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Extract from the Register of European Patents

About this file: EP1573923

EP1573923 - DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES [Right-click to bookmark this link]			
Status	The application is deemed to be withdrawn *Status updated on 12.11.2010* *Database last updated on 07.02.2023*		
Most recent event	12.11.2010	Application deemed to be withdrawn	published on 15.12.2010 [2010/50]
Applicant(s)	For all designated states INTERDIGITAL TECHNOLOGY CORPORATION Suite 527 300 Delaware Avenue Wilmington, DE 19801 / US		
	[N/P]		
Former [2005/37]	*For all designated states* *INTERDIGITAL TECHNOLOGY CORPORATION* *Suite 527, 300 Delaware Avenue* *Wilmington, DE 19801 / US*		
Inventor(s)	01 / PIETRASKI, Philip, J. 199 N. Oak Street North Massapequa, NY 11758 / US		
	02 / STERNBERG, Gregory S. 7 Brookwood Road Mt. Laurel, NJ 08054 / US		
	[2005/37]		
Representative(s)	Johansson, Magnus, et al , et al Awapatent AB Järnvägsgatan 10 A Box 1066 251 10 Helsingborg / SE		
	[N/P]		
Former [2008/14]	*Johansson, Magnus, et al , et al* *Awapatent AB Järnvägsgatan 10 A Box 1066* *251 10 Helsingborg / SE*		
Former [2005/37]	*Grönlund, Tim Linus Wilhelm* *AWAPATENT AB Berga Allé 1* *254 52 Helsingborg / SE*		
Application number, filing date	03796549.8	03.12.2003	
	[2005/37]		
	WO2003US38223		
Priority number, date	US20020434232P	16.12.2002 Original published format: US 434232 P	
	US20030444068P	30.01.2003 Original published format: US 444068 P	
	US20030470921P	15.05.2003 Original published format: US 470921 P	
	US20030494404P	11.08.2003 Original published format: US 494404 P	
	[2005/37]		
Filing language	EN		
Procedural language	EN		
Publication	**Type:**	A1 Application with search report	
	No.:	WO2004062113	
	Date:	22.07.2004	
	Language:	EN	
	[2004/30]		
	Type:	A1 Application with search report	
	No.:	EP1573923	
	Date:	14.09.2005	
	Language:	EN	
	The application published by WIPO in one of the EPO official languages on 22.07.2004 takes the place of the publication of the European patent application.		
	[2005/37]		
Search report(s)	**International search report - published on:**	US	22.07.2004
	(Supplementary) European search report - dispatched on:	EP	10.09.2008
Classification	**IPC:**	H03M13/35, H03M13/27	[2005/37]

	CPC:	**H04L1/0013 (EP); H03M13/27 (KR); H03M13/2771 (US); H03M13/2792 (US); H03M13/2957 (EP,US); H03M13/35 (KR);** (+)	
Designated contracting states	AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LI, LU, MC, NL, PT, RO, SE, SI, SK, TR [2005/37]		
xtension states	AL	Not yet paid	
	LT	Not yet paid	
	LV	Not yet paid	
	MK	Not yet paid	
Title	**German:**	ERKENNUNG, VERMEIDUNG UND/ODER KORREKTUR VON PROBLEMATISCHENPUNKTIERUNGSMUSTERN IN BEI DER IMPLEMENTIERUNG VON TURBOCODES VERWENDETENPARITÄTSBITSTRÖMEN	[2005/37]
	English:	DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES	[2005/37]
	French:	DETECTION, EVITEMENT ET/OU CORRECTION DE MODELES DE PERFORATION PROBLEMATIQUES DANS DES FLUX DE BITS DE PARITE UTILISES LORS DE L'APPLICATION DE TURBOCODES	[2005/37]
Entry into regional phase	17.06.2005	National basic fee paid	
	17.06.2005	Search fee paid	
	17.06.2005	Designation fee(s) paid	
	17.06.2005	Examination fee paid	
Examination procedure	22.06.2004	Request for preliminary examination filed International Preliminary Examining Authority: US	
	17.06.2005	Examination requested [2005/37]	
	23.01.2009	Amendment by applicant (claims and/or description)	
	22.06.2009	Despatch of a communication from the examining division (Time limit: M04)	
	26.10.2009	Reply to a communication from the examining division	
	09.12.2009	Despatch of a communication from the examining division (Time limit: M06)	
	22.06.2010	Application deemed to be withdrawn, date of legal effect [2010/50]	
	26.07.2010	Despatch of communication that the application is deemed to be withdrawn, reason: reply to the communication from the examining division not received in time [2010/50]	
Divisional application(s)	EP10166532.1 / EP2242182		
	EP21166803.3		
Fees paid	**Renewal fee**		
	15.12.2005	Renewal fee patent year 03	
	13.12.2006	Renewal fee patent year 04	
	12.12.2007	Renewal fee patent year 05	
	31.03.2008	Renewal fee patent year 06	
	11.12.2009	Renewal fee patent year 07	
Documents cited:	**Search**	[DA] - 3GPP, "3GPP TR 25.944", (200106), pages 1 - 64, URL: http://www.3gpp.org/ftp/specs/archive/25%5Fseries/25.944/, (20080820), XP002492854 [DA] 1-48 * the whole document *	
		[DA] - "Universal Mobile Telecommunications System (UMTS); Multiplexing and channel coding (TDD) (3GPP TS 25.222 version 3.8.0 Release 1999); ETSI TS 125 222", ETSI STANDARDS, LIS, SOPHIA ANTIPOLIS CEDEX, FRANCE, (20020301), vol. 3-R1, no. V3.8.0, ISSN 0000-0001, XP014008471 [DA] 1-48 * the whole document *	
	International search	[Y]US6370669 (EROZ MUSTAFA [US], et al);	
		[YP]US6601214 (HAMMONS JR A ROGER [US])	

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Questions about this communication ?
Contact Customer Services at www.epo.org/contact

Nederlandsch Octrooibureau
P.O. Box 29720
2502 LS The Hague
NETHERLANDS

Date
08.08.2017

Reference	Application No./Patent No.
	03796549.8 - 1903 / 1573923
Applicant/Proprietor	
INTERDIGITAL TECHNOLOGY CORPORATION	

Your request dated

Your request cannot be granted anymore, since

☒ the patent application has been refused or withdrawn or is deemed to have been withdrawn.

☐ the period for filing an opposition against the granted patent has expired or opposition proceedings before the EPO have been completed. The matter is now the sole responsibility of the national Offices of the designated Contracting States (see Articles 2(2), 64 EPC and Guidelines A-XI, 4).

If you do not agree with this finding, you may apply for an **appealable decision** within a period of **two months** from notification of this communication. If you do not apply for a decision within the prescribed period, your request will be placed on file and any administrative fee paid will be reimbursed.

For the Legal Division

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Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	5478400	
Application number	EP03796549.8	
Date of receipt	25 July 2017	
Receiving Office	European Patent Office, The Hague	
Your reference	P6069593EP1	
Applicant	All applicants as on file	
Documents submitted	package-data.xml epf1038.pdf (1 p.)	ep-sfd-request.xml FREP-1.pdf\P6069593EP1_20170724-113415_Correspondence_to_Authority_.pdf (1 p.)
Submitted by	CN=Willem Niesing 45128	
Method of submission	Online	
Date and time receipt generated	25 July 2017, 11:01 (CEST)	
Message Digest	51:3A:57:32:40:BA:C0:51:21:54:50:7E:EB:EE:DA:E7:81:CB:EF:43	

Correction by the EPO of errors in debit instructions filed by eOLF
Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

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Letter accompanying subsequently filed items

Representative:

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The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	03796549.8
Applicant's or representative's reference	P6069593EP1

	Description of document	Original file name	Assigned file name
1	Document concerning representation	P6069593EP1_20170724-113415_Correspondence_to_Authority_.pdf	FREP-1.pdf

	Payment	
1	Mode of payment	Not specified

Signatures

Place:	**The Hague**
Date:	**25 July 2017**
Signed by:	**Willem Niesing 45128**
Association:	**Nederlandsch Octrooibureau**
Representative name:	**NIESING, Willem**
Capacity:	**(Representative)**

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TRADEMARK ATTORNEYS

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Ede, 24 July 2017

Our ref: P6069593EP1
Re: European patent application 03796549.8
Subject: Detection, avoidance and/or correction of problematic puncturing patterns in parity bit streams used when implementing turbo codes
In the name of: InterDigital Technology Corporation/ Signal Trust for Wireless Innovation

Dear Sir/Madam,

With respect to the above indicated patent application please be informed that our office took over the representation of the above subject case. Our association number is 513.

Therefore, please send all further correspondence in this matter to the following address and use the above mentioned NLO reference P6069593EP1:

Nederlandsch Octrooibureau
P.O. Box 29720
2505 LS The Hague
The Netherlands

tel.: +31 (0)70 331 25 00
fax: +31 (0)70 352 75 28

Please have the change of representation registered.

Yours faithfully,

ADM023EN

Patents F +31 (0)70 352 75 28 | E patents@nlo.eu Trademarks F +31 (0)70 352 75 89 | E trademarks@nlo.eu

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SUEDE

For any questions about this communication:
Tel.:+31 (0)70 340 45 00

Date: 03.01.11

Reference	Application No./Patent No.
	03796549.8 - 1228 / 1573923

Applicant/Proprietor: INTERDIGITAL TECHNOLOGY CORPORATION

Refund of fees

The following fee(s) was/were paid in respect of the application 03796549.8:

Fee	Reference	Voucher No	Date	Currency	Amount
Renewal fee	038	00972365	15.12.10	EUR	1 155,00

According to the present state of the file the refund will be made by:

CREDITING THE DEPOSIT ACCOUNT 28050043 CPA Computer Patent Annuities Ltd.

Amount refundable:	Reference	Currency	Amount	Voucher No
	038	EUR	1.155,00	00392260

Reason for refund: Closure of the application took legal effect on 22.06.10

The Authorising Officer
Rey
(49)(89)23994297

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EPO Form 2907 12.07

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Closure of the procedure in respect of application No. 03796549.8 - 1228 04.11.10

1. The procedure in respect of the above application is closed for the following reason:

✓ ADWI 11/26.07.10 The time limit under Rule 112(2) EPC has expired.
No request for a decision under Rule 112(2), or for further processing under Article 121 EPC or for re-establishment of rights under Article 122 EPC has been filed.

2. The EPASYS situation has been verified in respect of item 1:

DFIL: 03.12.03
NOAP: ////
RDEC: ////
RFPR: //
REES: ///

DEAD

REFU 3/ADWI 3 and DEAD 1 coded. Date of legal effect 22.06.2010.

3. Position regarding **fees**:

FEFS01	002	00396439	17.06.05	EUR	552,00
DEST03	005	00396439	17.06.05	EUR	525,00
EXAM02	006	00396439	17.06.05	EUR	1 430,00
CLMS(2)	015	00396439	17.06.05	EUR	1 520,00
FFEE01	020	00396439	17.06.05	EUR	160,00
RFEE 03	033	00722555	15.12.05	EUR	380,00
RFEE 04	034	00770496	13.12.06	EUR	425,00
RFEE 05	035	00786335	12.12.07	EUR	450,00
RFEE 06	036	00421056	31.03.08	EUR	745,00
RFEE 07	037	00842994	11.12.09	EUR	1 000,00
ASOC03	055	00396439	17.06.05	EUR	20,00

☐ 3.1 Form **2058A** submitted to 1st examiner (if applicable)

☐ 3.2 Refund(s) ordered:

☐ 75% Exam fee ☐ Other fees: _____

4. Mark "DEAD" on the paper file and:

☐ Check whether a divisional application is pending and if so attach the DEAD file to it.

☐ Any **models** still in the Office's possession were returned on _____
(for dealing with models, please refer to Fil d'Ariane).

☐ Submit it to 1st examiner if a request for feedback is present.

☐ Keep paper file in file store (separate place) until next action for file destruction.

05-11-2010
Date

Flasshar, Claudia
Formalities Officer

To 1st examiner/Director for information : Van Staveren M room S08A28

EPO Form 2058 12.07

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For any questions about this communication:
Tel.:+31 (0)70 340 45 00
Flasshar, Claudia 4789

Date: 26-07-2010

Reference	Application No./Patent No.
	03796549.8 - 1228 / 1573923

Applicant/Proprietor
INTERDIGITAL TECHNOLOGY CORPORATION

Noting of loss of rights pursuant to Rule 112(1) EPC

The European patent application is deemed to be withdrawn under Article 94(4) EPC, because the invitation to file observations on the communication from the Examining Division dated 09.12.09 was not complied with.

Means of redress

Request for a decision (R. 112(2) EPC)
If the applicant considers that the finding of the European Patent Office is inaccurate, he may, within a (non-extendable) period of **two months** after notification of this communication, apply in writing for a decision on the matter. The application can only lead to the finding being reversed if this does not actually correspond to the factual or legal situation.

Further processing (Art. 121 EPC)
The legal consequence of the failure to observe the time limit shall be deemed not to have ensued if, within a (non-extendable) period of **two months** after notification of this communication, further processing is requested by payment of the fee prescribed under Article 2(12) of the Rules relating to Fees and the omitted act is completed (R. 135(1) EPC).

Important note to users of the automatic debiting procedure
The fee for further processing will be debited automatically on the day on which the above-mentioned omitted act is completed (see Arrangements for the automatic debiting procedure, Supplement to OJ EPO 3/2009).

For the Examining Division

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Flasshar, Claudia

Registered letter
EPO Form 2021A 12.07 (19/07/10) ADWI 11

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SUEDE

Date
13.04.10

Reference	Application No./Patent No.
	03796549.8 - 1228 / 1573923

Applicant/Proprietor
INTERDIGITAL TECHNOLOGY CORPORATION

Extension of time limit pursuant to Rule 132(2) EPC

Examination procedure

With reference to your request, the time limit for replying to the communication according to Article 94(3) EPC dated 09.12.09 has been extended

by 2 months

to a total of 6 months

from the date of notification of the above-mentioned communication.

Please note: To the extent that your request exceeded the above extension, your request has been refused.

Note
The granting of extensions to time limits is governed by the Implementing Regulations to the EPC and the Guidelines for Examination in the EPO, part E-VIII, 1.6.

If no reply to the communication is received in due time, the European patent application will be deemed to be withdrawn (Art. 94(4) EPC).

For the Examining Division

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Lahrech, Mohamed

Europäisches Patentamt
European Patent Office
Office européen des brevets

Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	795038	
Application number	EP03796549.8	
Date of receipt	07 April 2010	
Receiving Office	European Patent Office, The Hague	
Your reference	PC-EP-21020363	
Applicant	All applicants as on file	
Documents submitted	package-data.xml epf1038.pdf (1 p.)	ep-sfd-request.xml EXRE92-1.pdf\20100406_21020363_ Request for extension of time limit.pdf (1 p.)
Submitted by	CN=M. Johansson 6572,O=Awapatent AB,C=SE	
Method of submission	Online	
Date and time receipt generated	07 April 2010, 13:22 (CEST)	
Message Digest	AC:22:F2:21:AF:2D:F2:45:88:CA:A4:D1:A9:C6:6F:7F:93:1D:3D:2F	

Correction by the EPO of errors in debit instructions filed by eOLF
Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

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Letter accompanying subsequently filed items

Sender:

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The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	03796549.8
Applicant's or representative's reference	PC-EP-21020363

	Description of document	Original file name	Assigned file name
1	Request for extension of time limit during examination procedure	20100406_21020363_Request for extension of time limit.pdf	EXRE92-1.pdf

Signatures

Place:	**Helsingborg**
Date:	**07 April 2010**
Signed by:	**SE, Awapatent AB, M. Johansson 6572**
Capacity:	**(Representative)**

Helsingborg
6 April 2010

EUROPEAN PATENT OFFICE
DE-80298 MÜNCHEN

Handled by
Magnus Johansson/MKK

Our ref.
PC-EP-21020363

FILED VIA EPOLINE ONLINE FILING

European Patent Application No. 03796549.8
in the name of INTERDIGITAL TECHNOLOGY CORPORATION

Dear Sirs,

Under the provisions of Rule 132 EPC, I hereby request a two-month extension of the time limit for responding to your Article 94(3) Communication dated 09.12.2009.

Yours faithfully,

/Magnus Johansson/
Professional Representative
AWAPATENT AB

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SÖDERHAMN ÖSTERSUND MUNICH

J:\Word\Brev 10.1 V1_Norsk.dotm\WOLFF AND KOENIG PATENTANWÄLTE_INTERDIGITAL TECHNOLOGY_PC-EP-21020363_Request for extension of time limit.doc

The examination is being carried out on the **following application documents**:

Description, Pages

1-38 filed with entry into the regional phase before the EPO

Claims, Numbers

1-6 received on 26.10.2009 with letter of 26.10.2009

Drawings, Sheets

1/21-21/21 filed with entry into the regional phase before the EPO

1. In response to the letter of reply of 26.10.2009:

2. The following document (D) is cited. A copy of the document is annexed to the communication and the numbering will be adhered to in the rest of the procedure:

D1 = ETSI TS 125 212 V5.1.0 (2002-06).

3. Figure 10 of this application is identical to D1, figure 17. Some figures of this application are identified as "prior art", but figure 10 has been presented as being part of the invention. As D1, fig. 17 is completely identical to figure 10 of this application, it is clear that the applicant was aware of D1 (or of an earlier version which also showed this figure) at the time of filing. The applicant is requested to explain why a proper prior art source for figure 10 of the application was not provided at the time of filing; see Rule 42(1)(b) EPC.

4. It appears that large parts of the description of the present application are identical to parts of D1. For example, the description starting in par. [0130] of this application is highly similar to that starting in par. 4.5.4 of D1.

The applicant should therefore acknowledge D1 (see Rule 42(1)(b) EPC), and identify which parts of this application have been taken from D1.

5. D1, figure 17 shows a bit separation circuit,a virtual IR buffer and a rate matching unit as defined by claim 4 of this application.

Claim 4 defines that the virtual buffers buffers a "portion" of the interleaved systematic bits and the interleaved first and second parity bit streams in case in case the totality of interleaved bits is larger than the virtual buffer. This is the same as D1 (see 4.5.4.2), but the term "portion" allows that e.g. all systematic bits are discarded. The application as filed provides not basis for this term, and claim 4 is therefore contrary to Art. 123(2) EPC.

Furthermore, claim 4 now defines that there are three interleavers (for the systematic and first and second parity streams) between the bit separator and the virtual buffer. The letter of reply of 26.10.2009 points to paragraphs [0084] and [0085] of the application. In par. [0085] it is stated "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 wil require an additional interleaver for the systematic bits". It is not clear how this could provide a basis for the definition of the first, second and third interleavers in claim 4.

Also for this reason claim 4 is contrary to Art. 123(2) EPC.

The same objections under Art. 123(2) EPC apply, mutatis mutandis, to claim 1.

6. Claim 4 defines twice, in the definition of the virtual buffer, that something is, or is not, done "on a condition that the number of bits is larger [resp. not larger] than the virtual buffer". However, claim 4 does not define means that would allow the unit to determine which of the conditions is satisfied. Indeed, in par. [0136] of this application (which is identical to D1, par. 4.5.4.2, second paragraph) it is stated that "the number of soft bits

available in the virtual IR buffer is N_{IR} which is signaled from higher layers for each HARQ process". It thus appears that claim 4 lacks the features that allow the claimed unit to obtain such signalling from higher layers. Therefore claim 4 (and also claim 1) are not supported, which is contrary to Art. 84 EPC.

7. From par. [0084] of this application it is clear that interleaving before rate matching is an alternative to modification of the puncturing pattern. Therefore, the parts of the description that refer to modification of the puncturing pattern must be removed from the application.

8. In view of the above objections, examination under Art. 52(1) EPC is presently not feasible.

9. The attention of the applicant is drawn to the fact that the application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed (Article 123(2) EPC).

M. van Staveren

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Substantive Examiner
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Tel: +31 70 340 - 4037

Application No.	Ref.	Date
03 796 549.8 - 1228		09.12.2009
Applicant INTERDIGITAL TECHNOLOGY CORPORATION		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).

Van Staveren, Martin
Primary Examiner
For the Examining Division

Enclosure(s): 3 page/s reasons (Form 2906)
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Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	678578
Application number	EP03796549.8
Date of receipt	26 October 2009
Receiving Office	European Patent Office, The Hague
Your reference	PC-EP-21020363
Applicant	All applicants as on file
Documents submitted	package-data.xml epf1038.pdf (1 p.) CLMSPAMD-1.pdf\20091026_21020363_Amended claims.pdf (3 p.) ep-sfd-request.xml EXRE3-1.pdf\20091026_21020363_Reply first OA.pdf (4 p.)
Submitted by	CN=M. Johansson 6572,O=Awapatent AB,C=SE
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Correction by the EPO of errors in debit instructions filed by eOLF
Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

CLAIMS

1. A method of rate matching for turbo coded transport channels in wireless communications, the method comprising:

separating bits in a transport block into first, second and third code blocks,

interleaving turbo encoded systematic bits arranged in the first code block;

interleaving a first turbo encoded parity bit stream arranged in the second code block;

interleaving a second turbo encoded parity bit stream arranged in the third code block;

buffering the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream in a virtual buffer ~~when~~ on a condition that the number of bits of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream is not larger than the virtual buffer;

buffering a portion of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream ~~when~~ on a condition that the number of bits of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream is larger than the virtual buffer; and

using a rate-matching unit to perform rate matching on ~~at least one~~an output of the virtual buffer.

2. The method of claim 1 wherein the buffered portion includes all of the interleaved systematic bits.

3. The method of claim 1 further comprising:

collecting bits associated with the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream.

4. A wireless transmit/receive unit, WTRU, arranged to communicate via turbo coded transport channels, the WTRU comprising:

a bit separation circuit configured to separate bits in a transport block into first, second and third code blocks,

a first interleaver configured to interleave turbo encoded systematic bits arranged in the first code block;

a second interleaver configured to interleave a first turbo encoded parity bit stream arranged in the second code block;

a third interleaver configured to interleave a second turbo encoded parity bit stream arranged in the third code block;

a virtual buffer configured to:

buffer the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream ~~when~~ on a condition that the number of bits of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream is not larger than the virtual buffer; and

~~configured to~~ buffer a portion of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream ~~when~~ on a condition that the number of bits of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream is larger than the virtual buffer; and

a rate matching unit configured to perform rate matching on ~~at least one~~an output of the virtual buffer.

5. The WTRU of claim 4 wherein the buffered portion includes all of the interleaved systematic bits.

6. The WTRU of claim 4 further comprising:

a bit collection unit configured to collect bits associated with the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream.

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Letter accompanying subsequently filed items

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The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	03796549.8
Applicant's or representative's reference	PC-EP-21020363

	Description of document	Original file name	Assigned file name
1	Reply to examination report	20091026_21020363_Reply first OA.pdf	EXRE3-1.pdf
2	Amended claims	20091026_21020363_Amended claims.pdf	CLMSPAMD-1.pdf

	Payment	
1	Mode of payment	Not specified

Annotations

Signatures

Place:	**Helsingborg**
Date:	**26 October 2009**
Signed by:	**SE, Awapatent AB, M. Johansson 6572**
Capacity:	**(Representative)**

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Helsingborg
23 October 2009

EUROPEAN PATENT OFFICE
DE-80298 MÜNCHEN

Handled by
Magnus Johansson/JTN

Our ref.
PC-EP-21020363

FILED VIA EPOLINE ONLINE FILING

European Patent Application No 03796549.8
in the name of INTERDIGITAL TECHNOLOGY CORPORATION

Dear Sirs,

In response to the Communication dated June 22, 2009 I hereby submit amended claims 1-6 as full replacement for claims 1-6 presently on file together with my observations.

