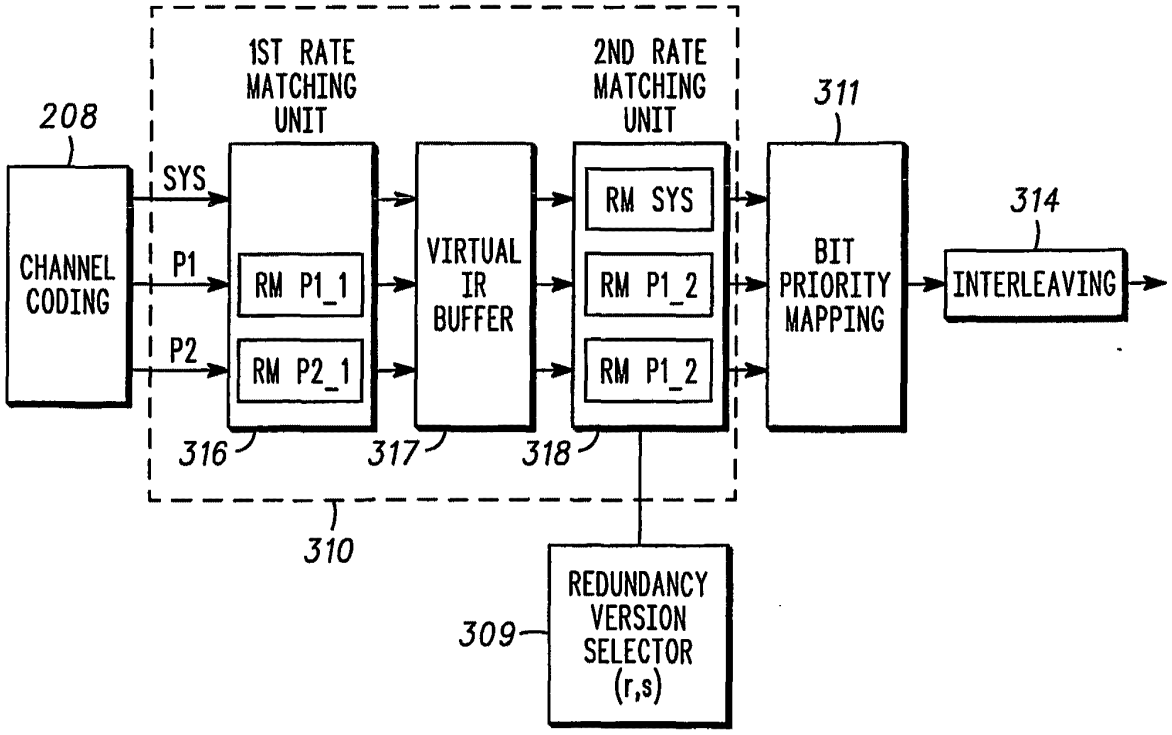
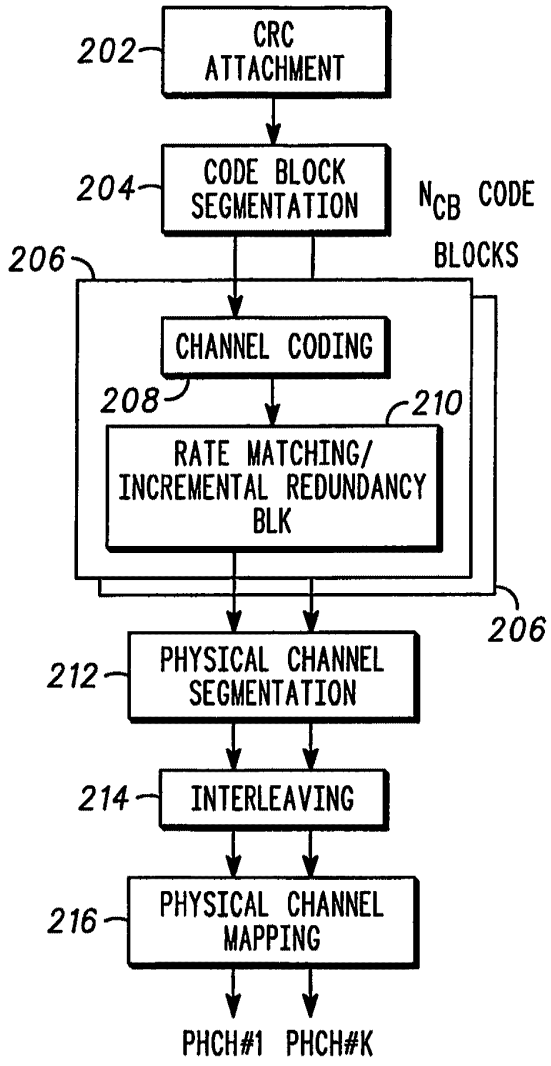


FIG.4



— PRIOR ART —

FIG.2

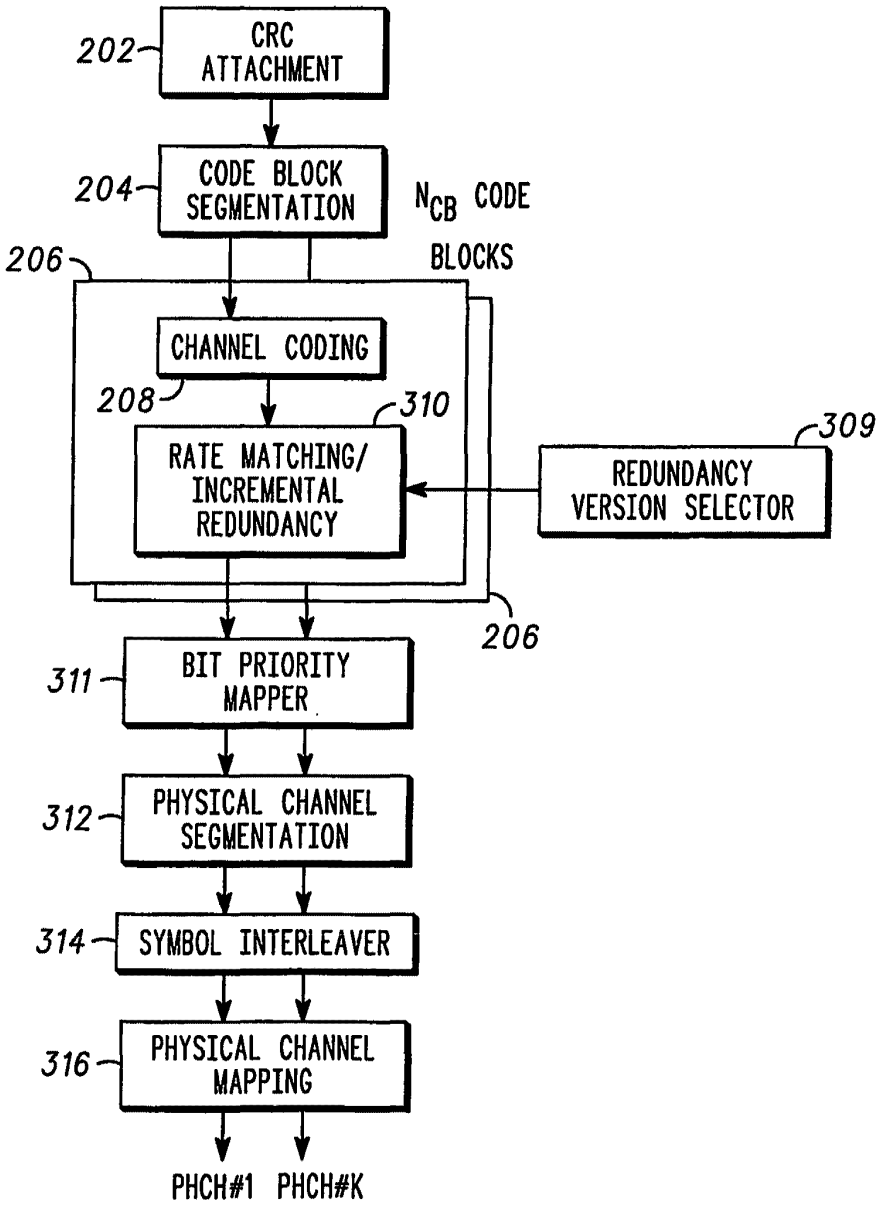
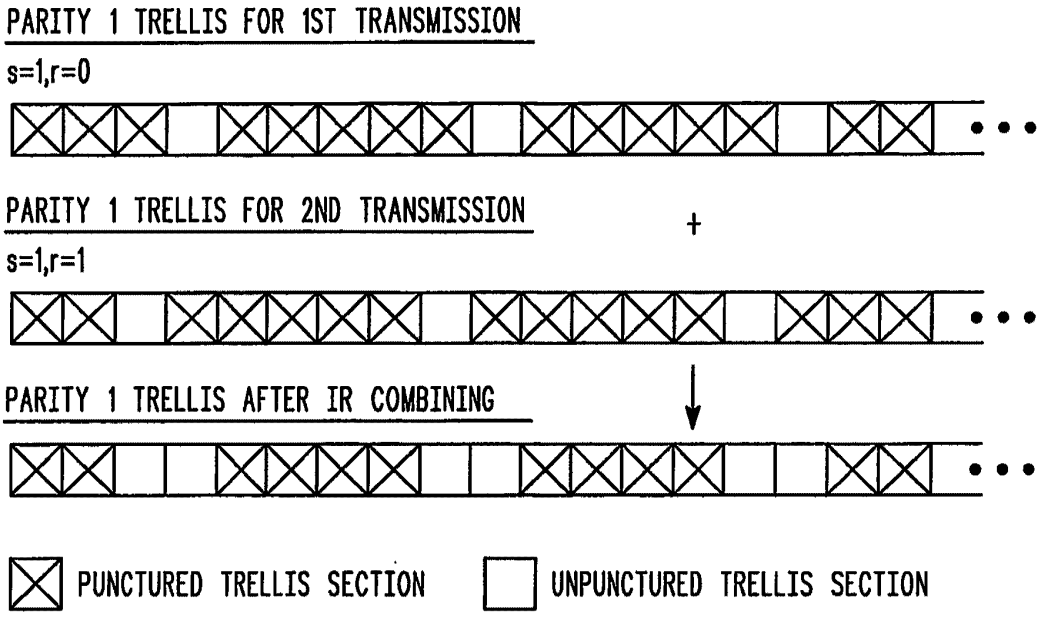

202
CRC ATTACHMENT
204
CODE BLOCK SEGMENTATION
N_{CB} CODE BLOCKS
206
CHANNEL CODING
208
310
RATE MATCHING/ INCREMENTAL REDUNDANCY
309
REDUNDANCY VERSION SELECTOR
206
311
BIT PRIORITY MAPPER
312
PHYSICAL CHANNEL SEGMENTATION
314
SYMBOL INTERLEAVER
316
PHYSICAL CHANNEL MAPPING
PHCH#1 PHCH#K

FIG.3



— PRIOR ART —

FIG.5

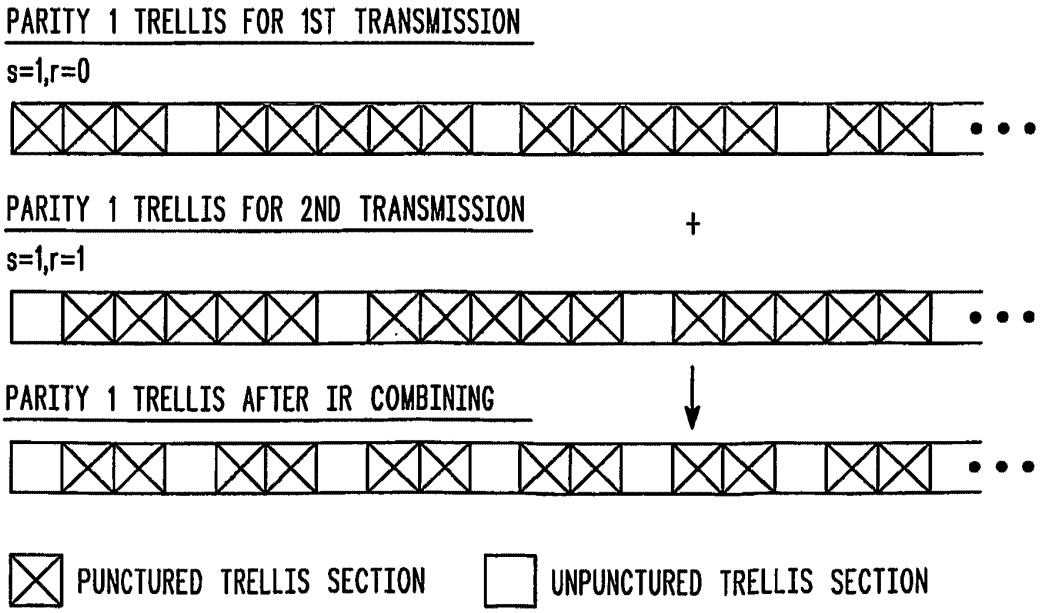


FIG.6

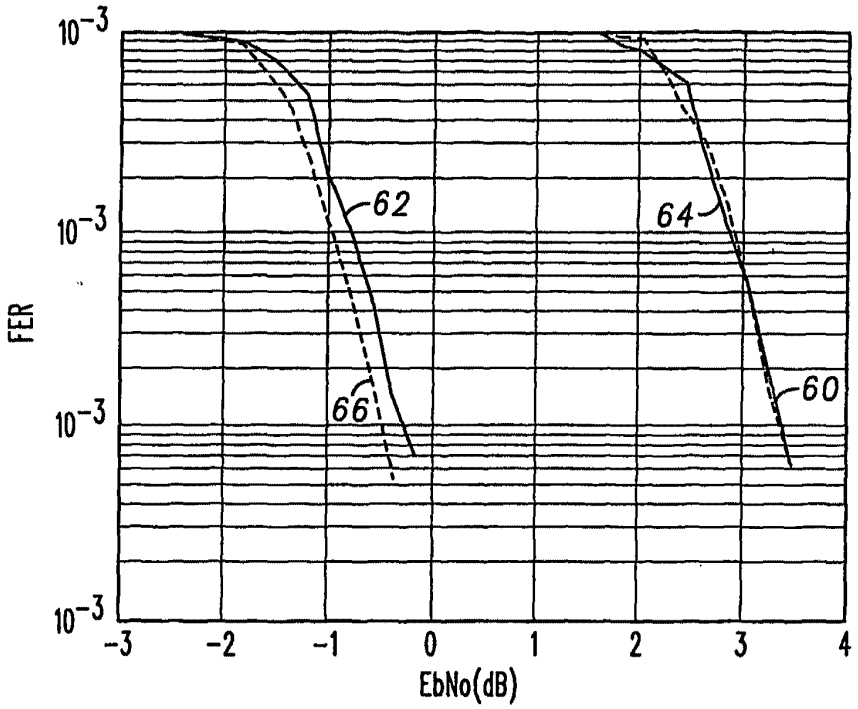


FIG. 7

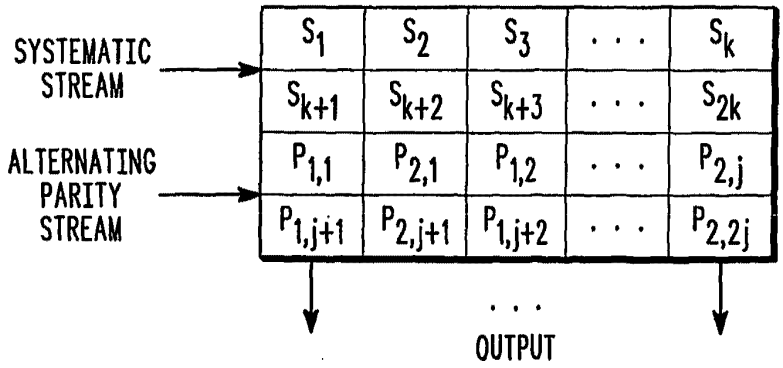


FIG. 8

$$\begin{bmatrix} y_{p,1} & y_{p,2} & y_{p,3} & y_{p,30} \\ y_{p,(30+1)} & y_{p,(30+2)} & y_{p,(30+3)} & y_{p,(2x30)} \\ \vdots & \vdots & \vdots & \vdots \\ y_{p,(16-1)x30+1)} & y_{p,(16-1)x30+2)} & y_{p,(16-1)x30+3)} & y_{p,(16x30)} \end{bmatrix}$$

FIG. 9

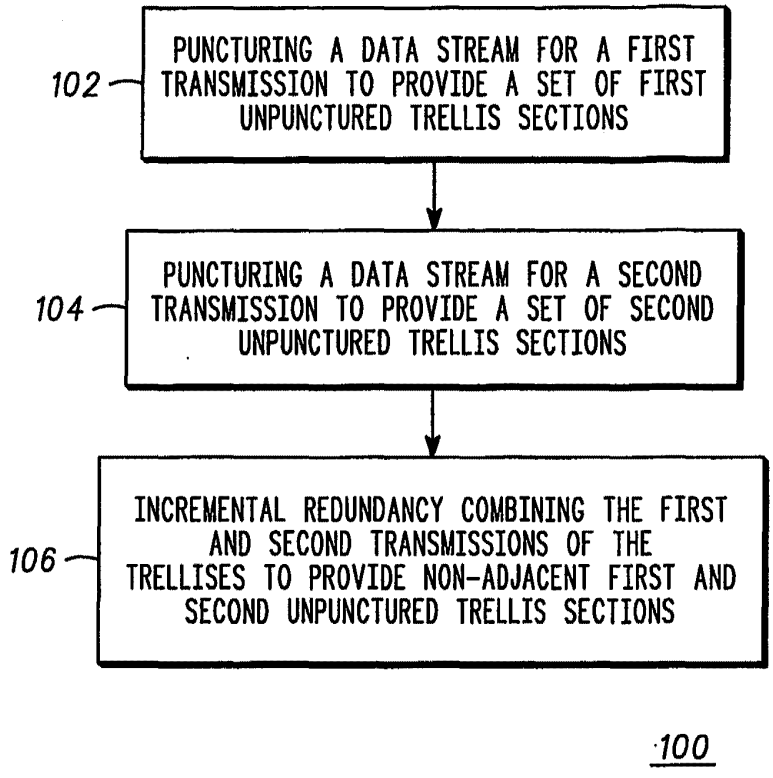

102
PUNCTURING A DATA STREAM FOR A FIRST TRANSMISSION TO PROVIDE A SET OF FIRST UNPUNCTURED TRELLIS SECTIONS
104
PUNCTURING A DATA STREAM FOR A SECOND TRANSMISSION TO PROVIDE A SET OF SECOND UNPUNCTURED TRELLIS SECTIONS
106
INCREMENTAL REDUNDANCY COMBINING THE FIRST AND SECOND TRANSMISSIONS OF THE TRELLISES TO PROVIDE NON-ADJACENT FIRST AND SECOND UNPUNCTURED TRELLIS SECTIONS
100

FIG.10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/01699

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H03M 13/00
US CL : 714/790
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 714/790

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IEEE, Research Index, IEICe

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
East

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2002/0009157 A1 (SIPOLA) 24 January 2002. col. 5, line 0068 to col. 6, line 0078.	1-3
---		---
A		4-10
Y	Chandran et al. Hybrid ARQ using Serial Concatenated Convolutional Codes over Fading Channels 2001, IEEE, pages 1410-1412.	1-3
---		---
A		4-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 April 2003 (01.04.2003)	24 APR 2003
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Albert Decady Peggy Harwood Telephone No. 703-305-9600

Form PCT/ISA/210 (second sheet) (July 1998)

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/725,779	12/02/2003	Philip J. Pietraski	I-2-0526.1US	3830

24374 7590 12/18/2006

VOLPE AND KOENIG, P.C.
DEPT. ICC
UNITED PLAZA, SUITE 1600
30 SOUTH 17TH STREET
PHILADELPHIA, PA 19103

EXAMINER	
ALPHONSE, FRITZ	
ART UNIT	**PAPER NUMBER**
2133	

SHORTENED STATUTORY PERIOD OF RESPONSE	MAIL DATE	DELIVERY MODE
3 MONTHS	12/18/2006	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

If NO period for reply is specified above, the maximum statutory period will apply and will expire 6 MONTHS from the mailing date of this communication.

Office Action Summary	Application No.	Applicant(s)	
	10/725,779	PIETRASKI ET AL.	
	Examiner	Art Unit	
	Fritz Alphonse	2133	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *14 February 2005*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-48* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1,2,6,7,11,14-26,30,31,35,36 and 38-43* is/are rejected.

7)☐ Claim(s) *3-5,8-10,12,13,27-29,32-34,37 and 44-48* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☒ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on *02 December 2003* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

ALBERT DECADY
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2100

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date *10*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

0.1 This Office Action is in response to the preliminary amendment filed on 2/14/2005. Claims 1-48 are pending.

Claim Objections

1. Claims 20-24 are objected to because of the following informalities: the letter (f) using in claims 21, 22, 23 and 24 for adding further limitations to claim 20 is confusing. Appropriate correction is required.

Claim Rejections - 35 USC § 102

2. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

3. Claims 1-2, 6-7, 11, 14-19, 25-26, 30, 31, 35-36, 38-43 are rejected under 35 U.S.C. 102(b) as being anticipated by Yun (U.S. Pat. No. 6,622,281).

As to claim 1, Yun (figs. 4-5) discloses a communications system employing rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method including determining whether or not a desired code rate, used to process the parity bit streams, results in a problematic puncturing pattern (col. 3, lines 22-31); and if a problematic puncturing pattern results in step (a), adjusting the number of bits punctured in each stage of the parity bit streams by increasing the number of bits punctured in one of the parity bit

streams and decreasing the number of bits punctured in another one of the parity bit streams (col. 5, lines 30-40; col. 12, lines 14-37).

As to claims 2 and 7, Yun (figs. 4-5) discloses a method comprises: adding punctured bits to the first group of bits; and removing punctured bits from the second group of bits; and step further comprises: biasing the puncturing rates of the P1 and P2 bits by adding a number of non-punctured P1 bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group (col. 5, lines 30-48).

As to claim 6, Yun (figs. 4-5) discloses a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method comprising adjusting the number of bits punctured in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams (col. 13, lines 28-37); and (b) adjusting the puncturing rates of each of the individual parity bit streams while maintaining a constant overall effective coding rate by biasing the puncturing rates (figs. 13; col. 14, lines 43-55).

As to claim 11, Yun (figs. 4-5) discloses a method of identifying degradations in quality of punctured error correction coded transmissions comprising identifying a puncturing pattern which approximates a particular code rate (col. 3, lines 22-31); and adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the

particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate (col. 5, lines 30-40; col. 12, lines 14-37).

As to claims 14-15, Yun (figs. 4-5) discloses a method comprising using Turbo code to implement the error correction coded transmissions (col. 2, lines 36-43); identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance (col. 31, lines 17-22).

As to claims 16 and 19, method claims 16 and 19 correspond to apparatus claim 1; therefore, they are analyzed as previously discussed in claim 1 above.

As to claims 17-18, Yun (figs. 4-5) discloses a method comprising using Turbo code to implement the error correction coded transmissions (col. 2, lines 36-43); identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance (col. 31, lines 17-22).

As to claims 25, 30 and 43, Yun (figs. 4-5) discloses a communications system for avoiding problematic Turbo code puncturing patterns, the system comprising a plurality of rate matching stages for processing a plurality of individual parity bit streams (col. 3, lines 21-31); means for adjusting the number of bits punctured in each stage of rate matching (col. 13, lines 28-37); and means for adjusting the number of bits punctured in each of the plurality of parity bit streams by increasing the number of bits punctured in one of the parity bit streams and

decreasing the number of bits punctured in another one of the parity bit streams, and biasing the puncturing rate of a problematic puncturing pattern (col. 5, lines 30-40; col. 12, lines 14-37).

As to claims 26, 31, 36 the claims have substantially the limitations of claim 1; therefore, they are analyzed as previously discussed in claim 1 above.

As to claims 38-39, Yun (figs. 4-5) discloses a system further comprising means for using Turbo code to implement the error correction coded transmissions (col. 2, lines 36-43); the system further comprising means for identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and means for using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance (col. 31, lines 17-22).

As to claims 35, Yun (figs. 4-5) discloses a communications system for identifying degradations in quality of punctured error correction coded transmissions, the system comprising means for identifying a puncturing pattern which approximates a particular code rate (col. 3, lines 22-31); and means for adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the puncturing rate of problematic puncturing pattern (col. 5, lines 30-40; col. 12, lines 14-37).

As to claim 40, the claim has substantially the limitations of claims 25 and 30; therefore, it is analyzed as previously discussed in claims 25 and 30 above.

As to claims 41-42, Yun (figs. 4-5) discloses a system further comprising means for using Turbo code to implement the error correction coded transmissions (col. 2, lines 36-43); the

system further comprising means for identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and means for using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance (col. 31, lines 17-22).

Allowable Subject Matter

4. Claims 3, 8, 12, 27, 32, 37, 44 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Claims 4-5, 9-10, 13, 28-29, 33-34, 45-48 are allowed by virtue of dependency.

Conclusion

5. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. See PTO-892

Any response to this action should be mailed to:

Commissioner of Patents and Trademarks, Washington, D.C. 20231

or faxed to: (703) 872-9306 for all formal communications.

Hand-delivered responses should be brought to Crystal Park II, 2121 Crystal Drive, Arlington, VA, Fourth Floor (Receptionist).

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Fritz Alphonse, whose telephone number is (571) 272-3813. The examiner can normally be reached on M-F, 8:30-6:00, Alt. Mondays off.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Albert De Cady, can be reached at (571) 272-3819.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the Group receptionist whose telephone number is (703) 305-3900.

Information regarding the status of an application may also be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Fritz Alphonse

Art Unit 2133

December 7, 2006

ALBERT DECADY
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2100

OIPE
JUN 18 2004
PATENT & TRADEMARK OFFICE

FORM PTO-1449 U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Use several sheets if necessary)	ATTY. DOCKET NO. I-2-0526.1US	SERIAL NO. 10/725,779
	APPLICANT Pietraski et al.	
	FILING DATE December 2, 2003	GROUP 2183

U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
FA	AA	6,370,669	04/2002	Eroz et al.			
FA	AB	6,601,214	07/2003	Hammons, Jr.			