Amendments

In the enclosed claims set, the following amendments have been made:

Claim 1 has been amended to relate to *"A method of rate matching for turbo coded transport channels in wireless communications..."*. Support for the amendment is found e.g. in paragraph [0031] of the PCT application, disclosing rate matching for a turbo coded transport channel in the form of a High Speed Downlink Shared Channel (HSDSCH).

Claim 1 has been further amended in that it now discloses *"separating bits in a transport block into first, second and third code blocks"*. Support for the amendment is found e.g. in paragraph [0049] and in Fig. 10 disclosing the separation of a bit stream *"C"* into three bit streams by means of a bit separation unit.

Claim 1 has been further amended in that it now clearly discloses *"interleaving turbo encoded systematic bits"*, *"interleaving a first turbo encoded parity bit stream"*, and *"interleaving a second turbo encoded parity bit stream"*. Support for the amendments are found in paragraphs [0084] and [0085] disclosing interleaving of the systematic bits and the parity bit streams.

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2009-10-23 11:17 "[illegible]" HELSINGBORG AWAPATENT 1/2 PC21020363 Reply to Art. 94(3) filing

Claim 1 has been clarified in that the phrase *"...at least one..."* has been changed to *"an"*. Support for the amendment is found e.g. in Fig. 10 which clearly discloses a rate matching unit (620) which is connected to the outputs of the virtual buffer.

Claim 4 has been amended in correspondence with claim 1.

Claim 4 has been further amended to disclose: *"a virtual buffer configured to: buffer the interleaved systematic bits... ~~when~~ on a condition that the number of bits ... is not larger than the virtual buffer; and ~~configured to~~ buffer a portion of the interleaved systematic bits... ~~when~~ on a condition that the number of bits ... is larger than the virtual buffer"*. By this clarifying amendment, it is trusted that the clarity objection raised under item 4 of the Communication has been met.

Arguments

Re Added subject-matter

Item 2 of the Communication

The Examiner states that claims 1 and 4 presently on file do not relate to the objective stated in the application text (paragraphs [0025] and [0026]). However, the objective of the present invention according to the above paragraphs is inter alia to avoid problematic puncturing patterns. More specifically, in paragraph [0049] (referring to Fig. 10) it is stated that periodicities in the puncturing pattern have shown to degrade the Turbo code performance. One way to combat this is, as disclosed in paragraph [0084], to interleave the parity bits before rate-matching occurs. This is also applicable, as disclosed in paragraph [0085], to the systematic bits. After interleaving the bits are received in a buffer as disclosed in paragraph [0131].

In view of this, amended claim 1 now specifies the environment in which the rate matching occurs, i.e. in *"turbo coded transport channels in a wireless communications"* and also specifies that it is *"turbo encoded"* systematic bits and parity streams that are interleaved. The bit streams are hence no longer unspecified.

Additionally, given that the objective is to avoid problematic puncturing patterns and that this is achieved through interleaving the way the rate matching is performed not essential. It must be considered implicit that rate matching simply matches the number of transport channel bits to the bits available in a physical channel radio frame by repeating or puncturing bits in the bit stream on a transport channel.

I trust that the objections raised under item 2 of the Communication hereby have been met.

Item 3 of the Communication

The Examiner objects that according to the present wording of claims 1 and 4, the bit streams may be infinitely long and that this introduces subject-matter in violation of Article 123(2) EPC.

According to amended claims 1 and 4, bits are arranged in a transport block and are separated into code blocks for further processing. By amended claims 1 and 4, it is thus clear that the size of the bit streams and the virtual buffer may vary but are restrained to the block size defined in the applicable standard (e.g. paragraph [0068] in the present application discloses that the MAC layer may decide on the appropriate size of the transport blocks).

I trust that the objections raised under item 3 of the Communication hereby have been met.

Item 5 of the Communication

The Examiner considers that the reference to "a portion" of interleaved streams and to "at least one output of the virtual buffer" lacks a basis in the original application in violation of Article 123(2) EPC.

Paragraph [0137] of the present application discloses that if all coded bits of the corresponding TTI can be stored, the first rate matching stage shall be transparent, i.e. if the bit streams are less than or equal to the size of the virtual buffer, the buffer will store all bits without overflow. The opposite is disclosed in paragraph [0138] which states that the parity bit streams are punctured if the size of the buffer is smaller than the parity bit streams, i.e. the buffer will only store a portion of the bit streams (the rest is removed by puncturing).

Consequently, the description provides a basis for the term "portion" which hence not introduces any new subject-matter into the application.

Moreover, by the above mentioned amendment of claim 1 of *"~~at least one~~an output of the virtual buffer"*, it is clear that the objection regarding added subject-matter in respect of the virtual buffer has been met.

Assuredly, Fig. 10 shows three outputs from the buffer that are connected to a rate matching unit. However, it is put forward that it would be an unfair restriction to only allow the claims to cover exactly three outputs considering that the exact number of outputs not is essential for the achieving the objected as presently formulated.

Requests

In view of the above, favourable action based on the new claims is hereby respectfully requested. In the event that the Examiner is not prepared to issue a communication in accordance with Rule 71(3) with regard to the new set of claims 1-6, I respectfully request an additional opportunity to submit amendments and/or arguments under Article 94(3) EPC, Rule 71(1) EPC and Guidelines C-VI 4.3. Alternatively, at the choice of the Examiner, I am prepared to discuss the case during an informal telephone conversation. As an auxiliary measure only, oral proceedings are requested.

Yours faithfully,

/Magnus Johansson/

Professional Representative
AWAPATENT AB

Encl. Amended claims 1-6

The examination is being carried out on the **following application documents**:

Description, Pages

1-38 filed with entry into the regional phase before the EPO

Claims, Numbers

1-6 received on 23.01.2009 with letter of 21.01.2009

Drawings, Sheets

1/21-21/21 filed with entry into the regional phase before the EPO

1. In response to the letter of reply of 21.01.2009:

2. As is clear from the introduction of this application, in particular from paragraphs [0025] and [0026], the objective of the invention is to avoid problematic interactions between a turbo encoder output and puncturing in following rate matching stages.

Claims 1 and 4 as presently on file do not relate to this objective. They merely refer to undefined "systematic" and "parity" bit streams, which are not necessarily the result of turbo encoding. They also refer to "rate matching" without defining how the rate matching would be done in view of said objective.

Therefore, claims 1 and 4 are contrary to Art. 123(2) EPC.

3. Furthermore, claims 1 and 4 refer to "the number of bits" of the systematic and parity

bit streams, without defining what this means. In particular, claims 1 and 4 do not refer to any frame size, and therefore appear to refer to the total number of bits in bit streams that can in principle be infinitely long. Therefore claims 1 and 4 are contrary to Art. 123(2) EPC for this reason, too.

4. Claim 4 defines a "wireless transmit/receive unit" that comprises a virtual buffer that may be configured in two possible ways. Claims 4 does not define that the claimed device would be able to configure itself based on a virtual buffer size, so that it is not clear what claim 4 defines, contrary to Art. 84 EPC.

5. Claim 1 refers to "a portion" of interleaved streams, and to "at least one output of the virtual buffer". It is not clear what the basis is for this definition in the original application, which means that this aspect of claim 1 is contrary to Art. 123(2) EPC, likewise.

6. In view of the above objections, further examination under Art. 52(1) EPC is currently not feasible.

The attention of the applicant is drawn to the fact that the application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed (Article 123(2) EPC).

Dr. ir. M.P.J. van Staveren

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Application No.	Ref.	Date
03 796 549.8 - 1247		22.06.2009
Applicant: INTERDIGITAL TECHNOLOGY CORPORATION		

Communication pursuant to Article 94(3) EPC

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of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

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Van Staveren, Martin
Primary Examiner
For the Examining Division

Enclosure(s): 2 page/s reasons (Form 2906)

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Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

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Receiving Office	European Patent Office, The Hague
Your reference	PC-EP-21020363
Applicant	All applicants as on file
Documents submitted	package-data.xml epf1038.pdf (1 p.) CLMSPAMD-1.pdf\20090121_21020363_Replacement claims under R137(2).pdf (17 p.) ep-sfd-request.xml EPLETT-1.pdf\20090121_21020363_Communication re R137(2).pdf (1 p.)
Submitted by	CN=M. Johansson 6572,O=Awapatent AB,C=SE
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Correction by the EPO of errors in debit instructions filed by eOLF
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/European Patent Office/

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

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

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

$$\Delta = \left| \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lfloor \frac{7\hat{N}+1}{2} \right\rfloor} \right\} \right|$$, 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:

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

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

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

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(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.

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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:

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(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.

1. A method of rate matching comprising:

interleaving systematic bits;

interleaving a first parity bit stream;

interleaving a second parity bit stream;

buffering the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream in a virtual buffer when the number of bits of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream is not larger than the virtual buffer;

buffering a portion of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream when the number of bits of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream is larger than the virtual buffer; and

using a rate-matching unit to perform rate matching on at least one output of the virtual buffer.

2. The method of claim 1 wherein the buffered portion includes all of the interleaved systematic bits.

3. The method of claim 1 further comprising:

collecting bits associated with the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream.

4. A wireless transmit/receive unit, WTRU, comprising:

a first interleaver configured to interleave systematic bits;

a second interleaver configured to interleave a first parity bit stream;

a third interleaver configured to interleave a second parity bit stream;

a virtual buffer configured to buffer the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream when the number of bits of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream is not larger than the virtual buffer and configured to buffer a portion of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream when the number of bits of the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream is larger than the virtual buffer; and

a rate matching unit configured to perform rate matching on at least one output of the virtual buffer.

5. The WTRU of claim 4 wherein the buffered portion includes all of the interleaved systematic bits.

6. The WTRU of claim 4 further comprising:

a bit collection unit configured to collect bits associated with the interleaved systematic bits, the interleaved first parity bit stream and the interleaved second parity bit stream.

Helsingborg
21 January 2009

EUROPEAN PATENT OFFICE
DE-80298 MÜNCHEN

Handled by
Magnus Johansson/JTN

Our ref.
PC-EP-21020363

FILED VIA EPOLINE ONLINE FILING

European Patent Application No 03796549.8
in the name of INTERDIGITAL TECHNOLOGY CORPORATION

Dear Sirs,

Under Rule 137(2) EPC I hereby submit claims 1-6 as full replacement for claims 1-48 presently on file. The Applicant requests the right to file one or more divisional applications on any subject-matter of the application as originally filed.

Amendments

In the enclosed claim set, the following amendments have been made:
Claims 1-48 presently on file have been deleted.
New claims 1-6 have been added.
New claims 1-3 are supported by paragraph [0049] disclosing (with reference to Fig. 10) a schematic block diagram for a rate matching circuit and that "systematic bits, Parity 1 (P1) and Parity 2 (P2) bits are processed through the first rate matching stage 610, virtual IR buffer 615, a second rate matching stage 620 and bit collection circuit 625". Moreover, paragraphs [0084-0086] discloses that parity bits may be interleaved and that an additional interleaver may be provided for the systematic bits.
New claims 4-6 are supported by the same passages as claims 1-3 in combination with paragraph [0046] disclosing that the methods disclosed in the application may be implemented in a WTRU.

Yours faithfully,

/Magnus Johansson/

Professional Representative
AWAPATENT AB

Encl. - Replacement claims

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2009-01-23 8:07 mmdmjo01 Sent by: Magnus Johansson/AWAPATENT AB/EPOLINE PC-EP-21020363 Communication to EPO - Replace claims P1307.doc

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European Patent Office
Office européen des brevets

Letter accompanying subsequently filed items

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The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	03796549.8
Applicant's or representative's reference	PC-EP-21020363

	Description of document	Original file name	Assigned file name
1	Letter relating to the search and examination procedure	20090121_21020363_Communication re R137(2).pdf	EPLETT-1.pdf
2	Amended claims	20090121_21020363_Replacement claims under R137(2).pdf	CLMSPAMD-1.pdf

	Payment	
1	Mode of payment	Not specified

Annotations

Statement
The undersigned hereby declares that the subsequently filed items do NOT contain or are NOT intended to contain any communication relating either an appeal, an opposition, a limitation, a revocation proceeding or any proceedings for review (Special edition No. 3 OJ EPO 2007, A.4. Article 2(3) "Paragraph 1 shall not apply to documents in opposition proceedings, in European patent limitation or revocation proceedings, in appeal proceedings, or in proceedings for review by the Enlarged Board of Appeal of decisions of the boards of appeal.").

Signatures

Place:	**Helsingborg**
Date:	**23 January 2009**
Signed by:	**SE, Awapatent AB, M. Johansson 6572**
Capacity:	**(Representative)**

Europäisches Patentamt
European Patent Office
Office européen des brevets

Acknowledgement of receipt

We hereby acknowledge receipt of the following subsequently filed document(s):

Submission number	484854
Application number	EP03796549.8
Date of receipt	25 November 2008
Receiving Office	European Patent Office, The Hague
Your reference	PC-EP-21020363
Applicant	All applicants as on file
Documents submitted	package-data.xml epf1038.pdf (1 p.) ep-sfd-request.xml MEPA-1.pdf\20081125_21020363_Reply 70_2_.pdf (1 p.)
Submitted by	CN=M. Johansson 6572,O=Awapatent AB,C=SE
Method of submission	Online
Date and time receipt generated	25 November 2008, 14:11 (CET)
Message Digest	D0:8E:84:78:86:4C:2B:38:45:3C:30:F9:B6:AA:8D:B1:D7:80:5B:8D

Correction by the EPO of errors in debit instructions filed by eOLF
Errors in debit instructions filed by eOLF that are caused by the editing of Form 1038E entries or the continued use of outdated software (all forms) may be corrected automatically by the EPO, leaving the payment date unchanged (see decision T 152/82, OJ EPO 1984, 301 and point 6.3 ff ADA, Supplement to OJ EPO 10/2007).

/European Patent Office/

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Letter accompanying subsequently filed items

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The document(s) listed below is (are) subsequently filed documents pertaining to the following application:

Application number	03796549.8
Applicant's or representative's reference	PC-EP-21020363

	Description of document	Original file name	Assigned file name
1	Maintenance of the application	20081125_21020363_Reply 70_2_.pdf	MEPA-1.pdf

	Payment	
1	Mode of payment	Not specified

Annotations

Awapatent´s reference(Maria Kusmark; 20.8-.1-25)

1. Remark(Annotate)

Please note our reference in your registers: PC-EP-21020363.

Statement
The undersigned hereby declares that the subsequently filed items do NOT contain or are NOT intended to contain any communication relating either an appeal, an opposition, a limitation, a revocation proceeding or any proceedings for review (Special edition No. 3 OJ EPO 2007, A.4. Article 2(3) "Paragraph 1 shall not apply to documents in opposition proceedings, in European patent limitation or revocation proceedings, in appeal proceedings, or in proceedings for review by the Enlarged Board of Appeal of decisions of the boards of appeal.").

Signatures

Place:	**Helsingborg**
Date:	**25 November 2008**
Signed by:	**SE, Awapatent AB, M. Johansson 6572**
Capacity:	**(Representative)**

Helsingborg
25 November 2008

EUROPEAN PATENT OFFICE
DE-80298 MÜNCHEN

Handled by
Maria Kusmark

Our ref.
PC-EP-21020363

FILED VIA EPOLINE ONLINE FILING

European Patent Application No. 03796549.8
in the name of INTERDIGITAL TECHNOLOGY CORPORATION

Dear Sirs,

In reply to your Communication of 29.09.2008 pursuant to Rule 70 EPC, please proceed further with the European Patent Application.

Yours faithfully,

/Magnus Johansson/
Professional Representative
AWAPATENT AB

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2008-11-25 11:01 S:_Nokugammalt\WORD\MAGNUS\EPO\EP\PC-EP21020363_EPO2008112511_FILING.doc_Ready

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Date
29.09.08

Reference	Application No./Patent No.
	03796549.8 - 1247 / 1573923 PCT/US0338223

Applicant/Proprietor
INTERDIGITAL TECHNOLOGY CORPORATION

Proceeding further with the European patent application pursuant to Rule 70(2) EPC

A supplementary European search report has been drawn up concerning the above European patent application (publication number 1573923).

Since a request for examination has been filed (R. 70(1) EPC) and the examination fee has been paid (Art. 94(1) EPC) prior to the transmission of the supplementary European search report, you are hereby invited to indicate within

two months

of notification of this invitation whether you desire to proceed further with the European patent application.

If you do not indicate in due time that you desire to proceed further with the European patent application, it will be deemed to be withdrawn (R. 70(3) EPC).

If you wish you may comment on the supplementary European search report and amend, where appropriate, the description, claims and drawings (R. 70(2) EPC).

Receiving Section

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EPO Form 1224 12.07 DMEX

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Date
10.09.08

Reference	Application No./Patent No.
	03796549.8 - 1247 / 1573923 PCT/US0338223

Applicant/Proprietor
INTERDIGITAL TECHNOLOGY CORPORATION

Communication

The European Patent Office herewith transmits as an enclosure the supplementary European search report under Article 153(7) EPC for the above-mentioned European patent application.

If applicable, copies of the documents cited in the European search report are attached.

☑ Additional set(s) of copies of the documents cited in the European search report is (are) enclosed as well.

Refund of the search fee

If applicable under Article 9 Rules relating to fees, a separate communication from the Receiving Section on the refund of the search fee will be sent later.

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European Patent Office

SUPPLEMENTARY PARTIAL EUROPEAN SEARCH REPORT

which under Rule 63 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number EP 03 79 6549

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
D,A	3GPP: "3GPP TR 25.944"[Online] June 2001 (2001-06), pages 1-64, XP002492854 Retrieved from the Internet: URL:http://www.3gpp.org/ftp/specs/archive/25%5Fseries/25.944/> [retrieved on 2008-08-20] * the whole document *	1-48	INV. H03M13/35 H03M13/27
D,A	"Universal Mobile Telecommunications System (UMTS); Multiplexing and channel coding (TDD) (3GPP TS 25.222 version 3.8.0 Release 1999); ETSI TS 125 222" ETSI STANDARDS, LIS, SOPHIA ANTIPOLIS CEDEX, FRANCE, vol. 3-R1, no. V3.8.0, 1 March 2002 (2002-03-01), XP014008471 ISSN: 0000-0001 * the whole document *	1-48	

TECHNICAL FIELDS SEARCHED (IPC)

H03M

The supplementary search report has been based on the last set of claims valid and available at the start of the search.

INCOMPLETE SEARCH

The Search Division considers that the present application, or some or all of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for the following claims:

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

Place of search	Date of completion of the search	Examiner
The Hague	21 August 2008	Van Staveren, Martin

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04E20)

Claim(s) searched incompletely:
1-48

Reason for the limitation of the search:

According to the description (see paragraphs 59, 63, 68, 73, 97, ...) the invention relates to the modification of the DESIGN of a communication system. Par. 59: "modifying Table in TS25.212/222", par. 68: "implementing modification to the current FDD standard", etc. There is indeed no disclosure of a communication system that would be able to change puncturing patterns on the fly. The claims of this application however suggest that the communication system, during operation, would change its own specifications. The claims therefore contradict the disclosure and are therefore neither clear nor supported. The invention as disclosed is therefore understood as a method of modifying a technical standard, in particular as a method of modifying puncturing patterns in a technical standard such as the 3GPP TS 25.212 and 25.222. This is not a technical operation, and therefore the the claims, in sofar as they are understood in the light of the description, relate to non-patentable subject-matter (Art. 52(2)(c) EPC).

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Date
29.02.08

Reference	Application No./Patent No.
	03796549.8 - 1247
Applicant/Proprietor	
INTERDIGITAL TECHNOLOGY CORPORATION	

Communication of amended entries concerning the representative (R. 143(1)(h) EPC)

As requested, for the above-mentioned European patent application / European patent the entries concerning the representative have been amended as follows:

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The amendment will be recorded in the Register of European Patents.

Client Data Registration
Tel.: +49 (0)89 2399 2780

AWAPATENT®

Helsingborg
1 February 2008

EUROPEAN PATENT OFFICE
DE-80298 MÜNCHEN

Handled by
Mikael Andersson

Our ref.
Change of representative, LGD

EPO - Munich
23
25. Feb. 2008

Change of Professional Representative

Dear Sirs,

Please be informed of a change of representative in the following cases:

Application No.	Applicant	Former representative	New representative	Registration No. of new representative
06110604	FOSS Analytical AB	GRÖNLUND, Tim Linus Wilhelm	ÅKESSON, Jan-Åke	9204560
05112794	Axis AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
05112519	Emotron AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
05112140	Sudnif S. A.	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
05111247	Sudnif S. A.	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
05008246	REGATH AB	GRÖNLUND, Tim Linus Wilhelm	ÅKESSON, Jan-Åke	9204560
06110903	Hemocue AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
06115338	Hemocue AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
06100433	P Mantorp AB	GRÖNLUND, Tim Linus Wilhelm	GIVER, Sören	0079100
05017355	MOVING AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
05012005	HMS Industrial Networks AB	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9208840
05712317	Interdigital Technology Corporation	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9208840
04815476	Interdigital Technology Corporation	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9209290
04815069	Interdigital Technology Corporation	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9208840
04801721	FOSS Analytical AB	GRÖNLUND, Tim Linus Wilhelm	ÅKESSON, Jan-Åke	9204560
04819104	Interdigital Technology Corporation	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9208840
04817901	Interdigital Technology Corporation	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9208840
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04800968	Interdigital Technology Corporation	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9208840
04800340	Scalado AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
04795404	Interdigital Technology Corporation	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9208840
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04775563	HÖGANÄS AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
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04783975	Interdigital Technology Corporation	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9208840
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04754269	Kim, Tae Joon	GRÖNLUND, Tim Linus Wilhelm	ÅKESSON, Jan-Åke	9204560
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04723886	HÖGANÄS AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
04722495	HÖGANÄS AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
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04711075	BJÖRKEBO GÅRD AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670
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03783365	Interdigital Technology Corporation	GRÖNLUND, Tim Linus Wilhelm	JOHANSSON, Magnus	9208840
03797784	FOSS Analytical AB	GRÖNLUND, Tim Linus Wilhelm	ÅKESSON, Jan-Åke	9204560
03738869	Zi Decuma AB	GRÖNLUND, Tim Linus Wilhelm	MILANOV, Nina	0143670
03733810	FOSS Analytical AB	GRÖNLUND, Tim Linus Wilhelm	ÅKESSON, Jan-Åke	9204560
03733734	FOSS Analytical AB	GRÖNLUND, Tim Linus Wilhelm	ÅKESSON, Jan-Åke	9204560
03723561	Secumanagement B.V.	GRÖNLUND, Tim Linus Wilhelm	MILANOV, Nina	0143670
02773099	Secumanagement B.V.	GRÖNLUND, Tim Linus Wilhelm	MILANOV, Nina	0143670
00989155	Secumanagement B.V.	GRÖNLUND, Tim Linus Wilhelm	MILANOV, Nina	0143670
00989154	Secumanagement B.V.	GRÖNLUND, Tim Linus Wilhelm	MILANOV, Nina	0143670
00989153	Secumanagement B.V.	GRÖNLUND, Tim Linus Wilhelm	MILANOV, Nina	0143670
97935247	HÖGANÄS AB	GRÖNLUND, Tim Linus Wilhelm	ANDERSSON, Mikael	9203670

Skandinaviska Enskilda Banken AB (publ), Stockholm, Reg. No. 502032-9081, VAT No. SE502032908101

Yours faithfully,

GRÖNLUND, Linus

JOHANSSON, Magnus

ÅKESSON, Jan-Åke

ANDERSSON, Mikael

MILANOV, Nina

GIVER, Sören

MATTSSON, Niklas

AWAPATENT®

Helsingborg
2007-01-30

Handled by
Stefan Hjelmqwist

Our reference

EUROPEAN PATENT OFFICE
DE-80298 MÜNCHEN

EPO - Munich
28
02. Feb. 2007

New address of our Helsingborg office

Dear Sirs,

Please, be informed that our office in Helsingborg on February 5 is moving into new premises with the following address.

Postal address: **Box 1066, 251 10 Helsingborg**

Visiting address: **Järnvägsgatan 10 A, Helsingborg**

Our telephone and telefax numbers remains the same, namely +46 42 32 99 00 (telephone) and +46 42 32 99 01 (telefax).

Yours faithfully,

AWAPATENT AB

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Date
21.11.06

Reference	Application No./Patent No.
	03796549.8 - 2223 PCT/US0338223

Applicant/Proprietor
INTERDIGITAL TECHNOLOGY CORPORATION

Notification pursuant to part A-III, 5.3 of the Guidelines for Examination in the EPO

The communication issued pursuant to Rule 17(3) EPC, sent to the inventor designated below, has been returned by the postal services.
You are requested to indicate the correct address of the inventor (R. 17(1) EPC).

Inventor : PIETRASKI, Philip, J.
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Date
29.09.06

Reference	Application No./Patent No.
	03796549.8-2223-US0338223
Applicant/Proprietor	
INTERDIGITAL TECHNOLOGY CORPORATION	

Notification of the data mentioned in Article 128(5) EPC pursuant to Rule 17(3) EPC

In the above-identified patent application you are designated as inventor/co-inventor.
Pursuant to Rule 17(3) EPC the data as mentioned in Article 128(5) EPC are notified herewith:

DATE OF FILING	: 03.12.03
PRIORITY	: US/16.12.02/ USP 434232 : US/30.01.03/ USP 444068 : US/15.05.03/ USP 470921 : US/11.08.03/ USP 494404
TITLE	: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES
DESIGNATED STATES	: AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR

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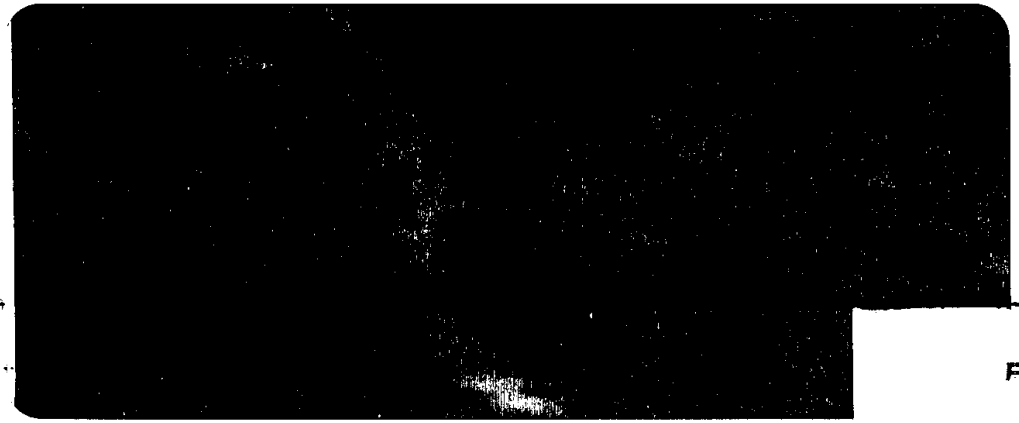
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17 OCT 2006

E. Verhulst



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Date
03.08.05

Reference	Application No./Patent No.
	03796549.8 - 2223 PCT/US0338223

Applicant/Proprietor
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Notification of European publication number and information on the application of Article 67(3) EPC

The provisional protection under Article 67(1) and (2) EPC in the individual contracting states becomes effective only when the conditions referred to in Article 67(3) EPC have been fulfilled (for further details, see information brochure of the European Patent Office "National Law relating to the EPC" and additional information in the Official Journal of the European Patent Office).

Pursuant to Article 158(1) EPC the publication under Article 21 PCT of an international application for which the European Patent Office is a designated Office takes the place of the publication of a European patent application.

The bibliographic data of the above-mentioned Euro-PCT application will be published on 14.09.05 in Section I.1 of the European Patent Bulletin. The European publication number is 1573923.

In all future communications to the European Patent Office, please quote the application number plus Directorate number.

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Date 27-07-2005

Reference	Application No./Patent No. 03796549.8 - 2223 PCT/US0338223
Applicant/Proprietor INTERDIGITAL TECHNOLOGY CORPORATION	

Communication pursuant to Rules 109 and 110 EPC

(1) Amendment of application documents, especially the claims (Rule 109 EPC)

The above mentioned international (Euro-PCT) application has entered the European phase, or can do so, once the necessary conditions are fulfilled.

Under Articles 28, 41 PCT, Rules 52, 78 PCT and Rule 86(2) to (4) EPC, the applicant may amend the application documents after receiving the international search report.

Whether or not he has already done so, he now has a further opportunity to file amended claims or other application documents within a non-extendable time limit of ONE MONTH after notification of the present communication (Rule 109 EPC).

The claims applicable on expiry of the above time limit, i.e. those filed on entry into the European phase or in response to the present communication, will form the basis for the calculation of any claims fee to be paid (see page 2) and for any supplementary search to be carried out under Article 157(2) EPC (Rule 109 EPC).

--2/

Registered letter
EPO Form 1226 01.02 EUCL

(2) Claims fees under Rule 110 EPC

If the application documents on which the European grant procedure is to be based comprise more than ten claims, a claims fee shall be payable for the eleventh and each subsequent claim within the period provided for in Rule 107(1) EPC.

☑ Based on the application documents currently on file, all necessary claims fees have already been paid (or the documents do not comprise more than 10 claims).

☐ All necessary fees will be/have been debited automatically according to the automatic debit order.

☐ The claims fee due for the claims ..... to ..... were not paid within the above-mentioned period.

Any non-paid claims fee, either based on the current set of claims or on any amended claims to be filed pursuant to Rule 109 EPC (see page 1), may still be validly paid within a non-extendable period of grace of **ONE MONTH** after notification of this communication.

If a payment is made for only some of the claims, it must be indicated for which claims it is intended. If a claims fee is not paid in due time, the claim concerned is deemed to be abandoned (Rule 110(4) EPC).

If claims fees have already been paid, but on expiry of the above-mentioned time limit there is a new set of claims containing fewer fee-incurring claims than previously, the claims fees in excess of those due under Rule 110(2), 2nd sentence, EPC will be refunded (Rule 110(3) EPC).

You are reminded that any supplementary search under Article 157(2) EPC will relate only to the last set of claims applicable on expiry of the above time limit AND will be confined to those fee-incurring claims for which fees have been paid in due time.

The fee for the eleventh and each subsequent claim is EUR 40,00.

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PATENT COOPERATION TREATY 30

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

WOLINSKY, Scott
Volpe and Koenig, P.C.
United Plaza, Suite 1600
30 South 17th Street
Philadelpha, PA 19103
United States of America

Date of mailing (day/month/year)
13 June 2005 (13.06.2005)

Applicant's or agent's file reference
I-2-0526.1WO

IMPORTANT NOTIFICATION

International application No.
PCT/US2003/038223

International filing date (day/month/year)
03 December 2003 (03.12.2003)

1. The following indications appeared on record concerning:

☐ the applicant ☒ the inventor ☐ the agent ☐ the common representative

Name and Address
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United States of America

State of Nationality | State of Residence
Telephone No.
Facsimile No.
Teleprinter No.

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

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Mt. Laurel, NJ 08054
United States of America

EPO-DG 1
05. 07. 2005

State of Nationality | State of Residence
Telephone No.
Facsimile No.
Teleprinter No.

3. Further observations, if necessary: TEAM 14

4. A copy of this notification has been sent to:

☒ the receiving Office
☐ the International Searching Authority
☐ the International Preliminary Examining Authority
☐ the designated Offices concerned
☒ the elected Offices concerned
☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No. (41-22) 338.71.30

Authorized officer
Miguel CORBEIRA (Fax 338-71-30)
Telephone No. (41-22) 338 9201

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

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

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

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

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.

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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:

(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.

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 Δ and the number of P2 bits is increased by Δ, 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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EPO - Munich
77
20. Juni 2005

An das Europäische Patentamt | To the European Patent Office | A l'office européen des brevets

Eintritt in die europäische Phase (EPA als Bestimmungsamt oder ausgewähltes Amt)

Entry into the European phase (EPO as designated or elected Office)

Entrée dans la phase européenne (l'OEB agissant en qualité d'office désigné ou élu)

Europäische Anmeldenummer oder, falls nicht bekannt, PCT-Aktenzeichen oder PCT-Veröffentlichungsnummer	European application number, or, if not known, PCT application or publication number **03796549.8**	Numéro de dépôt de la demande de brevet européen ou, à défaut, numéro de dépôt PCT ou de publication PCT
Zeichen des Anmelders oder Vertreters (max. 15 Positionen)	Applicant's or representative's reference (max. 15 spaces) **PC-EP-21020363**	Référence du demandeur ou du mandataire (15 caractères ou espaces au maximum)

☒ **1. Anmelder**
Die Angaben über den (die) Anmelder sind in der internationalen Veröffentlichung enthalten oder vom Internationalen Büro nach der internationalen Veröffentlichung vermerkt worden.

☐ Änderungen, die das Internationale Büro noch nicht vermerkt hat, sind auf einem Zusatzblatt angegeben.

Zustellanschrift
(siehe Merkblatt II, 1)

1. Applicant
Indications concerning the applicant(s) are contained in the international publication or recorded by the International Bureau after the international publication.

Changes which have not yet been recorded by the International Bureau are set out on an additional sheet.

Address for correspondence
(see Notes II, 1)

1. Demandeur
Les indications concernant le(s) demandeur(s) figurent dans la publication internationale ou ont été enregistrées par le Bureau international après la publication internationale.

Les changements qui n'ont pas encore été enregistrés par le Bureau international sont indiqués sur une feuille additionnelle.

Adresse pour la correspondance
(voir notice II, 1)

E4207 - CA Zur Kasse

2. Vertreter

Name (Nur einen Vertreter angeben, der in das europäische Patentregister eingetragen und an den zugestellt wird)

Geschäftsanschrift

Telefon

Telefax **Telex**

☐ Weitere(r) Vertreter auf Zusatzblatt

2. Representative

Name (Name **only one** representative who will be listed in the Register of European Patents and to whom notification will be made)
Linus Grönlund

Address of place of business
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Sweden

Telephone
+46 42 329900

Fax **Telex**
+46 42 329901

Additional representative(s) on additional sheet

2. Mandataire

Nom (N'indiquer **qu' un seul** mandataire, qui sera inscrit au Registre européen des brevets et auquel signification sera faite)

Adresse professionnelle

Téléphone

Téléfax **Télex**

Autre(s) mandataire(s) sur une feuille additionnelle

3. Vollmacht

☐ Einzelvollmacht ist beigefügt.

☒ Allgemeine Vollmacht ist registriert unter Nummer:

☐ Allgemeine Vollmacht ist eingereicht, aber noch nicht registriert.

☐ Die beim EPA als PCT-Anmeldeamt eingereichte Vollmacht schließt ausdrücklich die europäische Phase ein.

3. Authorisation

Individual authorisation is attached.

General authorisation has been registered under No:

47108

A general authorisation has been filed, but not yet registered.

The authorisation filed with the EPO as PCT receiving Office expressly includes the European phase.

3. Pouvoir

Un pouvoir spécial est joint.

Un pouvoir général a été enregistré sous le n°:

Un pouvoir général a été déposé, mais n'est pas encore enregistré.

Le pouvoir général déposé à l'OEB agissant en qualité d'office récepteur au titre du PCT s'applique expressément à la phase européenne.

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☒ **4. Prüfungsantrag**
Hiermit wird die Prüfung der Anmeldung gemäß Art. 94 EPÜ beantragt. Die Prüfungsgebühr wird (wurde) entrichtet.

Prüfungsantrag in einer zugelassenen Nichtamtssprache (siehe Merkblatt III, 5.2):

4. Request for examination
Examination of the application under Art. 94 EPC is hereby requested. The examination fee is being (has been, will be) paid.

Request for examination in an admissible non-EPO language (see Notes III, 5.2):

4. Requête en examen
Il est demandé que soit examinée la demande de brevet conformément à l'art. 94 CBE. Il est (a été, sera) procédé au paiement de la taxe d'examen.

Requête en examen dans une langue non officielle autorisée (voir notice III, 5.2):

☒ **5. Abschriften**
Zusätzliche Abschrift(en) der im ergänzenden europäischen Recherchenbericht angeführten Schriftstücke wird (werden) beantragt.

Anzahl der **zusätzlichen** Sätze von Abschriften

5. Copies
Additional copy (copies) of the documents cited in the supplementary European search report is (are) requested.

Number of **additional** sets of copies

1

5. Copies
Prière de fournir une ou plusieurs copies supplémentaires des documents cités dans le rapport complémentaire de recherche européenne.

Nombre de jeux **supplémentaires** de copies

6. Für das Verfahren vor dem EPA bestimmte Unterlagen

6.1 Dem Verfahren vor dem EPA als **Bestimmungsamt** (PCT I) sind folgende Unterlagen zugrunde zu legen:

☒ die vom Internationalen Büro **veröffentlichten Anmeldungsunterlagen** (mit **allen** Ansprüchen, Beschreibung und Zeichnungen), gegebenenfalls mit den geänderten Ansprüchen nach Art. 19 PCT

☐ soweit sie nicht ersetzt werden durch die beigefügten **Änderungen.**

Falls nötig, sind Klarstellungen auf einem Zusatzblatt einzureichen !

6.2 Dem Verfahren vor dem EPA als **ausgewähltem Amt** (PCT II) sind folgende Unterlagen zugrunde zu legen:

☒ die dem **internationalen vorläufigen Prüfungsbericht zugrunde gelegten Unterlagen,** einschließlich seiner eventuellen **Anlagen**
(Solche Anlagen müssen immer beigefügt werden)

☐ soweit sie nicht ersetzt werden durch die beigefügten **Änderungen.**

Falls nötig, sind Klarstellungen auf einem Zusatzblatt einzureichen!

☒ Sind dem EPA als mit der internationalen vorläufigen Prüfung beauftragten Behörde **Versuchsberichte** zugegangen, dürfen diese dem Verfahren vor dem EPA zugrunde gelegt werden.

6. Documents intended for proceedings before the EPO

6.1 Proceedings before the EPO as **designated Office** (PCT I) are to be based on the following documents:

the **application documents published** by the International Bureau (with **all** claims, description and drawings), where applicable with amended claims under Art. 19 PCT

unless replaced by the **amendments** enclosed.

Where necessary, clarifications must be submitted on a separate sheet!

6.2 Proceedings before the EPO as **elected Office** (PCT II) are to be based on the following documents:

the **documents on which the international preliminary examination report is based,** including its possible **annexes**
(Such annexes must always be filed)

unless replaced by the **amendments** enclosed.

Where necessary, clarifications must be submitted on a separate sheet!

If the EPO as International Preliminary Examining Authority has received **test reports**, these may be used as the basis of proceedings before the EPO.

6. Pièces destinées à la procédure devant l'OEB

6.1 La procédure devant l'OEB agissant en qualité **d'office désigné** (PCT I) doit se fonder sur les pièces suivantes:

les **pièces de la demande publiée** par le Bureau international (avec **toutes** les revendications, la description et les dessins), éventuellement avec les revendications modifiées conformément à l'article 19 du PCT

dans la mesure où elles ne sont pas remplacées par les **modifications** jointes.

Le cas échéant, des explications doivent être jointes sur une feuille additionnelle!

6.2 La procédure devant l'OEB **agissant en qualité d'office élu** (PCT II) doit se fonder sur les pièces suivantes :

les **pièces sur lesquelles se fonde le rapport d'examen préliminaire international,** y compris ses **annexes** éventuelles
(De telles annexes sont toujours à joindre)

dans la mesure où elles ne sont pas remplacées par les **modifications** jointes.

Le cas échéant, des explications doivent être jointes sur une feuille additionnelle!

Si l'OEB, agissant en qualité d'administration chargée de l'examen préliminaire international, a reçu des **rapports d'essais**, ceux-ci peuvent constituer la base de la procédure devant l'OEB.

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	7. Übersetzungen Beigefügt sind die nachfolgend angekreuzten Übersetzungen in einer der Amtssprachen des EPA (Deutsch, Englisch, Französisch):	**7. Translations** Translations in one of the official languages of the EPO (English, French, German) are enclosed as crossed below:	**7. Traductions** Vous trouverez, ci-joint, les traductions cochées ci-après dans l'une des langues officielles de l'OEB (allemand, anglais, français):
	• *Im Verfahren vor dem EPA als **Bestimmungsamt oder ausgewähltem Amt** (PCT I+II):*	• *In proceedings before the EPO as **designated or elected Office** (PCT I + II):*	• *Dans la procédure devant l'OEB agissant en qualité **d'office désigné ou élu** (PCT I + II):*
☐	Übersetzung der **ursprünglich eingereichten internationalen Anmeldung** (Beschreibung, Ansprüche, etwaige Textbestandteile in den Zeichnungen), der veröffentlichten Zusammenfassung, und etwaiger Angaben über biologisches Material nach Regel 13bis.3 und 13bis.4 PCT	Translation of the **international application** (description, claims, any text in the drawings) **as originally filed**, of the abstract as published and of any indication under Rule 13bis.3 and 13bis.4 PCT regarding biological material	Traduction de la **demande internationale telle que déposée initialement** (description, revendications, textes figurant éventuellement dans les dessins), de l'abrégé publié, et de toutes indications visées aux règles 13bis.3 et 13bis.4 du PCT concernant le matériel biologique
☐	Übersetzung der **prioritätsbegründenden Anmeldung(en)**	Translation of **the priority application(s)**	Traduction de la (des) **demande(s) ouvrant le droit de priorité**
☐	Es wird hiermit erklärt, daß die internationale Anmeldung in ihrer ursprünglich eingereichten Fassung eine vollständige Übersetzung der früheren Anmeldung ist (Regel 38(5) EPÜ)	It is hereby declared that the international application as originally filed is a complete translation of the previous application (Rule 38(5) EPC)	Il est déclaré par la présente que la demande internationale telle que déposée initialement est une traduction intégrale de la demande antérieure (règle 38(5) CBE)
	• ***Zusätzlich** im Verfahren vor dem EPA als **Bestimmungsamt** (PCT I):*	• ***In addition**, in proceedings before the EPO as **designated Office** (PCT I):*	• ***De plus**, dans la procédure devant l'OEB agissant en qualité **d'office désigné** (PCT I):*
☐	Übersetzung der nach Art. 19 PCT **geänderten Ansprüche** nebst Erklärung, falls diese dem Verfahren vor dem EPA zugrunde gelegt werden sollen (siehe Feld 6)	Translation of **amended claims** and any statement under Art. 19 PCT, if the claims as amended are to form the basis for the proceedings before the EPO (see Section 6)	Traduction des **revendications modifiées** et de la déclaration faite conformément à l'article 19 du PCT, si la procédure devant l'OEB doit être fondée sur les revendications modifiées (voir la rubrique 6)
	• ***Zusätzlich** im Verfahren vor dem EPA als **ausgewähltem Amt** (PCT II):*	• ***In addition**, in proceedings before the EPO as **elected office** (PCT II):*	• ***De plus**, dans la procédure devant l'OEB agissant en qualité **d'office élu** (PCT II):*
☐	Übersetzung der **Anlagen zum internationalen vorläufigen Prüfungsbericht**	Translation of any **annexes to the international preliminary examination report**	Traduction des **annexes du rapport d'examen préliminaire international**
☐	**8. Biologisches Material** Die Erfindung bezieht sich auf bzw. verwendet biologisches Material, das nach Regel 28 EPÜ hinterlegt worden ist.	**8. Biological material** The invention relates to and/or uses biological material deposited under Rule 28 EPC.	**8. Matière biologique** L'invention concerne et/ou utilise de la matière biologique, déposée conformément à la règle 28 CBE.
☐	Die **Angaben nach Regel 28(1)c) EPÜ** (falls noch nicht bekannt, die Hinterlegungsstelle und das (die) Bezugszeichen [Nummer, Symbole usw.] des Hinterlegers) sind in der internationalen Veröffentlichung oder in der gemäß Feld 7 eingereichten Übersetzung enthalten auf: Seite(n) / Zeile(n)	The **particulars referred to in Rule 28(1)(c) EPC** (if not yet known, the depository institution and the identification references(s) [number, symbols, etc.] of the depositor) are given in the international publication or in the translation submitted under Section 7 on: page(s) / line(s)	Les **indications visées à la règle 28(1)c) CBE** (si non encore connues, l'autorité de dépôt et la (les) référence(s) d'identification [numéro ou symboles etc.] du déposant) figurent dans la publication internationale ou dans une traduction produite conformément à la rubrique 7 à la / aux: page(s) / ligne(s)
	Die **Empfangsbescheinigung(en)** der Hinterlegungsstelle	The **receipt(s) of deposit** issued by the depositary institution	Le(s) **récépissé(s) de dépôt** délivré(s) par l'autorité de dépôt
☐	ist (sind) beigefügt	is (are) enclosed	est (sont) joint(s)
☐	wird (werden) nachgereicht	will be filed at a later date	sera (seront) produit(s) ultérieurement
☐	Verzicht auf die Verpflichtung des Antragstellers nach Regel 28(3) EPÜ auf gesondertem Schriftstück	Waiver of the right to an undertaking from the requester pursuant to Rule 28(3) EPC attached.	Renonciation, sur document distinct, à l'engagement du requérant au titre de la règle 28(3) CBE.

9. Nucleotid- und Aminosäuresequenzen

☐ Die nach Regeln 5.2 und 13ter PCT sowie Regel 111(3) EPÜ erforderlichen Unterlagen liegen dem EPA bereits vor.

☐ Das schriftliche Sequenzprotokoll wird anliegend nachgereicht.

☐ Das Sequenzprotokoll geht nicht über den Inhalt der Anmeldung in der ursprünglich eingereichten Fassung hinaus.

☐ Der vorgeschriebene Datenträger ist beigefügt.

☐ Die auf dem Datenträger gespeicherte Information stimmt mit dem schriftlichen Sequenzprotokoll überein.

9. Nucleotide and amino acid sequences

The items necessary in accordance with Rules 5.2 and 13ter PCT and Rule 111(3) EPC have already been furnished to the EPO.

The written sequence listing is furnished herewith.

The sequence listing does not include matter which goes beyond the content of the application as filed.

The prescribed data carrier is enclosed.

The information recorded on the data carrier is identical to the written sequence listing.

9. Séquences de nucléotides et d'acides aminés

Les pièces requises selon les règles 5.2 et 13ter PCT et la règle 111(3) CBE ont déjà été déposées auprès de l'OEB.

La liste de séquences écrite est produite ci-joint.