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc.)

FA	AC	Mo et al., "Analysis of Puncturing Pattern for High Rate Turbo Codes," IEEE International, 0-7803-5538-5/99, 1999, pgs. 547-550.
FA	AD	3GPP TS 25.212 v6.1.0 (2004-03), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Multiplexing and channel coding (FDD) (Release 6).
FA	AE	3GPP TS 25.222 v6.0.0 (2003-12), 3rd Generation Partnership Project, Technical Specification Group Radio Access Network; Multiplexing and channel coding (TDD) (Release 6).
FA	AF	3GPP TS 25.944 v4.1.0 (2001-06), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Channel coding and multiplexing examples (Release 4).

EXAMINER	DATE CONSIDERED
/Fritz Alphonse/	12/07/2006

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Notice of References Cited	Application/Control No. 10/725,779	Applicant(s)/Patent Under Reexamination PIETRASKI ET AL.	
	Examiner Fritz Alphonse	Art Unit 2133	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,601,214	07-2003	Hammons, Jr., A. Roger	714/790
*	B	US-6,665,813	12-2003	Forsman et al.	714/15
*	C	US-6,622,281	09-2003	Yun et al.	714/790
*	D	US-2002/0027956	03-2002	Lee et al.	375/262
*	E	US-7,076,726	07-2006	Yun et al.	714/790
*	F	US-2002/0141433	10-2002	Kwon et al.	370/441
*	G	US-2003/0007476	01-2003	Kim et al.	370/342
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
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	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Search Notes	Application/Control No.	Applicant(s)/Patent under Reexamination
	10/725,779	PIETRASKI ET AL.
	Examiner	Art Unit
	Fritz Alphonse	2133

SEARCHED			
Class	Subclass	Date	Examiner
714	755	12/7/2006	FA
	786		
	790		
	758		
	800		

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner
714	**755; 786**	**12/7/2006**	**FA**
	800		

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
East Search Updated	12/7/2006	FA

Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
10/725,779	PIETRASKI ET AL.
Examiner	**Art Unit**
Fritz Alphonse	2133

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

Claim		Date								
Final	Original	12/7/06								
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UNITED STATES PATENT AND TRADEMARK OFFICE

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Bib Data Sheet

CONFIRMATION NO. 3830

SERIAL NUMBER	FILING OR 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/725,779	12/02/2003 RULE	714	2133	I-2-0526.1US

APPLICANTS

Philip J. Pietraski, Huntington Station, NY;
Gregory S. Sternberg, Great Neck, NY;

**** CONTINUING DATA ***************************

This appln claims benefit of 60/434,232 12/16/2002 and claims benefit of 60/444,068 01/30/2003
and claims benefit of 60/470,921 05/15/2003
and claims benefit of 60/494,404 08/11/2003 yes / FA

**** FOREIGN APPLICATIONS ******************** NO / FA

IF REQUIRED, FOREIGN FILING LICENSE GRANTED
** 02/27/2004

Foreign Priority claimed	STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
☐ yes ☒ no	NY	12	48	10
35 USC 119 (a-d) conditions met ☐ yes ☒ no ☐ Met after Allowance				
Verified and Acknowledged Examiner's Signature Initials				

ADDRESS
24374

TITLE
Detection, avoidance and/or correction of problematic puncturing patterns in parity bit streams used when implementing turbo codes

FILING FEE RECEIVED	FEES: Authority has been given in Paper	
2006	No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	6	(detect$4 or avoid$4 or correct$4) same punctur$4 near5 pattern same parity near4 bit same turbo near4 code	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 15:16
L2	6	(detect$4 or avoid$4 or correct$4) same punctur$4 same pattern same parity near4 bit same turbo near4 code	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 15:16
L3	35	(detect$4 or avoid$4 or correct$4) same punctur$4 same parity near4 bit same turbo near4 code	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 15:17
L4	28	3 and code near4 rate	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 15:17
L5	28	4 and parity near4 bit	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 15:21
L6	4	5 and punctur$4 same turbo near4 code same match$5	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 15:18
S1	94324	wireless same transmit$4 same receiv$4	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 13:02
S2	224	S1 and capacity same buffer same wireless	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 13:04
S3	6	S2 and punctur$4	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 13:04

EAST Search History

S4	1	S3 and adjust$4 same code near4 rate	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 13:04
S5	1553	S1 and punctur$4	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 13:06
S6	6	S5 and capacity same buffer same wireless	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 13:05
S7	95045	S1 and punctur$4 same remov$4 bit same buffer	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 13:07
S8	3	S1 and punctur$4 same remov$4 same bit same buffer	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/12/07 15:13

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PATENT & TRADEMARK OFFICE

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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number	10/725,779
Filing Date	December 2, 2003
First Named Inventor	Pietraski et al
Art Unit	2133
Examiner Name	Albert Decady
Attorney Docket Number	I-2-0526.1US

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
  - ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☒ Status Letter
- ☐ Other Enclosure(s) (please Identify below):

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	VOLPE AND KOENIG, P.C.		
Signature			
Printed name	John C. Donch Jr.		
Date	9/21/2005	Reg. No.	43,593

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature			
Typed or printed name	John C. Donch Jr.	Date	9/21/2005

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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OIPE IAP4C SEP 23 2005 PATENT & TRADEMARK OFFICE

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the **PATENT APPLICATION** of:	Pietraski et al
Application No.:	10/725,779
Confirmation No.:	3830
Filed:	December 2, 2003
For:	DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES
Group:	2133
Examiner:	Albert Decady

Our File: I-2-0526.1US

Date: September 21, 2005

COMMUNICATION RE STATUS

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Applicants respectfully request notification of the status of the above-identified application. Over twenty-one (21) months have passed since the application was filed and applicants have not received any substantive action.

Respectfully submitted,

Pietraski et al

By

John C. Donch Jr.
Registration No. 43,593
(215) 568-6400

Volpe and Koenig, P.C.
United Plaza, Suite 1600
30 South 17th Street
Philadelphia, PA 19103

JCD/klw

PTO/SB/06 (08-03)
Approved for use through 7/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 10/725779

CLAIMS AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE	SMALL ENTITY FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY FEE
BASIC FEE (37 CFR 1.16(a))	48			$395.00	OR		$790.00
TOTAL CLAIMS (37 CFR 1.16(c))	48 minus 20 =	* 28	x $25 =		OR	x $50 =	1400.00
INDEPENDENT CLAIMS (37 CFR 1.16(b))	10 minus 3 =	* 7	x $100 =		OR	x $200 =	1400.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(d))			+ $ =		OR	+ $ =	
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL		OR	TOTAL	3570.00

CLAIMS AS AMENDED – PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE	SMALL ENTITY ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY ADDITIONAL FEE
AMENDMENT A	Total (37 CFR 1.16(c))	* 48	Minus	** 48	= 0	x $25 =		OR	x $50 =	0
	Independent (37 CFR 1.16(b))	* 10	Minus	*** 10	= 0	x $100 =		OR	x $200 =	
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(d))					+ $ =		OR	+ $ =	
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0

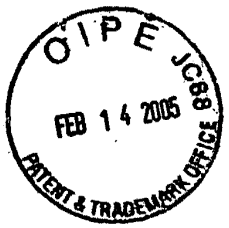
		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
AMENDMENT B	Total (37 CFR 1.16(c))	*	Minus	**	=	x $25 =		OR	x $50 =	
	Independent (37 CFR 1.16(b))	*	Minus	***	=	x $100 =		OR	x $200 =	
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(d))					+ $ =		OR	+ $ =	
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
AMENDMENT C	Total (37 CFR 1.16(c))	*	Minus	**	=	x $25 =		OR	x $50 =	
	Independent (37 CFR 1.16(b))	*	Minus	***	=	x $100 =		OR	x $200 =	
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(d))					+ $ =		OR	+ $ =	
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the **PATENT APPLICATION** of:

Pietraski et al.

Application No.: 10/725,779

Confirmation No.: 3830

Filed: December 2, 2003

For: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

Group: 2183

Examiner: Not Yet Known

Our File: I-2-0526.1US

Date: February 10, 2005

PRELIMINARY AMENDMENT

Mail Stop Amendment
Commissioner for Patents
Post Office Box 1450
Alexandria, Virginia 22313-1450

Sir:

Prior to examination, please amend the application without prejudice or disclaimer as follows:

Amendments to the Specification:

Please replace paragraph [0051] with the following amended paragraph:

[0051] In one embodiment, puncture biasing for parity bits P1 and P2 is implemented for one stage rate matching. Figure 10 is a schematic block diagram showing circuitry 600 for 3GPP rate matching for HSDPA, using a Turbo coded HS-DSCH. The circuitry 600 implements a 3GPP rate-matching scheme for HSDPA. The circuitry 600 includes a bit separation circuit 605, a first rate matching stage 610, a virtual incremental redundancy (IR) buffer 615, a second rate matching stage 620 and a bit collection circuit 625. The first rate matching stage ~~605~~ 610 includes a Parity 1 (P1) bit rate matching circuit 630 and Parity 2 (P2) bit rate matching circuit 635. The second rate matching stage 620 includes a systematic ~~bits~~ bit rate matching circuit 640, a Parity 1 (P1) bit rate matching circuit 645 for the second rate matching and a Parity 2 (P2) bit rate matching circuit 650 for the second rate matching. In operation, the systematic bits, Parity 1 (P1) and Parity 2 (P2) bits are processed through the first rate matching stage 610, virtual IR buffer 615, second rate matching stage 620 and bit collection circuit 625. Note that the Parity 1 (P1) and Parity 2 (P2) bits are treated separately. The systematic bits, Parity 1 (P1) and Parity 2 (P2) bits are combined at the bit collection circuit 625 to provide a single data output N_{data}. Also note that if the number of coded bits is less than or equal to the size of the virtual IR buffer 615, the first ~~stage of~~ rate matching stage 630 is transparent. The transparent first stage case and Rel-4 rate matching are considered.

Please replace paragraph [0053] with the following amended paragraph:

[0053] The rate matching algorithm performs puncturing if the overall code rate is greater than 1/3 and repetition if the code rate is less than 1/3. Currently code rates greater than 1/3 are accomplished by applying the same puncturing rate to both P1 and P2 bits (to within one bit) but with different puncturing pattern phases. In order to avoid non-puncturing periodicities that have been shown to degrade the Turbo code performance, the puncturing rates for P1 and P2 be independently biased. For example, if the number of P1 bits is decreased by $\underline{\Delta}$ and the number of P2 bits is increased by $\underline{\Delta}$, the overall code rate is unchanged but the problematic non-puncturing periods can be avoided. Given this approach to avoiding the problematic code rates, an analytical expression for the requisite bias, has been derived.

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. In a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) determining whether or not a desired code rate, used to process the parity bit streams, results in a problematic puncturing pattern; and

(b) ~~(a)~~ if a problematic puncturing pattern results in step (a), adjusting the number of bits punctured in each ~~stage of rate matching~~ of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams ; ~~and~~

~~(b) adjusting the number of bits punctured in each of the plurality of parity streams, wherein the problematic puncturing patterns are avoided~~.

2. The method of claim 1 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits; and

(b2) removing punctured bits from the second group of P2 bits~~; and (b3) biasing the punctured rates of the P1 and P2 bits to avoid problematic puncturing~~

~~patterns by: (i)~~ , wherein the puncturing rates of the P1 and P2 bits are biased by adding a number of non-punctured P1 bits to the first group~~; and (ii)~~ and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

3. The method of claim 2 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$$, otherwise set $\Delta = 0$.

4. The method of claim 3, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

5. The method of claim 4 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

6. In a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) adjusting the number of bits punctured in each ~~stage of rate matching~~ of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams; and

(b) adjusting the puncturing rates of each of the ~~individual~~ parity bit

streams while maintaining a constant overall effective coding rate by biasing the puncturing rates.

7. The method of claim 6 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, ~~and~~ step ~~(b)~~ (a) further comprises:

(a1) ~~(b1)~~ adding punctured bits to the first group of P1 bits; and

(a2) ~~(b2)~~ removing punctured bits from the second group of P2 bits; and step (b) further comprises:

(b1) ~~(b3)~~ biasing the puncturing rates of the P1 and P2 bits ~~to avoid problematic puncturing patterns by:(i)~~ by adding a number of non-punctured P1 bits to the first group~~; and (ii)~~ and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

8. The method of claim 7 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left| \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right|$$, otherwise set $\Delta = 0$.

9. The method of claim 8, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

10. The method of claim 9 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

11. A method of identifying degradations in quality of punctured error correction coded transmissions, the method comprising:

(a) identifying a puncturing pattern which approximates a particular code rate; and

(b) adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate.

12. The method of claim 11 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits;

(b2) removing punctured bits from the second group of P2 bits; and

(b3) biasing the ~~punctured~~ puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

13. The method of claim 12 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left| \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right|, \text{ otherwise set } \Delta = 0.$$

14. The method of claim 11 further comprising:

(c) using Turbo code to implement the error correction coded transmissions.

15. The method of claim 14 further comprising:

(d) identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(e) using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

16. A method of identifying degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits, the method comprising:

(a) adding punctured bits to the first group of P1 bits;

(b) removing punctured bits from the second group of P2 bits; and

(c) biasing the ~~punctured~~ puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

17. The method of claim 16 further comprising:

(d) using Turbo code to implement the error correction coded transmissions.

18. The method of claim 17 further comprising:

(e) identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(f) using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

19. A method for reducing degradations in quality of punctured error corrected code transmissions, the method comprising:

(a) identifying a puncturing pattern which approximates a particular code rate; and

(b) adjusting the parameters of the transmissions sufficiently to cause a

mismatch in the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate.

20. The method of claim 19 further comprising:

(c) determining a capacity of a wireless transmit and receive unit (WTRU), including buffer sizes that are supported by the WTRU;

(d) using puncturing to remove sufficient bits to fit into the buffer; and

(e) adjusting an overall code rate so as to provide sufficient error correction capability, thereby providing a first rate in a first stage of puncturing and providing a second rate in a second stage of puncturing.

21. The method of claim 20, further comprising:

(f) increasing non-punctured bits in one of the first stage and second stage of puncturing, and decreasing non-punctured bits in another of the first stage and second stage of puncturing, thereby adding additional puncturing to one stage and removing it from the other stage.

22. The method of claim 20 further comprising:

(f) increasing non-punctured bits in the first stage and decreasing non-punctured bits in the second stage.

23. The method of claim 20 further comprising:

(f) decreasing non-punctured bits in the first stage and increasing non-punctured bits in the second stage.

24. The method of claim 20 further comprising:

(f) interleaving parity bits before rate matching occurs; and

(g) subsequently de-interleaving the parity bits, thereby avoiding a need to periodically sample the parity bits when performing periodic sampling in rate matching, thereby mitigating the effect of the periodicity of the puncturing pattern.

25. A communications system for avoiding problematic Turbo code puncturing patterns, the system comprising:

(a) a plurality of rate matching stages for processing a plurality of individual parity bit streams;

(b) means for adjusting the number of bits punctured in each stage of rate matching; and

(c) means for adjusting the number of bits punctured in each of the plurality of parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams, and biasing the puncturing rate of a problematic puncturing pattern~~, wherein the problematic puncturing patterns are avoided~~.

26. The system of claim 25 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means ~~(e)~~ for adjusting the number of bits punctured in each of the plurality of parity bit streams further comprising:

(c1) means for adding punctured bits to the first group of P1 bits;

(c2) means for removing punctured bits from the second group of P2 bits; and

(c3) means for biasing the ~~punctured~~ puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

27. The system of claim 26 further comprising:

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein

I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; ~~and~~

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if

$\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(f) ~~(e)~~ means for setting bias $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

28. The system of claim 27, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

29. The system of claim 28 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

30. A communications system for avoiding problematic Turbo code puncturing patterns, the system comprising:

(a) a plurality of rate matching stages for processing a plurality of individual parity bit streams;

(b) means for adjusting the number of ~~bits~~ punctured bits in each ~~stage of rate matching~~ of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams; and

(c) means for ~~adjusting~~ biasing the puncturing rates of each of the individual parity bit streams while maintaining a constant overall effective

coding rate.

31. The system of claim 30 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, wherein the means ~~(e)~~ for adjusting the ~~puncturing rates of each of the individual parity streams further comprising:~~ number of punctured bits comprises:

(b1) ~~(e1)~~ means for adding punctured bits to the first group of P1 bits; and

(b2) ~~(e2)~~ means for removing punctured bits from the second group of P2 bits; and the means for biasing the puncturing rates comprises:

(c1) ~~(e3)~~ means for biasing the ~~punctured~~ puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means ~~(e3)~~ including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

32. The system of claim 31 further comprising:

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if

$\left|\frac{I}{(P/2)}-\frac{7\hat{N}}{2}\right|<1-\frac{\hat{N}}{2}+\left\lfloor\frac{\hat{N}}{2}\right\rfloor$; and

(f) ~~(e)~~ means for setting bias $\Delta=0$ if $\left|\frac{I}{(P/2)}-\frac{7\hat{N}}{2}\right|\geq 1-\frac{\hat{N}}{2}+\left\lfloor\frac{\hat{N}}{2}\right\rfloor$.

33. The system of claim 32, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

34. The system of claim 33 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

35. A communications system for identifying degradations in quality of punctured error correction coded transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; and

(b) means for adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the puncturing rate of a problematic puncturing pattern.

36. The system of claim 35 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means ~~(b)~~ for adjusting a value for anticipated degradation further comprising:

(b1) means for adding punctured bits to the first group of P1 bits;

(b2) means for removing punctured bits from the second group of P2 bits;

and

(b3) means for biasing the ~~punctured~~ puncturing rates of the P1 and P2 bits to avoid

problematic puncturing patterns, the biasing means ~~(b3)~~ including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

37. The system of claim 36 further comprising:

(c) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(d) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if

$\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(e) means for setting bias $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

38. The system of claim 35 further comprising:

(c) means for using Turbo code to implement the error correction coded transmissions.

39. The system of claim 38 further comprising:

(d) means for identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(e) means for using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

40. A communications system for identifying degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits, the system comprising:

(a) means for adding punctured bits to the first group of P1 bits;

(b) means for removing punctured bits from the second group of P2 bits; and

(c) means for biasing the ~~punctured~~ puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means ~~(c)~~ including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

41. The system of claim 40 further comprising:

(d) means for using Turbo code to implement the error correction coded transmissions.

42. The system of claim 41 further comprising:

(e) means for identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(f) means for using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

43. A communications system for reducing degradations in quality of punctured error corrected code transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; and

(b) means for adjusting the parameters of the transmissions sufficiently to cause a mismatch in the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate.

44. The system of claim 43 further comprising:

(c) means for determining a capacity of a wireless transmit and receive unit (WTRU), including buffer sizes that are supported by the WTRU;

(d) means for using puncturing to remove sufficient bits to fit into the buffer; and

(e) means for adjusting an overall code rate so as to provide sufficient

error correction capability, thereby providing a first rate in a first stage of puncturing and providing a second rate in a second stage of puncturing.

45. The system of claim 44, further comprising:

(f) means for increasing non-punctured bits in one of the first stage and second stage of puncturing, and decreasing non-punctured bits in another of the first stage and second stage of puncturing, thereby adding additional puncturing to one stage and removing it from the other stage.

46. The system of claim 44 further comprising:

(f) means for increasing non-punctured bits in the first stage and decreasing non-punctured bits in the second stage.

47. The system of claim 44 further comprising:

(f) means for decreasing non-punctured bits in the first stage and increasing non-punctured bits in the second stage.

48. The system of claim 44 further comprising:

(f) means for interleaving parity bits before rate matching occurs; and

(g) means for subsequently de-interleaving the parity bits, thereby avoiding a need to periodically sample the parity bits when performing periodic sampling in rate matching, thereby mitigating the effect of the periodicity of the puncturing pattern.

REMARKS

After the foregoing Amendment, claims 1-48 are currently pending in this application. The specification and claims have been amended in the same manner as in the Reply to a Written Opinion for the corresponding PCT application (PCT/US03/38223), after which a favorable International Preliminary Report on Patentability was issued on December 16, 2002. A copy of the International Preliminary Report on Patentability, which indicates that claims 1-48 meet the criteria set out in PCT Article 33(2)-(3) with regard to novelty, inventive step and industrial applicability is submitted herewith. The Applicants submit that no new matter has been introduced into the application by the amendments.

The Applicants respectfully submit that the presently claimed invention is patentable over the prior art. Prompt consideration and allowance of the pending claims is respectfully requested.

Respectfully submitted,

Pietraski et al.

By Scott Wolinsky
Scott Wolinsky
Registration No. 46,413
(215) 568-6400

Volpe and Koenig, P.C.
United Plaza, Suite 1600
30 South 17th Street
Philadelphia, PA 19103

SW/dmm
Enclosures

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ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
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- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☒ Other Enclosure(s) (please Identify below):

Preliminary Amendment

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	VOLPE AND KOENIG, P.C.		
Signature	Scott Wolinsky		
Printed name	Scott Wolinsky		
Date	February 10, 2005	Reg. No.	46,413

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Filed: December 2, 2003	Our File: I-2-0526.1US
For: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES	Date: February 10, 2005
Group: 2183	
Examiner: Not Yet Known	

COMMUNICATION RE FAVORABLE IPER BY IPEA/US IN CORRESPONDING INTERNATIONAL APPLICATION

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This communication is to advise the Examiner of the favorable International Preliminary Examination Report (IPER) issued by the United States Patent and Trademark Office acting as International Preliminary Examination Authority in a corresponding international application. A copy of the IPER is enclosed.

The original PCT claims correspond to the claims in this U.S. application. A copy of the approved claims as published is also enclosed.

In view of the fact that PCT claims 1-48 have all been found to meet the international standards of patentability, prompt examination and allowance are respectfully requested.

Respectfully submitted,

Pietraski et al.

By Scott Wolinsky
Scott Wolinsky
Registration No. 46,413
(215) 568-6400

Volpe and Koenig, P.C.
United Plaza, Suite 1600
30 South 17th Street
Philadelphia, PA 19103

SW/dmm
Enclosures (2)

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What is claimed is:

1. In a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) determining whether or not a desired code rate, used to process the parity bit streams, results in a problematic puncturing pattern; and

(b) if a problematic puncturing pattern results in step (a), adjusting the number of bits punctured in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams.

2. The method of claim 1 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits; and

(b2) removing punctured bits from the second group of P2 bits, wherein the puncturing rates of the P1 and P2 bits are biased by adding a number of non-punctured P1 bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

3. The method of claim 2 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$$, otherwise set $\Delta = 0$.

4. The method of claim 3, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

5. The method of claim 4 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

6. In a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) adjusting the number of bits punctured in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams; and

(b) adjusting the puncturing rates of each of the parity bit streams

while maintaining a constant overall effective coding rate by biasing the puncturing rates.

7. The method of claim 6 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, step (a) further comprises:

(a1) adding punctured bits to the first group of P1 bits; and

(a2) removing punctured bits from the second group of P2 bits; and step (b) further comprises:

(b1) biasing the puncturing rates of the P1 and P2 bits by adding a number of non-punctured P1 bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

8. The method of claim 7 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$$, otherwise set $\Delta = 0$.

9. The method of claim 8, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

10. The method of claim 9 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

11. A method of identifying degradations in quality of punctured error correction coded transmissions, the method comprising:

(a) identifying a puncturing pattern which approximates a particular code rate; and

(b) adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate.

12. The method of claim 11 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits;

(b2) removing punctured bits from the second group of P2 bits; and

(b3) biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

13. The method of claim 12 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left| \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right|$$, otherwise set $\Delta = 0$.

14. The method of claim 11 further comprising:

(c) using Turbo code to implement the error correction coded transmissions.

15. The method of claim 14 further comprising:

(d) identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(e) using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

16. A method of identifying degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits, the method comprising:

(a) adding punctured bits to the first group of P1 bits;

(b) removing punctured bits from the second group of P2 bits; and

(c) biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

17. The method of claim 16 further comprising:

(d) using Turbo code to implement the error correction coded transmissions.

18. The method of claim 17 further comprising:

(e) identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(f) using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

19. A method for reducing degradations in quality of punctured error corrected code transmissions, the method comprising:

(a) identifying a puncturing pattern which approximates a particular code rate; and

(b) adjusting the parameters of the transmissions sufficiently to cause a mismatch in the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate.

20. The method of claim 19 further comprising:

(c) determining a capacity of a wireless transmit and receive unit (WTRU), including buffer sizes that are supported by the WTRU;

(d) using puncturing to remove sufficient bits to fit into the buffer; and

(e) adjusting an overall code rate so as to provide sufficient error correction capability, thereby providing a first rate in a first stage of puncturing and providing a second rate in a second stage of puncturing.

21. The method of claim 20, further comprising:

(f) increasing non-punctured bits in one of the first stage and second stage of puncturing, and decreasing non-punctured bits in another of the first stage and second stage of puncturing, thereby adding additional puncturing to one stage and removing it from the other stage.

22. The method of claim 20 further comprising:

(f) increasing non-punctured bits in the first stage and decreasing non-punctured bits in the second stage.

23. The method of claim 20 further comprising:

(f) decreasing non-punctured bits in the first stage and increasing non-punctured bits in the second stage.

24. The method of claim 20 further comprising:

(f) interleaving parity bits before rate matching occurs; and

(g) subsequently de-interleaving the parity bits, thereby avoiding a need to periodically sample the parity bits when performing periodic sampling in rate matching, thereby mitigating the effect of the periodicity of the puncturing pattern.

25. A communications system for avoiding problematic Turbo code puncturing patterns, the system comprising:

(a) a plurality of rate matching stages for processing a plurality of individual parity bit streams;

(b) means for adjusting the number of bits punctured in each stage of rate matching; and

(c) means for adjusting the number of bits punctured in each of the plurality of parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams, and biasing the puncturing rate of a problematic puncturing pattern.

26. The system of claim 25 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means for adjusting the number of bits punctured in each of the plurality of parity bit streams further comprising:

(c1) means for adding punctured bits to the first group of P1 bits;

(c2) means for removing punctured bits from the second group of P2 bits; and

(c3) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

27. The system of claim 26 further comprising:

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein

I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if

$\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(f) means for setting bias $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

28. The system of claim 27, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

29. The system of claim 28 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

30. A communications system for avoiding problematic Turbo code puncturing patterns, the system comprising:

(a) a plurality of rate matching stages for processing a plurality of individual parity bit streams;

(b) means for adjusting the number of punctured bits in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams; and

(c) means for biasing the puncturing rates of each of the individual parity bit streams while maintaining a constant overall effective

coding rate.

31. The system of claim 30 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, wherein the means for adjusting the number of punctured bits comprises:

(b1) means for adding punctured bits to the first group of P1 bits; and

(b2) means for removing punctured bits from the second group of P2 bits; and the means for biasing the puncturing rates comprises:

(c1) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

32. The system of claim 31 further comprising:

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(f) means for setting bias $\Delta = 0$ if $\left|\frac{I}{(P/2)} - \frac{7\hat{N}}{2}\right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

33. The system of claim 32, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

34. The system of claim 33 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

35. A communications system for identifying degradations in quality of punctured error correction coded transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; and

(b) means for adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the puncturing rate of a problematic puncturing pattern.

36. The system of claim 35 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means for adjusting a value for anticipated degradation further comprising:

(b1) means for adding punctured bits to the first group of P1 bits;

(b2) means for removing punctured bits from the second group of P2 bits; and

(b3) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

37. The system of claim 36 further comprising:

(c) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(d) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(e) means for setting bias $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

38. The system of claim 35 further comprising:

(c) means for using Turbo code to implement the error correction coded transmissions.

39. The system of claim 38 further comprising:

(d) means for identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(e) means for using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

40. A communications system for identifying degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits, the system comprising:

(a) means for adding punctured bits to the first group of P1 bits;

(b) means for removing punctured bits from the second group of P2 bits; and

(c) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means ~~(c)~~ including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

41. The system of claim 40 further comprising:

(d) means for using Turbo code to implement the error correction coded transmissions.

42. The system of claim 41 further comprising:

(e) means for identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(f) means for using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

43. A communications system for reducing degradations in quality of punctured error corrected code transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; and

(b) means for adjusting the parameters of the transmissions sufficiently to cause a mismatch in the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate.

44. The system of claim 43 further comprising:

(c) means for determining a capacity of a wireless transmit and receive unit (WTRU), including buffer sizes that are supported by the WTRU;

(d) means for using puncturing to remove sufficient bits to fit into the buffer; and

(e) means for adjusting an overall code rate so as to provide sufficient error correction capability, thereby providing a first rate in a first stage of puncturing and providing a second rate in a second stage of puncturing.

45. The system of claim 44, further comprising:

(f) means for increasing non-punctured bits in one of the first stage and second stage of puncturing, and decreasing non-punctured bits in another of the first stage and second stage of puncturing, thereby adding additional puncturing to one stage and removing it from the other stage.

46. The system of claim 44 further comprising:

(f) means for increasing non-punctured bits in the first stage and decreasing non-punctured bits in the second stage.

47. The system of claim 44 further comprising:

(f) means for decreasing non-punctured bits in the first stage and increasing non-punctured bits in the second stage.

48. The system of claim 44 further comprising:

(f) means for interleaving parity bits before rate matching occurs; and

(g) means for subsequently de-interleaving the parity bits, thereby avoiding a need to periodically sample the parity bits when performing periodic sampling in rate matching, thereby mitigating the effect of the periodicity of the puncturing pattern.

P ENT COOPERATION TREAT

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:
SCOTT WOLINSKY
VOLPE AND KOENIG, P.C.
UNITED PLAZA, SUITE 1600
30 SOUTH 17TH STREET
PHILADELPHA, PA 19103

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NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY REPORT ON PATAENTABILITY
(Chapter II of the Patent Cooperation Treaty)
(PCT Rule 71.1)

Applicant's or agent's file reference I-2-0526.1WO	Date of mailing *(day/month/year)* **IMPORTANT NOTIFICATION**

International ation No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US03/38	03 December 2003 (03.12.2003)	16 December 2002 (16.12.2002)

Applicant
INTERDI AL T. /KA

1. The oplic eby ed that t ional Preliminary Examining A ority transmits herewith the international p. iminary report on patent ility and its annexes, if any, establish on the international application.

2. A copy of the report and its annexes, if any, is being tra mitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary report on patentability. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the *PCT Applicant's Guide*.

The applicant's attention is drawn to Article 33(5), which provides that the criteria of novelty, inventive step and industrial applicability described in Article 33(2) to (4) merely serve the purposes of international preliminary examination and that "any Contracting State may apply additional or different criteria for the purposes of deciding whether, in that State, the claimed invention is patentable or not" (see also Article 27(5)). Such additional criteria may relate, for example, to exemptions from patentability, requirements for enabling disclosure, clarity and support for the claims.

Name and mailing address of the IPEA/ US Mail Stop PCT, Attn: IPEA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703)305-3230	Authorized officer for Albert DeCady Telephone No. (572) 272-3819

Form PCT/IPEA/416 (January 2004)

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VOLPE AND KOENIG, P.C.
UNITED PLAZA, SUITE 1600
30 SOUTH 17TH STREET
PHILADELPHA, PA 19103

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NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY REPORT ON PATAENTABILITY
(Chapter II of the Patent Cooperation Treaty)

(PCT Rule 71.1)

Date of mailing *(day/month/year)*	20 DEC 2004
Applicant's or agent's file reference I-2-0526.1WO	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US03/38223	03 December 2003 (03.12.2003)	16 December 2002 (16.12.2002)

Applicant
INTERDIGITAL TECHNOLOGY CORPORATION

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary report on patentability and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

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Name and mailing address of the IPEA/ US Mail Stop PCT, Attn: IPEA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703)305-3230	Authorized officer for Michelle L. Eason Albert DeCady Telephone No. (572) 272-3819

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Form PCT/IPEA/416
I-2-0526.1WO		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US03/38223	03 December 2003 (03.12.2003)	16 December 2002 (16.12.2002)

International Patent Classification (IPC) or national classification and IPC

IPC(7): H03M 13/35, 13/27 and US Cl.: 714/786, 790; 375/265

Applicant

INTERDIGITAL TECHNOLOGY C ORPORATION

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 3 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:

a. [X] *(sent to the applicant and to the International Bureau)* a total of 13 sheets, as follows:

- [ ] sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
- [ ] sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

b. [ ] *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s))

_____ , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

- [X] Box No. I Basis of the report
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [X] Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [ ] Box No. VIII Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22 June 2004 (22.06.2004)	18 November 2004 (18.11.2004)
Name and mailing address of the IPEA/ US Mail Stop PCT, Attn: IPEA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703)305-3230	Authorized officer Michelle L. Colon Albert DeCady Telephone No. (571) 272-3819

Form PCT/IPEA/409 (cover sheet)(January 2004)

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International Application No.
PCT/US03/38223

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ This report is based on translations from the original language into the following language _____, which is the language of a translation furnished for the purposes of:

☐ international search (under Rules 12.3 and 23.1(b))

☐ publication of the international application (under Rule 12.4)

☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

☐ the international application as originally filed/furnished

☒ the description:
pages 1-8 and 11-38 as originally filed/furnished
pages* 9 and 10 received by this Authority on 22 October 2004 (22.10.2004)
pages* NONE received by this Authority on _____

☒ the claims:
pages 43,45,50 and 53 as originally filed/furnished
pages* NONE as amended (together with any statement) under Article 19
pages* 39-42,44,46-49,51 and 52 received by this Authority on 22 October 2004 (22.10.2004)
pages* NONE received by this Authority on _____

☒ the drawings:
pages 1/12-12/12 as originally filed/furnished
pages* NONE received by this Authority on _____
pages* NONE received by this Authority on _____

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing.

3. ☒ The amendments have resulted in the cancellation of:

☒ the description, pages NONE
☒ the claims, Nos. NONE
☒ the drawings, sheets/figs NONE
☒ the sequence listing (*specify*): NONE
☒ any table(s) related to the sequence listing (*specify*): NONE

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

☐ the description, pages _____
☐ the claims, Nos _____
☐ the drawings, sheets/figs _____
☐ the sequence listing (*specify*): _____
☐ any table(s) related to the sequence listing (*specify*): _____

* *If item 4 applies, some or all of those sheets may be marked "superseded."*

Form PCT/IPEA/409 (Box No. I) (January 2004)

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International Application No.
PCT/US03/38223

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 1-48	YES
	Claims NONE	NO
Inventive Step (IS)	Claims 1-48	YES
	Claims NONE	NO
Industrial Applicability (IA)	Claims 1-48	YES
	Claims NONE	NO

2. Citations and Explanations (Rule 70.7)

Claims1-48 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest adjusting the number of bits punctured in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams (as in claims 1, 6, 10, 19, 25, 30, 35, 43) and biasing puncturing rates of P1 and P2 bits to avoid puncturing patterns by adding a number of non-punctured bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group (as in claims 16 and 40).

Claims 1-48 the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

---------- NEW CITATIONS ----------

Additionally, methods are described hereinafter for modifying the puncturing patterns such that performance of degraded Turbo code is restored.

[0046] In accordance with the present invention, the methods disclosed herein may be implemented in a wireless transmit/receive unit (WTRU) and/or a base station. Hereinafter, a WTRU includes but is not limited to a UE, mobile station, fixed or mobile subscriber unit, pager, or any other type of device capable of operating in a wireless environment. When referred to hereafter, a base station includes but is not limited to a base station, Node-B, site controller, access point or other interfacing deice in a wireless environment.

[0047] Figure 8 graphically depicts the SNR required to successfully decode a data block (critical SNR) with high probability versus Code Rate when biasing of parity bits P1/P2 is applied. As shown in Figure 7, it has been found that particular codes created by puncturing the rate 1/3 3GPP Turbo code exhibit poorer than expected performance, as can be seen from the peaks in the figure.

[0048] Figure 9 is a plot of the problematic regions with respect to an ordered pair (r1,r2) which are the rates of puncturing the parity streams in the first and second stages of rate matching, respectively. As can be seen, there are particular regions where the rates of puncturing of the parity streams are such that some combinations of rates are particularly problematic.

[0049] In one embodiment, puncture biasing for parity bits P1 and P2 is implemented for one stage rate matching. Figure 10 is a schematic block diagram showing circuitry 600 for 3GPP rate matching for HSDPA, using a Turbo coded HS-DSCH. The circuitry 600 implements a 3GPP rate-matching scheme for HSDPA. The circuitry 600 includes a bit separation circuit 605, a first rate matching stage 610, a virtual incremental redundancy (IR) buffer 615, a second rate matching stage 620 and a bit collection circuit 625. The first rate matching stage 610 includes a Parity 1 (P1) bit rate matching circuit 630 and Parity 2 (P2) bit rate matching circuit 635. The second rate matching stage 620 includes a systematic bit rate matching circuit 640, a Parity 1 (P1) bit rate matching circuit 645 for the second rate matching and a Parity 2 (P2) bit rate matching circuit 650 for the second rate matching. In operation, the systematic

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bits, Parity 1 (P1) and Parity 2 (P2) bits are processed through the first rate matching stage 610, virtual IR buffer 615, second rate matching stage 620 and bit collection circuit 625. Note that the Parity 1 (P1) and Parity 2 (P2) bits are treated separately. The systematic bits, Parity 1 (P1) and Parity 2 (P2) bits are combined at the bit collection circuit 625 to provide a single data output N_{data}. Also note that if the number of coded bits is less than or equal to the size of the virtual IR buffer 615, the first rate matching stage 630 is transparent. The transparent first stage case and Rel-4 rate matching are considered.

[0050] In its actual implementation, it is anticipated that the different circuit functions will be executed by a common circuit or circuits, such as microprocessor circuitry, and in accordance with program instructions. The specific circuit functions used to implement the invention would therefore be a matter of choice of those configuring the circuitry within the rate matching circuitry 600.

[0051] The rate matching algorithm performs puncturing if the overall code rate is greater than 1/3 and repetition if the code rate is less than 1/3. Currently code rates greater than 1/3 are accomplished by applying the same puncturing rate to both P1 and P2 bits (to within one bit) but with different puncturing pattern phases. In order to avoid non-puncturing periodicities that have been shown to degrade the Turbo code performance, the puncturing rates for P1 and P2 be independently biased. For example, if the number of P1 bits is decreased by $\underline{\Delta}$ and the number of P2 bits is increased by $\underline{\Delta}$, the overall code rate is unchanged but the problematic non-puncturing periods can be avoided. Given this approach to avoiding the problematic code rates, an analytical expression for the requisite bias, has been derived.

[0052] A simple and efficient method of modifying the puncture patterns is biasing the number of punctured bits in P1 and P2 by adding additional puncturing to one and removing it from the other. The amount of the bias should be no more than is needed to avoid certain periodicities. In biasing the puncturing rates of P1 and P2 bits, two constraints must be met.

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What is claimed is:

1. In a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) determining whether or not a desired code rate, used to process the parity bit streams, results in a problematic puncturing pattern; and

(b) if a problematic puncturing pattern results in step (a), adjusting the number of bits punctured in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams.

2. The method of claim 1 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits; and

(b2) removing punctured bits from the second group of P2 bits, wherein the puncturing rates of the P1 and P2 bits are biased by adding a number of non-punctured P1 bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

3. The method of claim 2 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left| \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right|$$, otherwise set $\Delta = 0$.

4. The method of claim 3, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

5. The method of claim 4 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

6. In a communications system employing a plurality of rate matching stages for processing a plurality of individual parity bit streams derived through puncturing a selected number of bits, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) adjusting the number of bits punctured in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams; and

(b) adjusting the puncturing rates of each of the parity bit streams

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while maintaining a constant overall effective coding rate by biasing the puncturing rates.

7. The method of claim 6 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, step (a) further comprises:

(a1) adding punctured bits to the first group of P1 bits; and

(a2) removing punctured bits from the second group of P2 bits; and step (b) further comprises:

(b1) biasing the puncturing rates of the P1 and P2 bits by adding a number of non-punctured P1 bits to the first group and decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

8. The method of claim 7 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$$, otherwise set $\Delta = 0$.

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9. The method of claim 8, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

10. The method of claim 9 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

11. A method of identifying degradations in quality of punctured error correction coded transmissions, the method comprising:

(a) identifying a puncturing pattern which approximates a particular code rate; and

(b) adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate.

12. The method of claim 11 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits;

(b2) removing punctured bits from the second group of P2 bits; and

(b3) biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

13. The method of claim 12 further comprising:

(b) removing punctured bits from the second group of P2 bits; and

(c) biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

17. The method of claim 16 further comprising:

(d) using Turbo code to implement the error correction coded transmissions.

18. The method of claim 17 further comprising:

(e) identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(f) using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

19. A method for reducing degradations in quality of punctured error corrected code transmissions, the method comprising:

(a) identifying a puncturing pattern which approximates a particular code rate; and

(b) adjusting the parameters of the transmissions sufficiently to cause a mismatch in the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate.

20. The method of claim 19 further comprising:

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(a) a plurality of rate matching stages for processing a plurality of individual parity bit streams;

(b) means for adjusting the number of bits punctured in each stage of rate matching; and

(c) means for adjusting the number of bits punctured in each of the plurality of parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams, and biasing the puncturing rate of a problematic puncturing pattern.

26. The system of claim 25 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means for adjusting the number of bits punctured in each of the plurality of parity bit streams further comprising:

(c1) means for adding punctured bits to the first group of P1 bits;

(c2) means for removing punctured bits from the second group of P2 bits; and

(c3) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

27. The system of claim 26 further comprising:

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein

I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if

$\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(f) means for setting bias $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

28. The system of claim 27, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

29. The system of claim 28 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

30. A communications system for avoiding problematic Turbo code puncturing patterns, the system comprising:

(a) a plurality of rate matching stages for processing a plurality of individual parity bit streams;

(b) means for adjusting the number of punctured bits in each of the parity bit streams by increasing the number of bits punctured in one of the parity bit streams and decreasing the number of bits punctured in another one of the parity bit streams; and

(c) means for biasing the puncturing rates of each of the individual parity bit streams while maintaining a constant overall effective

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coding rate.

31. The system of claim 30 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, wherein the means for adjusting the number of punctured bits comprises:

(b1) means for adding punctured bits to the first group of P1 bits; and

(b2) means for removing punctured bits from the second group of P2 bits; and the means for biasing the puncturing rates comprises:

(c1) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

32. The system of claim 31 further comprising:

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if

$\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

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(f) means for setting bias $\Delta = 0$ if $\left|\frac{I}{(P/2)} - \frac{7\hat{N}}{2}\right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

33. The system of claim 32, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

34. The system of claim 33 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

35. A communications system for identifying degradations in quality of punctured error correction coded transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; and

(b) means for adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the puncturing rate of a problematic puncturing pattern.

36. The system of claim 35 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means for adjusting a value for anticipated degradation further comprising:

(b1) means for adding punctured bits to the first group of P1 bits;

(b2) means for removing punctured bits from the second group of P2 bits; and

(b3) means for biasing the puncturing rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

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43. A communications system for reducing degradations in quality of punctured error corrected code transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; and

(b) means for adjusting the parameters of the transmissions sufficiently to cause a mismatch in the puncturing pattern and the particular code rate by increasing and decreasing the number of bits punctured in respective parity bit streams, and biasing the particular code rate.

44. The system of claim 43 further comprising:

(c) means for determining a capacity of a wireless transmit and receive unit (WTRU), including buffer sizes that are supported by the WTRU;

(d) means for using puncturing to remove sufficient bits to fit into the buffer; and

(e) means for adjusting an overall code rate so as to provide sufficient error correction capability, thereby providing a first rate in a first stage of puncturing and providing a second rate in a second stage of puncturing.

45. The system of claim 44, further comprising:

(f) means for increasing non-punctured bits in one of the first stage and second stage of puncturing, and decreasing non-punctured bits in another of the first stage and second stage of puncturing, thereby adding additional puncturing to one stage and removing it from the other stage.

46. The system of claim 44 further comprising:

(f) means for increasing non-punctured bits in the first stage and decreasing non-punctured bits in the second stage.

47. The system of claim 44 further comprising:

AMENDED SHEET

PATENT APPLICATION FEE DETERMINATION RECORD

Effective October 1, 2003 10/725779

Application or Docket Number 1-2-0526.1US

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	48	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	48 minus 20=	* 28
INDEPENDENT CLAIMS	10 minus 3 =	* 7
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	385.00	OR	BASIC FEE	770.00
XS 9=		OR	XS18=	504
X43=		OR	X86=	602
+145=		OR	+290=	
TOTAL		OR	TOTAL	1876

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 48	Minus	**	=
Independent	* 10	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
XS 9=		OR	XS18=	
X43=		OR	X86=	
+145=		OR	+290=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
XS 9=		OR	XS18=	
X43=		OR	X86=	
+145=		OR	+290=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X43=		OR	X86=	
+145=		OR	+290=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

OIPE JC37 JUN 18 2004 PATENT & TRADEMARK OFFICE

IFW

PTO/SB/21 (04-04)
Approved for use through 07/31/2006. OMB 0651-0031
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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	10/725,779
Filing Date	December 2, 2003
First Named Inventor	Pietraski et al.
Art Unit	2183
Examiner Name	Not Yet Known
Total Number of Pages in This Submission	Attorney Docket Number: I-2-0526.1US

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☒ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Response to Missing Parts/ Incomplete Application
  - ☐ Response to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
- ☐ After Allowance communication to Technology Center (TC)
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☒ Other Enclosure(s) (please Identify below):

Form PTO-1449, Copy of PCT Search Report and Copies of Four (4) Cited References

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm or Individual name	Scott Wolinsky Reg. No. 46,413 Volpe and Koenig, P.C.
Signature	Scott Wolinsky
Date	JUNE 16, 2004

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Mail Stop Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below.

Typed or printed name	Scott Wolinsky		
Signature	Scott Wolinsky	Date	6/16/04

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE



In the **PATENT APPLICATION** of:	
Pietraski et al.	
Application No.: 10/725,779	Our File: I-2-0526.1US
Confirmation No.: 3830	Date: June 16, 2004
Filed: December 2, 2003	
For: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES	
Group: 2183	
Examiner: Not Yet Known	

INFORMATION DISCLOSURE STATEMENT
INCLUDING RULE 1.97(e)(1) STATEMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Further to Applicants' Duty of Disclosure pursuant to 37 C.F.R. §1.56, Applicants wish to bring to the Examiner's attention the material cited on the enclosed Form PTO-1449, which was cited in a search report in a counterpart international application. Copies of cited references AC-AF are enclosed along with a copy of the search report.

Pursuant to 37 C.F.R. §1.98, copies of the cited U.S. patents are not provided.

Although not required since no office action has issued yet in the instant application, Applicant hereby makes a statement under 37 C.F.R.1.97(e)(1): the undersigned certifies that references AA and AB contained in this Information Disclosure Statement (IDS) was first cited in any communication from a patent office

in a counterpart foreign application not more than three months prior to the filing of this IDS.

It is respectfully requested that the Examiner consider these documents and return an initialed copy of the Form PTO-1449 indicating consideration of the cited materials.

Respectfully submitted,

Pietraski et al.

By Scott Wolinsky
Scott Wolinsky
Registration No. 46,413
(215) 568-6400

Volpe and Koenig, P.C.
United Plaza, Suite 1600
30 South 17th Street
Philadelphia, PA 19103

SW/sag
Enclosures

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OIPE
JUN 18 2004
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FORM PTO-1449 U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Use several sheets if necessary)	ATTY. DOCKET NO. I-2-0526.1US	SERIAL NO. 10/725,779
	APPLICANT Pietraski et al.	
	FILING DATE December 2, 2003	GROUP 2183

U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
	AA	6,370,669	04/2002	Eroz et al.			
	AB	6,601,214	07/2003	Hammons, Jr.			

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc.)

	AC	Mo et al., "Analysis of Puncturing Pattern for High Rate Turbo Codes," IEEE International, 0-7803-5538-5/99, 1999, pgs. 547-550.
	AD	3GPP TS 25.212 v6.1.0 (2004-03), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Multiplexing and channel coding (FDD) (Release 6).
	AE	3GPP TS 25.222 v6.0.0 (2003-12), 3rd Generation Partnership Project, Technical Specification Group Radio Access Network; Multiplexing and channel coding (TDD) (Release 6).
	AF	3GPP TS 25.944 v4.1.0 (2001-06), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Channel coding and multiplexing examples (Release 4).

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☐ Declaration Submitted with Initial Filing OR ☒ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	I-2-0526.1US
First Named Inventor	Pietraski et al.
COMPLETE IF KNOWN	
Application Number	10/725,779
Filing Date	December 2, 2003
Group Art Unit	2183
Examiner Name	Not Yet Known

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

(Title of the Invention)

the specification of which
☐ is attached hereto
OR
☒ was filed on (MM/DD/YYYY) 12/02/2003 as United States Application Number or PCT International Application Number 10/725,779 and was amended on (MM/DD/YYYY) _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)
60/434,232	12/16/2002
60/444,068	01/30/2003
60/470,921	05/15/2003
60/494,404	08/11/2003

☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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OR
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Name	Registration Number	Name	Registration Number
Namely, the Attorneys of Volpe and Koenig, P.C.			

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Name	VOLPE AND KOENIG, P.C. DEPT ICC				
Address					
Address					
City		State		ZIP	
Country		Telephone		Fax	

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Philip J.	Pietraski

Inventor's Signature						Date	
Residence: City	Huntington Station	State	NY	Country	USA	Citizenship	USA
Post Office Address	7 Talbot Place						
Post Office Address							
City	Huntington Station	State	NY	ZIP	11746	Country	USA

☒ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

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DECLARATION

ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page 3 of 3

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any])	Family Name or Surname		
Gregory S.	Sternberg		
Inventor's Signature			**Date** 04/28/2009
Residence: City Great Neck	**State** NY	**Country** USA	**Citizenship** USA
Mailing Address 50 Brompton Road, Apartment 2B			
Mailing Address			
City Great Neck	**State** NY	**ZIP** 11021	**Country** USA

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any])	Family Name or Surname		
Inventor's Signature			**Date**
Residence: City	**State**	**Country**	**Citizenship**
Mailing Address			
Mailing Address			
City	**State**	**ZIP**	**Country**

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any])	Family Name or Surname		
Inventor's Signature			**Date**
Residence: City	**State**	**Country**	**Citizenship**
Mailing Address			
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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☐ Declaration Submitted with Initial Filing **OR** ☒ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	I-2-0526.1US
First Named Inventor	Pietraski et al.
COMPLETE IF KNOWN	
Application Number	10/725,779
Filing Date	December 2, 2003
Group Art Unit	2183
Examiner Name	Not Yet Known

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

(Title of the Invention)

the specification of which
☐ is attached hereto
OR
☒ was filed on (MM/DD/YYYY) 12/02/2003 as United States Application Number or PCT International Application Number 10/725,779 and was amended on (MM/DD/YYYY) _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

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Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
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			☐	☐	☐
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Application Number(s)	Filing Date (MM/DD/YYYY)
60/434,232	12/16/2002
60/444,068	01/30/2003
60/470,921	05/15/2003
60/494,404	08/11/2003

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U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number *(if applicable)*

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☒ Customer Number 24374 → *Place Customer Number Bar Code Label here*

OR

☐ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
Namely, the Attorneys of Volpe and Koenig, P.C.			