La liste de séquences ne contient pas d'éléments s'étendant au-delà du contenu de la demande telle qu'elle a été déposée.

Le support de données prescrit est joint.

L'information figurant sur le support de données est identique à celle que contient la liste de séquences écrite.

10. Benennungsgebühren

☒ 10.1 Es ist derzeit beabsichtigt, den **siebenfachen** Betrag einer Benennungsgebühr zu entrichten. Damit gelten die Benennungsgebühren für **alle Vertragsstaaten des EPÜ**[1] als entrichtet (Art. 2 Nr. 3 GebO), soweit sie **in der internationalen Anmeldung** bestimmt sind[2].

☐ 10.2 Abweichend von der Erklärung in Nr. 10.1 ist derzeit beabsichtigt, **weniger als sieben** Benennungsgebühren für folgende **in der internationalen Anmeldung bestimmte Vertragsstaaten des EPÜ**[2] zu entrichten:

(1) ☐ ____ (4) ☐ ____

(2) ☐ ____ (5) ☐ ____

(3) ☐ ____ (6) ☐ ____

Soweit unter Nr. 10.2 Vertragstaaten aufgeführt sind, wird beantragt, für die dort nicht angeführten Vertragsstaaten von der Zustellung einer Mitteilungen nach Regel 108(3) EPÜ abzusehen.

☐ 10.3 Wird ein **automatischer Abbuchungsauftrag** erteilt (Feld 12), so wird das EPA beauftragt, bei Ablauf der Grundfrist nach Regel 107 (1)d) EPÜ den siebenfachen Betrag einer Benennungsgebühr abzubuchen. Ist eine Erklärung nach Nr. 10.2 abgegeben worden, so sollen die Benennungsgebühren nur für die dort angegebenen Vertragsstaaten abgebucht werden, sofern dem EPA nicht bis zum Ablauf der Grundfrist ein anderslautender Auftrag zugeht.

10. Designation fees

10.1 It is currently intended to pay **seven times** the amount of the designation fee. The designation fees for **all the EPC contracting states**[1] **designated in the international application**[2] are thereby deemed to have been paid (Art. 2 No. 3 RFees).

10.2 The declaration in No. 10.1 does not apply. Instead, it is currently intended to pay **fewer the seven** designation fees for the following **EPC contracting states**[2] **designated in the international application:**

If contracting states are indicated under No. 10.2, it is requested that no communication under Rule 108(3) EPC be issued for contracting states not thus indicated.

10.3 If an **automatic debit order** has been issued (Section 12), the EPO is authorised, on expiry of the basic period under Rule 107(1)(d) EPC, to debit seven times the amount of the designation fee. If states are indicated under No. 10.2, the EPO will debit designation fees only for those states, unless instructed otherwise before the basic period expires.

10. Taxes de désignation

10.1 Il est actuellement envisagé de payer un montant correspondant à **sept fois** la taxe de désignation. Les taxes de désignation sont ainsi réputées payées pour **tous les Etats contractants de la CBE**[1] **désignés dans la demande internationale**[2] (art. 2, point 3 du RRT).

10.2 Contrairement à ce qui est indiqué au n° 10.1, il est actuellement envisagé de payer **moins de sept** taxes de désignation pour les **Etats contractants de la CBE**[2] suivants **désignés dans la demande internationale:**

Si des Etats contractants sont mentionnés au n° 10.2, prière de ne pas procéder à la signification d'une notifications prévue par la règle 108(3) CBE pour les Etats contractants n'y étant pas mentionnés.

10.3 Si un **ordre de prélèvement automatique** est donné (rubrique 12), il est demandé à l'OEB de prélever, à l'expiration du délai normal visé à la règle 107(1)d) CBE, un montant correspondant à sept fois la taxe de désignation. Si une déclaration a été faite au n° 10.2, les taxes de désignation ne sont à prélever que pour les Etats contractants qui y sont indiqués, sauf instruction contraire reçue par l'OEB avant l'expiration du délai normal.

1 Stand bei Drucklegung: 27 Vertragsstaaten, und zwar: / Status when this form was printed: 27 contracting states, namely / Situation à la date d'impression : 27 Etats contractants, à savoir: **AT** Österreich / Austria / Autriche, **BE** Belgien / Belgium / Belgique, **BG** Bulgarien / Bulgaria / Bulgarie, **CH/LI** Schweiz und Liechtenstein / Switzerland and Liechtenstein / Suisse et Liechtenstein, **CY** Zypern / Cyprus / Chypre, **CZ** Tschechische Republik / Czech Republic / République tchèque, **DE** Deutschland / Germany / Allemagne, **DK** Dänemark / Denmark / Danemark, **EE** Estland / Estonia / Estonie, **ES** Spanien / Spain / Espagne, **FI** Finnland / Finland / Finlande, **FR** Frankreich / France / France, **GB** Vereinigtes Königreich / United Kingdom / Royaume-Uni, **GR** Griechenland / Greece / Grèce, **HU** Ungarn / Hungary / Hongrie, **IE** Irland / Ireland / Irlande, **IT** Italien / Italy / Italie, **LU** Luxemburg / Luxembourg / Luxembourg, **MC** Monaco / Monaco / Monaco, **NL** Niederlande / Netherlands / Pays-Bas, **PT** Portugal / Portugal / Portugal, **RO** Rumänien / Romania / Roumanie, **SE** Schweden / Sweden / Suède, **SI** Slowenien / Slovenia / Slovénie, **SK** Slowakische Republik / Slovak Republic / République slovaque, **TR** Türkei / Turkey / Turquie

2 Für folgende Staaten nur möglich, falls in der internationalen Anmeldung am oder nach folgendem Tag bestimmt: Slowakische Republik, Bulgarien, Tschechische Republik und Estland: 1. Juli 2002, Slowenien: 1 Dezember 2002, Ungarn: 1 Januar 2003 und Rumänien: 1 März 2003. / For the following states this is possible only if they are designated in the international application on or after the stated date: Slovak Republic, Bulgaria, Czech Republic and Estonia: 1 July 2002, Slovenia: 1 December 2002, Hungary: 1 January 2003 and Romania: 1 March 2003. / En ce qui concerne les Etats suivants seulement si la désignation a été effectuée dans la demande internationale à la date suivante ou à une date ultérieure: République slovaque, Bulgarie, République tchèque et Estonie: 1er juillet 2002, Slovénie: 1er décembre2002, Hongrie: 1er janvier 2003 et Roumanie: 1er mars 2003

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☒ **11. Erstreckung des europäischen Patents**
Bei Zahlung der Erstreckungsgebühr(en) gilt diese Anmeldung auch als wirksamer Erstreckungsantrag für die in der internationalen Anmeldung bestimmten »Erstreckungsstaaten«.
Es ist beabsichtigt, diese Gebühr(en) für folgende Staaten zu entrichten:

11. Extension of the European patent
On payment of the extension fee(s) this application is also deemed to be a request for extension to all the "extension states" designated in the international application. It is intended to pay the fee(s) for the following states:

11. Extension des effets du brevet européen
La taxe (Les taxes) d'extension payée(s), la présente demande est également réputée être une demande d'extension à tous les «Etats autorisant l'extension» désignés dans la demande internationale. Il est envisagé de payer la taxe (les taxes) d'extension pour les Etats suivants:

☐	SI	Slowenien [1]	Slovenia [1]	Slovénie [1]
☐	LT	Litauen	Lithuania	Lituanie
☐	LV	Lettland	Latvia	Lettonie
☐	AL	Albanien	Albania	Albanie
☐	RO	Rumänien [1]	Romania [1]	Roumanie [1]
☐	MK	Ehemalige jugoslawische Republik Mazedonien	Former Yugoslav Republic of Macedonia	Ex-République yougoslave de Macédoine
☐	___	_____ [2]	_____ [2]	_____ [2]

1) Für Slowenien und Rumänien nur möglich, falls in der internationalen Anmeldung bis 30. November 2002 (Slowenien) oder bis 28. Februar 2003 (Rumänien) bestimmt. / For Slovenia and Romania this is possible only if they are designated in the international application up to 30 Novmeber 2002 (Slovenia) or 28 February 2003 (Romania). / En ce qui concerne la Slovénie et la Roumanie, seulement si la désignation a été effectuée dans la demande internationale jusqu'au 30 novembre 2002 (Slovénie) ou jusqu'au 28 février 2003 (Roumanie).

2) Platz für Staaten, mit denen »Erstreckungsabkommen« nach Drucklegung dieses Formblatts in Kraft treten und die in der internationalen Anmeldung bestimmt waren. / Space for States with which "extension agreements" enter into force after this form has been printed and which were designated in the international application. / Prévu pour des Estats à l'égard desquels des «accords d'extension» entreront en vigueur après l'impression du présent formulaire et qui ont été désignés dans la demande internationale.

12. Automatischer Abbuchungsauftrag ***(Nur möglich für Inhaber von beim EPA geführten laufenden Konten)***

☐ Das EPA wird beauftragt, nach Maßgabe der Vorschriften über das automatische Abbuchungsverfahren fällige Gebühren und Auslagen vom untenstehenden laufenden Konto abzubuchen. Im Bezug auf **die Benennungsgebühren** wird auf Feld 10.3 verwiesen. Das EPA wird ferner beauftragt, die **Erstreckungsgebühren** für jeden in Feld 11 angekreuzten »Erstreckungsstaat« bei Ablauf der Grundfrist zu ihrer Zahlung abzubuchen, sofern ihm nicht bis dahin ein anderslautender Auftrag zugeht.

Nummer und Kontoinhaber

_____

12. Automatic debit order ***(for EPO deposit account holders only)***

The EPO is hereby authorised, under the Arrangements for the automatic debiting procedure, to debit from the deposit account below any fees and costs falling due. **For designation fees**, see Section 10.3. The EPO is also authorised, on expiry of the basic period for paying the **extension fees**, to debit those fees for each of the "extension states" marked with a cross in Section 11, unless instructed otherwise before the said period expires.

Number and account holder

_____

12. Ordre de prélèvement automatique ***(uniquement possible pour les titulaires de comptes courants ouverts auprès de l'OEB)***

Par la présente, il est demandé à l'OEB de prélever du compte courant ci-dessous les taxes et frais venant à échéance, conformément à la réglementation relative au prélèvement automatique. Pour les **taxes de désignation**, se reporter à la rubrique 10.3. Il est en outre demandé à l'OEB de prélever, à l'expiration du délai normal prévu pour leur paiement, les **taxes d'extension** pour chaque « Etat autorisant l'extension» coché à la rubrique 11, sauf instruction contraire reçue avant l'expiration de ce délai.

Numéro et titulaire du compte

_____

☒ **13. Eventuelle Rückzahlungen** auf das beim EPA geführte laufende Konto

Nummer und Kontoinhaber

_____

13. Any reimbursement to EPO deposit account

Number and account holder

2810 0022 AWAPATENT AB

13. Remboursements éventuels à effectuer sur le compte courant ouvert auprès de l'OEB
Numéro et titulaire du compte

_____

14. Unterschrift(en) des (der) Anmelder(s) oder Vertreters

Ort / Datum
Für Angestellte (Art. 133(3) EPÜ) mit allgemeiner Vollmacht:

Nr. _____

Name(n) des (der) Unterzeichneten bitte in Druckschrift wiederholen. Bei juristischen Personen bitte auch die Stellung des (der) Unterzeichneten innerhalb der Gesellschaft in Druckschrift angeben.

14. Signature(s) of applicant(s) or representative

Lindis Grönlund

Place / Date Helsingborg 2005-06-17
For employees (Art. 133(3) EPC) having a general authorisation:

No. _____

Please print name(s) under signature(s). In the case of legal persons, the position of the signatory within the company should also be printed.

14. Signature(s) du (des) demandeur(s) ou du mandataire

Lieu / Date
Pour les employés (art. 133(3) CBE) disposant d'un pouvoir général:

N° _____

Le ou les noms des signataires doivent être indiqués en caractères d'imprimerie. S'il s'agit d'une personne morale, la position occupée au sein de celle-ci par le ou les signataires doit également être indiquée en caractères d'imprimerie.

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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

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 Δ and the number of P2 bits is increased by Δ, 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.

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:

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(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

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

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

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(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

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

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(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.

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An das Europäische Patentamt | To the European Patent Office | A l'office européen des brevets

Eintritt in die europäische Phase (EPA als Bestimmungsamt oder ausgewähltes Amt)

Entry into the European phase (EPO as designated or elected Office)

Entrée dans la phase européenne (l'OEB agissant en qualité d'office désigné ou élu)

Europäische Anmeldenummer oder, falls nicht bekannt, PCT-Aktenzeichen oder PCT-Veröffentlichungsnummer	European application number, or, if not known, PCT application or publication number **03796549.8**	Numéro de dépôt de la demande de brevet européen ou, à défaut, numéro de dépôt PCT ou de publication PCT
Zeichen des Anmelders oder Vertreters (max. 15 Positionen)	Applicant's or representative's reference (max. 15 spaces) **PC-EP-Z1020363**	Référence du demandeur ou du mandataire (15 caractères ou espaces au maximum)
☒ **1. Anmelder** Die Angaben über den (die) Anmelder sind in der internationalen Veröffentlichung enthalten oder vom Internationalen Büro nach der internationalen Veröffentlichung vermerkt worden.	**1. Applicant** Indications concerning the applicant(s) are contained in the international publication or recorded by the International Bureau after the international publication.	**1. Demandeur** Les indications concernant le(s) demandeur(s) figurent dans la publication internationale ou ont été enregistrées par le Bureau international après la publication internationale.
☐ Änderungen, die das Internationale Büro noch nicht vermerkt hat, sind auf einem Zusatzblatt angegeben.	Changes which have not yet been recorded by the International Bureau are set out on an additional sheet.	Les changements qui n'ont pas encore été enregistrés par le Bureau International sont indiqués sur une feuille additionnelle.
Zustellanschrift *(siehe Merkblatt II, 1)*	**Address for correspondence** *(see Notes II, 1)*	**Adresse pour la correspondance** *(voir notice II, 1)*
2. Vertreter **Name** (Nur einen Vertreter angeben, der in das europäische Patentregister eingetragen und an den zugestellt wird)	**2. Representative** **Name** (Name **only one** representative who will be listed in the Register of European Patents and to whom notification will be made) **Linus Grönlund**	**2. Mandataire** **Nom** (N'indiquer **qu'un seul** mandataire, qui sera inscrit au Registre européen des brevets et auquel signification sera faite)
Geschäftsanschrift	**Address of place of business** **AWAPATENT AB** **Berga Allé 1** **SE-254 54 Helsingborg** **Sweden**	**Adresse professionnelle**
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☐ Weitere(r) Vertreter auf Zusatzblatt	Additional representative(s) on additional sheet	Autre(s) mandataire(s) sur une feuille additionnelle
3. Vollmacht	**3. Authorisation**	**3. Pouvoir**
☐ Einzelvollmacht ist beigefügt.	Individual authorisation is attached.	Un pouvoir spécial est joint.
☒ Allgemeine Vollmacht ist registriert unter Nummer:	General authorisation has been registered under No: **47108**	Un pouvoir général a été enregistré sous le n°:
☐ Allgemeine Vollmacht ist eingereicht, aber noch nicht registriert.	A general authorisation has been filed, but not yet registered.	Un pouvoir général a été déposé, mais n'est pas encore enregistré.
☐ Die beim EPA als PCT-Anmeldeamt eingereichte Vollmacht schließt ausdrücklich die europäische Phase ein.	The authorisation filed with the EPO as PCT receiving Office expressly includes the European phase.	Le pouvoir général déposé à l'OEB agissant en qualité d'office récepteur au titre du PCT s'applique expressément à la phase européenne.

Zur Kasse
€420,- (A)

☒ **4. Prüfungsantrag**
Hiermit wird die Prüfung der Anmeldung gemäß Art. 94 EPÜ beantragt. Die Prüfungsgebühr wird (wurde) entrichtet.

Prüfungsantrag in einer zugelassenen Nichtamtssprache (siehe Merkblatt III, 5.2):

4. Request for examination
Examination of the application under Art. 94 EPC is hereby requested. The examination fee is being (has been, will be) paid.

Request for examination in an admissible non-EPO language (see Notes III, 5.2):

4. Requête en examen
Il est demandé que soit examinée la demande de brevet conformément à l'art. 94 CBE. Il est (a été, sera) procédé au paiement de la taxe d'examen.

Requête en examen dans une langue non officielle autorisée (voir notice III, 5.2):

☒ **5. Abschriften**
Zusätzliche Abschrift(en) der im ergänzenden europäischen Recherchenbericht angeführten Schriftstücke wird (werden) beantragt.

Anzahl der zusätzlichen Sätze von Abschriften

5. Copies
Additional copy (copies) of the documents cited in the supplementary European search report is (are) requested.

Number of additional sets of copies

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Prière de fournir une ou plusieurs copies supplémentaires des documents cités dans le rapport complémentaire de recherche européenne.

Nombre de jeux supplémentaires de copies

6. Für das Verfahren vor dem EPA bestimmte Unterlagen

6.1 Dem Verfahren vor dem EPA als **Bestimmungsamt** (PCT I) sind folgende Unterlagen zugrunde zu legen:

☒ die vom Internationalen Büro veröffentlichten Anmeldungsunterlagen (mit allen Ansprüchen, Beschreibung und Zeichnungen), gegebenenfalls mit den geänderten Ansprüchen nach Art. 19 PCT

☐ soweit sie nicht ersetzt werden durch die beigefügten Änderungen.

Falls nötig, sind Klarstellungen auf einem Zusatzblatt einzureichen !

6.2 Dem Verfahren vor dem EPA als **ausgewähltem Amt** (PCT II) sind folgende Unterlagen zugrunde zu legen:

☒ die dem internationalen vorläufigen Prüfungsbericht zugrunde gelegten Unterlagen, einschließlich seiner eventuellen Anlagen
(Solche Anlagen müssen immer beigefügt werden)

☐ soweit sie nicht ersetzt werden durch die beigefügten Änderungen.

Falls nötig, sind Klarstellungen auf einem Zusatzblatt einzureichen!

☒ Sind dem EPA als mit der internationalen vorläufigen Prüfung beauftragten Behörde Versuchsberichte zugegangen, dürfen diese dem Verfahren vor dem EPA zugrunde gelegt werden.

6. Documents intended for proceedings before the EPO

6.1 Proceedings before the EPO as **designated Office** (PCT I) are to be based on the following documents:

the **application documents published** by the International Bureau (with all claims, description and drawings), where applicable with amended claims under Art. 19 PCT

unless replaced by the **amendments** enclosed.

Where necessary, clarifications must be submitted on a separate sheet!

6.2 Proceedings before the EPO as **elected Office** (PCT II) are to be based on the following documents:

the **documents on which the international preliminary examination report is based**, including its possible **annexes**
(Such annexes must always be filed)

unless replaced by the **amendments** enclosed.

Where necessary, clarifications must be submitted on a separate sheet!

If the EPO as International Preliminary Examining Authority has received **test reports**, these may be used as the basis of proceedings before the EPO.

6. Pièces destinées à la procédure devant l'OEB

6.1 La procédure devant l'OEB agissant en qualité **d'office désigné** (PCT I) doit se fonder sur les pièces suivantes:

les **pièces de la demande publiée** par le Bureau international (avec **toutes** les revendications, la description et les dessins), éventuellement avec les revendications modifiées conformément à l'article 19 du PCT

dans la mesure où elles ne sont pas remplacées par les **modifications** jointes.

Le cas échéant, des explications doivent être jointes sur une feuille additionnelle!

6.2 La procédure devant l'OEB agissant en qualité **d'office élu** (PCT II) doit se fonder sur les pièces suivantes :

les **pièces sur lesquelles se fonde le rapport d'examen préliminaire international**, y compris ses annexes éventuelles
(De telles annexes sont toujours à joindre)

dans la mesure où elles ne sont pas remplacées par les **modifications** jointes.

Le cas échéant, des explications doivent être jointes sur une feuille additionnelle!

Si l'OEB, agissant en qualité d'administration chargée de l'examen préliminaire international, a reçu des **rapports d'essais**, ceux-ci peuvent constituer la base de la procédure devant l'OEB.

7. Übersetzungen Beigefügt sind die nachfolgend angekreuzten Übersetzungen in einer der Amtssprachen des EPA (Deutsch, Englisch, Französisch): • *Im Verfahren vor dem EPA als **Bestimmungsamt oder ausgewähltem Amt** (PCT I+II):*	**7. Translations** Translations in one of the official languages of the EPO (English, French, German) are enclosed as crossed below: • *In proceedings before the EPO as **designated or elected Office** (PCT I + II):*	**7. Traductions** Vous trouverez ci-joint, les traductions cochées ci-après dans l'une des langues officielles de l'OEB (allemand, anglais, français): • *Dans la procédure devant l'OEB agissant en qualité d'**office désigné ou élu** (PCT I + II):*
☐ Übersetzung der **ursprünglich eingereichten internationalen Anmeldung** (Beschreibung, Ansprüche, etwaige Textbestandteile in den Zeichnungen), der veröffentlichten Zusammenfassung, und etwaiger Angaben über biologisches Material nach Regel 13bis.3 und 13bis.4 PCT	Translation of the **international application** (description, claims, any text in the drawings) as **originally filed**, of the abstract as published and of any indication under Rule 13bis.3 and 13bis.4 PCT regarding biological material	Traduction de la **demande internationale telle que déposée initialement** (description, revendications, textes figurant éventuellement dans les dessins), de l'abrégé publié, et de toutes indications visées aux règles 13bis.3 et 13bis.4 du PCT concernant le matériel biologique
☐ Übersetzung der **prioritätsbegründenden Anmeldung(en)**	Translation of the **priority application(s)**	Traduction de la (des) **demande(s) ouvrant le droit de priorité**
☐ Es wird hiermit erklärt, daß die internationale Anmeldung in ihrer ursprünglich eingereichten Fassung eine vollständige Übersetzung der früheren Anmeldung ist (Regel 38(5) EPÜ)	It is hereby declared that the international application as originally filed is a complete translation of the previous application (Rule 38(5) EPC)	Il est déclaré par la présente que la demande internationale telle que déposée initialement est une traduction intégrale de la demande antérieure (règle 38(5) CBE)
• ***Zusätzlich** im Verfahren vor dem EPA als **Bestimmungsamt** (PCT I):*	• *In **addition**, in proceedings before the EPO as **designated Office** (PCT I):*	• *De **plus**, dans la procédure devant l'OEB agissant en qualité d'**office désigné** (PCT I):*
☐ Übersetzung der nach Art. 19 PCT **geänderten Ansprüche** nebst Erklärung, falls diese dem Verfahren vor dem EPA zugrunde gelegt werden sollen (siehe Feld 6)	Translation of **amended claims** and any statement under Art. 19 PCT, if the claims as amended are to form the basis for the proceedings before the EPO (see Section 6)	Traduction des **revendications modifiées** et de la déclaration faite conformément à l'article 19 du PCT, si la procédure devant l'OEB doit être fondée sur les revendications modifiées (voir la rubrique 6)
• ***Zusätzlich** im Verfahren vor dem EPA als **ausgewähltem Amt** (PCT II):*	• *In **addition**, in proceedings before the EPO as **elected office** (PCT II):*	• *De **plus**, dans la procédure devant l'OEB agissant en qualité d'**office élu** (PCT II):*
☐ Übersetzung der **Anlagen zum internationalen vorläufigen Prüfungsbericht**	Translation of **any annexes to the international preliminary examination report**	Traduction des **annexes du rapport d'examen préliminaire international**
8. Biologisches Material ☐ Die Erfindung bezieht sich auf bzw. verwendet biologisches Material, das nach Regel 28 EPÜ hinterlegt worden ist.	**8. Biological material** The invention relates to and/or uses biological material deposited under Rule 28 EPC.	**8. Matière biologique** L'invention concerne et/ou utilise de la matière biologique, déposée conformément à la règle 28 CBE.
☐ Die Angaben nach **Regel 28(1)c) EPÜ** (falls noch nicht bekannt, die Hinterlegungsstelle und das (die) Bezugszeichen [Nummer, Symbole usw.] des Hinterlegers) sind in der internationalen Veröffentlichung oder in der gemäß Feld 7 eingereichten Übersetzung enthalten auf: Seite(n) / Zeile(n)	The particulars **referred to in Rule 28(1)(c) EPC** (if not yet known, the depository institution and the identification references(s) [number, symbols, etc.] of the depositor) are given in the international publication or in the translation submitted under Section 7 on: page(s) / line(s)	Les indications **visées à la règle 28(1)c) CBE** (si non encore connues, l'autorité de dépôt et la (les) référence(s) d'identification [numéro ou symboles etc.] du déposant) figurent dans la publication internationale ou dans une traduction produite conformément à la rubrique 7 à la / aux: page(s) / ligne(s)
Die Empfangsbescheinigung(en) der Hinterlegungsstelle	The **receipt(s) of deposit** issued by the depositary institution	Le(s) **récépissé(s) de dépôt** délivré(s) par l'autorité de dépôt
☐ ist (sind) beigefügt	is (are) enclosed	est (sont) joint(s)
☐ wird (werden) nachgereicht	will be filed at a later date	sera (seront) produit(s) ultérieurement
☐ Verzicht auf die Verpflichtung des Antragstellers nach Regel 28(3) EPÜ auf gesondertem Schriftstück	Waiver of the right to an undertaking from the requester pursuant to Rule 28(3) EPC attached.	Renonciation, sur document distinct, à l'engagement du requérant au titre de la règle 28(3) CBE.

9. Nucleotid- und Aminosäuresequenzen

☐ Die nach Regeln 5.2 und 13ter PCT sowie Regel 111(3) EPÜ erforderlichen Unterlagen liegen dem EPA bereits vor.

☐ Das schriftliche Sequenzprotokoll wird anliegend nachgereicht.

☐ Das Sequenzprotokoll geht nicht über den Inhalt der Anmeldung in der ursprünglich eingereichten Fassung hinaus.

☐ Der vorgeschriebene Datenträger ist beigefügt.

☐ Die auf dem Datenträger gespeicherte Information stimmt mit dem schriftlichen Sequenzprotokoll überein.

9. Nucleotide and amino acid sequences

The items necessary in accordance with Rules 5.2 and 13ter PCT and Rule 111(3) EPC have already been furnished to the EPO.

The written sequence listing is furnished herewith.

The sequence listing does not include matter which goes beyond the content of the application as filed.

The prescribed data carrier is enclosed.

The information recorded on the data carrier is identical to the written sequence listing.

9. Séquences de nucléotides et d'acides aminés

Les pièces requises selon les règles 5.2 et 13ter PCT et la règle 111(3) CBE ont déjà été déposées auprès de l'OEB.

La liste de séquences écrite est produite ci-joint.

La liste de séquences ne contient pas d'éléments s'étendant au-delà du contenu de la demande telle qu'elle a été déposée.

Le support de données prescrit est joint.

L'information figurant sur le support de données est identique à celle que contient la liste de séquences écrite.

10. Benennungsgebühren

☒ 10.1 Es ist derzeit beabsichtigt, den **siebenfachen Betrag einer Benennungsgebühr** zu entrichten. Damit gelten die Benennungsgebühren für **alle Vertragsstaaten des EPÜ**[1] als entrichtet (Art. 2 Nr. 3 GebO), soweit sie **in der internationalen Anmeldung** bestimmt sind[2].

☐ 10.2 Abweichend von der Erklärung in Nr. 10.1 ist derzeit beabsichtigt, **weniger als sieben** Benennungsgebühren für folgende **in der internationalen Anmeldung bestimmte Vertragsstaaten des EPÜ**[2] zu entrichten:

(1) ____ (4) ____

(2) ____ (5) ____

(3) ____ (6) ____

Soweit unter Nr. 10.2 Vertragstaaten aufgeführt sind, wird beantragt, für die dort nicht angeführten Vertragsstaaten von der Zustellung einer Mitteilungen nach Regel 108(3) EPÜ abzusehen.

☐ 10.3 Wird ein **automatischer Abbuchungsauftrag** erteilt (Feld 12), so wird das EPA beauftragt, bei Ablauf der Grundfrist nach Regel 107 (1)d) EPÜ den siebenfachen Betrag einer Benennungsgebühr abzubuchen. Ist eine Erklärung nach Nr. 10.2 abgegeben worden, so sollen die Benennungsgebühren nur für die dort angegebenen Vertragsstaaten abgebucht werden, sofern dem EPA nicht bis zum Ablauf der Grundfrist ein anderslautender Auftrag zugeht.

10. Designation fees

10.1 It is currently intended to pay **seven times** the amount of the designation fee. The designation fees for **all the EPC contracting states**[1] **designated in the international application**[2] are thereby deemed to have been paid (Art. 2 No. 3 RFees).

10.2 The declaration in No. 10.1 does not apply. Instead, it is currently intended to pay **fewer the seven** designation fees for the following **EPC contracting states**[2] **designated in the international application:**

If contracting states are indicated under No. 10.2, it is requested that no communication under Rule 108(3) EPC be issued for contracting states not thus indicated.

10.3 If an **automatic debit order** has been issued (Section 12), the EPO is authorised, on expiry of the basic period under Rule 107(1)(d) EPC, to debit seven times the amount of the designation fee. If states are indicated under No. 10.2, the EPO will debit designation fees only for those states, unless instructed otherwise before the basic period expires.

10. Taxes de désignation

10.1 Il est actuellement envisagé de payer un montant correspondant à sept fois la taxe de désignation. Les taxes de désignation sont ainsi réputées payées pour **tous les Etats contractants de la CBE**[1] **désignés dans la demande internationale**[2] (art. 2, point 3 du RRT).

10.2 Contrairement à ce qui est indiqué au n° 10.1, il est actuellement envisagé de payer **moins de sept taxes de désignation pour les Etats contractants de la CBE**[2] **suivants désignés dans la demande internationale:**

Si des Etats contractants sont mentionnés au n° 10.2, prière de ne pas procéder à la signification d'une notifications prévue par la règle 108(3) CBE pour les Etats contractants n'y étant pas mentionnés.

10.3 Si un **ordre de prélèvement automatique** est donné (rubrique 12), il est demandé à l'OEB de prélever, à l'expiration du délai normal visé à la règle 107(1)d) CBE, un montant correspondant à sept fois la taxe de désignation. Si une déclaration a été faite au n° 10.2, les taxes de désignation ne sont à prélever que pour les Etats contractants qui y sont indiqués, sauf instruction contraire reçue par l'OEB avant l'expiration du délai normal.

1 Stand bei Drucklegung: 27 Vertragsstaaten, und zwar: / Status when this form was printed: 27 contracting states, namely / Situation à la date d'impression : 27 Etats contractants, à savoir: AT Österreich / Austria / Autriche, BE Belgien / Belgium / Belgique, BG Bulgarien / Bulgaria / Bulgarie, CH/LI Schweiz und Liechtenstein / Switzerland and Liechtenstein / Suisse et Liechtenstein, CY Zypern / Cyprus / Chypre, CZ Tschechische Republik / Czech Republic / République tchèque, DE Deutschland / Germany / Allemagne, DK Dänemark / Denmark / Danemark, EE Estland / Estonia / Estonie, ES Spanien / Spain / Espagne, FI Finnland / Finland / Finlande, FR Frankreich / France / France, GB Vereinigtes Königreich / United Kingdom / Royaume-Uni, GR Griechenland / Greece / Grèce, HU Ungarn / Hungary / Hongrie, IE Irland / Ireland / Irlande, IT Italien / Italy / Italie, LU Luxemburg / Luxembourg / Luxembourg, MC Monaco / Monaco / Monaco, NL Niederlande / Netherlands / Pays-Bas, PT Portugal / Portugal / Portugal, RO Rumänien / Romania / Roumanie, SE Schweden / Sweden / Suède, SI Slowenien / Slovenia / Slovénie, SK Slowakische Republik / Slovak Republic / République slovaque, TR Türkei / Turkey / Turquie

2 Für folgende Staaten nur möglich, falls in der internationalen Anmeldung seit oder nach folgendem Tag bestimmt: Slowakische Republik, Bulgarien, Tschechische Republik und Estland: 1. Juli 2002, Slowenien: 1 Dezember 2002, Ungarn: 1 Januar 2003 und Rumänien: 1 März 2003. / For the following states this is possible only if they are designated in the international application on or after the stated date: Slovak Republic, Bulgaria, Czech Republic and Estonia: 1 July 2002, Slovenia: 1 December 2002, Hungary: 1 January 2003 and Romania: 1 March 2003. / En ce qui concerne les Etats suivants seulement si la désignation a été effectuée dans la demande internationale à la date suivante ou à une date ultérieure: République slovaque, Bulgarie, République tchèque et Estonie: 1er juillet 2002, Slovénie: 1er décembre2002, Hongrie: 1er janvier 2003 et Roumanie: 1er mars 2003

	11. Erstreckung des europäischen Patents Bei Zahlung der Erstreckungsgebühr(en) gilt diese Anmeldung auch als wirksamer Erstreckungsantrag für die in der internationalen Anmeldung bestimmten »Erstreckungsstaaten«. Es ist beabsichtigt, diese Gebühr(en) für folgende Staaten zu entrichten:	11. Extension of the European patent On payment of the extension fee(s) this application is also deemed to be a request for extension to all the "extension states" designated in the international application. It is intended to pay the fee(s) for the following states:	11. Extension des effets du brevet européen La taxe (Les taxes) d'extension payée(s), la présente demande est également réputée être une demande d'extension à tous les «Etats autorisant l'extension» désignés dans la demande internationale. Il est envisagé de payer la taxe (les taxes) d'extension pour les Etats suivants:
☐	SI Slowenien [1]	Slovenia [1]	Slovénie [1]
☐	LT Litauen	Lithuania	Lituanie
☐	LV Lettland	Latvia	Lettonie
☐	AL Albanien	Albania	Albanie
☐	RO Rumänien [1]	Romania [1]	Roumanie [1]
☐	MK Ehemalige jugoslawische Republik Mazedonien	Former Yugoslav Republic of Macedonia	Ex-République yougoslave de Macédoine
☐	___ [2]	___ [2]	___ [2]

1) Für Slowenien und Rumänien nur möglich, falls in der internationalen Anmeldung bis 30. November 2002 (Slowenien) oder bis 28. Februar 2003 (Rumänien) bestimmt. / For Slovenia and Romania this is possible only if they are designated in the international application up to 30 November 2002 (Slovenia) or 28 February 2003 (Romania). / En ce qui concerne la Slovénie et la Roumanie, seulement si la désignation a été effectuée dans la demande internationale jusqu'au 30 novembre 2002 (Slovénie) ou jusqu'au 28 février 2003 (Roumanie).

2) Platz für Staaten, mit denen »Erstreckungsabkommen« nach Drucklegung dieses Formblatts in Kraft treten und die in der internationalen Anmeldung bestimmt waren. / Space for States with which "extension agreements" enter into force after this form has been printed and which were designated in the international application. / Prévu pour des Etats à l'égard desquels des «accords d'extension» entreront en vigueur après l'impression du présent formulaire et qui ont été désignés dans la demande internationale.

	12. Automatischer Abbuchungsauftrag *(Nur möglich für Inhaber von beim EPA geführten laufenden Konten)*	12. Automatic debit order *(for EPO deposit account holders only)*	12. Ordre de prélèvement automatique *(uniquement possible pour les titulaires de comptes courants ouverts auprès de l'OEB)*
☐	Das EPA wird beauftragt, nach Maßgabe der Vorschriften über das automatische Abbuchungsverfahren fällige Gebühren und Auslagen vom untenstehenden laufenden Konto abzubuchen. Im Bezug auf die **Benennungsgebühren** wird auf Feld 10.3 verwiesen. Das EPA wird ferner beauftragt, die **Erstreckungsgebühren** für jeden in Feld 11 angekreuzten »Erstreckungsstaat« bei Ablauf der Grundfrist zu ihrer Zahlung abzubuchen, sofern ihm nicht bis dahin ein anderslautender Auftrag zugeht.	The EPO is hereby authorised, under the Arrangements for the automatic debiting procedure, to debit from the deposit account below any fees and costs falling due. **For designation fees**, see Section 10.3. The EPO is also authorised, on expiry of the basic period for paying the **extension fees**, to debit those fees for each of the "extension states" marked with a cross in Section 11, unless instructed otherwise before the said period expires.	Par la présente, il est demandé à l'OEB de prélever du compte courant ci-dessous les taxes et frais venant à échéance, conformément à la réglementation relative au prélèvement automatique. Pour les **taxes de désignation**, se reporter à la rubrique 10.3. Il est en outre demandé à l'OEB de prélever, à l'expiration du délai normal prévu pour leur paiement, les **taxes d'extension** pour chaque « Etat autorisant l'extension» coché à la rubrique 11, sauf instruction contraire reçue avant l'expiration de ce délai.
	Nummer und Kontoinhaber	Number and account holder	Numéro et titulaire du compte
	___	___	___

	13. Eventuelle **Rückzahlungen** auf das beim EPA geführte laufende Konto	13. Any **reimbursement** to EPO deposit account	13. **Remboursements** éventuels à effectuer sur le compte courant ouvert auprès de l'OEB
☒	Nummer und Kontoinhaber	Number and account holder **2810 0022 AWAPATENT AB**	Numéro et titulaire du compte
	___	___	___

14. **Unterschrift(en)** des (der) Anmelder(s) oder Vertreters	14. **Signature(s)** of applicant(s) or representative	14. **Signature(s)** du (des) demandeur(s) ou du mandataire
Ort / Datum **Für Angestellte (Art. 133(3) EPÜ) mit allgemeiner Vollmacht:**	Lidis Grönlund **Place / Date Helsingborg 2005-06-17** **For employees (Art. 133(3) EPC) having a general authorisation:**	**Lieu / Date** **Pour les employés (art. 133(3) CBE) disposant d'un pouvoir général:**
Nr. ___	**No.** ___	**N°** ___
Name(n) des (der) Unterzeichneten bitte in Druckschrift wiederholen. Bei juristischen Personen bitte auch die Stellung des (der) Unterzeichneten innerhalb der Gesellschaft in Druckschrift angeben.	Please print name(s) under signature(s). In the case of legal persons, the position of the signatory within the company should also be printed.	Le ou les noms des signataires doivent être indiqués en caractères d'imprimerie. S'il s'agit d'une personne morale, la position occupée au sein de celle-ci par le ou les signataires doit également être indiquée en caractères d'imprimerie.

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Date
30.05.05

Reference	Application No./Patent No.
	03796549.8 - 2223 PCT/US0338223

Applicant/Proprietor
INTERDIGITAL TECHNOLOGY CORPORATION

Entry into the European phase before the European Patent Office

These notes describe the procedural steps required for entry into the European phase before the European Patent Office (EPO). You are advised to read them carefully: failure to take the necessary action in time can lead to your application being deemed withdrawn.

1. The above-mentioned international patent application has been given European application No. **03796549.8**.

2. Applicants **without** a residence or their principal place of business in an EPC contracting state may themselves initiate European processing of their international applications, provided they do so before expiry of the 31st month from the priority date (see also point 6 below).

   During the European phase before the EPO as designated or elected Office, however, such applicants must be represented by a professional representative (Arts. 133(2) and 134(1), (7) EPC).

   Procedural acts performed after expiry of the 31st month by a professional representative who acted during the international phase but is not authorised to act before the EPO have no legal effect and therefore lead to loss of rights.

   Please note that a professional representative authorised to act before the EPO and who acted for the applicant during the international phase does not automatically become the representative for the European phase. Applicants are therefore strongly advised to appoint in good time any representative they wish to initiate the European phase for them; otherwise, the EPO has to send all communications direct to the applicant.

3. Applicants **with** a residence or their principal place of business in an EPC contracting state are not obliged to appoint, for the European phase before the EPO as designated or elected Office, a professional representative authorised to act before the EPO.
   However, in view of the complexity of the procedure it is recommended that they do so.

4. Applicants and professional representatives are also strongly advised to initiate the European phase using EPO Form 1200 (available free of charge from the EPO). This however is not compulsory.

5. **To enter the European phase before the EPO**, the following acts must be performed.
(N.B.: Failure validly to do so will entail loss of rights or other adverse legal consequences.)

5.1 If the EPO is acting as **designated** or **elected** Office (Arts. 22(1)(3) and 39(1) PCT respectively), applicants must, within 31 months from the date of filing or (where applicable) the earliest priority date:

a) Supply a translation of the international application into an EPO official language, if the International Bureau did not publish the application in such a language (Art. 22(1) PCT and Rule 107(1)(a) EPC).
If the translation is not filed in time, the international application is deemed withdrawn before the EPO (Rule 108(1) EPC).
This loss of rights is deemed not to have occurred if the translation is then filed within a two-month grace period as from notification of an EPO communication, provided a surcharge is paid at the same time (Rule 108(3) EPC).

b) Pay the national basic fee (EUR 160,00) and, where a supplementary European search report has to be drawn up, the search fee (EUR 690,00 ; Rule 107(1)(c) and (e) EPC).

c) If the time limit under Article 79(2) EPC expires before the 31-month time limit, pay the designation fee (EUR 75,00) for each contracting state designated (Rule 107(1)(d) EPC).

d) If the time limit under Article 94(2) EPC expires before the 31-month time limit, file the written request for examination **and** pay the examination fee (EUR 1430,00 ; Rule 107(1)(f) EPC).

e) Pay the third-year renewal fee (EUR 380,00) if it falls due before expiry of the 31-month time limit (Rule 107(1)(g) EPC).

If the fees under (b) to (d) above are not paid in time, or the written request for examination is not filed in time, the international application is deemed withdrawn before the EPO, or the contracting-state designation(s) in question is (are) deemed withdrawn (Rule 108(1) and (2) EPC). However, the fees may still be validly paid within a two-month grace period as from notification of an EPO communication, provided the necessary surcharges are paid at the same time (Rule 108(3) EPC). For the renewal fee under (e) above, the grace period is **six** months from the fee's due date (Article 86(2) EPC).

5.2 If the application documents on which the European grant procedure is to be based comprise more then ten claims, a claims fee is payable within the 31-month time limit under Rule 107(1) EPC for the eleventh and each subsequent claim (Rule 110(1) EPC). The fee can however still be paid within a one-month grace period as from notification of an EPO communication pointing out the failure to pay (Rule 110(2) EPC).

6. If the applicant had a representative during the application's international phase, the present notes will be sent to the representative, asking him to inform the applicant accordingly.

All subsequent communications will be sent to the applicant, or - if the EPO is informed of his appointment in time - to the applicant's European representative.

7. For more details about time limits and procedural acts before the EPO as designated and elected Office, see the EPO brochure

   How to get a European patent
   Guide for applicants - Part 2
   PCT procedure before the EPO - "Euro-PCT"

   This brochure, the list of professional representatives before the EPO, Form 1200 and details of the latest fees are now all available on the Internet under

   http://www.european-patent-office.org

RECEIVING SECTION

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 Δ and the number of P2 bits is increased by Δ, 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

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

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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

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

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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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(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.

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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:

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

REC'D 23 DEC 2004
WIPO PCT

Applicant's or agent's file reference I-2-0526.1WO	FOR FURTHER ACTION	See Form PCT/IPEA/416
International application No. PCT/US03/38223	International filing date *(day/month/year)* 03 December 2003 (03.12.2003)	Priority date *(day/month/year)* 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 for 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 ----------

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office

March 01, 2004

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE.

APPLICATION NUMBER: *60/494,404*
FILING DATE: *August 11, 2003*
RELATED PCT APPLICATION NUMBER: *PCT/US03/38223*

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

M. Sias

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08/11/03 17638 U.S. PTO

PTO/SB/16 (06-03)
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. EV 318163197 US

03916 U.S. PTO

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Philip J.	Pietraski	North Massapequa, New York

Additional inventors are being named on the 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

METHOD FOR DETECTING AND ADDRESSING PERFORMANCE-DEGRADATION IN PUNCTURED TURBO CODES

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

[X] Customer Number: 24374

OR

[X] Firm or Individual Name	VOLPE AND KOENIG, P.C., DEPT ICC				
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ENCLOSED APPLICATION PARTS *(check all that apply)*

[X] Specification *Number of Pages* 48 [ ] CD(s), Number

[X] Drawing(s) *Number of Sheets* 9 [ ] Other (specify)

[X] Application Date Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

[ ] Applicant claims small entity status. See 37 CFR 1.27.

[ ] A check or money order is enclosed to cover the filing fees.

[X] The Director is herby authorized to charge the filing fees or credit any overpayment to Deposit Account Number: 09-0435

[ ] Payment by credit card. Form PTO-2038 is attached.

FILING FEE Amount ($): 160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[X] No.

[ ] Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

SIGNATURE

TYPED or PRINTED NAME C. Frederick Koenig, III

TELEPHONE 215-568-6400

Date August 11, 2003

REGISTRATION NO. 29,662 *(if appropriate)*

Docket Number: I-2-0449.1US

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. 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 8 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: Mail Stop Provisional Application, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PROVISIONAL APPLICATION COVER SHEET
Additional Page

PTO/SB/16 (06-03)
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Docket Number I-2-0449.1US

INVENTOR(S)/APPLICANT(S)		
Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
Gregory S.	Sternberg	Great Neck, New York

Number _____ of _____

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APPLICATION DATA SHEET
UNDER 37 CFR ' 1.76

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Telephone No.::	215-568-6400

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(4) Application Information

Title Line One::	METHOD FOR DETECTING AND ADDRESSING
Title Line Two::	PERFORMANCE-DEGRADATION IN
Title Line Three::	PUNCTURED TURBO CODES
Total Drawing Sheets::	Nine (9)
Drawing Type::	Formal
Application Type::	Provisional
Docket No.::	I-2-0449.1US

(5) Representative Information

Representative Customer No.:: 24374

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METHOD FOR DETECTING AND ADDRESSING PERFORMANCE-DEGRADATION IN PUNCTURED TURBO CODES

[0001] FIELD OF THE INVENTION

[0002] 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.

[0003] BACKGROUND

[0004] Wireless communication systems are well known in the art. Generally, such systems comprise communication stations which 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 CDMA systems specified by the Third Generation Partnership Project (3GPP), base stations are called Node Bs, subscriber stations are called User Equipments (UEs) and the wireless interface between the Node Bs and UEs is known as the Uu interface. Figure 1 illustrates a typical 3GPP CDMA system.

[0005] The Uu radio interface of a 3GPP system uses Transport Channels (TrCHs) 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 (TBs) defined as Transport Block Sets (TBSs). 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.

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[0006] Figure 2a 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 Transport Block (TB) of data, Cyclic Redundancy Check (CRC) bits are attached and Transport Block concatenation and Code Block segmentation is performed. Convolutional 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.

[0007] 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.