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Address					
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Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Philip J.	Pietraski

Inventor's Signature	Philip Pietraski					Date	10-5 2004
Residence: City	Huntington Station	State	NY	Country	USA	Citizenship	USA
Post Office Address	7 Talbot Place						
Post Office Address							
City	Huntington Station	State	NY	ZIP	11746	Country	USA

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IPR2023-01272 Page 290

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DECLARATION

ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page 3 of 3

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any])	Family Name or Surname		
Gregory S.	Sternberg		
Inventor's Signature			**Date**
Residence: City Great Neck	**State** NY	**Country** USA	**Citizenship** USA
Mailing Address 50 Brompton Road, Apartment 2B			
Mailing Address			
City Great Neck	**State** NY	**ZIP** 11021	**Country** USA

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any])	Family Name or Surname		
Inventor's Signature			**Date**
Residence: City	**State**	**Country**	**Citizenship**
Mailing Address			
Mailing Address			
City	**State**	**ZIP**	**Country**

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Given Name (first and middle [if any])	Family Name or Surname		
Inventor's Signature			**Date**
Residence: City	**State**	**Country**	**Citizenship**
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APPLICATION NUMBER	FILING OR 371 (c) DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
10/725,779	12/02/2003	Philip J. Pietraski	I-2-0526.1US

CONFIRMATION NO. 3830

FORMALITIES LETTER

OC000000011996639

24374
VOLPE AND KOENIG, P.C.
DEPT. ICC
UNITED PLAZA, SUITE 1600
30 SOUTH 17TH STREET
PHILADELPHIA, PA 19103

Date Mailed: 03/02/2004

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
- To avoid abandonment, a late filing fee or oath or declaration surcharge as set forth in 37 CFR 1.16(e) of $130 for a non-small entity, must be submitted with the missing items identified in this letter.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is **$130** for a Large Entity

- **$130** Late oath or declaration Surcharge.

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[0001] DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

[0002] CROSS REFERENCE TO RELATED APPLICATION(S)

[0003] This application claims priority from U.S. Provisional Patent Applications Serial No. 60/434,232, filed December 16, 2002, Serial No. 60/444,068, filed on January 30, 2003, Serial No. 60/470,921, filed on May 15, 2003, and Serial No. 60/494,404 filed on August 11, 2003.

[0004] FIELD OF THE INVENTION

[0005] This invention generally relates to the use of Turbo codes in general, and, more particularly to a method for detecting and correcting performance degradation in punctured Turbo codes using a Turbo encoder.

[0006] BACKGROUND

[0007] Wireless communication systems are well known in the art. Generally, such systems comprise communication stations that transmit and receive wireless communication signals between each other. Typically, base stations are provided which are capable of conducting wireless concurrent communications with a plurality of subscriber stations. In Code Division Multiple Access (CDMA) systems specified by the Third Generation Partnership Project (3GPP), base stations are called Node Bs, subscriber stations are called User Equipments (UE) and the wireless interface between the Node Bs and UEs is known as the Uu interface. Figure 1 illustrates a typical 3GPP CDMA system.

[0008] The Uu radio interface of a 3GPP communications system uses Transport Channels (TrCH) for transfer of user data and signaling between UEs and Node Bs. In 3GPP Time Division Duplex (TDD) communications, TrCH data is conveyed by one or more physical channels defined by mutually exclusive physical resources. TrCH data

is transferred in sequential groups of Transport Blocks (TB) defined as Transport Block Sets (TBS). Each TBS is transmitted in a given Transmission Time Interval (TTI) which may span a plurality of consecutive system time frames. A typical system time frame is 10 milliseconds and TTIs are currently specified as spanning 1, 2, 4 or 8 of such time frames.

[0009] Figure 2 illustrates the processing of TrCHs in TTD mode into a Coded Composite TrCH (CCTrCH) and then into one or more physical channel data streams in accordance with 3GPP TS 25.222 v3.8.0. Starting with the TB of data, Cyclic Redundancy Check (CRC) bits are attached and TB concatenation and code block segmentation is performed. Convolution coding or turbo coding is then performed, but in some instances no coding is specified. The steps after coding, include radio frame equalization, a first interleaving, radio frame segmentation and rate matching. The radio frame segmentation divides the data over the number of frames in the specified TTI. The rate matching function operates by means of bit repetition or puncturing and defines the number of bits for each processed TrCH which are thereafter multiplexed to form a CCTrCH data stream.

[0010] The processing of the CCTrCH data stream includes bit scrambling, physical channel segmentation, a second interleaving and mapping onto one or more physical channels. The number of physical channels corresponds to the physical channel segmentation. For uplink transmissions, UE to Node B, the maximum number of physical channels for transmission of a CCTrCH is currently specified as two. For downlink transmissions, Node B to UEs, the maximum number of physical channels for transmission of a CCTrCH is currently specified as sixteen. Each physical channel data stream is then spread with a channelization code and modulated for over air transmission on an assigned frequency.

[0011] In the reception/decoding of the TrCH data, the processing is essentially reversed by the receiving station. Accordingly, UE and Node B physical reception of TrCHs require knowledge of TrCH processing parameters to reconstruct the TBS data. For each TrCH, a Transport Format Set (TFS) is specified containing a predetermined

number of Transport Formats (TF). Each TF specifies a variety of dynamic parameters, including TB and TBS sizes, and a variety of semi static parameters, including TTI, coding type, coding rate, rate matching parameter and CRC length. The predefined collection of TFSs for the TrCHs of a CCTrCH for a particular frame is denoted as a Transport Format Combination (TFC).

[0012] Receiving station processing is facilitated by the transmission of a Transport Format Combination Indicator (TFCI) for a CCTrCH. 3GPP optionally provides for "blind transport format detection" by the receiving station, in which case the receiving station considers the potential valid TFCIs. Where there is only one valid TFCI, that TFCI is used in either case.

[0013] In 3GPP, time slot transmissions are made in predefined bursts where the transmitted physical channel data is divided into a beginning time slot portion and an ending time slot portion. A selected midamble is included between the two physical channel data portions. The TFCI is currently specified as transmitted in two parts on either side of the midamble and also between the two physical channel data portions. Two examples from 3GPP TR 25.944 V3.5.0 are illustrated in Figures 3 and 4 respectively where the block labeled MA represents the midamble and the block labeled T represents the parts of the TFCI. In Figure 4, the CCTrCH is mapped to two physical channels, but only one physical channel includes the TFCI.

[0014] Figures 5A, 5B and 6 are diagrams of channel coding and multiplexing examples in accordance with 3GPP Frequency Division Duplex (FDD) specifications.

[0015] The various encoding steps implemented in communication systems play a key role in both performance and capacity of a wireless telecommunications systems. In particular, the turbo coding of the data being processed for wireless transmission plays a significant role for both TDD and FDD communications in a 3GPP system.

[0016] Turbo coding principles have found widespread applications in information theory and, in part, have entered into mainstream telecommunication theory and practice. These principles are used in error control, detection, interference suppression, equalization, and other communications-related areas. Turbo codes are a

form of parallel, recursive systematic convolution codes, which can be used for channel coding and decoding in order to detect and correct errors that may occur in the transmission of digital data through different channels. Turbo codes are particularly useful for data transfers in which, under certain conditions, the data transfer rate can approach the theoretical limits of Shannon's Law. These favorable conditions generally include large block size transfers, which are particularly useful in mobile communications.

[0017] Figure 7 shows how particular codes created by puncturing exhibit poorer than expected performance. As much as a 4dB loss can be measured in the critical Signal-to-Noise Ratio (SNR) value.

[0018] Typically, high-rate Turbo codes are created by puncturing (i.e., eliminating) parity bits of a lower-rate code until the desired code rate is attained. Particular codes created by puncturing exhibit poorer than expected performance due to certain punctured bit patterns. Because the recursive encoding blocks in a Turbo encoder have an infinite impulse response, information about each systematic bit is distributed across many of the parity bits.

[0019] In any error control coding scheme that employs puncturing, the location of the punctured bits will have an impact on performance. This is because puncturing strings of successive bits can be viewed as burst errors by the decoder. All error control mechanisms can only correct burst errors that are less than some threshold. Therefore, it is important when designing the puncturing scheme that the burst error correcting abilities of the code be considered. In the absence of specific knowledge of the error control coding scheme, a good rule is to minimize the maximum string of punctured bits. For high coding rates this corresponds to distributing the non-punctured bits uniformly across the transmitted block. Puncturing schemes that uniformly distribute the non-punctured bits can deleteriously interact with certain error control codes, causing a degradation of decoder performance.

[0020] Because the recursive encoding blocks in the Turbo encoder have infinite impulse response, information about each systematic bit is distributed across many of

the parity bits. The impact of certain periodic non-puncture patterns in the parity bits can be qualitatively illustrated by considering how much information remains in the surviving parity bits.

[0021] Regions where performance of the punctured Turbo code is degraded can be determined by measuring how close the puncturing pattern is to being periodic with period related to the period of the semi-periodic impulse response of the recursive encoding blocks of the Turbo encoder.

[0022] For a 3GPP Turbo encoder, the constituent recursive encoders have an impulse response that is periodic with a period of 7 symbols for positive time (semi-periodic). This can readily be seen by interpretation of the encoder as an M-sequence generator, i.e., if the shift register starts in the zero state and a one is applied only at $t = 0$, then the encoder is exactly a Linear Feedback Shift Register (LFSR) with an associated 3rd order primitive polynomial and initial state {1 0 0}, thus a period $2^3-1 = 7$ M-sequence is generated for positive time.

[0023] The encoder is a Linear Time Invariant (LTI) system on a binary field. Therefore, the output of the encoder is a sum of shifted versions of the impulse response of the encoder, each shifted impulse response corresponding to the locations of the 1's in the TB. If we consider an input that is all 0's for $t > T$, then the output of the constituent recursive encoding block will also be semi-periodic for $t > T$.

[0024] Certain non-puncturing periods may result in a loss of distributed information about a small group of bits across the set of parity bits. For example, let the TB consist of 7 bits followed by many zeros. Now consider the problem of trying to determine the seven bits by observation of the output of one encoder after heavy puncturing. Each observation is made at the output is a sum of a subset of the 7 bits, the subset being determined by the non-puncture period and the impulse response of the recursive encoding block. For most non-puncture patterns (those that have a period relatively prime with the period of the semi-periodic impulse response), sums over 7 different subsets can eventually be observed. Therefore, a system of 7 equations with 7 unknowns can be formed. Assuming they are linearly independent, the values

of the 7 bits may be determined. However, consider the case where the non-puncture period is simple (one surviving parity bit per period) and the same as the period of the recursive encoding block, 7. Then every observation for $t > 6$ is the sum of the same subset of the 7 bits and so no new information is obtained, i.e., a rank-1 system of equations is formed and a unique solution does not exist. This is due to the periodic nature of the signal. When the non-puncture period is relatively prime with the period of the recursive encoding block, a series of observations of the parity bits will eventually form a rank-7 system of equations. For our 7-bit group, this is sufficient to uniquely determine the bits, i.e., information sufficient to determine the bits is distributed across the surviving parity bits. When the periods are not relatively prime, the rank of the system becomes L/K where L is the period of the recursive encoding block and K is the Greatest Common Divider (GCD) of L and N where N is the period of the non-puncture pattern.

[0025] In the above illustration, a long sequence of zeros after the small group of bits was supposed for clarity sake. However, allowing additional groups of bits to follow the first group does not add to the distributed information about earlier groups. This can be seen from the causality of the system.

[0026] It is also possible that some distributed information is lost even for non-simple periods, e.g., consider the case where the non-puncture pattern alternates between a simple period of three and four. This results in a period 7 non-puncture pattern but with two surviving parity bits per period. The same argument above leads to a rank-2 system of seven equations which is still insufficient to uniquely determine the group of bits, but does reduce the dimension of the space they may span. Clearly, some information about the small group of bits is lost for some non-punctured patterns.

[0027] In order to obtain adequate performance, it is necessary to detect, avoid and/or correct the problematic puncturing patterns in the parity bit streams without having to avoid code rates. Typically, problematic interactions occur between the Turbo coder output and puncturing in the rate matching stages.

[0028] It would be desirable to have a method for creating high-rate Turbo codes that avoids problematic interactions by modifying the puncturing patterns.

[0029] SUMMARY OF THE INVENTION

[0030] According to the present invention, degradations in quality of punctured error correction coded transmissions are identified and the code transmissions are modified accordingly. A puncturing pattern which approximates a particular code rate is identified, and a value for anticipated degradation is adjusted in accordance with a matching of the puncturing pattern and the particular code rate.

[0031] For both FDD and TDD, two stages of rate matching and two puncturing operations are included, and this is done because of a certain technique called, incremental redundancy, which allows for a wireless transmit/receive unit (WTRU) to receive and soft combine multiple transmissions of the same TB from the base station. If the transmission fails the first time, the signal is retransmitted with more data in an attempt to obtain a successful communication the second time. In order to do that, two different stages of puncturing are used because the WTRU has certain capabilities, certain buffer sizes that it can support, and in order to be able to fit the retransmissions that are combined into the buffer, there are two stages of puncturing. The first stage of rate matching punctures enough bits such that the surviving bits fit into a buffer, and the second stage of puncturing (or repetition) is to achieve the desired overall code rate. When the two stages of rate matching are combined, a plot of problematic regions of coding rate is a multidimensional plot. Thus, there are two rates now involved, which are a rate in a first stage of puncturing and a rate in a second stage of puncturing.

[0032] According to a first embodiment of the present invention, P1/P2 puncturing biasing for a single stage of rate matching is implemented using the punctured error correction coded transmissions.

[0033] According to a second embodiment, two or more stages may be employed at each stage of rate matching for detecting and correcting performance in punctured

Turbo codes on a High Speed Downlink Shared Channel (HS-DSCH) in R5 High Speed Downlink Packet Access (HSDPA).

[0034] BRIEF DESCRIPTION OF THE DRAWINGS

[0035] A more detailed understanding of the invention may be had from the following description of a preferred embodiment, to be understood in conjunction with the accompanying drawing wherein:

[0036] Figure 1 is a schematic diagram of a typical CDMA system in accordance with current 3GPP specifications;

[0037] Figure 2 is a processing diagram of TrCH data for a CCTrCH in accordance with 3GPP TDD specifications;

[0038] Figures 3 and 4 are diagrams of channel coding and multiplexing examples in accordance with 3GPP TDD specifications;

[0039] Figures 5A, 5B and 6 are diagrams of channel coding and multiplexing examples in accordance with 3GPP FDD specifications;

[0040] Figure 7 shows typical results of particular codes being created by puncturing, where as much as 4 dB loss can be measured in critical SNR value;

[0041] Figure 8 graphically depicts the SNR required to successfully decode a data block (critical SNR) with high probability vs. Code Rate when P1/P2 biasing is applied;

[0042] Figure 9 is a plot of the problematic regions with respect to an ordered pair (r1,r2) which are the rates of puncturing the parity streams in the first and second stages of rate matching, respectively;

[0043] Figure 10 is a schematic block diagram showing a circuit for 3GPP rate matching for HSDPA, using a Turbo coded HS-DSCH; and

[0044] Figure 11 graphically depicts initial Block Error Rate (BLER) for HS-DSCH transport blocks with certain effective coding rates.

[0045] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0046] In accordance with the present invention, several methods and embodiments are disclosed for detecting, avoiding and/or correcting the problematic puncturing patterns in the parity bit streams without having to avoid code rates.

[0047] The present invention is potentially applicable to layers 1 and 2 in a FDD, CDMA 2000 and TDD Universal Mobile Telecommunications System (UMTS) modes of transmission as well as other modes of transmission. Additionally, methods are described hereinafter for modifying the puncturing patterns such that performance of degraded Turbo code is restored.

[0048] In accordance with the present invention, the methods disclosed herein may be implemented in a wireless transmit/receive unit (WTRU) and/or a base station. Hereinafter, a WTRU includes but is not limited to a UE, mobile station, fixed or mobile subscriber unit, pager, or any other type of device capable of operating in a wireless environment. When referred to hereafter, a base station includes but is not limited to a base station, Node-B, site controller, access point or other interfacing deice in a wireless environment.

[0049] Figure 8 graphically depicts the SNR required to successfully decode a data block (critical SNR) with high probability versus Code Rate when biasing of parity bits P1/P2 is applied. As shown in Figure 7, it has been found that particular codes created by puncturing the rate 1/3 3GPP Turbo code exhibit poorer than expected performance, as can be seen from the peaks in the figure.

[0050] Figure 9 is a plot of the problematic regions with respect to an ordered pair (r1,r2) which are the rates of puncturing the parity streams in the first and second stages of rate matching, respectively. As can be seen, there are particular regions where the rates of puncturing of the parity streams are such that some combinations of rates are particularly problematic.

[0051] In one embodiment, puncture biasing for parity bits P1 and P2 is implemented for one stage rate matching. Figure 10 is a schematic block diagram showing circuitry 600 for 3GPP rate matching for HSDPA, using a Turbo coded

HS-DSCH. The circuitry 600 implements a 3GPP rate-matching scheme for HSDPA. The circuitry 600 includes a bit separation circuit 605, a first rate matching stage 610, a virtual incremental redundancy (IR) buffer 615, a second rate matching stage 620 and a bit collection circuit 625. The first rate matching stage 605 includes a Parity 1 (P1) bit rate matching circuit 630 and Parity 2 (P2) bit rate matching circuit 635. The second rate matching stage 620 includes a systematic bits rate matching circuit 640, a Parity 1 (P1) bit matching circuit 645 for the second rate matching and a Parity 2 (P2) bit matching circuit 650 for the second rate matching. In operation, the systematic bits, Parity 1 (P1) and Parity 2 (P2) bits are processed through the first rate matching stage 610, virtual IR buffer 615, second rate matching stage 620 and bit collection circuit 625. Note that the Parity 1 (P1) and Parity 2 (P2) bits are treated separately. The systematic bits, Parity 1 (P1) and Parity 2 (P2) bits are combined at the bit collection circuit 625 to provide a single data output N_{data}. Also note that if the number of coded bits is less than or equal to the size of the virtual IR buffer 615, the first stage of rate matching 630 is transparent. The transparent first stage case and Rel-4 rate matching are considered.

[0052] In its actual implementation, it is anticipated that the different circuit functions will be executed by a common circuit or circuits, such as microprocessor circuitry, and in accordance with program instructions. The specific circuit functions used to implement the invention would therefore be a matter of choice of those configuring the circuitry within the rate matching circuitry 600.

[0053] The rate matching algorithm performs puncturing if the overall code rate is greater than 1/3 and repetition if the code rate is less than 1/3. Currently code rates greater than 1/3 are accomplished by applying the same puncturing rate to both P1 and P2 bits (to within one bit) but with different puncturing pattern phases. In order to avoid non-puncturing periodicities that have been shown to degrade the Turbo code performance, the puncturing rates for P1 and P2 be independently biased. For example, if the number of P1 bits is decreased by and the number of P2 bits is increased by, the overall code rate is unchanged but the problematic non-puncturing

periods can be avoided. Given this approach to avoiding the problematic code rates, an analytical expression for the requisite bias, has been derived.

[0054] A simple and efficient method of modifying the puncture patterns is biasing the number of punctured bits in P1 and P2 by adding additional puncturing to one and removing it from the other. The amount of the bias should be no more than is needed to avoid certain periodicities. In biasing the puncturing rates of P1 and P2 bits, two constraints must be met.

[0055] When non-puncturing patterns with period $7\hat{N}/2$ ($\hat{N} = 1, 2, 3\ldots$) are used, degradation in performance results. These periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

[0056] The average non-puncturing rate of the P1 and P2 rate matching blocks is $I/(P/2)$ where I is the number of bits at the input to each branch of rate matching and P is the total number of parity bits (P1 and P2) at the output of rate matching. Therefore, the desired code rate will lead to a problematic puncturing pattern if,

$$\left|\frac{I}{(P/2)} - \frac{7\hat{N}}{2}\right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor, \qquad \text{Equation 1}$$

for $\hat{N} > 0$ where,

$$\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor. \qquad \text{Equation 2}$$

[0057] In biasing the puncturing rates of the parity bit streams 1 and 2, P1 and P2, two constraints must be met.

[0058] First, the number of surviving bits in parity bit stream 1 must be increased sufficiently by an amount Δ to avoid the problematic puncturing patterns. Second, the number of surviving bits in parity bit stream 2 must be decreased by an equal amount Δ that is also sufficient to avoid problematic puncturing patterns.

[0059] These two constraints can be combined in to the following expression for Δ, where:

[0060] $$\Delta = \left\lceil \max\left\{ \left\lfloor \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2} \right\rfloor, \frac{P}{2} - \left\lceil \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\rceil \right\} \right\rceil \quad \text{Equation 3}$$

[0061] Alternatively, non-punctured bits may be increased in P2 and decreased in P1. The procedure to determine and apply the necessary P1/P2 bias is as follows:

Step 1) Compute $\hat{N}$ using Equation 2.

Step 2) Determine if the desired code rate results in a problematic puncturing pattern using Equation 1. If it does, continue to Step 3, otherwise set $\Delta = 0$ (if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$).

Step 3) Compute the bias Δ using Equation 3.

Step 4) Compute rate matching parameters by modifying Table in TS25.212/222.

[0062] In order to avoid puncturing patterns that degrade Turbo code performance, the amount of puncturing applied to parity bit streams 1 and 2 respectively could be slightly different, while keeping the overall number of punctured bits constant.

[0063] If the number of punctured bits in parity bit stream 1 is decreased by Δ and accordingly, the number punctured bits in parity bit stream 2 bits is increased by Δ, the overall code rate is unchanged, but the problematic puncturing patterns can be avoided. Note that bit collection and bit de-collection stages need to be adjusted correspondingly for this case. Since individual regions of degraded performance tend to be small, it may be advantageous to simply avoid the use of code rates with degraded

performance. Since code rates with degraded performance can now be identified using the above equation, it is a simple matter to avoid them.

[0064] For Hybrid Automatic Repeat reQuest (HARQ) as deployed in 3GPP, it may be necessary to employ two stages of rate matching. This occurs whenever incremental redundancy (IR) is employed and the number of bits input to the rate-matching algorithm is larger than the virtual IR buffer. Note that when Chase combining HARQ is used, there is no need for a special IR buffer; a received bit buffer would be sufficient. (If constellation rearrangement were not used, a buffer of received symbols would be sufficient.) If it is determined that IR provides only a small improvement over Chase combining, then removal of IR from the standards may be advisable.

[0065] In order to obtain higher data rates, the 3GPP has introduced the HSDPA option wherein link adaptation is performed. One component of the link adaptation is Adaptive Modulation and Coding (AMC). With AMC, a channel quality estimate is used to select the modulation type and code rate that attains the largest throughput. When the channel quality is high, QAM modulation and a high code rate are selected. High code rates are obtained by puncturing a rate 1/3 Turbo code. During the design of the channel quality indication (CQI) table, it was observed that certain Transport Block Set Sizes (TBSS) exhibited poorer than expected performance. The CQI table is used to map a channel quality estimate into a recommended modulation and TBSS. This problem of poorer than expected performance is currently addressed by simply "hand tweaking" the CQI table to avoid the TBSSs that cause problems. In AMC, this leads to less than optimal throughput since optimal code rates will inevitably be avoided.

[0066] Support for link adaptation by means of AMC is an integral feature of R5 HSDPA. With AMC, modulation type and code rate on HS-DSCH can be varied according to channel conditions. Variable coding rates on HS-DSCH are achieved by means of rate matching (repetition or puncturing) output of the R99 Turbo-coder in a pre-determined manner, i.e. as a function of TBSS and available number of Physical

Channel bits. Both R99/R4 and R5 use the same code rate 1/3 Turbo-coder. While the principle of rate-matching is the same for both R4 and R5, the likely and more frequent use of higher effective code rates (>1/2), the use of multiple stages of rate matching, and the standard allowing for the possibility of Incremental Redundancy (IR) differentiate R99/R4 and R5.

[0067] HSDPA performance requirements in WG4 have indicated unusually high and rather unpredictable SNR performance degradations for Turbo-coded and punctured transport blocks on HS-DSCH up to several dB for a range of effective coding rates above 1/2.

[0068] The Turbo-coding performance on HS-DSCH is heavily impacted by unfavorable puncturing patterns of the parity bit streams output by the baseline rate 1/3 Turbo-coder. Although the original WG4 simulation results were provided in a TDD-context, exactly the same degradations also occur in FDD, the reason being that Turbo-coding and rate-matching (TS25.212 and TS25.222) on HS-DSCH transport blocks (where the problematic interactions originate) are done exactly the same way for both modes.

[0069] The poorer than expected performance at some data rates is also a problem with a fixed modulation and coding scheme. If a user is assigned a code rate that exhibits the problem, the poor performance of the code will be compensated for by power control thus reducing cell capacity.

[0070] In another embodiment, adjustments to the parity stream puncturing allows the Medium Access Control – High Speed (MAC-hs) to simply select any desired transport block size as an outcome of the scheduler decision. It would be required to slightly change the generation of the puncturing patterns in the rate-matching stages in TS25.212/222. For example, one implementing modification to the current FDD standard as set for in TS 25.212 is appended hereto along with a brief discussion of why the modification is desirable.

[0071] For both the case of 1st rate-matching stage being transparent and the case of both 1st and 2nd rate-matching stage being employed, a number of acceptable

solutions exist to avoid the problematic interactions by means of adjustments to the parity bit puncturing.

[0072] One of these solutions, e.g. a simple biasing method, is outlined below in the interest of providing a conceptual example for the case of the 1st rate-matching stage being transparent.

[0073] Currently, coding rates >1/3 are accomplished by applying the same amount of puncturing to both parity bit streams 1 and 2 at the output W of the Turbo-coder (Figure 10), although the puncturing pattern "phases" can be adjusted.

[0074] When a particular code rate is desired and it is determined that its use will result in degraded performance, a slightly lower code rate may be selected to avoid the degradation. Good choice for the substituted code rate would be the largest allowable code rate less than the desired code rate that has been determined to have an acceptable degradation.

[0075] If it is desirable for a system to be allowed to make unrestricted use of available code rates, then performance may be restored by modification of the puncture pattern. The key to restoring performance to the punctured Turbo code is to avoid the case where the surviving parity bits are overly redundant with respect to the systematic bits, i.e., modify the puncturing pattern to improve performance. One way to accomplish this is to sample the parity bits such that all the points corresponding to one complete period of the semi-periodic impulse response are sampled with as few samples as possible while maintaining the same code rate and not overly distorting the uniformity of the puncturing over the data block or creating overly large imbalances in the number of surviving parity bits in P1 and P2.

[0076] It should also be noted that this method of mitigation could also be applied to systems with more than 2 parity streams. For example, the 3GPP Turbo code (CDMA 2000) includes four parity streams. If a problematic puncturing pattern occurs it can be alleviated by adjusting the puncturing rates of each of the individual parity streams while maintaining a constant overall effective coding rate.