[0008] 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 TB set (TBS) data. For each TrCH, a Transport Format Set (TFS) is specified containing a predetermined number of Transport Formats (TFs). 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).

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[0009] 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.

[0010] In TDD 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 2b and 2c respectively where the block labeled MA represents the midamble and the block labeled T represents the parts of the TFCI. In second example, Figure 2c, the CCTrCH is mapped to two physical, but only one physical channel includes the TFCI.

[0011] 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.

[0012] 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.

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[0013] Figure 3 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 (SNR) value, the SNR required to properly decode the data in the TB.

[0014] 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.

[0015] 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 length. 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. Note that interleaving used in 3GPP does not help disperse burst errors due to puncturing since the puncturing occurs before interleaving.

[0016] 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.

[0017] 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

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(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.

[0018] 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.

[0019] 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

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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.

[0020] 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.

[0021] In order to obtain adequate performance, it is necessary to ensure proper detecting, avoiding and/or correcting 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.

[0022] It would be desirable to have a method for creating high-rate Turbo codes that avoids problematic interactions by modifying the puncturing patterns.

[0023] SUMMARY OF THE INVENTION

[0024] According to the present invention, degradations in quality of punctured error corrected code 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.

[0025] 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.

[0026] 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

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Turbo codes on High Speed Downlink Shared Channel (HS-DSCH) in R5 High Speed Downlink Packet Access (HSDPA).

[0027] BRIEF DESCRIPTION OF THE DRAWINGS

[0028] 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:

[0029] Figure 1 is a schematic diagram of a typical CDMA system in accordance with current 3GPP specifications;

[0030] Figure 2a is a processing diagram of TrCH data for a CCTrCH in accordance with 3GPP TDD specifications;

[0031] Figures 2b and 2c are diagrams of channel coding and multiplexing examples in accordance with 3GPP TDD specifications;

[0032] Figure 3 shows typical results of particular codes being created by puncturing, where as much as 4 dB loss can be measured in critical SNR value;

[0033] Figure 4 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;

[0034] Figure 5 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;

[0035] Figure 6 is a schematic block diagram showing a circuit for Third Generation Partnership Project (3GPP) rate matching for High Speed Downlink Packet Access (HSDPA), using a Turbo coded HS-DSCH; and

[0036] Figure 7 graphically depicts initial Block Error Rate (BLER) for High Speed Downlink Shared Channel (HS-DSCH) transport blocks with certain effective coding rates.

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[0037] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0038] 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.

[0039] The present invention is potentially applicable to layers 1 and 2 in a Frequency Division Duplex (FDD), Code Division Multiple Access (CDMA) 2000 and Time Division Duplex (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.

[0040] Figure 4 graphically depicts the SNR required to successfully decode a data block (critical SNR) with high probability versus Code Rate when biasing the number of parity bits in parity stream 1 and 2 (P1/P2) is applied. As shown in Figure 3, 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.

[0041] Figure 5 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.

[0042] In one embodiment, puncture biasing for parity bits P1 and P2 is implemented for one stage rate matching. Figure 6 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

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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 first.

[0043] 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.

[0044] 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, it is proposed that 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.

[0045] 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

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one and removing it from the other. The amount of the bias should be no more than is needed to avoid certain periodicities for better overall performance, however, over biasing by modest amounts has shown little degeadation and can be tolerated in practice. In biasing the puncturing rates of P1 and P2 bits, two constraints must be met.

[0046] When non-puncturing patterns with period $7\hat{N}/2$ ($\hat{N} = 1, 2, 3...$) 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. The averaging may be defined over the entire TB or any subset of the TB.

[0047] 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,

$$\hat{N} = \left\lfloor\frac{4I}{7P} + \frac{1}{2}\right\rfloor. \qquad \text{Equation (2)}$$

[0048] In biasing the puncturing rates of the parity bit streams 1 and 2, P1 and P2, two constraints must be met.

[0049] 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.

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[0050] These two constraints can be combined in to the following expression for Δ, where:

[0051] $$\Delta = \left\lceil \max\left\{ \left\lfloor \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} \right\rfloor - \frac{P}{2}, \frac{P}{2} - \left\lfloor \frac{I}{\left\lfloor \frac{7\hat{N}+1}{2} \right\rfloor} \right\rfloor \right\} \right\rceil \quad \text{Equation (3)}$$

[0052] 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 $\Delta = 0$.

Step 3) Compute the bias Δ using Equation (3).

[0053] 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.

[0054] 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.

[0055] For Hybrid Automatic Repeat reQuest (HARQ) as deployed in 3GPP, it may be necessary to employ two stages of rate matching. This occurs whenever

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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.

[0056] In order to obtain higher data rates, the 3rd Generation Partnership Project (3GPP) has introduced the high-speed downlink packet access (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 (TBSSs) 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.

[0057] 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.

[0058] A typical method for creating high-rate Turbo codes is to puncture the parity bits of a lower-rate code until the desired code rate is attained. In a 3GPP-coding scheme selected for data services, in order to achieve an optimum performance with the scheme, puncturing may be needed to ensure rate matching. By combining Turbo codes and puncturing, high data rates are possible. A typical method for

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creating high-rate Turbo codes is to puncture the parity bits of a lower-rate code until the desired code rate is attained.

[0059] It is therefore possible to lose the distribution of information about a group of bits when certain non-puncture patterns are employed. In the 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.

[0060] In another embodiment, adjustments to the parity stream puncturing allows the 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.

[0061] 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.

[0062] 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.

[0063] 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 6), although the puncturing pattern "phases" can be adjusted.

[0064] 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.

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[0065] 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.

[0066] 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. The following mitigation techniques apply when only a single stage of rate matching is employed (or the first stage of rate matching is transparent.)

[0067] Likewise, the number of P2 bits must be decreased by an equal amount that is also sufficient to avoid problematic puncturing patterns. These two constraints can be combined in to the following expression for Δ, where:

[0068] $$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil \quad \text{Equation (3)}$$

[0069] 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 (3).

Step 2) Determine if the desired code rate results in a problematic puncturing pattern using Equation(2). If it does, continue to Step 3), otherwise set $\Delta = 0$.

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Step 3) Compute the bias Δ using Equation (3).

Step 4) Compute rate matching parameters by modifying Table in TS25.212/222.

[0070] 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 3GPP2 Turbo code (CDMA2000) 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.

[0071] 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.

[0072] 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 (4) 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 (4) is a piecewise linear and continuous function in r1, r2 and is therefore trivial to evaluate.

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$$\lambda(r1,r2)=\sum_{n=1}^{L-1}\alpha_n\left[\left(1-\left\lceil\frac{1}{L}\lceil r1\lceil nr2\rceil\rceil-\left\lfloor\frac{1}{L}\lceil r1\lceil nr2\rceil\rceil\right\rfloor\right)(nr2-\lfloor r2\rfloor)(r1\lceil nr2\rceil-\lfloor r1\lceil nr2\rceil\rfloor)+\right.$$
$$\left(1-\left\lceil\frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor-\left\lfloor\frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor\right\rfloor\right)(nr2-\lfloor nr2\rfloor)(-r1\lceil nr2\rceil-\lfloor r1\lceil nr2\rceil\rfloor+1)+$$
$$\left(1-\left\lceil\frac{1}{L}\lceil r1\lfloor nr2\rfloor\rceil-\left\lfloor\frac{1}{L}\lceil r1\lfloor nr2\rfloor\rceil\right\rfloor\right)(-nr2+\lfloor nr2\rfloor+1)(r1\lfloor nr2\rfloor-\lfloor r1\lfloor nr2\rfloor\rfloor)+ \quad \text{Equation (4)}$$
$$\left.\left(1-\left\lceil\frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor-\left\lfloor\frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor\right\rfloor\right)(-nr2+\lfloor nr2\rfloor+1)(-r1\lfloor nr2\rfloor+\lfloor r1\lfloor nr2\rfloor\rfloor+1)\right]$$

[0073] 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.

[0074] 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.

[0075] 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.

[0076] 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.

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[0077] Certain parameters may be made to vary as a function of time (or bit index, or other parameter(s)) to generate puncturing patterns that will mitigate performance degradations. One such example for 3GPP includes modification of the rate matching parameters such as the X_i, e_ini, e_minus and e_plus parameters throughout the execution of the rate-matching algorithm. 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 coderates may be different from the desired overall coderate (thereby avoiding the puncturing interaction) while still maintaining the same overall coderate. 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.

[0078] 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. Any permutation (and methods of generating such permutations) of the puncturing pattern is claimed by the invention.

[0079] 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.

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[0080] 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.

[0081] 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.

[0082] 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.

[0083] 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.

[0084] When creating 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 be used to identify all puncturing patterns with degraded performance.

[0085] In a particular embodiment of the invention, the capacity of a wireless transmit and receive unit (WTRU) is determined, including buffer sizes that supported by the WTRU. The puncturing is used to reduce sufficient bits to fit into the buffer,

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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.

[0086] 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 block error rate (BLER), bit error rate (BER), required signal-to-interference ratio (SIR), or required signal-to-noise ratio (SNR).

[0087] 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.

[0088] The present invention is particularly useful for 3GPP-coding, and can be used for low chip rate TDD, high chip rate TDD and FDD.

[0089] 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

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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. 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.

[0090] Codes with degraded performance are detected, and 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 a period related to the period of the semi-periodic impulse response of the recursive encoding blocks of the Turbo encoder.

[0091] 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.

[0092] In accordance with the present invention, improved restoration of performance to the punctured Turbo code is achieved by avoiding 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.

[0093] One case is exemplified by changing puncture rates in P1 and P2. A simple and efficient method of modifying the puncture patterns consists in biasing the number of punctured bits in P1 and P2 by adding additional puncturing to one and

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removing it from the other. The amount of the bias should be no more than is needed to avoid certain periodicities. Alternatively, non-punctured bits may be increased in P2 and decreased in P1.

[0094] Regarding block interleaving before rate matching, interleaving the parity bits before rate matching occurs can also mitigate the effect of the periodicity of the puncturing pattern. In this way, after de-interleaving, periodic sampling of the parity bits is avoided even when periodic sampling is done in rate matching. 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, small time-varying interleavers can be used. This has the advantage of requiring less memory and helps to minimize the distortion of the uniformity of the puncturing.

[0095] When a particular code rate is desired and it is determined that its use will results in degraded performance, a slightly smaller code rate may be selected to avoid the degradation. A 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.

[0096] 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. Any permutation (and methods of generating such permutations) of the puncturing pattern is claimed by the invention.

[0097] 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.

[0098] One can achieve the desired overall code rate while avoiding problematic puncturing patterns by adjusting the amount of puncturing performed in each stage.

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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.

[0099] 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.

[0100] 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.

[0101] 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.

[0102] The real system for both FDD and TDD include two stages of rate matching, two puncturing operations, and this is done because of a certain technique called, incremental redundancy, which allows for the user equipment to receive multiple transmissions 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 the 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 repatition) is to achieve the desired overall code rate. When the two stages of rate matching are combined, a similar plot of problematic regions of

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coding rate turns into 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.

[0103] Adaptive coding means that on the fly, information is obtained from the user equipment that indicates whether channel is providing good data. Based on that, the transmitter adjusts its code rate. In instances of poor reception, a substantial amount of redundancy is added, which results in a very low code rate, but which allows only a small transfer of data through with the required block error probability.

[0104] Channel quality will not take into account the errors or the problems due to the puncturing pattern. The channel quality is based on signal power and noise power, but it doesn't take into account the fact that the encoder may have been punctured in a problematic way. The channel doesn't directly include information about that. So in that sense, the adaptive modulation and coding isn't going to naturally determine that the signal is bad or that it should be switched off. Instead, the purpose of the adaptive modulation and coding is to provide information which will allow the primary signal to vary. Since there are multiple primaries inherent in modulation and coding, it is possible to change the primaries in accordance with channel quality. 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 this data rate control.

[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 see more errors. In many cases the problematic coding rates are known 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

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error patterns or by using a 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] Support for link adaptation by means of Adaptive Modulation and Coding (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 Transport Block Set Size (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.

[0109] High-speed downlink packet access (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.

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[0110] 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.

[0111] Figure 7 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 HS-PDSCHs. 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.

[0112] 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%.

[0113] 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.

[0114] 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

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puncturing rates leading to SNR degradation are predictable in principle, but would require a rather complex set of parameters to be taken into account.

[0115] 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.

[0116] 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. a modification to the parameters in Table 10 "Parameters for hybrid automatic repeat request (HARQ) second rate matching", and more importantly do not require any additional signaling.

[0117] 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.

[0118] 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.

[0119] 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).

[0120] Note that the constituent recursive convolutional encoder is a Linear Time Invariant (LTI) system on GF_2. Therefore, the output of the encoder is a sum of

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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 Transport Block (TB).

[0121] 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.

[0122] 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.

[0123] 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.

[0124] 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.

[0125] 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).

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[0126] This results in a period seven 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.

[0127] 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.

[0128] 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.

[0129] The code rates at the center of these regions are determined by:

$$CR = \frac{1}{1+\frac{2}{3.5N}} = \frac{3.5N}{3.5N+2} \qquad N = 1,2,... \qquad \text{Equation (5)}$$

[0130] 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.

[0131] 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

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bits of the parity bit streams 1 or 2 is within ±1 or ±½ of $7N/2$ for even and odd N respectively.

[0132] A closed form expression based upon similar considerations as above is possible. This expression takes as input either the triplet {Bits Before 1st stage of rate Matching, Bits after 1st Rate Matching, Bits after 2nd Rate matching} or the pair {1st stage parity puncturing rate, 2nd stage parity puncturing rate}.

[0133] At least two alternative approaches exist to avoid the problematic interactions between Turbo-coder output and puncturing in the rate-matching stages.

[0134] 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.

[0135] 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.

[0136] 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.

[0137] 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 UE for H-ARQ; and

(3) number of physical channel bits allocated for the HS-PDSCHs.

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[0138] 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.

[0139] 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.

[0140] Since every surviving parity bit can be written as a function of all preceding systematic bits, the constraints that can be placed on the systematic bits are determined by observing the surviving parity bits with certain non-puncture patterns. For example, the constituent recursive encoders of a 3GPP Turbo encoder have an impulse response that is periodic with period 7 for positive time (semi-periodic). The encoder is interpreted as a 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 equivalent to a Linear Feedback Shift Register (LFSR) with an associated third order primitive polynomial and initial state {1 0 0}. Thus, a period 2^3-1 = 7 M-sequence is generated for positive time.

[0141] The encoder is a Linear Time Invariant (LTI) system on the 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 Transport Block (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 $t > T$.

[0142] 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 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

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encoding block. For most non-puncture patterns, (those that have 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.

[0143] However, for 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, 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, i.e., a rank-1 system of equations is formed and a unique solution does not exist. When the non-puncture period is relatively prime with the period of the recursive encoding block, making 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.

[0144] 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 seven non-puncture pattern but with two surviving parity bits per period. The same argument above leads to a rank-2 system of seven equations. 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.

[0145] 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

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art that various changes in form and details may be made therein without departing from the scope of the invention as described hereinabove.

* * *

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CLAIMS

What is claimed is:

1. A method of calculating a bias used to modify problematic Turbo code puncturing patterns in parity bit streams without having to avoid code rates, the method comprising:

(a) determining $\hat{N}$ 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 parity bits (P1 and P2) at the output of rate matching; and

(b) if $\left| \frac{I}{(P/2)}-\frac{7\hat{N}}{2} \right| < 1-\frac{\hat{N}}{2}+\left\lfloor \frac{\hat{N}}{2} \right\rfloor$, 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 $\Delta=0$.

1a. A method of avoiding problematic Turbo code puncturing patterns in systems employing a plurality of rate matching stages, the method comprising:

(a) adjusting the number of bits punctured in each stage of rate matching; and/or,

(b) adjusting the number of bits punctured in each of the plurality of parity streams such that the problematic puncturing patters are avoided.

2. A method for identifying degradations in quality of punctured error correction coded transmissions, comprising:

identifying a puncturing pattern which approximates a particular code

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rate; and

adjusting a value for anticipated degradation in accordance with the matching of the puncturing pattern and the particular code rate.

3. The method of claim 2 further comprising using Turbo code to implement the error correction coded transmissions.

4. The method of claim 3 further comprising:

identifying when a non-punctured bit pattern of the transmissions exhibits a periodic characteristic (e.g., periodic on short time scale), 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.

5. A method for reducing degradations in quality of punctured error corrected code transmissions, the method comprising:

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

adjusting the parameters of the transmissions sufficiently to cause a mismatch in the puncturing pattern and the particular code rate.

6. The method of claim 5 further comprising:

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

using puncturing to remove sufficient bits to fit into the buffer; and

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.

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7. The method of claim 6, further comprising 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.

8. The method of claim 7 further comprising increasing non-punctured bits in the first stage and decreasing non-punctured bits in the second stage.

9. The method of claim 7 further comprising decreasing non-punctured bits in the first stage and increasing non-punctured bits in the second stage.

10. The method of claim 6 further comprising:

interleaving parity bits before rate matching occurs; and 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.

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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 – puncturing interactions when two or more stages of rate matching are employed, are presented.

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APPENDIX

4.5.4 Hybrid ARQ for HS-DSCH

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.

The hybrid ARQ functionality consists of two rate-matching stages and a virtual buffer as shown in the figure below.

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.

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.

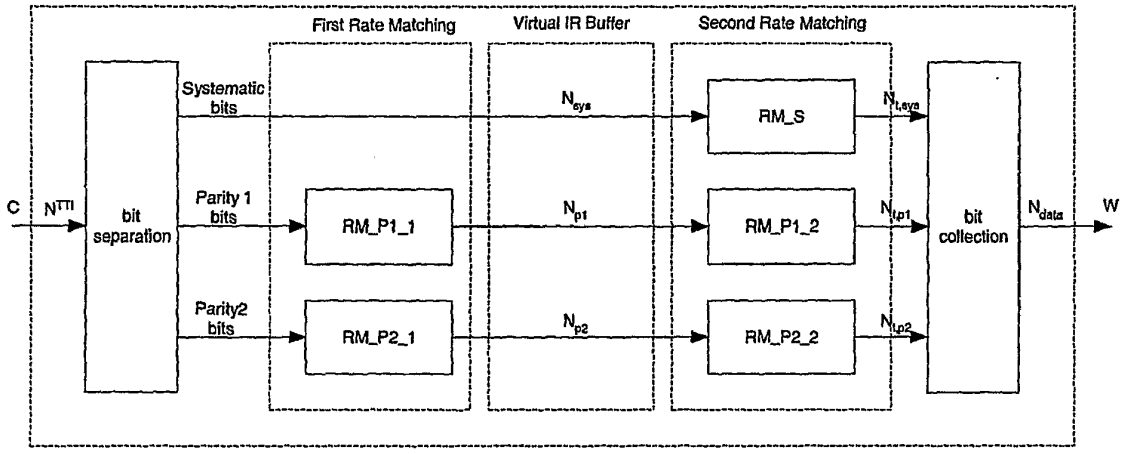


Figure 17: HS-DSCH hybrid ARQ functionality

Notation used in sub clause 4.5.4 and sub clauses:

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.

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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 of subclause 4.2.7.5.

e_{plus} Increment of variable e in the rate matching pattern determination algorithm of subclause4.2.7.5.

e_{minus} Decrement of variable e in the rate matching pattern determination algorithm of subclause 4.2.7.5.

b: Indicates systematic and parity bits

b=1: Systematic bit. x_k in subclause 4.2.3.2.1.

b=2: 1st parity bit (from the upper Turbo constituent encoder). z_k in subcaluse 4.2.3.2.1.

b=3: 2nd parity bit (from the lower Turbo constituent encoder). z'_k in subclause 4.2.3.2.1.

4.5.4.1 HARQ bit separation

The HARQ bit separation function shall be performed in the same way as bit separation for turbo encoded TrCHs in 4.2.7.4 above.

4.5.4.2 HARQ First Rate Matching Stage

HARQ first stage rate matching for the HS-DSCH transport channel shall be done with the method described in 4.5.4.2.1 below with the following specific parameters.
The maximum number of soft bits available in the virtual IR buffer is N_{IR} which is signalled 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 signalled from higher layers and parameters signalled on the HS-SCCH for each TTI. Note that HARQ processing and physical layer storage occurs independently for each HARQ process currently active.
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.
If N_{IR} is smaller than N^{TTI} the parity bit streams are punctured as in 4.5.4.2.1 below 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 in the algorithm in 4.2.7 above shall be discarded and not counted in the totals for the streams through the virtual IR buffer.

4.5.4.2.1 HARQ First Rate Matching Parameters

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

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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

$$X_i = \lfloor N^{TTI}/3 \rfloor; \qquad PR = \frac{\lfloor -\Delta N_{il}^{TTI}/2 \rfloor}{X_i}; \qquad \Delta N_{PARITY} = 0; \quad \delta_{PR} = 49; \qquad \alpha = 1$$

while $(\alpha \le 4)$

$$round = \frac{\left\lfloor 7 \cdot \alpha \cdot PR + \frac{1}{2} \right\rfloor}{7 \cdot \alpha}$$

$$\lambda = PR - round$$

if $\left(|\lambda| > \frac{1}{\delta_{PR}} \right) or \left(PR > \frac{48}{49} \right) or \left(PR < \frac{1}{49} \right)$ then

$$\alpha = \alpha + 1$$

$$\delta_{PR} = 98$$

else if $(\lambda > 0)$ then

$$\Delta N_{PARITY} = \left\| \lfloor -\Delta N_{il}^{TTI}/2 \rfloor - X_i \cdot \left(round - \frac{1}{\delta_{PR}} \right) \right\|$$

$$\alpha = 5$$

else

$$\Delta N_{PARITY} = \left\| \lfloor -\Delta N_{il}^{TTI}/2 \rfloor - X_i \cdot \left(round + \frac{1}{\delta_{PR}} \right) \right\|$$

$$\alpha = 5$$

end if

end while

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$$\Delta N_i = \begin{cases} \lfloor -\Delta N_{il}^{TTI}/2 \rfloor - \Delta N_{PARITY}, b = 2 \\ \lceil -\Delta N_{il}^{TTI}/2 \rceil + \Delta N_{PARITY}, b = 3 \end{cases}$$

a = 2 when b=2

a = 1 when b=3

If ΔN_i is calculated as 0 for b=2 or b=3, then the following procedure and the rate matching algorithm of subclause 4.2.7.5 shall not be performed for the corresponding parity bit stream. For each radio frame, the rate-matching pattern shall be calculated using the algorithm in subclause 4.2.7.5, where:

X_i is as above,

$e_{ini} = X_i$

$e_{plus} = a \times X_i$

$e_{minus} = a \times |\Delta N_i|$

4.5.4.3 HARQ Second Rate Matching Stage

HARQ second stage rate matching for the HS-DSCH transport channel shall be done using one of two possible methods.

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 done using the method described in 4.5.4.3.1. Note, puncturing using the method in 4.5.4.3.1 maybe carried out on one, both, or neither of the two parity streams, but never on the systematic parity stream.

Composite Puncturing Ratio, $CPR = \begin{cases} \dfrac{\lfloor N^{TTI}/3 \rfloor - N_{t,p1}}{N^{TTI}/3}, b = 2 \\ \dfrac{\lfloor N^{TTI}/3 \rfloor - N_{t,p2}}{N^{TTI}/3}, b = 3 \end{cases}$

Otherwise, second stage rate matching for the HS-DSCH transport channel shall be done with the general method described in 4.2.7.5 above with the following specific parameters. Bits selected for puncturing which appear as δ in the algorithm in 4.2.7.5 above shall be discarded and are not counted in the streams towards the bit collection.