[0077] In the case of single stage of rate matching, as used in R99/R4 and in many R5 configurations, the problematic interactions between the Turbo-coded output and the punctured transmitted sequence occurs in regions where the puncturing patterns are nearly periodic with surviving bit period equal to a multiple of 7, and when an average 1 out of every 3.5 parity bits survive.

[0078] These degradations correspond to rank-1 and rank-2 scenario respectively. This case corresponds to the rank-1 scenario. Rank-2 scenarios have less impact on the SNR degradation than rank-1 scenarios. Since higher rank scenarios (>2) do not significantly contribute to performance degradation, ranks other than rank-1 and rank-2 scenarios are not considered here.

[0079] The code rates at the center of these regions are determined by:

[0080] $$CR = \frac{1}{1+\frac{2}{3.5N}} = \frac{3.5N}{3.5N+2} \qquad N = 1,2,... \qquad \text{Equation 4}$$

[0081] The critical code rate, *CR,* corresponds to a rank-1 scenario when N is even and rank-2 when N is odd. For rank-1, we have critical code rates CR = 7/9, 7/8, 21/23,... and for rank-2, we have CR = 7/11, 21/25,....

[0082] The ratio of the number of systematic bits and the number of parity bits in either parity bit stream 1 or 2 can be considered as "parity puncturing rate". When surviving bit patterns with parity puncturing rate close or equal to $7N/2$ (N =1,2,3...) are used, degradation in performance results. Some amount of Turbo-coding and puncturing interaction will also occur whenever the average periodicity of surviving bits of the parity bit streams 1 or 2 is within ±1 or ±½ of $7N/2$ for even and odd N respectively.

[0083] When two (or more) stages of rate matching are employed, problematic puncturing patterns can be generated by any stage, or by the interaction between the stages of rate matching.

[0084] A closed form expression(s) has been developed for the Release 5 3GPP Turbo coder / Rate Matching that predicts the performance degradation. The

expression takes as input either the triplet {Bits Before 1st stage of rate Matching, Max Bits after 1st Rate Matching, Bits after 2nd Rate matching} or the pair {Rate of 1st stage Rate Matching with respect to parity bits, Rate of 2nd stage Rate Matching with respect to parity bits}. The output, as depicted in Equation 5 below, is a rational number that may be compared to a threshold to accept/reject the configuration as providing/not providing acceptable performance. The parameters *r1* and *r2* represent the rates associated with the 1st and 2nd stages of rate matching with respect to the parity bit streams. Although complicated, the Equation 5 is a piecewise linear and continuous function in r1, r2 and is therefore trivial to evaluate.

$$\begin{aligned}\lambda(r1,r2)=\sum_{n=1}^{L-1}\alpha_n\Bigg[&\left(1-\left\lceil\frac{1}{L}\left\lceil r1\lceil nr2\rceil\right\rceil-\left\lfloor\frac{1}{L}\left\lceil r1\lceil nr2\rceil\right\rceil\right\rfloor\right)\left(nr2-\lfloor r2\rfloor\right)\left(r1\lceil nr2\rceil-\lfloor r1\lceil nr2\rceil\rfloor\right)+\\&\left(1-\left\lceil\frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor-\left\lfloor\frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor\right\rfloor\right)\left(nr2-\lfloor nr2\rfloor\right)\left(-r1\lceil nr2\rceil-\lfloor r1\lceil nr2\rceil\rfloor+1\right)+\\&\left(1-\left\lceil\frac{1}{L}\left\lceil r1\lfloor nr2\rfloor\right\rceil-\left\lfloor\frac{1}{L}\left\lceil r1\lfloor nr2\rfloor\right\rceil\right\rfloor\right)\left(-nr2+\lfloor nr2\rfloor+1\right)\left(r1\lfloor nr2\rfloor-\lfloor r1\lfloor nr2\rfloor\rfloor\right)+\\&\left(1-\left\lceil\frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor-\left\lfloor\frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor\right\rfloor\right)\left(-nr2+\lfloor nr2\rfloor+1\right)\left(-r1\lfloor nr2\rfloor+\lfloor r1\lfloor nr2\rfloor\rfloor+1\right)\Bigg]\end{aligned}$$

Equation 5

[0085] A threshold comparison could then be based on this equation to test whether or not the Code Rate pair will perform adequately. Equivalently, the triple: {Data Block Size, Size After 1st Stage Rate-Matching, Size After 2nd Stage Rate-Matching} can be used since this triple maps directly into the Code Rate pair.

[0086] The effect of the periodicity of the puncturing pattern can also be mitigated by interleaving the parity bits before rate-matching occurs. In this way, after de-interleaving, periodic sampling of the parity bits is avoided even when periodic sampling is done in rate-matching.

[0087] The functionality of the channel interleaver can be incorporated into the rate-matching block interleaver. This can be accomplished by adding additional constraints to the rate-matching block Interleaver (those defined by the channel

interleaver) when the interleaver is designed. This however will require an additional interleaver for the systematic bits.

[0088] Note that the rearrangement of the non-punctured bits only needs to occur on a range equal to the period of the semi-periodic impulse response of the recursive encoding blocks of the Turbo encoder. Therefore, small time-varying interleavers can be added to the parity bit steams to prevent problematic puncturing patterns. This has the advantage of requiring less memory and helps to minimize the distortion of the uniformity of the puncturing.

[0089] Certain parameters may be made to vary as a function of time (or bit index) to generate puncturing patterns that will mitigate performance degradations. One such example for 3GPP includes modification of the rate-matching parameters X_i, e_ini, e_minus and e_plus parameters throughout the execution of the rate-matching. In this way, the parameters affecting the puncturing pattern may change at one or more locations within the block of bits being punctured. By allowing the parameters to change, the instantaneous code rates may be different from the desired overall code rate (thereby avoiding the puncturing interaction) while still maintaining the same overall code rate. For example: 1) e_plus and e_minus may change frequently throughout the puncturing algorithm thus breaking up any possible long runs of deleterious puncturing. 2) Parameters may be changed so that the code rate is changed so that it is higher in some portions of the code block and lower in others.

[0090] The above methods are examples of modifications to the puncturing pattern used to generate specific code rates. All such methods may be considered special cases and specific implementations of the more general concept of a permutation of the puncturing pattern. Any method of changing the puncturing pattern, i.e., generating some permutation of the original puncturing pattern, has the potential of changing the overall performance of a code.

[0091] One can achieve the desired overall code rate while avoiding problematic puncturing patterns by adjusting the amount of puncturing performed in each stage. This method, when placed in the context of the 3GPP HSDPA Turbo Code / Rate

Matching algorithm leads to artificially reducing the size of the virtual Incremental Redundancy (IR) buffer. In general the approach implies a modification to the individual puncturing rates of each of the stages such that a desirable overall puncturing pattern results.

[0092] Stage Rate Biasing is easily accomplished by changing the operating point (the *r1*, *r2* pair) to some point on a curve of constant code rate (i.e., where the product *r1*r2* is unchanged) where performance degradation is tolerable.

[0093] The combination of adjusting the stage puncturing rates as well as the relative rates of puncturing in the two parity streams can also mitigate the problematic interaction between the puncturing pattern and the Turbo Code performance.

[0094] This can be envisioned as splitting the operating point in to two points. One of the points corresponds to the rates of 1st and 2nd stage rate matching for the first parity bit stream and the second point for the second parity bit stream. The two points should be selected so that the overall code rate is unchanged, both points lie in regions of acceptable performance, and the total number of surviving bits after the first stage of rate matching does not exceed imposed limits such as an IR buffer.

[0095] The present invention provides several simple and efficient techniques of detecting, avoiding and/or correcting problematic puncturing patterns in the parity bit streams without having to avoid desired code rates. According to the present invention, degradations in punctured error correction coded transmissions are reduced by identifying a puncturing pattern which approximates a particular code rate, and adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate.

[0096] When creating high rate codes via puncturing, it is generally desirable to distribute, as uniformly as possible, the bits that are punctured. Using this guideline, it is inevitable that certain code rates will require the resulting non-punctured bit pattern to be less effective. One such example occurs when the non-punctured bit pattern is periodic, with a period equal to the period of the semi-periodic impulse

response of the recursive encoding blocks of the Turbo encoder. An algorithm may used to identify all puncturing patterns with degraded performance.

[0097] In a particular embodiment of the invention, the capacity of a WTRU is determined, including buffer sizes that are supported by the WTRU. The puncturing is used to reduce the number of bits to fit into the buffer, and the overall code rate is adjusted so as to provide sufficient error correction capability. This provides a first rate in a first stage of puncturing and a second rate in a second stage of puncturing.

[0098] According to the present invention, detecting, avoiding and/or correcting problematic puncture patterns in parity bit streams and punctured Turbo codes is achieved without having to avoid desirable code rates. This is applicable without limitation, to FDD, TDD and other modes of transmission, and enables identification/avoidance of regions of relatively poor Turbo code performance, which might result from the prior art bit-puncturing scheme. The invention provides for forward error correction comprising Turbo coding and puncturing that achieve a smooth functional relationship between any measure of performance and the effective coding rate resulting from combining the lower rate code generated by the Turbo encoder with puncturing of the parity bits. Examples of measures of performance would be BLER, bit error rate (BER), required signal-to-interference ratio (SIR), or required SNR.

[0099] The patterns of the puncturing are created by creating an encoded transmission at a particular data rate and excluding some of the encoded bits. At the receiver end, zeros or other "filler" bits are put in place of the punctured bits, and the decoding operation is based on the received signal with the missing bits. According to the present invention, the puncturing pattern is modified in order to eliminate degradation which would occur under particular puncturing patterns. In particular, if the puncturing pattern is regular or has a periodic nature, it is more likely to result in signal degradation. By eliminating the degradation, it is possible to achieve the desired code rate.

[00100] The present invention is particularly useful for 3GPP-coding, and can be used for low chip rate TDD, high chip rate TDD and FDD.

[00101] One such example of a periodicity occurs when the non-punctured bit pattern is periodic with period equal to the period of the semi-periodic impulse response of the recursive encoding blocks of the Turbo encoder. An algorithm is provided to identify all puncturing patterns with degraded performance. Additionally, modification of the puncturing patterns is performed such that performance of the Turbo code is restored.

[0102] Modifications to puncturing are used to restore Turbo performance. If it is desirable for a system to be allowed to make unrestricted use of available code rates, then performance may be restored by modification of the puncture pattern. Therefore if it is deemed desirable for a system to be allowed to make unrestricted use of available code rates, then performance may be restored by modification of the puncture pattern.

[0103] Adaptive coding means that on the fly, information is obtained from the WTRU that indicates the channel quality. Based on that, the transmitter adjusts its code rate amongst other parameters. In instances of poor reception, a substantial amount of redundancy is added, which results in a very low code rate, but which allows transfer of data through with the required block error probability.

[0104] The channel quality estimation procedure does not inherently take into account the possibility that problematic puncturing may have been used, nor should it. The channel quality is typically based on signal power and noise power, but it does not take into account the fact that the encoder may have been punctured in a problematic way, therefore AMC will not serve to avoid problematic code rates. With good channel quality, very little coding is needed and it is possible to use a higher order modulation. If the channel quality is poor, the code rate is reduced. Therefore, a reduced data rate is used to provide the desired error performance. The channel quality indicator is used to monitor the channel quality and in turn provides input to the data rate controller.

[0105] Capacity is measured by determining a combined data rate to all users supported. If one or more users in a cell are tuned to a problematic code rate, then those users are presumed to require more power and thereby reduce capacity. In many cases the problematic coding rates are known or can be determined via this invention and therefore it is possible to avoid these rates.

[0106] The present invention provides an ability to identify problem rates in advance through some analytical means, and responding to this information by avoiding these rates either dynamically or statically. This can be achieved by detecting problematic patterns or by using a formula or table of rates to avoid. If a transmission calls for one of the problem rates, the actual transmission is provided at a rate which is slightly different. The result is, the problem rate is avoided.

[0107] These are representative examples of modifications to the puncturing pattern used to generate specific code rates, as applicable to layer 1 and layer 2 in the TDD and FDD mode of transmission in accordance with the present invention. Variations to the examples described are conceivable. All such variations may be considered special cases and specific implementations of the more general concept of a permutation of the puncturing pattern. Any method of changing the puncturing pattern, i.e., generating some permutation of the original puncturing pattern, has the potential of changing the overall performance of a code, and it is the intent to include permutations and methods of generating such permutations of the puncturing pattern envisaged in the present invention. All modifications and improvements to the basic concept of the invention as set forth hereinabove are envisaged to be within the ambit of the present invention.

[0108] Figure 11 shows the BLER performance of 3 different HS-DSCH transport blocks of increasing size 4554, 4705 and 4858 bits respectively. All of them are rate 1/3 Turbo-coded, and then punctured down to 6072 bits mapped to the High Speed Physical Downlink Shared Channels (HS-PDSCH). This results in an effective coding rate of 0.75 (labeled 7/9-), 0.77 (labeled 7/9) and 0.80 (labeled 7/9+) for the 3 increasing transport blocks sizes.

[0109] When increasing the effective coding rate (or equivalently increasing the puncturing rate) of a Turbo-coded transport block on HS-DSCH, one should expect that BLER performance degrades in a proportioned manner, i.e. gets increasingly worse for increasingly higher effective coding rates. This unfortunately does not always happen, and it can be seen in this example that the rate 0.77 (7/9) coded transport block needs some 3dB more SNR than a rate 0.80 coded transport block to achieve the same BLER of approximately 10%.

[0110] The reason for the observed degradations is that the periodicity (period = 7) in the output of the two Turbo-coder parity bit streams, as given by the impulse responses of the constituent recursive convolutional encoders, deleteriously interacts with the periodicity of the puncturing patterns applied by the second and/or the first rate matching stages in many cases. This effect is increasingly more frequent for increasingly higher puncturing rates.

[0111] In the analyses that follow, a single R99 rate-matching block is assumed. However, the concepts apply more generally to R4 and R5 with and without incremental redundancy. The main conclusion for both cases is that the critical puncturing rates leading to SNR degradation are predictable in principle, but would require a rather complex set of parameters to be taken into account.

[0112] The setting of critical puncturing rates is avoided in the MAC-hs in the Node B, which has the particular advantage that it would not require a change in current standards and could leave details open to vendor-specific implementation. While this approach is preferable, the look-up tables used are complex and restrictions on possible MAC-hs scheduler decisions are imposed.

[0113] Alternatively, slight modifications are made to the puncturing patterns as generated by the current rate-matching stages for HS-DSCH in TS25.212/222. These modifications constitute only a small change in the way the rate matching parameters are generated in TS25.212/222, e.g., parameters for HARQ second rate matching, and more importantly do not require any additional signaling.

[0114] Due to the apparent simplicity of the second option (slight modification of the generation of the puncturing pattern on Turbo-coded parity bit streams) and its transparency for the MAC-hs scheduler (simply selects whatever transport block size is desired as outcome of the scheduler decision), a corresponding change is made in TS25.212/222 to remedy this problem.

[0115] The constituent recursive convolutional encoders in the Turbo-coder as by TS25.212/222 have infinite impulse responses that are periodic with period 7 for positive time. The impact of certain patterns of surviving (i.e. non-punctured) bits in the parity bit stream can be qualitatively illustrated by considering how much information remains in these surviving parity bits.

[0116] The Turbo-coder produces 3 bit streams, systematic bits corresponding to the input sequence, parity bit stream 1 (output of 1st constituent encoder) and parity bit stream 2 (output of 2nd constituent encoder).

[0117] Note that the constituent recursive convolutional encoder is an LTI system on GF_2. Therefore, the output of the encoder is a sum of shifted versions of the impulse response of the encoder. Each shifted version of the impulse response corresponds to the locations of the 1's in the TB.

[0118] Certain puncturing patterns may result in a loss of distributed information about a small group of bits across the set of bits in one of the parity bit streams. For example, let the TB consist of 7 bits followed by many zeros. Now consider the problem of trying to determine the seven bits by observation of the output of one encoder after heavy puncturing. Each observation made at the output is a sum of a subset of the 7 bits. The subset for each particular observation is determined by the surviving bit period and the impulse response of the recursive encoding block.

[0119] For most puncture patterns, sums over 7 different subsets of the 7 bits can eventually be observed. Therefore, a system of 7 equations with 7 unknowns can be formed. Assuming that they are linearly independent, the values of the 7 bits may be determined.

[0120] However, when the periodicity of surviving bits is simple (one surviving parity bit per period) and the same as the period of the recursive encoding block, 7, then, due to the periodicity of the signal, every observation for $t > 6$ is the sum of the same subset of the 7 bits and so no new information is obtained by subsequent observations. Thus, a rank-1 system of equations is formed and a unique solution does not exist.

[0121] When the periodicity of surviving bits is not a multiple of 7, making observations of the parity bits will eventually form a rank-7 system of equations after several observations. For our 7-bit group, this is sufficient to uniquely determine the bits, i.e. information sufficient to determine the bits is distributed across the surviving parity bits.

[0122] It is also possible that some distributed information is lost even for non-simple periods, e.g., consider the case where the non-puncture pattern alternates between a simple period of three and four (two surviving parity bits per period with period = 7).

[0123] This results in a period 7 non-puncture pattern but with two surviving parity bits per period. The same argument above leads to a rank-2 system of seven equations. This is still insufficient to uniquely determine the group of bits, but does reduce the dimension of the space they may span. Clearly, some information about the TB may also be lost for non-simple surviving bit patterns.

[0124] At least two alternative approaches exist to avoid the problematic interactions between Turbo-coder output and puncturing in the rate-matching stages.

[0125] The avoidance of problematic puncturing patterns is an approach that requires the MAC-hs to avoid using puncturing patterns that lead to SNR degradation and does not use certain combinations for mapping incoming transport blocks sizes to HS-PDSCHs.

[0126] Avoidance would either require building lookup tables that identify the problematical configurations or evaluating the predicted degradation expression described previously in the MAC-hs scheduler.

[0127] An advantage of the look-up table approach is that no change in current standards would be required and that any particular implementation could be left vendor-specific.

[0128] A disadvantage of the avoidance approach is that it is complicated by the fact that there are several dimensions to the problem that will all play a role in determining if a particular configuration will give rise to degradation. Parameters the MAC-hs scheduler would need to take into account in addition include:

(1) transport block set size of HS-DSCH transmission;

(2) number of soft information bits to be stored at the WTRU for HARQ; and

(3) number of physical channel bits allocated for the HS-PDSCHs.

[0129] For FDD, these parameters are implied by the combination indicator for number of channelization codes and modulation format i ($1 < i < 29$), and the transport block size k_i, ($0 < k_i < 62$) in TS25.321.

[0130] Described below is one embodiment of the present invention that includes a combination of previously described techniques.

[0131] The hybrid ARQ functionality matches the number of bits at the output of the channel coder to the total number of bits of the HS-PDSCH set to which the HS-DSCH is mapped. The hybrid ARQ functionality is controlled by the redundancy version (RV) parameters. The exact set of bits at the output of the hybrid ARQ functionality depends on the number of input bits, the number of output bits, and the RV parameters.

[0132] The hybrid ARQ functionality consists of two rate-matching stages and a virtual buffer.

[0133] The first rate matching stage matches the number of input bits to the virtual IR buffer, information about which is provided by higher layers. Note that, if the number of input bits does not exceed the virtual IR buffering capability, the first rate-matching stage is transparent.

[0134] The second rate matching stage matches the number of bits after first rate matching stage to the number of physical channel bits available in the HS-PDSCH set in the TTI.

[0135] Definitions of notations used:

N^{TTI}: Number of bits in a transmission time interval before rate matching.

ΔN_i: An intermediate calculation variable.

$\Delta N_{i,l}^{TTI}$: If positive - number of bits to be repeated in each transmission time interval on TrCH i with transport format l.

If negative - number of bits to be punctured in each transmission time interval on TrCH i with transport format l.

ΔN_{PARITY} : Number of bits to adjust the length of parity streams by, in HARQ 1st stage rate-matching.

N_{data}: Total number of bits that are available for the HS-DSCH in a TTI.

e_{ini} Initial value of variable e in the rate matching pattern determination algorithm.

e_{plus} Increment of variable e in the rate matching pattern determination algorithm.

e_{minus} Decrement of variable e in the rate matching pattern determination algorithm.

b: Indicates systematic and parity bits

b=1: Systematic bit, x_k .

b=2: 1st parity bit (from the upper Turbo constituent encoder), z_k.

b=3: 2nd parity bit (from the lower Turbo constituent encoder), z'_k.

[0136] The HARQ bit separation function shall be performed in the same way as bit separation for turbo encoded TrCHs.

[0137] HARQ first stage rate matching for the HS-DSCH transport channel shall be performed using the method described below with the following specific parameters.

[0138] The maximum number of soft bits available in the virtual IR buffer is N_{IR} which is signaled from higher layers for each HARQ process. The number of coded bits in a TTI before rate matching is N^{TTI} this is deduced from information signaled from higher layers and parameters signaled on the High Speed Synchronization Control Channel (HS-SCCH) for each TTI. Note that HARQ processing and physical layer storage occurs independently for each HARQ process currently active.

[0139] If N_{IR} is greater than or equal to N^{TTI} (i.e. all coded bits of the corresponding TTI can be stored) the first rate matching stage shall be transparent. This can, for example, be achieved by setting $e_{minus} = 0$. Note that no repetition is performed.

[0140] If N_{IR} is smaller than N^{TTI} the parity bit streams are punctured by setting the rate matching parameter $\Delta N_{il}^{TTI} = N_{IR} - N^{TTI}$ where the subscripts i and l refer to transport channel and transport format in the referenced sub-clause. Note the negative value is expected when the rate matching implements puncturing. Bits selected for puncturing which appear as δ shall be discarded and not counted in the totals for the streams through the virtual IR buffer.

[0141] If first stage puncturing is to be performed, the procedure below shall be applied. Index b is used to indicate systematic (b=1), 1st parity (b=2), and 2nd parity bit (b=3). The parameter ΔN_{PARITY} : is the change in length to the parity streams to circumvent problematic puncturing rates.

The first stage rate matching delta is calculated as follows:

if puncturing is to be performed

$$X_i = \lfloor N^{TTI}/3 \rfloor; \qquad PR = \frac{\lfloor -\Delta N_{il}^{TTI}/2 \rfloor}{X_i}; \quad \Delta N_{PARITY} = 0; \quad \delta_{PR} = 49; \qquad \alpha = 1$$

while $(\alpha \le 4)$

$$round = \frac{\left\lfloor 7 \cdot \alpha \cdot PR + \frac{1}{2} \right\rfloor}{7 \cdot \alpha}$$

$\lambda = PR - round$

$\text{if}\left(|\lambda| > \frac{1}{\delta_{PR}}\right) or \left(PR > \frac{48}{49}\right) or \left(PR < \frac{1}{49}\right) \text{then}$

$\alpha = \alpha + 1$

$\delta_{PR} = 98$

else if$(\lambda > 0)$ then

$$\Delta N_{PARITY} = \left\| \left\lfloor -\Delta N_{il}^{TTI} / 2 \right\rfloor - X_i \cdot \left(round - \frac{1}{\delta_{PR}} \right) \right\|$$

$\alpha = 5$

else

$$\Delta N_{PARITY} = \left\| \left\lfloor -\Delta N_{il}^{TTI} / 2 \right\rfloor - X_i \cdot \left(round + \frac{1}{\delta_{PR}} \right) \right\|$$

$\alpha = 5$

end if

end while

$$\Delta N_i = \begin{cases} \left\lfloor -\Delta N_{il}^{TTI} / 2 \right\rfloor - \Delta N_{PARITY}, b = 2 \\ \left\lceil -\Delta N_{il}^{TTI} / 2 \right\rceil + \Delta N_{PARITY}, b = 3 \end{cases}$$

a = 2 when b=2

a = 1 when b=3

[0142] If ΔN_i is calculated as 0 for b=2 or b=3, then the following procedure and the rate matching algorithm shall not be performed for the corresponding parity bit stream.

[0143] For each radio frame, the rate-matching pattern shall be calculated, where:

X_i is as above,

$e_{ini} = X_i$

$e_{plus} = a \times X_i$

$e_{minus} = a \times |\Delta N_i|$

[0144] HARQ second stage rate matching for the HS-DSCH transport channel shall be done using one of two possible methods.

[0145] If second stage puncturing is to be performed, and the Composite Puncturing Rate of one of the parity streams, calculated using the formula below falls in any of the intervals [91/128,92/128], [217/256, 222/256], [231/256, 232/256], [237/256, 238/256] or [487/512, 488/512], then puncturing of that parity stream shall be performed. Note, puncturing maybe carried out on one, both, or neither of the two parity streams, but never on the systematic parity stream.

[0146] Composite Puncturing Ratio, $CPR = \begin{cases} \dfrac{\lfloor N^{TTI}/3 \rfloor - N_{t,p1}}{N^{TTI}/3}, b = 2 \\ \dfrac{\lfloor N^{TTI}/3 \rfloor - N_{t,p2}}{N^{TTI}/3}, b = 3 \end{cases}$

[0147] Otherwise, second stage rate matching for the HS-DSCH transport channel shall be done with the following specific parameters. Bits selected for puncturing which appear as δ shall be discarded and are not counted in the streams towards the bit collection.

[0148] The parameters of the second rate matching stage depend on the value of the RV parameters s and r. The parameter s can take the value 0 or 1 to distinguish between transmissions that prioritize systematic bits (s = 1) and non systematic bits (s = 0). The parameter r (range 0 to r_{max}-1) changes the initial error variable e_{ini} in the case of puncturing. In case of repetition both parameters r and s change the initial error variable e_{ini}. The parameters X_i, e_{plus} and e_{minus} are calculated as per table 1 below.

[0149] Denote the number of bits before second rate matching as N_{sys} for the systematic bits, N_{p1} for the parity 1 bits, and N_{p2} for the parity 2 bits, respectively. Denote the number of physical channels used for the HS-DSCH by P. N_{data} is the number of bits available to the HS-DSCH in one TTI and defined as $N_{data}=P\times 3\times N_{data1}$. The rate matching parameters are determined as follows.

[0150] For $N_{data} \le N_{sys} + N_{p1} + N_{p2}$, puncturing is performed in the second rate matching stage. The number of transmitted systematic bits in a transmission is $N_{t,sys} = \min\{N_{sys}, N_{data}\}$ for a transmission that prioritizes systematic bits and $N_{t,sys} = \max\{N_{data} - (N_{p1} + N_{p2}), 0\}$ for a transmission that prioritizes non systematic bits.

[0151] For $N_{data} > N_{sys} + N_{p1} + N_{p2}$ repetition is performed in the second rate matching stage. A similar repetition rate in all bit streams is achieved by setting the number of transmitted systematic bits to $N_{t,sys} = \left\lfloor N_{sys} \cdot \frac{N_{data}}{N_{sys} + 2N_{p1}} \right\rfloor$.

[0152] The number of parity bits in a transmission is: $N_{t,p1} = \max\left(\left\lfloor \frac{N_{data} - N_{t,sys}}{2} \right\rfloor - \Delta N_{PARITY}, 0\right)$ and $N_{t,p2} = N_{data} - (N_{t,sys} + N_{t,p1})$ for the parity 1 and parity 2 bits, respectively.

	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys} - N_{t,sys} \rvert$
Parity 1 RM P1_2	N_{p1}	$2 \cdot N_{p1}$	$2 \cdot \lvert N_{p1} - N_{t,p1} \rvert$
Parity 2 RM P2_2	N_{p2}	N_{p2}	$\lvert N_{p2} - N_{t,p2} \rvert$

Table 1: Parameters for HARQ second rate matching

[0153] Table 1 above summarizes the resulting parameter choice for the second rate matching stage. The rate matching parameter e_{ini} is calculated for each bit stream according to the RV parameters r and s using

$e_{ini}(r) = \{(X_i - \lfloor r \cdot e_{plus} / r_{\max} \rfloor - 1) \bmod e_{plus}\} + 1$ in the case of puncturing ,

i.e., $N_{data} \le N_{sys} + N_{p1} + N_{p2}$, and

$e_{ini}(r) = \{(X_i - \lfloor (s + 2 \cdot r) \cdot e_{plus} / (2 \cdot r_{\max}) \rfloor - 1) \bmod e_{plus}\} + 1$ for repetition, i.e., $N_{data} > N_{sys} + N_{p1} + N_{p2}$. Where $r \in \{0,1,\cdots, r_{\max} - 1\}$ and $r_{\max}$ is the total number of redundancy versions allowed by varying r. Note that r_{max} varies depending on the modulation mode, i.e. for 16QAM $r_{max} = 2$ and for QPSK $r_{max} = 4$.

[0154] Note: For the modulo operation the following clarification is used: the value of (x mod y) is strictly in the range of 0 to y-1 (i.e. -1 mod 10 = 9).

[0155] HARQ second stage rate matching for the HS-DSCH transport channel shall be done with the method described below, which separates each stream into segments with specific parameters calculated below. Bits selected for puncturing which appear as δ shall be discarded and are not counted in the streams towards the bit collection.

[0156] The parity stream will be segmented into 3 segments, the first segment will be made up of the first X_{seg1} bits of the parity stream, the second segment will be made up of the next X_{seg2} bits, and the last segment will be made up of the remaining X_{seg3} bits.

[0157] The first segment is denoted by $x_{i,1}, x_{i,2}, \ldots x_{i,Xseg1}$

The second segment by $x_{i,Xseg1+1}, x_{i,Xseg1+2}, \ldots x_{i,Xseg2}$;

And the final segment by $x_{i,Xseg1+Xseg2+1}, x_{i,Xseg1+Xseg2+2}, \ldots x_{i,X_i}$

Where $X_{seg1} = 42 \cdot \lfloor X_i / 98 \rfloor$, $X_{seg2} = 56 \cdot \lfloor X_i / 98 \rfloor$, $X_{seg3} = X_i \bmod 98$

[0158] Note: If X_i is less than 98 only the third segment exists, and if X_i is a multiple of 98 then the third segment will be empty. For the case where a particular

segment is empty, then of course no puncturing is performed on that non-existent segment.

[0159] Additional parameters for HARQ Second Rate Matching Stage for problematic puncturing rates

[0160] Parameters P, N_{data}, N_{sys}, N_{p1}, N_{p2}, $N_{p,t1}$, and $N_{p,t2}$ are calculated, additional parameters are defined below.

[0161] Denote the number of parity 1 bits before second rate matching after segmentation as $N_{p1,seg1}$, $N_{p1,seg2}$, $N_{p1,seg3}$ for the parity 1 bits in the 1st, 2nd and 3rd segment respectively. Denote the number of parity 2 bits before second rate matching after segmentation as $N_{p2,seg1}$, $N_{p2,seg2}$, $N_{p2,seg3}$ for the parity 1 bits in the 1st, 2nd and 3rd segment respectively. The rate matching parameters are determined as follows.

[0162] For $N_{data} \le N_{sys} + N_{p1} + N_{p2}$, puncturing is performed in the second rate matching stage.

[0163] The number of parity bits after segmentation is

$$N_{pb,seg1} = 42 \cdot \lfloor N_{pb} / 98 \rfloor$$
$$N_{pb,seg2} = 56 \cdot \lfloor N_{pb} / 98 \rfloor$$
$$N_{pb,seg3} = N_{pb} \bmod 98$$

[0164] The number of parity bits in each segment for parity 1 bits (b=2), and parity 2bits (b=3) is:

$$N_{t,pb,seg1} = \left\lfloor \frac{49 \cdot N_{t,pb} \cdot \lfloor N_{pb} / 98 \rfloor}{N_{pb}} + \frac{1}{2} \right\rfloor;$$
$$N_{t,pb,seg2} = \left\lfloor \frac{49 \cdot N_{t,pb} \cdot \lfloor N_{pb} / 98 \rfloor}{N_{pb}} + \frac{1}{2} \right\rfloor;$$
$$N_{t,pb,seg3} = N_{t,pb} - \left(N_{t,pb,seg1} + N_{t,pb,seg2}\right)$$

[0165] The parameters X_i, e_{plus} and e_{minus} are calculated as per table 2 below.

Stream	*Segment*	X_i	e_{plus}	e_{minus}
Systematic RM S		N_{sys}	N_{sys}	$\lvert N_{sys} - N_{t,sys} \rvert$
Parity 1 RM P1_2	1st	$N_{p1,seg1}$	$2 \cdot N_{p1,seg1}$	$2 \cdot \lvert N_{p1,seg1} - N_{t,p1,seg1} \rvert$
	2nd	$N_{p1,seg2}$	$2 \cdot N_{p1,seg2}$	$2 \cdot \lvert N_{p1,seg2} - N_{t,p1,seg2} \rvert$
	3rd	$N_{p1,seg3}$	$2 \cdot N_{p1,seg3}$	$2 \cdot \lvert N_{p1,seg3} - N_{t,p1,seg3} \rvert$
Parity 2 RM P2_2	1st	$N_{p2,seg1}$	$N_{p2,seg1}$	$\lvert N_{p2,seg1} - N_{t,p2,seg1} \rvert$
	2nd	$N_{p2,seg2}$	$N_{p2,seg2}$	$\lvert N_{p2,seg2} - N_{t,p2,seg2} \rvert$
	3rd	$N_{p2,seg3}$	$N_{p2,seg3}$	$\lvert N_{p2,seg3} - N_{t,p2,seg3} \rvert$

Table 2: Parameters for dithered HARQ second rate matching

[0166] The rate matching parameter e_{ini} is calculated for each segment of bit stream according to the RV parameters r and s using $e_{ini}(r) = \{(X_i - \lfloor r \cdot e_{plus} / r_{\max} \rfloor - 1) \bmod e_{plus}\} + 1$ in the case of puncturing. Where $r \in \{0,1,\cdots,r_{\max} - 1\}$ and $r_{\max}$ is the total number of redundancy versions allowed by varying r. Note that r_{max} varies depending on the modulation mode, i.e. for 16QAM $r_{max} = 2$ and for QPSK $r_{max} = 4$.

[0167] Note: For the modulo operation the following clarification is used: the value of (x mod y) is strictly in the range of 0 to y-1 (i.e. -1 mod 10 = 9). The rate matching algorithm is called for each segment of the parity stream in turn.

[0168]

[0169] For both parity streams, after the rate matching algorithm has been called for each of the three segments, the three punctured segments should be concatenated together in their original order.

[0170] The re-concatenated bit stream is denoted by: $x_{o,seg1,1}, x_{o,seg1,2}, \ldots x_{o,seg1,N_{t,p1,seg1}}, x_{o,seg2,1}, x_{o,seg2,2}, \ldots x_{o,seg2,N_{t,p1,seg2}}, x_{o,seg3,1}, x_{o,seg3,2}, \ldots x_{o,seg3,N_{t,p1,seg3}}$

[0171] The HARQ bit collection is achieved using a rectangular interleaver of size $N_{row} \times N_{col}$. The number of rows and columns are determined from:

$$N_{row} = 4 \text{ for 16QAM and } N_{row} = 2 \text{ for QPSK}$$

$$N_{col} = N_{data} / N_{row}$$

where N_{data} is used.

[0172] Data is written into the interleaver column by column, and read out of the interleaver column by column starting from the first column.

[0173] $N_{t,sys}$ is the number of transmitted systematic bits. Intermediate values N_r and N_c are calculated using:

$$N_r = \left\lfloor \frac{N_{t,sys}}{N_{col}} \right\rfloor \text{ and } N_c = N_{t,sys} - N_r \cdot N_{col}.$$

[0174] If N_c=0 and $N_r > 0$, the systematic bits are written into rows 1...N_r.

[0175] Otherwise systematic bits are written into rows 1...N_r+1 in the first N_c columns and, if $N_r > 0$, also into rows 1...N_r in the remaining N_{col}-N_c columns.

[0176] The remaining space is filled with parity bits. The parity bits are written column wise into the remaining rows of the respective columns. Parity 1 and 2 bits are written in alternating order, starting with a parity 2 bit in the first available column with the lowest index number. If the two parity streams are of unequal length, Parity 1 and 2 bits shall be written alternately, again starting with a parity 2 bit, until the end of the shorter parity stream, then the remaining parity bits from the longer stream shall be written.

[0177] In the case of 16QAM for each column the bits are read out of the interleaver in the order row 1, row 2, row 3, row 4. In the case of QPSK for each column the bits are read out of the interleaver in the order row1, row2.

[0178] when the analysis of the rate matching issue was restricted to the situation in which the first stage HS-DSCH rate matching is transparent it was shown

that the performance degradation arises from an interaction between the periodicity of the rate matching pattern and the inherent periodicity of the turbo encoder. In particular, it was shown that at the problematic code rates, the positions (in the unpunctured bit stream) of survivor (i.e. non punctured) bits lie in the same position or positions within a modulo 7 period for long segments of the unpunctured stream. It has been demonstrated that performance degradations arise via exactly the same mechanism when the first stage is not transparent.

[0179] In the following description, a "puncturing pattern" is defined to be the pattern of positions of bits that are punctured from an original stream. "Puncturing Rate" is defined to be the reciprocal of the number of bits between punctured bit positions (inclusive of the punctured positions) in the original bit stream.

[0180] In the case of two-stage rate matching, puncturing that leads to degradation may occur in two ways:

1) A pattern arising from bits punctured in the first stage only

2) A pattern arising from bits punctured after the second stage; this pattern is dependent upon both the first and second rate matching stages.

[0181] In order to avoid either of these puncturing mechanisms that cause a performance degradation, the following methodology has been adopted:

[0182] In the first stage, test whether the puncturing will cause a problematic puncturing pattern. This is achieved by evaluating an "implicit duration" function, which predicts the length of periodicity in the puncturing pattern. The first stage rate matching is only adjusted if the calculated implicit duration indicates a necessity. In this case, the amount of bits punctured in the first parity stream is increased slightly, whilst in the second stream the number is correspondingly decreased slightly. This has the effect of shifting the puncturing rates in both streams to break up modulo 7 periodicity, whilst keeping the total amount of punctured bits the same. The adjustment in the puncturing rate in each of the streams is kept sufficiently small to leave the coding performance in each stream unaffected.

[0183] In the second stage, a composite puncturing rate for each stream, taking into account adjustments to the puncturing rate carried out at the first stage is calculated. The composite puncturing rate in each stream is compared with a look up table, which predicts rates at which modulo-7 periodic patterns, and hence coding degradations will arise. If the composite rate of a stream falls within a range of problematic rates, a "dithering" algorithm is applied.

[0184] Differing puncturing rates are applied in the two parity streams if the puncturing pattern in the first stage will lead to a performance degradation, or is likely to contribute to an unwanted pattern after second stage rate matching. In this case, the number of bits punctured in the first parity stream is reduced by an amount ΔN_{PARITY}, whilst the number of bits punctured in the second stream is increased by the same amount. The decision as to whether such a change should take place is based upon a calculated parameter, which estimates the inverse of the length of runs of survivor bits which hold the same modulo 7 position in the unpunctured stream. This length becomes greater than 49 bits (i.e. 7 modulo 7 periods), then the adjustment to the lengths of the streams is applied.

[0185] The dithered puncturing algorithm may be applied to either or both of the two parity streams in the second stage. When processing a parity stream, the algorithm employs two puncturing rates, one higher than the original, and one lower, it then switches between these two puncturing rates whilst applying puncturing to the parity bit stream. The total number of bits punctured is kept the same as it would have been with the original algorithm. Generically it is possible to have one or many switching points between the two puncturing rates within a parity stream. The number of points is not critical to the performance, since the fraction of the bit stream punctured at each rate is independent of the number of switching points.

[0186] The number of switching points is set to one (or two), meaning that the punctured stream consists of two (or three) segments in which the first segment uses a lower puncturing rate than the original, the second uses a higher puncturing rate. If the two segments do not account for the whole of the parity stream, a third segment is

allowed at the end that is punctured at the original rate. The third segment is kept short, and allows for puncturing exactly the correct amount of bits to maintain the overall puncturing rate. By breaking the parity stream into a low number of segments in this way, the original rate matching algorithm can easily be used with some minor parameter changes.

[0187] The difference between the higher puncturing rate in the first segment and the original rate, and also between the lower puncturing rate in the second segment and the original has been set to 1/49. This selection allows for problematic rates to be avoided in all cases whilst not representing a significant change in coding rate.

[0188] In the majority of cases, the modified rate matching algorithm operates in exactly the same manner as previously defined. In the minority of cases in which either the first or second stage rate matching would lead to a performance degradation, unequal length streams and/or dithering are applied. Both of these modifications do not change the body of the rate matching procedure in any way, but rather the rate matching parameters that are applied. Furthermore, in an implementation, the modifications can be achieved with a modification to the Rate Matching DSP software without affecting any other part of the system.

[0189] The foregoing is a description of a preferred embodiment and alternative solutions to providing detecting, avoiding/correcting problematic Turbo code puncturing patterns. While this invention has been particularly shown and described with reference to preferred embodiments, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention as described hereinabove.

* * *

CLAIMS

What is claimed is:

1. In a communications system employing a plurality of rate matching stages, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) adjusting the number of bits punctured in each stage of rate matching; and

(b) adjusting the number of bits punctured in each of the plurality of parity streams, wherein the problematic puncturing patterns are avoided.

2. The method of claim 1 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits;

(b2) removing punctured bits from the second group of P2 bits; and

(b3) biasing the punctured rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

3. The method of claim 2 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil, \text{ otherwise set } \Delta = 0.$$

4. The method of claim 3, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

5. The method of claim 4 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

6. In a communications system employing a plurality of rate matching stages, a method of avoiding problematic Turbo code puncturing patterns, the method comprising:

(a) adjusting the number of bits punctured in each stage of rate matching; and

(b) adjusting the puncturing rates of each of the individual parity streams while maintaining a constant overall effective coding rate.

7. The method of claim 6 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits;

(b2) removing punctured bits from the second group of P2 bits; and

(b3) biasing the punctured rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

8. The method of claim 7 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$$, otherwise set $\Delta = 0$.

9. The method of claim 8, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

10. The method of claim 9 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

11. A method of identifying degradations in quality of punctured error correction coded transmissions, the method comprising:

(a) identifying a puncturing pattern which approximates a particular code rate; and

(b) adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate.

12. The method of claim 11 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, and step (b) further comprises:

(b1) adding punctured bits to the first group of P1 bits;

(b2) removing punctured bits from the second group of P2 bits; and

(b3) biasing the punctured rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

13. The method of claim 12 further comprising:

(c) determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(d) if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$, calculate the bias

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$$, otherwise set $\Delta = 0$.

14. The method of claim 11 further comprising:

(c) using Turbo code to implement the error correction coded transmissions.

15. The method of claim 14 further comprising:

(d) identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(e) using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

16. A method of identifying degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits, the method comprising:

(a) adding punctured bits to the first group of P1 bits;

(b) removing punctured bits from the second group of P2 bits; and

(c) biasing the punctured rates of the P1 and P2 bits to avoid problematic puncturing patterns by:

(i) adding a number of non-punctured P1 bits to the first group; and

(ii) decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

17. The method of claim 16 further comprising:

(d) using Turbo code to implement the error correction coded transmissions.

18. The method of claim 17 further comprising:

(e) identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(f) using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

19. A method for reducing degradations in quality of punctured error corrected code transmissions, the method comprising:

(a) identifying a puncturing pattern which approximates a particular code rate; and

(b) adjusting the parameters of the transmissions sufficiently to cause a mismatch in the puncturing pattern and the particular code rate.

20. The method of claim 19 further comprising:

(c) determining a capacity of a wireless transmit and receive unit (WTRU), including buffer sizes that are supported by the WTRU;

(d) using puncturing to remove sufficient bits to fit into the buffer; and

(e) adjusting an overall code rate so as to provide sufficient error correction capability, thereby providing a first rate in a first stage of puncturing and providing a second rate in a second stage of puncturing.

21. The method of claim 20, further comprising:

(f) increasing non-punctured bits in one of the first stage and second stage of puncturing, and decreasing non-punctured bits in another of the first stage and second stage of puncturing, thereby adding additional puncturing to one stage and removing it from the other stage.

22. The method of claim 20 further comprising:

(f) increasing non-punctured bits in the first stage and decreasing non-punctured bits in the second stage.

23. The method of claim 20 further comprising:

(f) decreasing non-punctured bits in the first stage and increasing non-punctured bits in the second stage.

24. The method of claim 20 further comprising:

(f) interleaving parity bits before rate matching occurs; and

(g) subsequently de-interleaving the parity bits, thereby avoiding a need to periodically sample the parity bits when performing periodic sampling in rate matching, thereby mitigating the effect of the periodicity of the puncturing pattern.

25. A communications system for avoiding problematic Turbo code puncturing patterns, the system comprising:

(a) a plurality of rate matching stages;

(b) means for adjusting the number of bits punctured in each stage of rate matching; and

(c) means for adjusting the number of bits punctured in each of the plurality of parity streams, wherein the problematic puncturing patterns are avoided.

26. The system of claim 25 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means (c) for adjusting the number of bits punctured in each of the plurality of parity streams further comprising:

(c1) means for adding punctured bits to the first group of P1 bits;

(c2) means for removing punctured bits from the second group of P2 bits; and

(c3) means for biasing the punctured rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

27. The system of claim 26 further comprising:

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching; and

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(e) means for setting bias $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

28. The system of claim 27, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

29. The system of claim 28 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

30. A communications system for avoiding problematic Turbo code puncturing patterns, the system comprising:

(a) a plurality of rate matching stages;

(b) means for adjusting the number of bits punctured in each stage of rate matching; and

(c) means for adjusting the puncturing rates of each of the individual parity

streams while maintaining a constant overall effective coding rate.

31. The system of claim 30 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means (c) for adjusting the puncturing rates of each of the individual parity streams further comprising:

(c1) means for adding punctured bits to the first group of P1 bits;

(c2) means for removing punctured bits from the second group of P2 bits; and

(c3) means for biasing the punctured rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means (c3) including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

32. The system of claim 31 further comprising:

(d) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(e) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if

$\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(e) means for setting bias $\Delta = 0$ if $\left|\frac{I}{(P/2)} - \frac{7\hat{N}}{2}\right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

33. The system of claim 32, wherein non-puncturing patterns with a period of $7\hat{N}/2$ cause degradation in performance results and $\hat{N}$ is a whole number.

34. The system of claim 33 wherein the periods will be employed whenever the average non-puncturing period of P1 or P2 bits is within ±1 or ±½ of $7\hat{N}/2$ for even and odd $\hat{N}$ respectively.

35. A communications system for identifying degradations in quality of punctured error correction coded transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; and

(b) means for adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate.

36. The system of claim 35 wherein degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits are identified, the means (b) for adjusting a value for anticipated degradation further comprising:

(b1) means for adding punctured bits to the first group of P1 bits;

(b2) means for removing punctured bits from the second group of P2 bits; and

(b3) means for biasing the punctured rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means (b3) including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the

second group by the number of non-punctured P1 bits added to the first group.

37. The system of claim 36 further comprising:

(c) means for determining a number of bits $\hat{N}$ using $\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor$ wherein I is the number of bits at the input to each branch of rate matching and P is the total number of the P1 and P2 bits at the output of rate matching;

(d) means for calculating the bias $\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2} , \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$; and

(e) means for setting bias $\Delta = 0$ if $\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| \geq 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor$.

38. The system of claim 35 further comprising:

(c) means for using Turbo code to implement the error correction coded transmissions.

39. The system of claim 38 further comprising:

(d) means for identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(e) means for using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded

performance.

40. A communications system for identifying degradations in the quality of punctured error correction coded transmissions having a first group of parity 1 (P1) bits and a second group of parity 2 (P2) bits, the system comprising:

(a) means for adding punctured bits to the first group of P1 bits;

(b) means for removing punctured bits from the second group of P2 bits; and

(c) means for biasing the punctured rates of the P1 and P2 bits to avoid problematic puncturing patterns, the biasing means (c) including:

(i) means for adding a number of non-punctured P1 bits to the first group; and

(ii) means for decreasing the number of non-punctured P2 bits in the second group by the number of non-punctured P1 bits added to the first group.

41. The system of claim 40 further comprising:

(d) means for using Turbo code to implement the error correction coded transmissions.

42. The system of claim 41 further comprising:

(e) means for identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic, with a period equal to a period of a semi-periodic impulse response of recursive encoding blocks of the Turbo code; and

(f) means for using the identified non-punctured bit patterns which exhibit a periodic characteristic to identify puncturing patterns with degraded performance.

43. A communications system for reducing degradations in quality of punctured error corrected code transmissions, the system comprising:

(a) means for identifying a puncturing pattern which approximates a particular code rate; and

(b) means for adjusting the parameters of the transmissions sufficiently to cause a mismatch in the puncturing pattern and the particular code rate.

44. The system of claim 43 further comprising:

(c) means for determining a capacity of a wireless transmit and receive unit (WTRU), including buffer sizes that are supported by the WTRU;

(d) means for using puncturing to remove sufficient bits to fit into the buffer; and

(e) means for adjusting an overall code rate so as to provide sufficient error correction capability, thereby providing a first rate in a first stage of puncturing and providing a second rate in a second stage of puncturing.

45. The system of claim 44, further comprising:

(f) means for increasing non-punctured bits in one of the first stage and second stage of puncturing, and decreasing non-punctured bits in another of the first stage and second stage of puncturing, thereby adding additional puncturing to one stage and removing it from the other stage.

46. The system of claim 44 further comprising:

(f) means for increasing non-punctured bits in the first stage and decreasing non-punctured bits in the second stage.

47. The system of claim 44 further comprising:

(f) means for decreasing non-punctured bits in the first stage and increasing non-punctured bits in the second stage.

48. The system of claim 44 further comprising:

(f) means for interleaving parity bits before rate matching occurs; and

(g) means for subsequently de-interleaving the parity bits, thereby avoiding a need to periodically sample the parity bits when performing periodic sampling in rate matching, thereby mitigating the effect of the periodicity of the puncturing pattern.

ABSTRACT

Detecting, avoiding and/or correcting problematic puncturing patterns in parity bit streams used when implementing punctured Turbo codes is achieved without having to avoid desirable code rates. This enables identification/avoidance of regions of relatively poor Turbo code performance. Forward error correction comprising Turbo coding and puncturing achieves a smooth functional relationship between any measure of performance and the effective coding rate resulting from combining the lower rate code generated by the Turbo encoder with puncturing of the parity bits. In one embodiment, methods to correct/avoid degradations due to Turbo coding are implemented by puncturing interactions when two or more stages of rate matching are employed.