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

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prioritise 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 10 below.

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 $N_{data}=P\times3\times N_{data1}$, where N_{data1} is defined in [2]. 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. The number of transmitted systematic bits in a transmission is $N_{t,sys} = \min\{N_{sys}, N_{data}\}$ for a transmission that prioritises systematic bits and $N_{t,sys} = \max\{N_{data} - (N_{p1} + N_{p2}), 0\}$ for a transmission that prioritises non systematic bits.

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 $N_{t,sys} = \left\lfloor N_{sys} \cdot \frac{N_{data}}{N_{sys} + 2N_{p1}} \right\rfloor$.

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.

Table 10 below summarizes the resulting parameter choice for the second rate matching stage.

Table 10: Parameters for HARQ second rate matching

	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}	$\lvert N_{p2} - N_{t,p2} \rvert$

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 as defined in 4.6.2. Note that r_{max} varies depending on the modulation mode, i.e. for 16QAM $r_{max} = 2$ and for QPSK $r_{max} = 4$.

Note: For the modulo operation the following clarification is used: the value of (x mod y) is

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strictly in the range of 0 to y-1 (i.e. -1 mod 10 = 9).

4.5.4.3.1 HARQ Second Rate Matching Stage for problematic puncturing rates

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 and then applies the general method described in 4.2.7.5 above to each of the segments with specific parameters calculated below. Bits selected for puncturing which appear as δ in the algorithm in 4.2.7.5 above shall be discarded and are not counted in the streams towards the bit collection.

4.5.4.3.1.1 Parity stream segmentation

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.

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 $X_{seg1} = 42 \cdot \lfloor X_i / 98 \rfloor$

, $X_{seg2} = 56 \cdot \lfloor X_i / 98 \rfloor$, $X_{seg3} = X_i \bmod 98$

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.

4.5.4.3.1.2 Additional parameters for HARQ Second Rate Matching Stage for problematic puncturing rates

Parameters P, N_{data}, N_{sys}, N_{p1}, N_{p2}, $N_{p,t1}$, and $N_{p,t2}$ are calculated as in 4.5.4.3 above, additional parameters are defined below.

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.

For $N_{data} \le N_{sys} + N_{p1} + N_{p2}$, puncturing is performed in the second rate matching stage.

The number of parity bits after segmentation is

$N_{pb,seg1} = 42 \cdot \lfloor N_{pb} / 98 \rfloor$

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$$N_{pb,seg2} = 56 \cdot \lfloor N_{pb}/98 \rfloor$$
$$N_{pb,seg3} = N_{pb} \bmod 98$$

The number of parity bits in each segment for parity 1 bits(b=2), and parity 2bits (b=3) is:

$$N_{t,pb,seg1} = \left\lfloor \frac{49 \cdot N_{t,pb} \cdot \lfloor N_{pb}/98 \rfloor}{N_{pb}} + \frac{1}{2} \right\rfloor;$$
$$N_{t,pb,seg2} = \left\lfloor \frac{49 \cdot N_{t,pb} \cdot \lfloor N_{pb}/98 \rfloor}{N_{pb}} + \frac{1}{2} \right\rfloor;$$
$$N_{t,pb,seg3} = N_{t,pb} - \left(N_{t,pb,seg1} + N_{t,pb,seg2}\right)$$

The parameters X_i, e_{plus} and e_{minus} are calculated as per table 10a below.

Table 10a: Parameters for dithered HARQ second rate matching

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	$N_{p2,seg3}$	$N_{p2,seg3}$	$\lvert N_{p2,seg3} - N_{t,p2,seg3} \rvert$

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 as defined in 4.6.2. Note that r_{max} varies depending on the modulation mode, i.e. for 16QAM r_{max} = 2 and for QPSK $r_{max} = 4$.
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 in 4.2.7.5 is called for each segment of the parity stream in turn.

4.5.4.3.1.3 Parity stream segment concatenation

For both parity streams, after the rate matching algorithm in 4.2.7.5 has been called for each of

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the three segments, the three punctured segments should be concatenated together in their original order.
The re-concatenated bit stream is denoted by:

$$x_{o,seg1,1}, x_{o,seg1,2}, \ldots x_{o,seg1,N_{t,p1,seg1}}, x_{o,seg2,1}, x_{o,seg2,2}, \ldots x_{o,seg2,N_{t,p1,seg2}}, x_{o,seg3,1}, x_{o,seg3,2}, \ldots x_{o,seg3,N_{t,p1,seg3}}$$

4.5.4.4 HARQ bit collection

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 as defined in 4.5.4.3.
Data is written into the interleaver column by column, and read out of the interleaver column by column starting from the first column.
$N_{t,sys}$ is the number of transmitted systematic bits. Intermediate values N_r and N_c are calculated using:

$$N_r = \left\lfloor \frac{N_{t,sys}}{N_{col}} \right\rfloor \text{ and } N_c = N_{t,sys} - N_r \cdot N_{col}.$$

If N_c=0 and $N_r > 0$, the systematic bits are written into rows $1 \ldots N_r$.
Otherwise systematic bits are written into rows $1 \ldots N_r+1$ in the first N_c columns and, if $N_r > 0$, also into rows $1 \ldots N_r$ in the remaining N_{col}-N_c columns.
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.
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.

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APPENDIX

3GPP TSG-RAN Working Group 1 #33 **Tdoc R1-030xxx**

New York, U.S.A.
Aug 25-29th, 2003

Source:

Title: **Proposed modified HS-DSCH rate matching algorithm**

Agenda Item: **5.3**

Document for: **Discussion**

1. Introduction

In RAN WG1 #32, two contributions were presented [1],[2] indicating a performance reduction in the HS-DSCH associated with certain coding rates. In a separate TDOC (x.x), a CR is to be presented to WG1 #33 proposing a modification to the HS-DSCH rate matching algorithm which overcomes the performance degradation. Some simulation results indicating the need to introduce this change will also be presented in a separate TDOC (x.x). The purpose of this document is to elaborate on the contents of the CR and the mechanism by which the performance degradation is avoided.

2. Proposed HS-DSCH Rate matching algorithm

In [1], analysis of the rate matching issue was restricted to the situation in which the first stage HS-DSCH rate matching is transparent. In this case, 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. In [2] it was demonstrated that performance degradations arise via exactly the same mechanism when the first stage is not transparent.

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 bitstream.

In the case of two-stage rate matching, puncturing that leads to degradation may occur in two ways:

- A pattern arising from bits punctured in the first stage only

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- A pattern arising from bits punctured after the second stage; this pattern is dependent upon both the first and second rate matching stages.

In order to avoid either of these puncturing mechanisms that cause a performance degradation, the following methodology has been adopted:

- 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.

- 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, the "dithering" algorithm described in the section 2.2 is applied.

2.1. Application of different puncturing rates in the two parity streams

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 λ, which estimates the inverse of the length of runs of survivor bits which hold the same modulo 7 position in the unpunctured stream [1]. If this length becomes greater than 49 bits (i.e. 7 modulo 7 periods), then the adjustment to the lengths of the streams is applied.

The procedure for deciding to apply the split rates, and calculating ΔN_{PARITY} is captured in section 4.5.4.2.1 in TDOC x.x. In the CR, a search is made for periods modulo 7, 14, 21 and 28 (controlled by the α parameter). The calculated value of ΔN_{PARITY} depends on the side of the implicit duration peak at which the coding rate lies; this is indicated by the sign of λ.

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2.2. Dithered puncturing algorithm

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.

In the proposed CR, 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, as is currently defined in section 4.2.7.5 of TS25.212 can easily be used with some minor parameter changes.

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.

The procedure for applying the dithering in the second stage is captured in section 4.5.4.3 of TDOC x.x

3. Conclusion

A CR for 25.212, modifying the rate matching algorithm for HS-DSCH to avoid degradations in performance will be presented alongside this contribution.

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.

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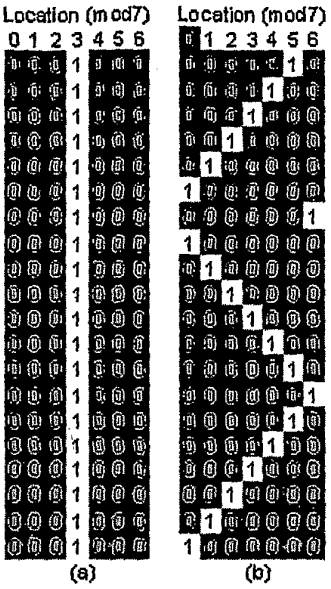


Figure 1: Sample puncturing patterns before and after application of the physical layer modification.

4. References

[1] R1-030421 "Turbo coder irregularities in HSDPA" Siemens, presented in RAN WG1 #32

[2] R1-030444 "Turbo-coding and puncturing interactions on HS-DSCH in R5 HSDPA", InterDigital, presented in RAN WG1 #32

[3] R4-030223 "HSDPA for the 1,28 Mcps TDD option – A-VRC test methodology and simulation assumptions", Siemens, presented in RAN WG4 #26

[4] 3GPP TS 25.212 v5.4.0 "Channel coding and Multiplexing (FDD)"

[5] 3GPP TS 25.222 v5.4.0 "Channel coding and Multiplexing (TDD)"

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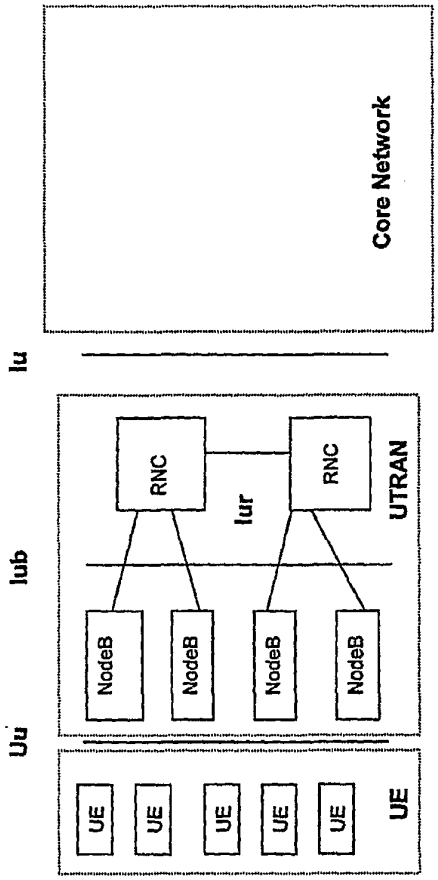


Figure 1
(Prior Art)

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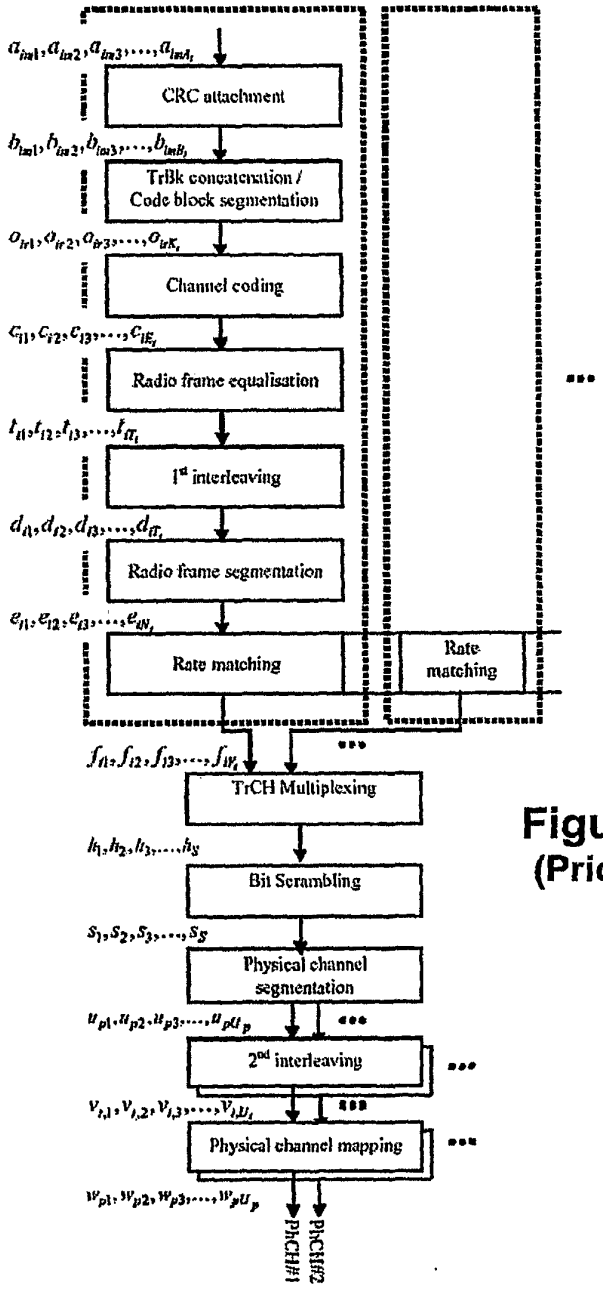


Figure 2a
(Prior Art)

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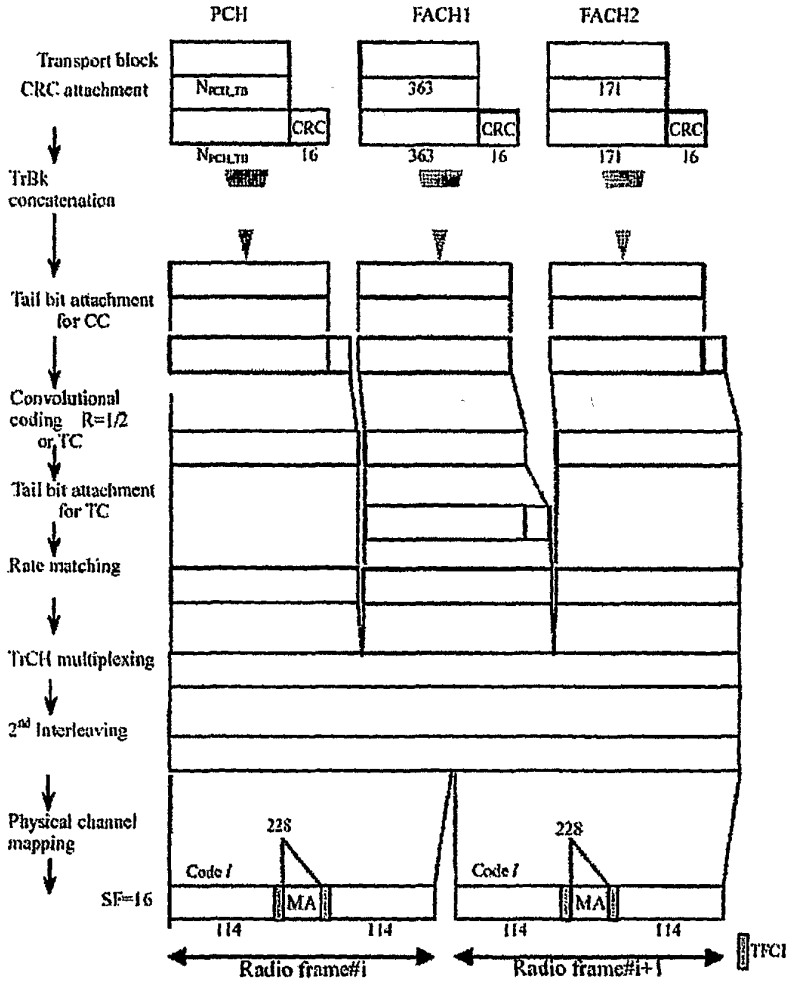


Figure 2b
(Prior Art)

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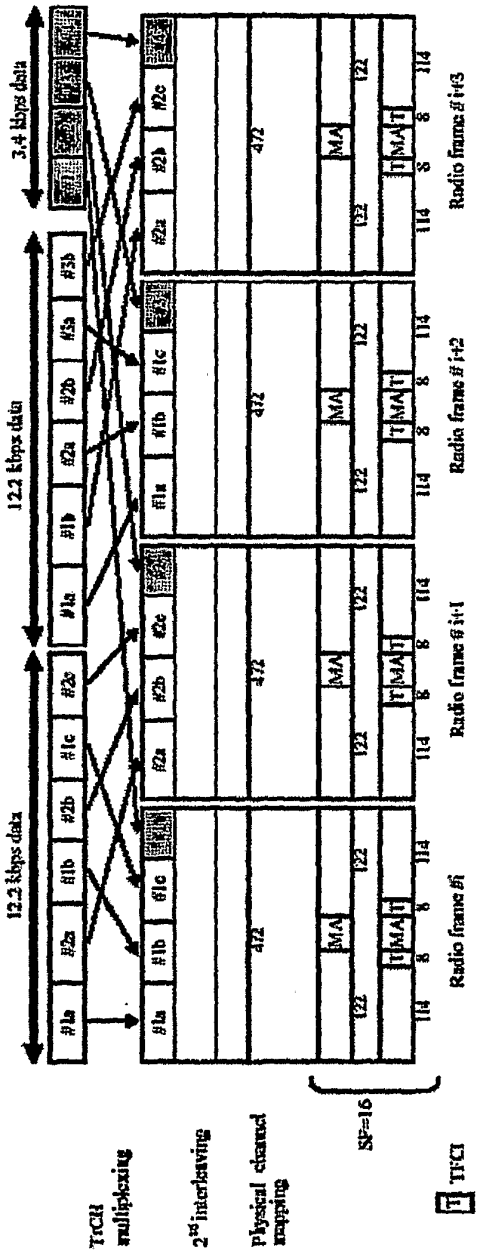


Figure 2c
(Prior Art)

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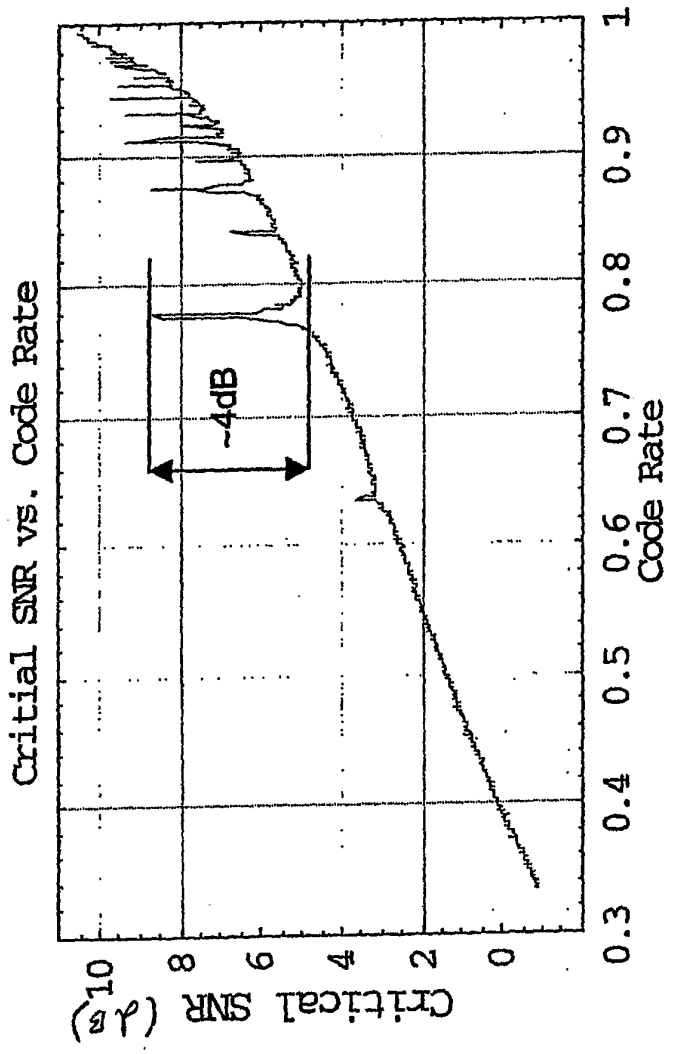


FIG. 3 (PRIOR ART)

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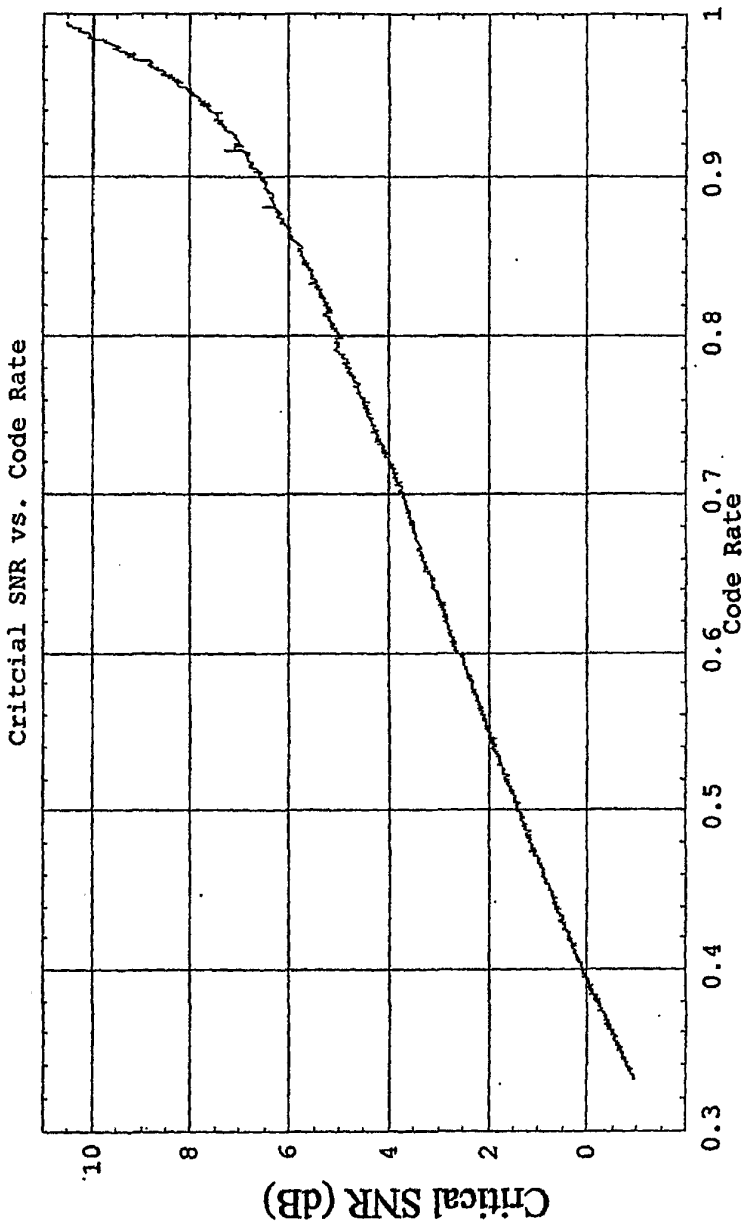