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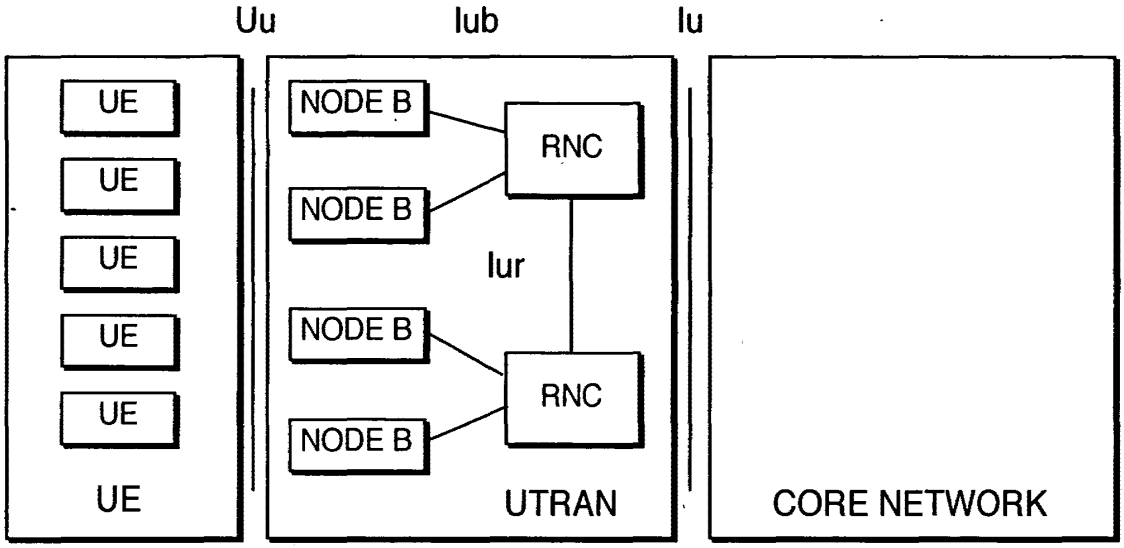


FIG. 1
PRIOR ART

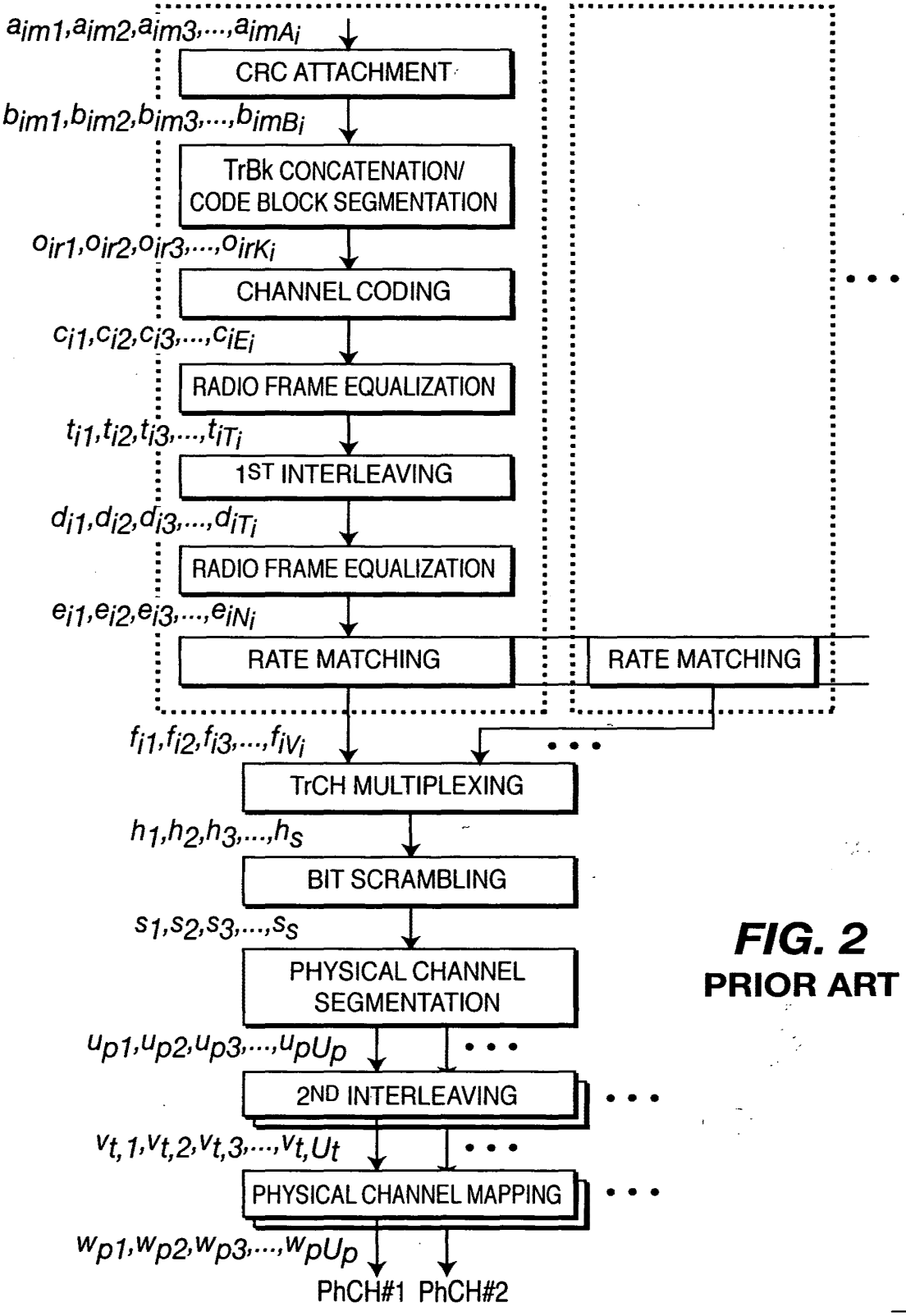


FIG. 2
PRIOR ART

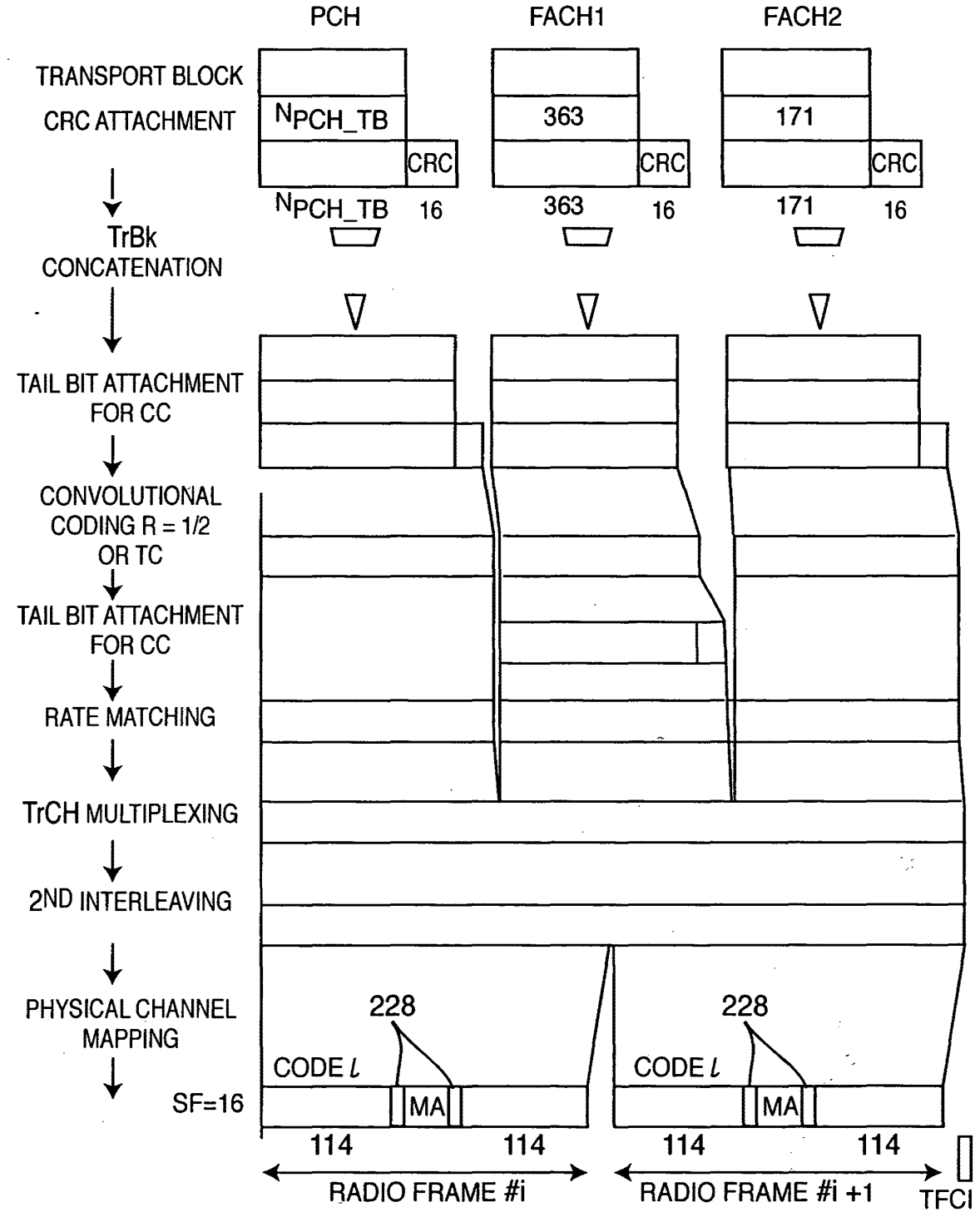


FIG. 3
PRIOR ART

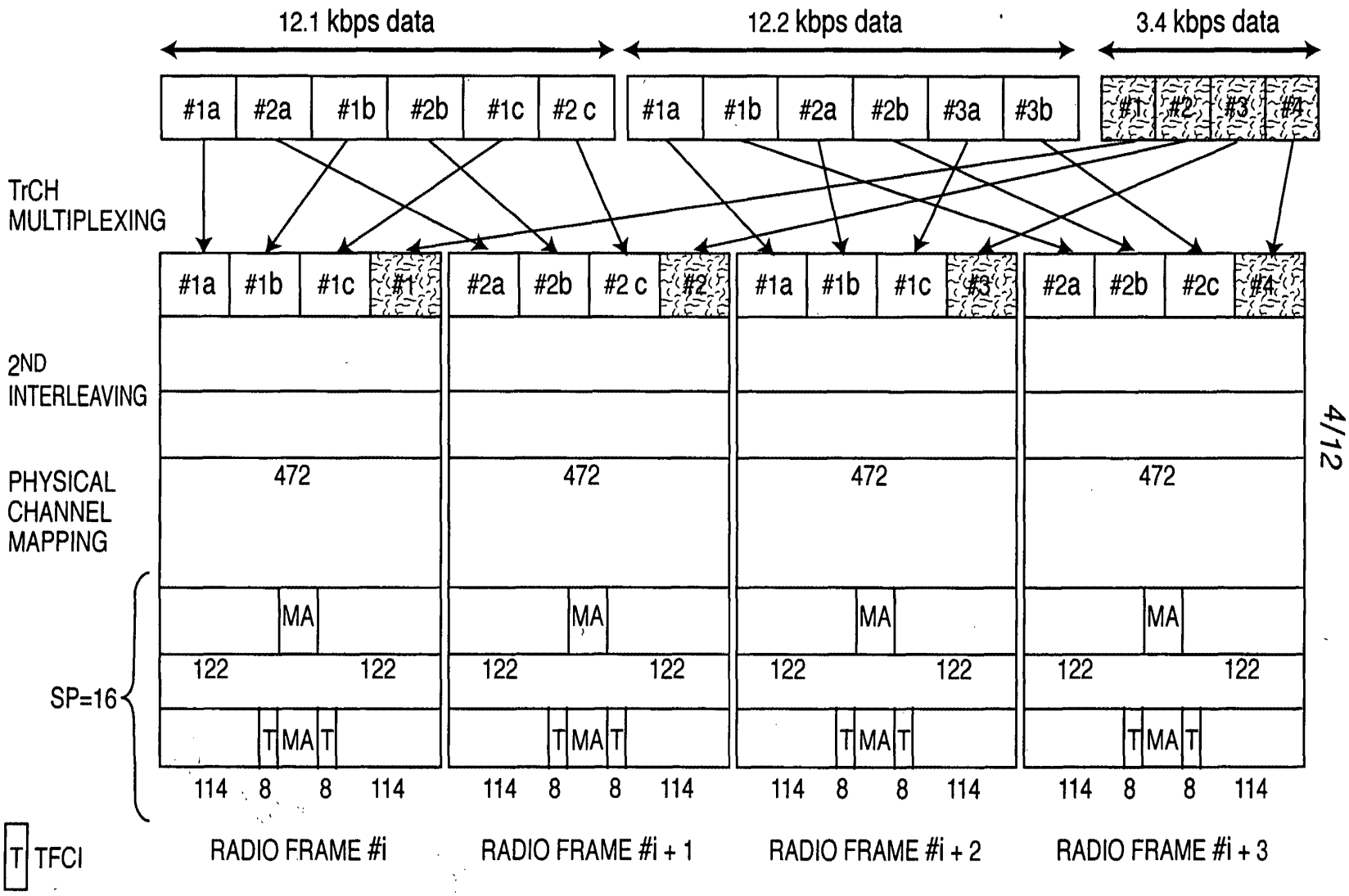


FIG. 4 PRIOR ART

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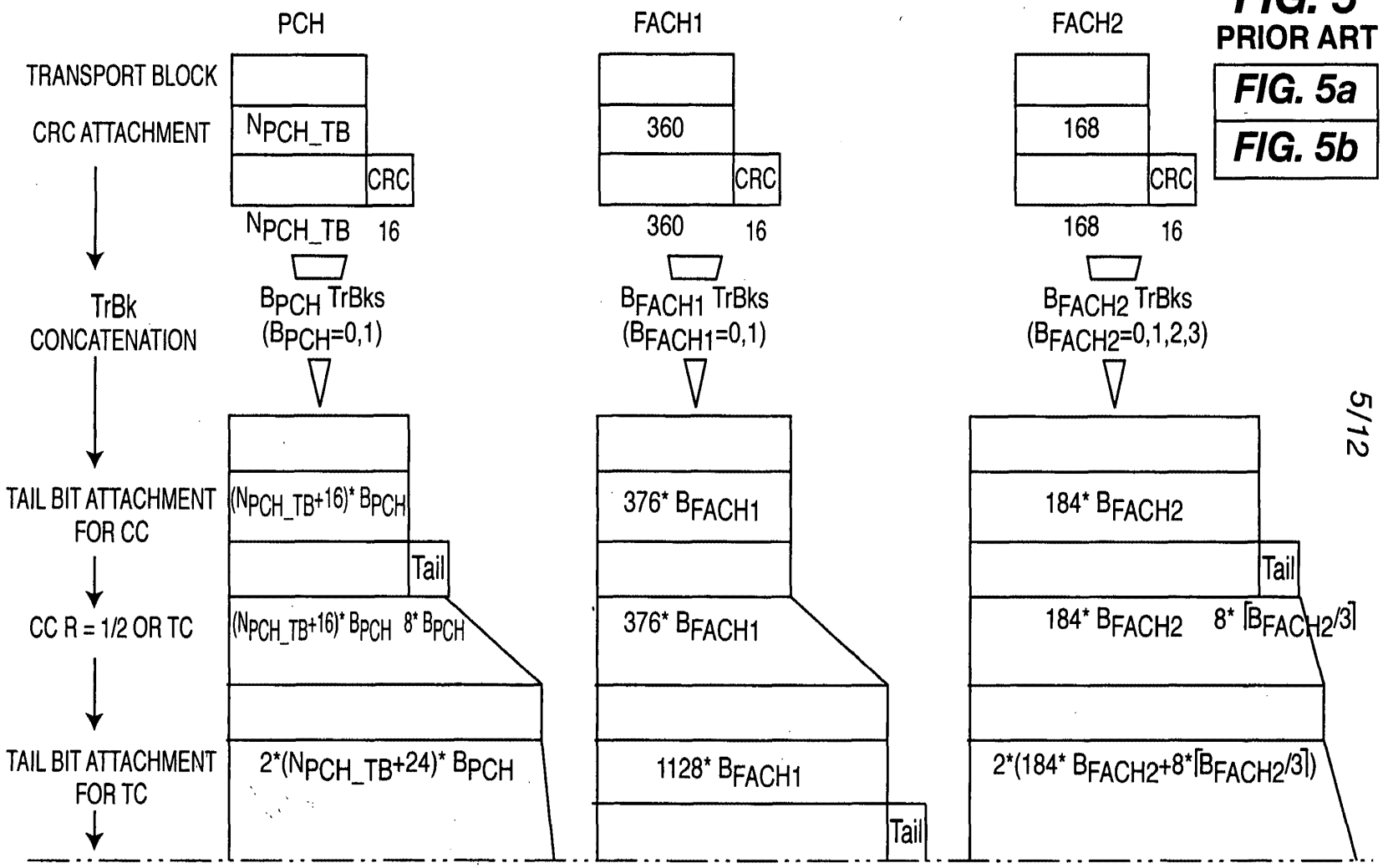


FIG. 5
PRIOR ART

FIG. 5a

FIG. 5b

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FIG. 5a

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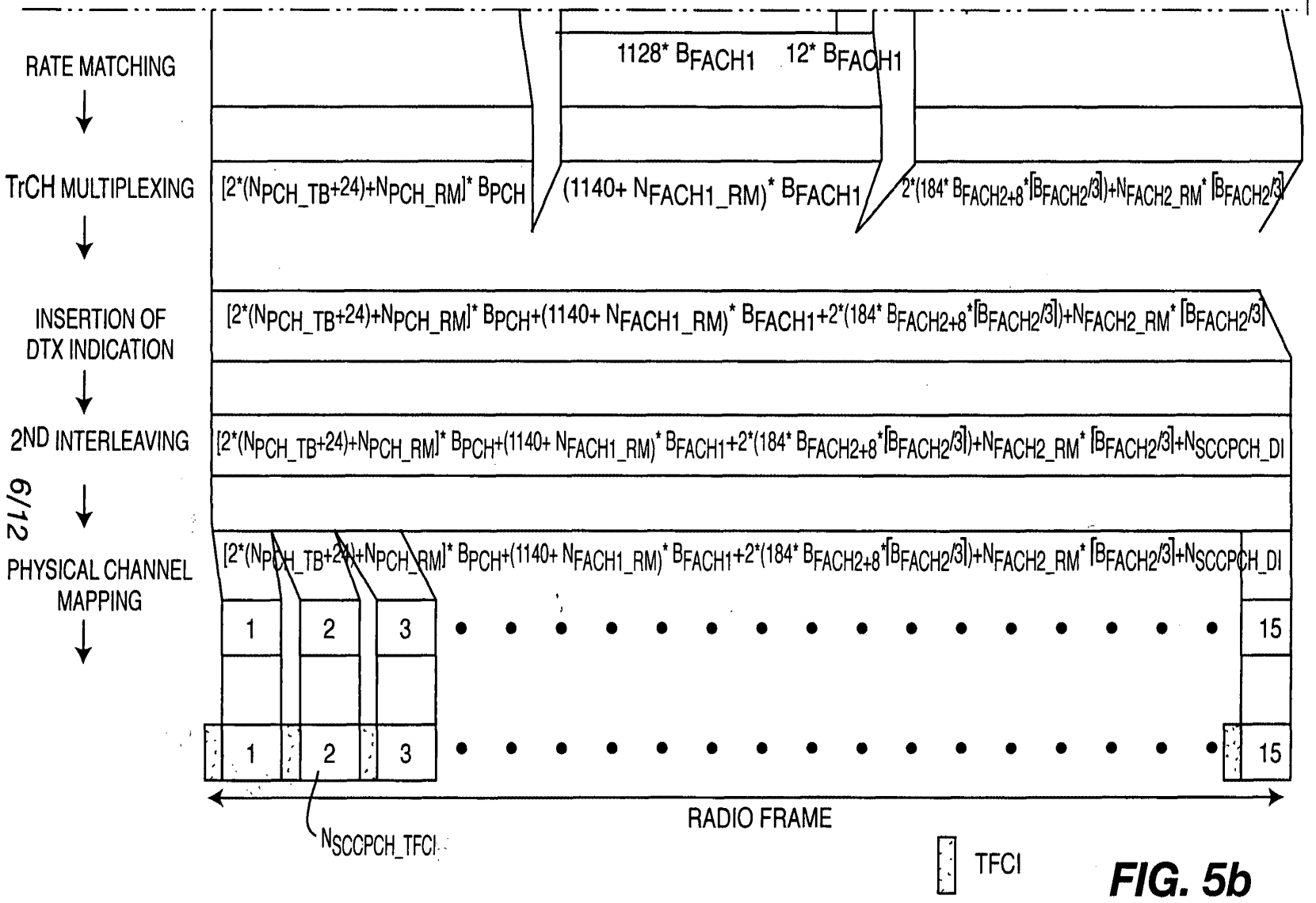


FIG. 5b

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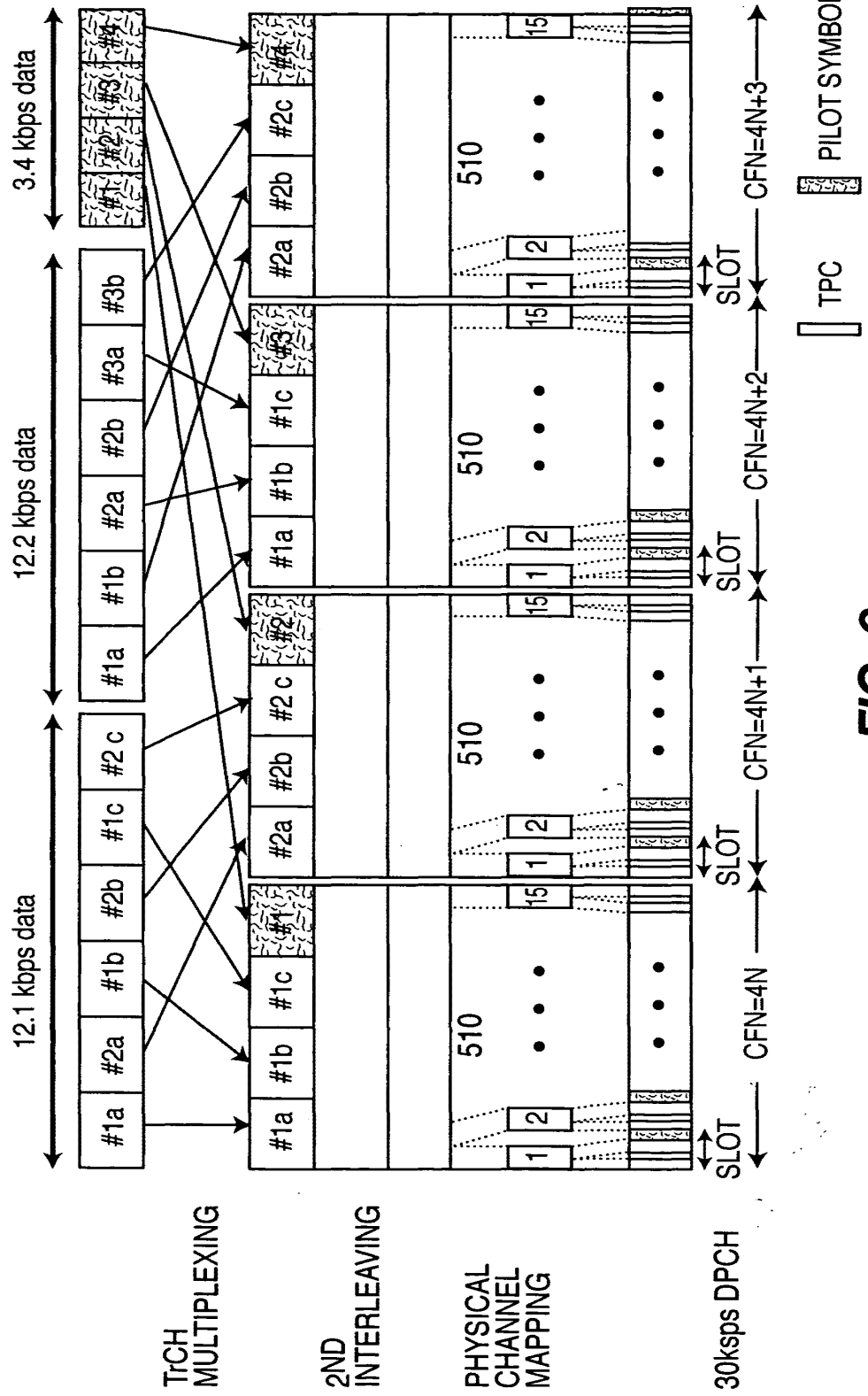


FIG. 6
PRIOR ART

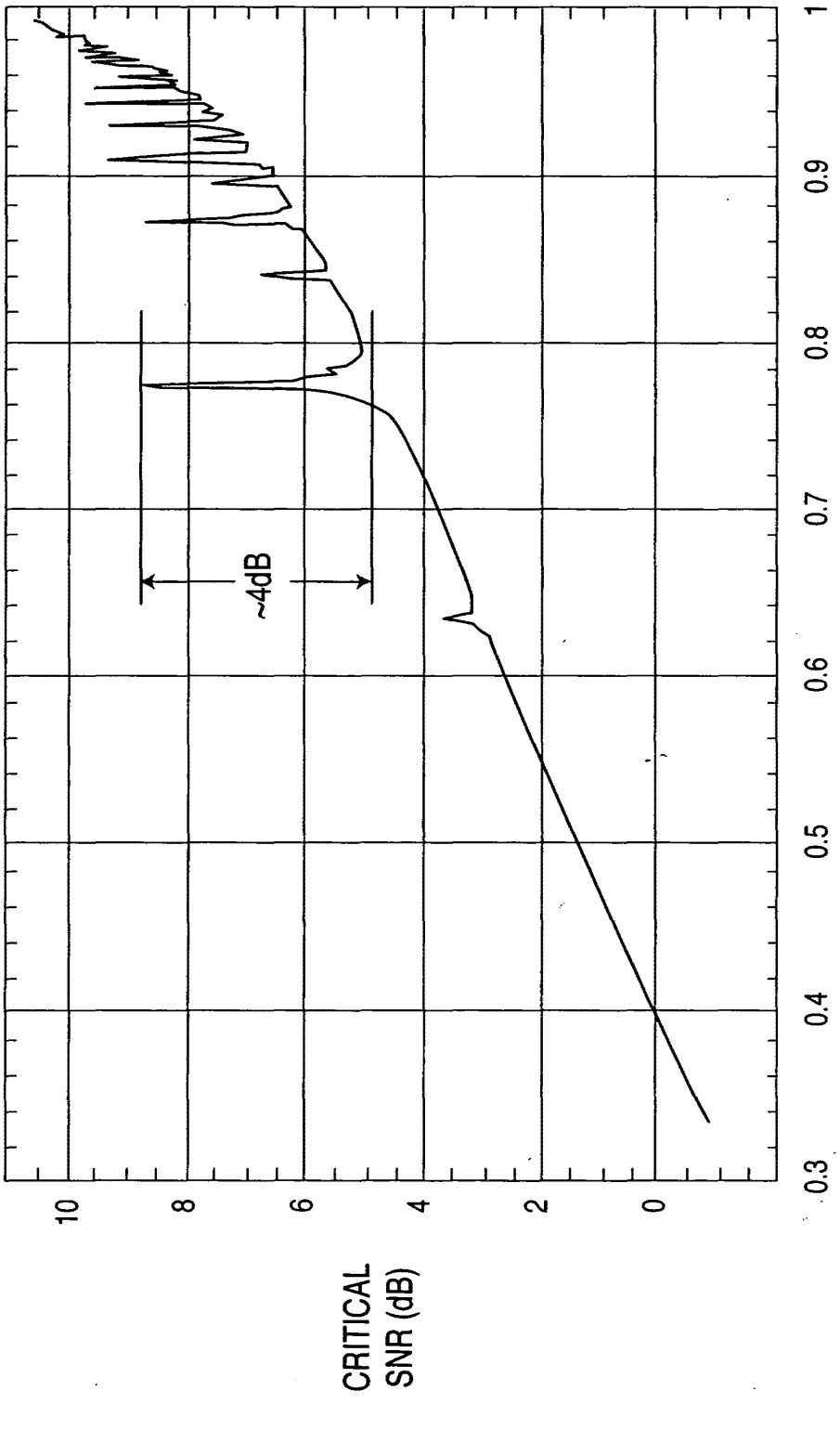


FIG. 7
PRIOR ART

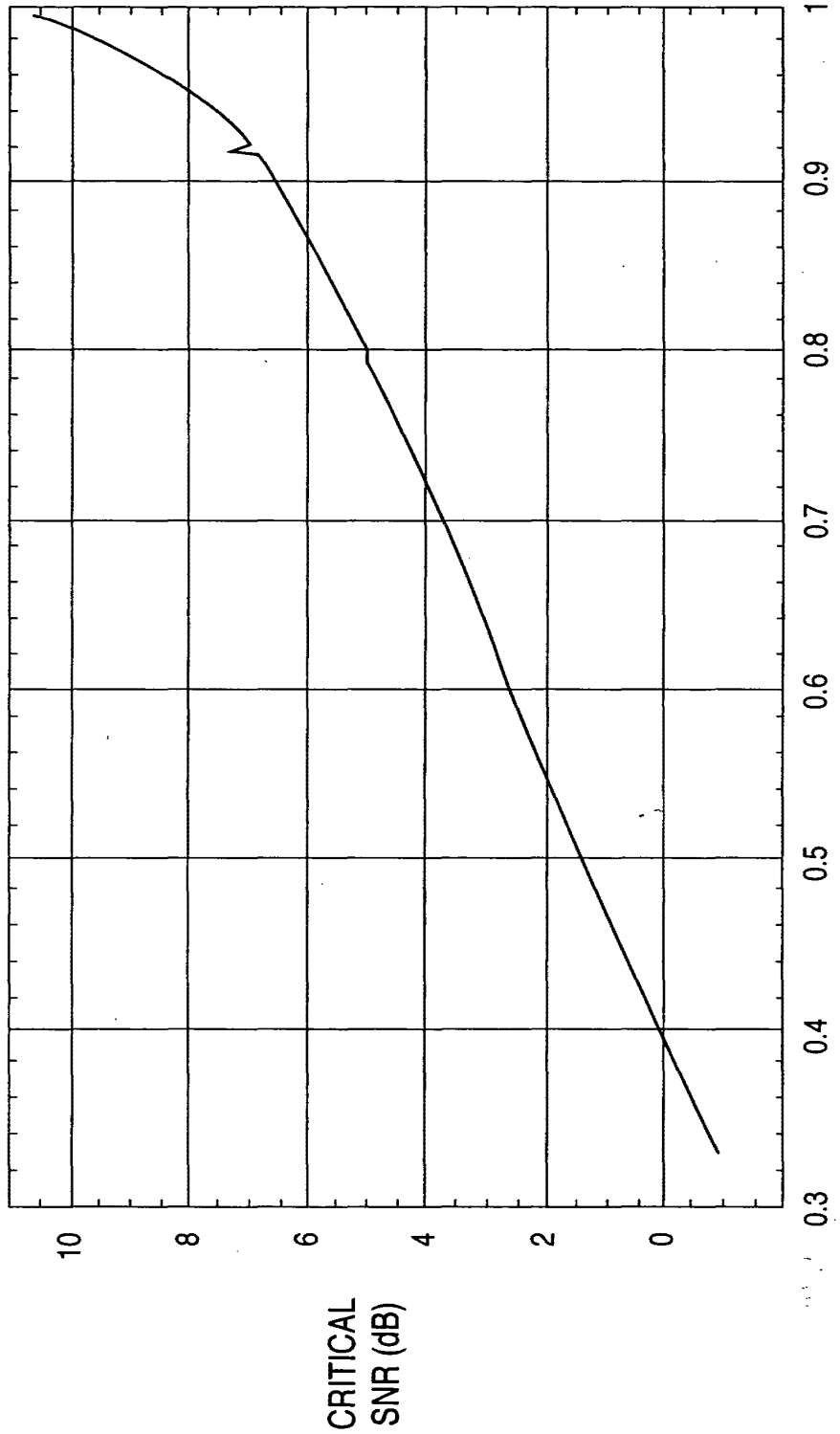


FIG. 8

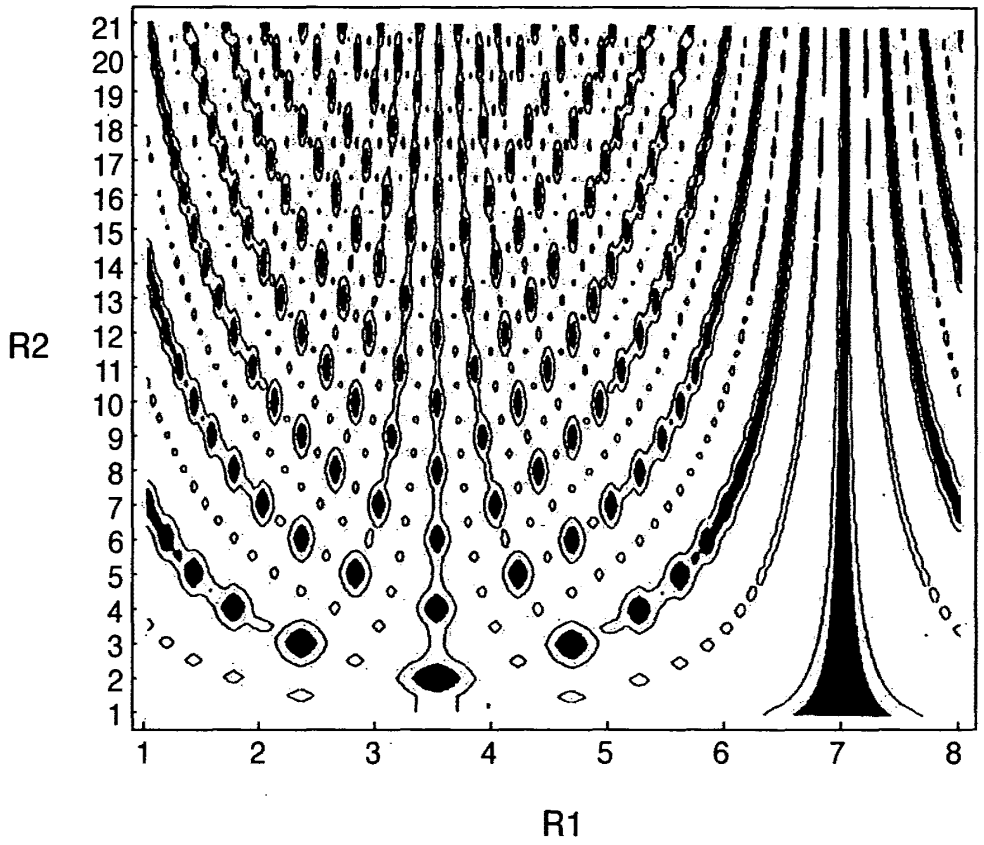


FIG. 9

BEST AVAILABLE COPY

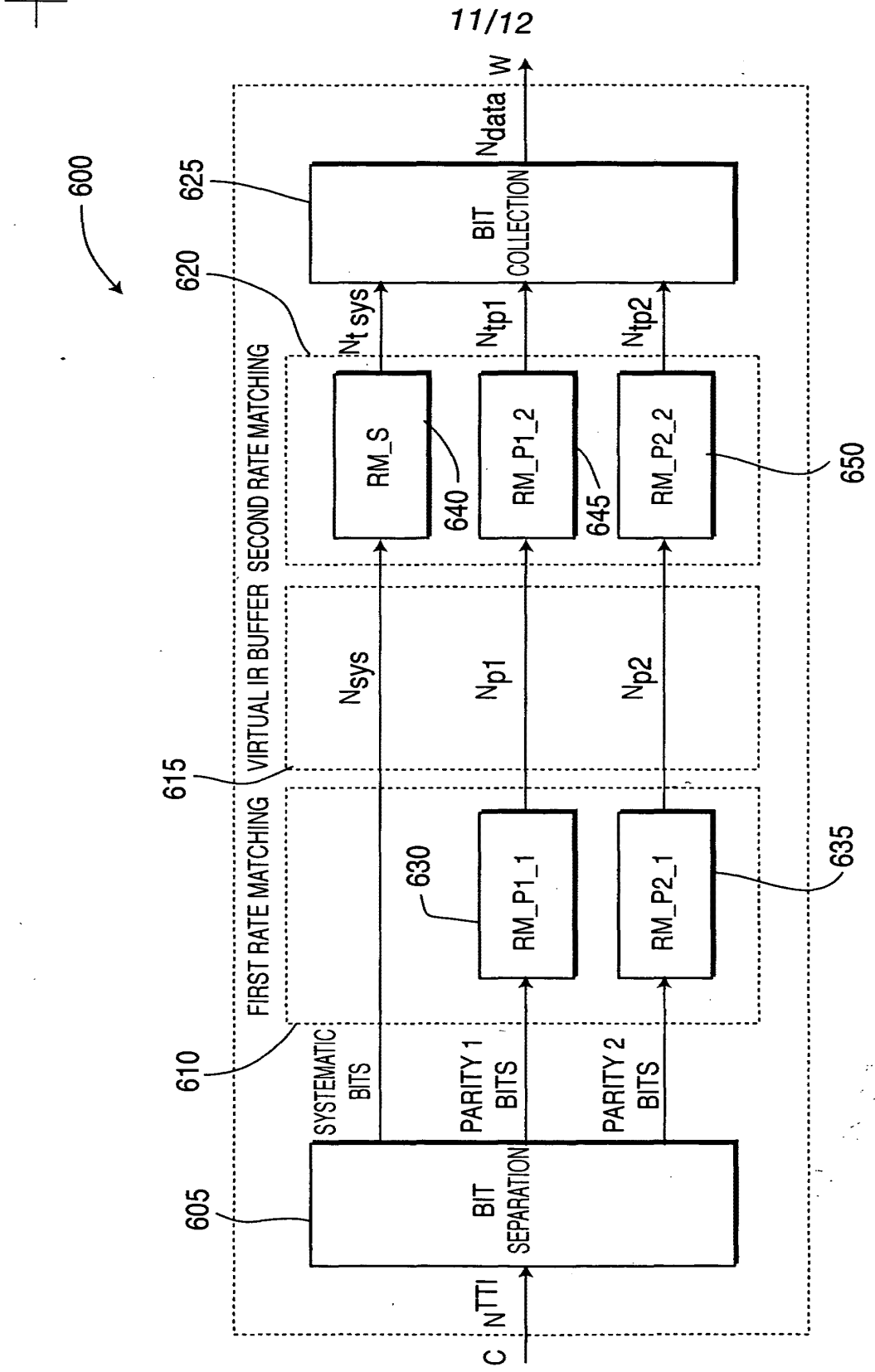

600
625
620
615
610
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630
640
645
650
635
C
N^{TTI}
BIT SEPARATION
SYSTEMATIC BITS
PARITY 1 BITS
PARITY 2 BITS
FIRST RATE MATCHING
VIRTUAL IR BUFFER
SECOND RATE MATCHING
N_{sys}
N_{p1}
N_{p2}
RM_S
RM_P1_1
RM_P2_1
RM_P1_2
RM_P2_2
$N_{t\,sys}$
N_{tp1}
N_{tp2}
BIT COLLECTION
N_{data}
W

FIG. 10

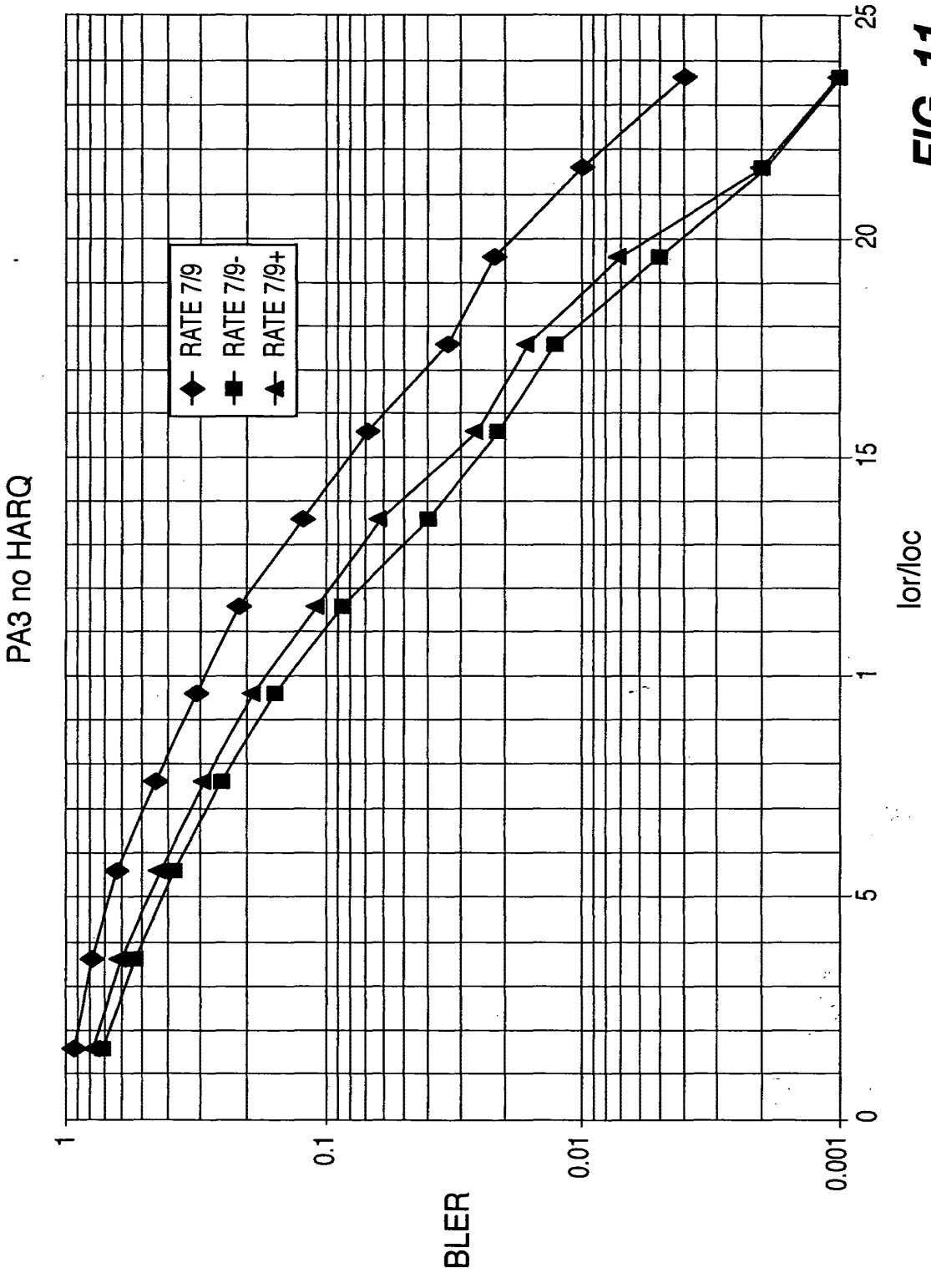

PA3 no HARQ
RATE 7/9
RATE 7/9-
RATE 7/9+
BLER
1
0.1
0.01
0.001
0
5
1
15
20
25
Ior/Ioc

FIG. 11

Express Mail Label No. EV 320890803 US

APPLICATION DATA SHEET
UNDER 37 CFR §1.76

(1) Inventor Information

Inventor One Given Name::	Philip J.
Family Name::	Pietraski
Postal Address Line One::	199 N. Oak Street
City::	North Massapequa
State or Province::	New York
Postal or ZIP Code::	11758
Citizenship Country::	United States of America
Residence::	North Massapequa, New York, U.S.A.

Inventor Two Given Name::	Gregory S.
Family Name::	Sternberg
Postal Address Line One::	50 Brompton Road, Apt. 2B
City::	Great Neck
State or Province::	New York
Postal or ZIP Code::	11021
Citizenship Country::	United States of America
Residence::	Great Neck, New York, U.S.A.

(2) Assignee Information

Name Line One::	InterDigital Technology Corporation
Address Line One::	300 Delaware Avenue
Address Line Two::	Suite 527
City::	Wilmington
State or Province::	Delaware, U.S.A.
Postal or ZIP Code::	19801

(3) Correspondence Information

Customer No.::	24374
Name Line One::	C. Frederick Koenig, III
Name Line Two::	Volpe and Koenig, P.C., DEPT ICC
Telephone No.::	215-568-6400

(4) Application Information

Title Line One::	DETECTION, AVOIDANCE AND/OR
Title Line Two::	CORRECTION OF PROBLEMATIC
Title Line Three::	PUNCTURING PATTERNS IN PARITY BIT
Title Line Four::	STREAMS USED WHEN IMPLEMENTING
Title Line Five::	TURBO CODES
Total Drawing Sheets::	Twelve (12)
Drawing Type::	Formal
Application Type::	Utility
Docket No.::	I-2-0526.1US

(5) Representative Information

Representative Customer No.:: 24374

(6) Domestic Priority Information

This application is a::	Non Prov. of Provisional
Application One::	60/434,232
Filing Date::	December 16, 2002
This application is a::	Non Prov. of Provisional
Application Two::	60/444,068
Filing Date::	January 30, 2003
This application is a::	Non Prov. of Provisional
Application Three::	60/470,921
Filing Date::	May 15, 2003
This application is a::	Non Prov. of Provisional
Application Four::	60/494,404
Filing Date::	August 11, 2003

PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

12/05/2003 EHAILE1 00000031 090435 10725779

01 FC:1001 770.00 DA
02 FC:1201 602.00 DA
03 FC:1202 504.00 DA

PTO-1556
(5/87)

*U.S. Government Printing Office: 2002 — 489-267/69033

PATENT APPLICATION FEE DETERMINATION RECORD
Effective October 1, 2003

Application or Docket Number: 1-2-0526.1US

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	48	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	48 minus 20=	* 28
INDEPENDENT CLAIMS	10 minus 3 =	* 7
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	385.00	OR	BASIC FEE	770.00
XS 9=		OR	XS18=	504
X43=		OR	X86=	602
+145=		OR	+290=	
TOTAL		OR	TOTAL	1876

CLAIMS AS AMENDED - PART II

AMENDMENT A	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
XS 9=		OR	XS18=	
X43=		OR	X86=	
+145=		OR	+290=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X43=		OR	X86=	
+145=		OR	+290=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X43=		OR	X86=	
+145=		OR	+290=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
***If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

331088 U.S.PTO
10/725779
120203

PTO/SB/05 (06-03)
Approved for use through 07/31/2003. OMB 0651-0032
U.S. Patent and Trademark Office. U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	I-2-0526.1US
First Inventor	Pietraski et al.
Title	DETECTION, AVOIDANCE AND/OR CORRECTION...
Express Mail Label No.	EV 320890803 US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. [x] Fee Transmittal Form (e.g., PTO/SB/17) *(Submit an original and a duplicate for fee processing)*
2. [ ] Applicant claims small entity status. See 37 CFR 1.27.
3. [x] Specification [*Total Pages* 53]
   (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [x] Drawing(s) (*35 U.S.C. 113*) [*Total Sheets* 12]
5. Oath or Declaration [*Total Sheets* _____]
   a. [ ] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [x] Application Data Sheet. See 37 CFR 1.76
7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program *(Appendix)*
8. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. [ ] Computer Reader Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or
      ii. [ ] Paper
   c. [ ] Statements verifying identity of above copies

ADDRESS TO: **Mail Stop Patent Application, Commissioner for Patents, P.O. Box 1450, Alexandria VA 22313-1450**

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
11. [ ] English Translation Document *(if applicable)*
12. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [x] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. [ ] Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: .....

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: .....

Prior application information: *Examiner* _____ *Art Unit:* _____

For CONTINUATION OF DIVISIONAL APPS only; The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[x] Customer Number: 24374 *OR* [ ] Correspondence address below

Name	VOLPE AND KOENIG, P.C., DEPT ICC				
Address					
City		*State*		*Zip Code*	
Country		*Telephone*		*Fax*	

Name (Print/Type)	C. Frederick Koenig, III	*Registration No. (Attorney/Agent)*	29,662
Signature		*Date*	December 2, 2003

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop Patent Application, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

16805 U.S. PTO
120203

Express Mail Label No. EV 320890803 US

PTO/SB/17 (10-03)
Approved for use through 07/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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FEE TRANSMITTAL for FY 2004

Effective 10/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 1,876.00

Complete if Known	
Application Number	Not Yet Known
Filing Date	Not Yet Known
First Named Inventor	Pietraski et al.
Examiner Name	Not Yet Known
Art Unit	Not Yet Known
Attorney Docket No.	I-2-0526.1US

METHOD OF PAYMENT *(check all that apply)*

☐ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

☒ Deposit Account:

Deposit Account Number: 09-0435

Deposit Account Name: InterDigital Communications Corporation

The Director is authorized to: *(check all that apply)*

☒ Charge fee(s) indicated below ☒ Credit any overpayments

☒ Charge any additional fee(s) or any underpayment of fee(s)

☐ Charge fee(s) indicated below, **except for the filing fee** to the above-identified deposit account.

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	770	2001	385	Utility filing fee	770.00
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fee	
1004	770	2004	385	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	

SUBTOTAL (1) ($) 770.00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below	=	Fee Paid
Total Claims	48	- 20	= 28	X	18.00	=	504.00
Independent Claims	10	- 3	= 7	X	86.00	=	602.00
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 1,106.00

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1,480	2254	740	Extension for reply within fourth month	
1255	2,010	2255	1,005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing a brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,330	2453	665	Petition to revive - unintentional	
1501	1,330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR 1.129(b))	
1801	770	2801	385	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0.00

SUBMITTED BY				(Complete *(if applicable)*)	
Name (Print/Type)	C. Frederick Koenig, III	*Registration No. (Attorney/Agent)*	29,662	*Telephone*	215-568-6400
Signature				*Date*	December 2, 2003

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

This collection of information is required by 37 CFR 1.17 and 1.27. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

331088 U.S.PTO
10/725779
120203

PTO/SB/05 (06-03)
Approved for use through 07/31/2003. OMB 0651-0032
U.S. Patent and Trademark Office. U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	I-2-0526.1US
First Inventor	Pietraski et al.
Title	DETECTION, AVOIDANCE AND/OR CORRECTION...
Express Mail Label No.	EV 320890803 US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. [x] Fee Transmittal Form (e.g., PTO/SB/17) *(Submit an original and a duplicate for fee processing)*
2. [ ] Applicant claims small entity status. See 37 CFR 1.27.
3. [x] Specification [*Total Pages* 53]
   (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [x] Drawing(s) (*35 U.S.C. 113*) [*Total Sheets* 12]
5. Oath or Declaration [*Total Sheets* _____]
   a. [ ] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [x] Application Data Sheet. See 37 CFR 1.76
7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program *(Appendix)*
8. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. [ ] Computer Reader Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or
      ii. [ ] Paper
   c. [ ] Statements verifying identity of above copies

ADDRESS TO:

Mail Stop Patent Application
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
11. [ ] English Translation Document *(if applicable)*
12. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [x] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. [ ] Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: .....

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: .....

Prior application information: *Examiner* _____ *Art Unit:* _____

For CONTINUATION OF DIVISIONAL APPS only; The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[x] Customer Number: 24374 ***OR*** [ ] Correspondence address below

Name	VOLPE AND KOENIG, P.C., DEPT ICC				
Address					
City		*State*		*Zip Code*	
Country		*Telephone*		*Fax*	

Name (Print/Type)	C. Frederick Koenig, III	*Registration No. (Attorney/Agent)*	29,662
Signature		*Date*	December 2, 2003

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop Patent Application, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

16805 U.S. PTO
120203

Express Mail Label No. EV 320890803 US

PTO/SB/17 (10-03)
Approved for use through 07/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

FEE TRANSMITTAL for FY 2004

Effective 10/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 1,876.00

Complete if Known	
Application Number	Not Yet Known
Filing Date	Not Yet Known
First Named Inventor	Pietraski et al.
Examiner Name	Not Yet Known
Art Unit	Not Yet Known
Attorney Docket No.	I-2-0526.1US

METHOD OF PAYMENT *(check all that apply)*

☐ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

☒ Deposit Account:

Deposit Account Number: 09-0435

Deposit Account Name: InterDigital Communications Corporation

The Director is authorized to: *(check all that apply)*

☒ Charge fee(s) indicated below ☒ Credit any overpayments

☒ Charge any additional fee(s) or any underpayment of fee(s)

☐ Charge fee(s) indicated below, **except for the filing fee** to the above-identified deposit account.

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	770	2001	385	Utility filing fee	770.00
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fee	
1004	770	2004	385	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	

SUBTOTAL (1) ($) 770.00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below	=	Fee Paid
Total Claims	48	- 20	= 28	X	18.00	=	504.00
Independent Claims	10	- 3	= 7	X	86.00	=	602.00
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 1,106.00

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1,480	2254	740	Extension for reply within fourth month	
1255	2,010	2255	1,005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing a brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,330	2453	665	Petition to revive - unintentional	
1501	1,330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR 1.129(b))	
1801	770	2801	385	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0.00

SUBMITTED BY				(Complete *(if applicable)*)	
Name (Print/Type)	C. Frederick Koenig, III	*Registration No. (Attorney/Agent)*	29,662	*Telephone*	215-568-6400
Signature				*Date*	December 2, 2003

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This collection of information is required by 37 CFR 1.17 and 1.27. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**