FIG. 4

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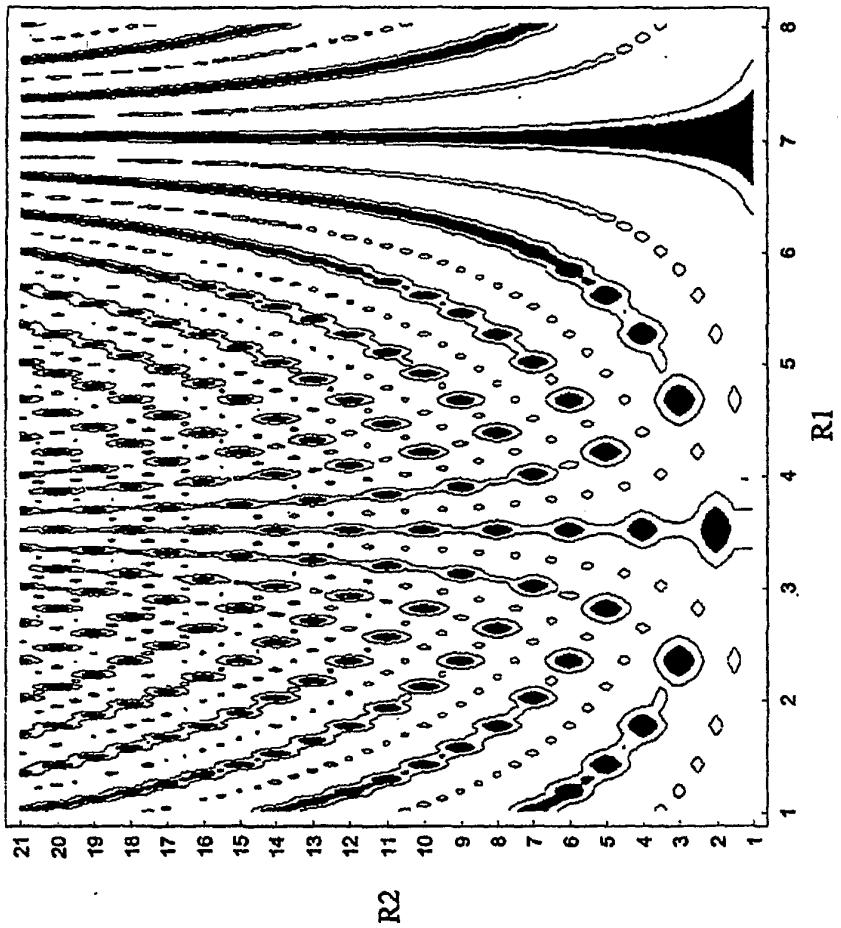


FIG. 5

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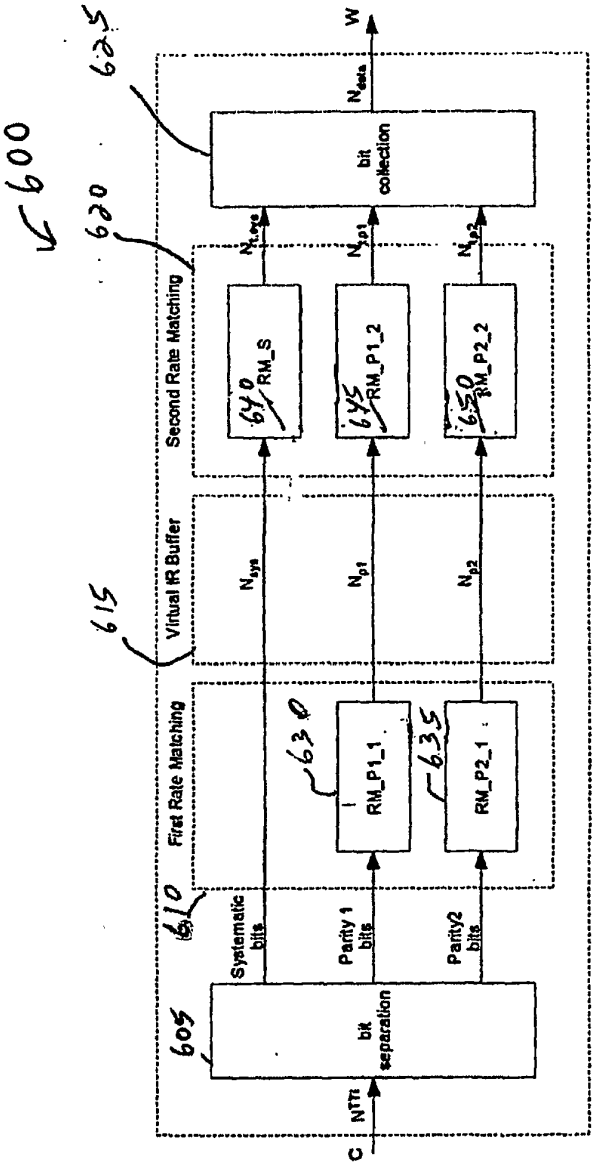
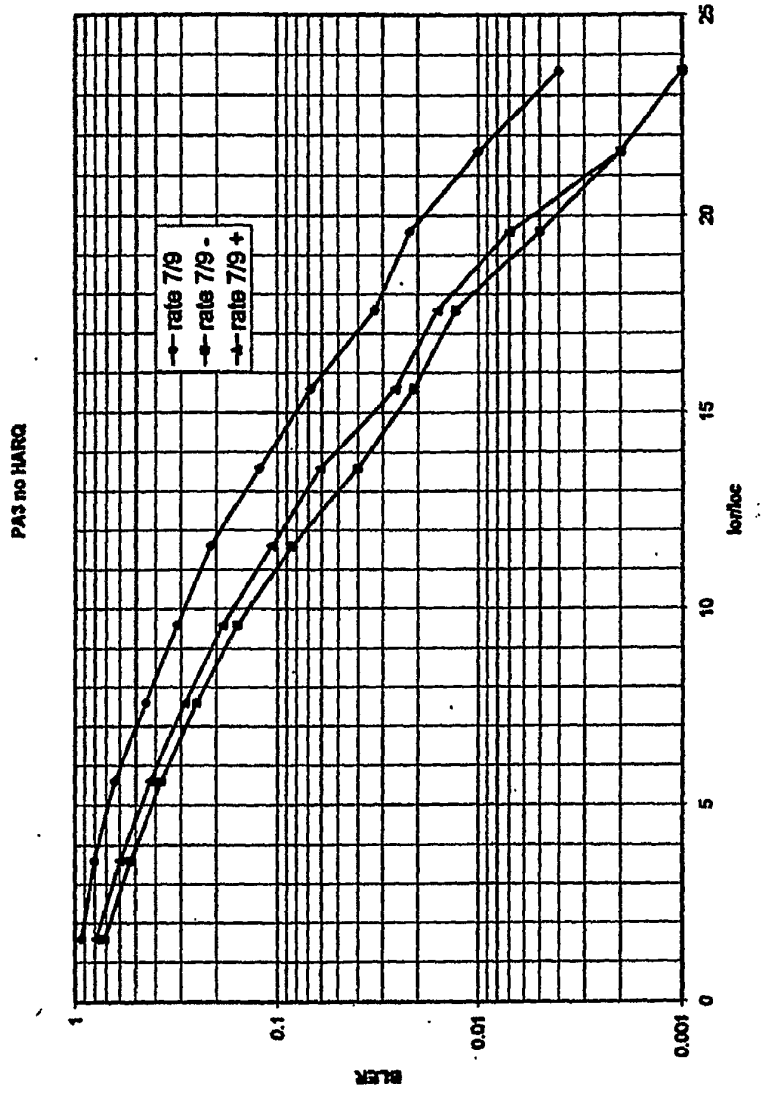


FIG. 6

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FIG. 7



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P1 1126823

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February 17, 2004

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APPLICATION NUMBER: *60/434,232*
FILING DATE: *December 16, 2002*
RELATED PCT APPLICATION NUMBER: *PCT/US03/38223*

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JC850 U.S. PTO 60/434232

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Philip J.	Pietraski	199 N. Oak Street, N. Massapequa, NY 11758

[X] *Additional inventors are being named on the* 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

METHOD FOR DETECTING AND ADDRESSING PERFORMANCE-DEGRADATION IN PUNCTURED TURBO CODES

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

[X] Customer Number 24374 → *Place Customer Number Bar Code Label here*

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[X] Firm *or* Individual Name	Volpe and Koenig, P.C. DEPT ICC				
Address					
Address					
City		State		ZIP	
Country		Telephone		Fax	

ENCLOSED APPLICATION PARTS *(check all that apply)*

[X] Specification *Number of Pages* 9
[X] Drawing(s) *Number of Sheets* 1
[ ] Application Data Sheet. See 37 CFR 1.76
[ ] CD(s), Number
[X] Other (specify) Fee Transmittal

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

[ ] Applicant claims small entity status. See 37 CFR 1.27.
[ ] A check or money order is enclosed to cover the filing fees
[X] The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 09-0435
[ ] Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): 160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[X] No.

[ ] Yes, the name of the U.S. Government agency and the Government contract number are: _____

Respectfully submitted,

SIGNATURE _____ Date 12 / 16 / 02

TYPED or PRINTED NAME Rama B. Nath

REGISTRATION NO. *(if appropriate)* 27,072

Docket Number: 2-449US

TELEPHONE 215-568-6400

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PROVISIONAL APPLICATION COVER SHEET
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Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
Gregory S.	Sternberg	50 Brompton Road, Apt. 2B Great Neck, NY 11021

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TOTAL AMOUNT OF PAYMENT ($) 160.00

Complete if Known	
Application Number	Not Yet Known
Filing Date	December 16, 2002
First Named Inventor	PIETRASKI et al.
Examiner Name	Not Yet Known
Group Art Unit	Not Yet Known
Attorney Docket No.	2-449US

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[ ] Applicant claims small entity status. See 37 CFR 1.27

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FEE CALCULATION

1. BASIC FILING FEE

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101	740	201	370	Utility filing fee	-0-
106	330	206	165	Design filing fee	
107	510	207	255	Plant filing fee	
108	740	208	370	Reissue filing fee	
114	160	214	80	Provisional filing fee	160.00

SUBTOTAL (1) ($) 160.00

2. EXTRA CLAIM FEES

	Extra Claims		Fee from below		Fee Paid
Total Claims		- ** =		X	= -0-
Independent Claims		- ** =		X	=
Multiple Dependent					= -0-

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) -0-

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FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	-0-
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	740	249	370	For each additional invention to be examined (37 CFR § 1.129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid SUBTOTAL (3) ($) -0-

SUBMITTED BY				Complete (if applicable)	
Name (Print/Type)	Rama B. Nath	Registration No. (Attorney/Agent)	27,072	Telephone	215-568-6400
Signature				Date	12/16/2002

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Practitioner's Docket No. 2-449US ***PATENT***

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: PIETRASKI, Philip J.; STERNBERG, Gregory S.

Application No.: Not Yet Known Group No.: Not Yet Known

Filed: Not Yet Known Examiner: Not Yet Known

For: METHOD FOR DETECTING AND ADDRESSING PERFORMANCE-DEGRADATION IN PUNCTURED TURBO CODES

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Arlington, VA 22202

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Lucy Ann Mahjoubian

Lucy Ann Mahjoubian

Signature of person mailing paper or fee

Date: December 16, 2002

InterDigital Communications Corporation
781 Third Avenue
King of Prussia, PA 19406
(610) 878-5633

METHOD FOR DETECTING AND ADDRESSING PERFORMANCE-DEGRADATION IN PUNCTURED TURBO CODES

FIELD OF THE INVENTION

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.

BACKGROUND OF THE INVENTION

This application includes the following acronyms:

3GPP	third generation partnership project
BER	bit error rate
BLER	block error rate
FDD	frequency-division duplex
SNR	signal to noise ratio
TDD	time-division duplex
UMTS	universal mobile telecommunication system

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 can be viewed as parallel, recursive systematic convolution codes, which can be used for channel coding and decoding in order to detect and correct errors that might occur in the transmission of digital data through different channels. In a 3GPP-coding scheme selected for data services, in order to achieve an optimum performance with the scheme, puncturing may be needed to ensure rate matching A typical method for creating high-rate turbo codes is to puncture the parity bits of a lower-rate code until the desired code rate is attained. It has been discovered that particular codes created by puncturing exhibit poorer than expected performance. The poorer performance can be attributed to certain punctured bit patterns.

It is desirable to provide an improved method for creating high rate turbo codes without the disadvantages of prior art.

SUMMARY OF THE INVENTION

This invention provides several simple and efficient methods of detecting, avoiding and/or correcting problematic puncturing patterns in the parity bit streams without having to avoid desired code rates.

When creating 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. Also covered by the invention is an algorithm to identify all puncturing patterns with degraded performance. The invention is applicable without limitation to layers 1 and 2 in the FDD and TDD UMTS modes of transmission as well as other modes of transmission. Additionally, methods are described hereinafter for modification to the puncturing patterns such that performance of the turbo code is restored.

BRIEF DESCRIPTION OF THE DRAWING

A more detailed understanding of the invention may be had from the following description of preferred embodiments, given by way of example and to be understood in conjunction with the accompanying drawing wherein:

Figure 1 is an illustration of the SNR required to successfully decode a data block with high probability vs. code rate for the 3GPP turbo encoding method.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 shows how particular codes created by puncturing exhibit poorer than expected performance. As shown in figure 1, as much as a 4dB loss can be measured in the critical SNR value.

The following passage relates to detecting codes with degraded performance. 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.
One such exemplary method for detecting such patterns is described below for the 3GPP turbo code:

When non-puncturing patterns with period $7\hat{N}/2$ ($\hat{N}$ =1,2,3...) are used, certain 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.

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,

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

for $\hat{N}>0$ where,

$$\hat{N}=\left\lfloor\frac{4I}{7P}+\frac{1}{2}\right\rfloor. \qquad (2)$$

In order to avoid code rates with degraded performance, 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.

This paragraph concerns modifications to "puncturing", 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.

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.

This paragraph relates to changing puncture rates in P1 and P2. A simple and efficient method of modifying the puncture patterns consists in 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. First, the number of non-punctured P1 bits must be increased sufficiently to avoid the problematic puncturing patterns. Likewise, the number of P2 bits must be decreased by an equal amount that is also sufficient to avoid problematic puncturing patterns. These two constraints can be combined into the following expression for Δ ,

$$\Delta = \left\lceil \max\left\{ \left\lfloor \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} \right\rfloor - \frac{P}{2}, \frac{P}{2} - \left\lfloor \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\rfloor \right\} \right\rceil \qquad (3)$$

Alternatively, non-punctured bits may be increased in P2 and decreased in P1.

Regarding block interleaving before rate matching, interleaving the parity bits before rate matching occurs can also mitigate the effect of the periodicity of the puncturing pattern. In this way, after de-interleaving, periodic sampling of the parity bits is avoided even when periodic sampling is done in rate matching.

As regards time varying interleaving, noting that 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, small time-varying interleavers can be used. This has the advantage of requiring less memory and helps to minimize the distortion of the uniformity of the puncturing.

The above methods are 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. Variations to the examples described above 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. Any permutation (and methods of generating such permutations) of the puncturing pattern envisaged as novel 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.

ABSTRACT

A method of detecting, avoiding and/or correcting problematic puncture patterns in parity bit streams and punctured turbo codes without having to avoid desirable code rates. The inventive method 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 inventive method herein provides for forward error correction comprising turbo coding and puncturing that achieve a smooth functional relationship between any measure of performance (e.g., BLER, BER, or required SNR) and the effective coding rate resulting from combining the lower rate code generated by the turbo encoder with puncturing of the parity bits.

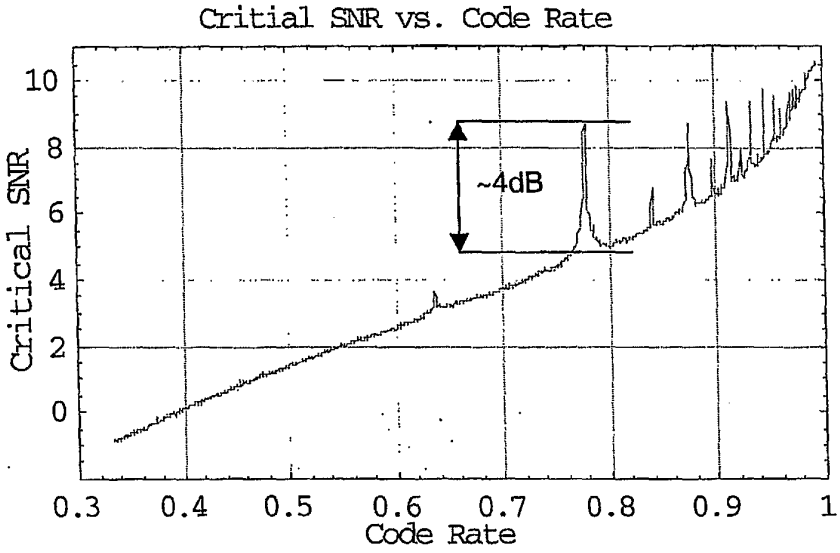

Critial SNR vs. Code Rate
Critical SNR
10
8
6
4
2
0
~4dB
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Code Rate

FIGURE 1

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APPLICATION NUMBER: *60/444,068*
FILING DATE: *January 30, 2003*
RELATED PCT APPLICATION NUMBER: *PCT/US03/38223*

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JC879 U.S. PTO 60/444068

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Philip J.	Pietraski	199 N. Oak Street N. Massapequa, NY 11758

[X] *Additional inventors are being named on the* 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

METHOD AND SYSTEM FOR DETECTING, AVOIDING, AND/OR CORRECTING PERFORMANCE DEGRADATION IN PUNCTURED TURBO CODES

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[X] Firm *or* Individual Name: Volpe and Koenig, P.C. DEPT ICC

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ENCLOSED APPLICATION PARTS *(check all that apply)*

[X] Specification *Number of Pages* 14

[X] Drawing(s) *Number of Sheets* 1

[ ] Application Data Sheet. See 37 CFR 1.76

[ ] CD(s), Number

[X] Other (specify) Fee Transmittal

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[ ] Applicant claims small entity status. See 37 CFR 1.27.

[ ] A check or money order is enclosed to cover the filing fees

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[ ] Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): 160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[X] No.

[ ] Yes, the name of the U.S. Government agency and the Government contract number are: _____

Respectfully submitted,

SIGNATURE _____ Date 01 / 30 / 03

TYPED or PRINTED NAME Kimberly S. Chotkowski, Esquire

TELEPHONE 215-568-6400

REGISTRATION NO. *(if appropriate)* 45,012

Docket Number: 2-461US

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Docket Number	2-461US	Type a plus sign (+) inside this box →	+

INVENTOR(S)/APPLICANT(S)

Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
Gregory S.	Sternberg	50 Brompton Rd., Apt. 2B Great Neck, NY 11021

Number 1 of 1

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Volpe and Koenig Revision of PTO/SB/17 (10-01)
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Complete if Known	
Application Number	Not Yet Known
Filing Date	January 30, 2003
First Named Inventor	PIETRASKI et al.
Examiner Name	Not Yet Known
Group Art Unit	Not Yet Known
Attorney Docket No.	2-461US

METHOD OF PAYMENT

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Deposit Account Name: InterDigital Comm. Corp.

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[ ] Applicant claims small entity status. See 37 CFR 1.27

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101	740	201	370	Utility filing fee	-0-
106	330	206	165	Design filing fee	
107	510	207	255	Plant filing fee	
108	740	208	370	Reissue filing fee	
114	160	214	80	Provisional filing fee	160.00

SUBTOTAL (1) ($) 160.00

2. EXTRA CLAIM FEES

		Extra Claims		Fee from below		Fee Paid
Total Claims	-	** =	X		=	-0-
Independent Claims	-	** =	X		=	
Multiple Dependent					=	-0-

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) -0-

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FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	-0-
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	740	249	370	For each additional invention to be examined (37 CFR § 1.129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

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SUBMITTED BY				Complete *(if applicable)*	
Name (Print/Typo)	Kimberly S. Chotkowski, Esquire	Registration No. (Attorney/Agent)	45,012	Telephone	215-568-6400
Signature	Kimberly S. Chotkowski			Date	1/30/2003

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Practitioner's Docket No. 2-461US ***PATENT***

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: PIETRASKI, Philip J.; STERNBERG, Gregory S.

Application No.: Not Yet Known Group No.: Not Yet Known

Filed: Not Yet Known Examiner: Not Yet Known

For: METHOD AND SYSTEM FOR DETECTING, AVOIDING, AND/OR CORRECTING PERFORMANCE DEGRADATION IN PUNCTURED TURBO CODES

Box Provisional Applications
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Lucy Ann Mahjoubian

Lucy Ann Mahjoubian

Signature of person mailing paper or fee

Date: January 30, 2003

InterDigital Communications Corporation
781 Third Avenue
King of Prussia, PA 19406
(610) 878-5633

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METHOD AND SYSTEM FOR DETECTING, AVOIDING, AND/OR CORRECTING PERFORMANCE DEGRADATION IN PUNCTURED TURBO CODES

FIELD OF THE INVENTION

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.

BACKGROUND OF THE INVENTION

A typical method for creating high-rate Turbo codes is to puncture the parity bits of a lower-rate code until the desired code rate is attained. It was recently discovered that particular codes created by puncturing exhibit poorer than expected performance. The poorer performance can be attributed to certain punctured bit patterns.

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.

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Since every surviving parity bit can be written as a function of all preceding systematic bits, we will examine the constraints that can be placed on the systematic bits by observation of the surviving parity bits with certain non-puncture patterns, i.e., how much can be learned from the surviving parity bits. We illustrate this with an example based on the 3GPP Turbo coder.

For the 3GPP Turbo encoder, the constituent recursive encoders have an impulse response that is periodic with period 7 for positive time (semi-periodic). This can readily be seen by interpretation of the encoder as a 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 an 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.

The encoder is a Linear Time Invariant (LTI) system on the 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 Transport Block (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 $t > T$. Now consider the following simplistic example to illustrate how certain non-puncturing periods may result in a loss of distributed information about a small group of bits across the set of parity bits:

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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 being determined by the non-puncture period and the impulse response of the recursive encoding block. For most non-puncture patterns, (those that have 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 (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, i.e., a rank-1 system of equations is formed and a unique solution does not exist. When the non-puncture period is relatively prime with the period of the recursive encoding block, making 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.

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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 seven non-puncture pattern but with two surviving parity bits per period. The same argument above leads to a rank-2 system of seven equations. 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.

This shows how the distribution of information about a group of bits is lost when certain non-puncture patterns are employed. In the 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 does not add to the distributed information about earlier groups. This can be seen from the causality of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 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.

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DETAILED DESCRIPTION OF THE INVENTION

According to the present invention there is provided several method embodiments for detecting, avoiding and/or correcting the problematic puncturing patterns in the parity bit streams without having to avoid code rates.

When creating codes via puncturing, it is generally wise to distribute, as uniformly as possible, the bits that are punctured. Using this rule, 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 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, methods are described for modification to the puncturing patterns such that performance of the Turbo code is restored.

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.

One such method to detecting such patterns is described below for the Release 99 and Release 4 3GPP Turbo code:

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When non-puncturing patterns with period $7\hat{N}/2$ ($\hat{N}$=1,2,3...) 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.

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,

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

for $\hat{N}>0$ where,

$$\hat{N}=\left\lfloor\frac{4I}{7P}+\frac{1}{2}\right\rfloor. \qquad (2)$$

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.

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When a particular code rate is desired and it is determined that its use will results in degraded performance, a slightly smaller 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.

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. The following mitigation techniques apply when only a single stage of rate matching is employed (or the first stage of rate matching is transparent.)

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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. First, number of non-punctured P1 bits must be increased sufficiently to avoid the problematic puncturing patterns. Likewise, the number of P2 bits must be decreased by an equal amount that is also sufficient to avoid problematic puncturing patterns. These two constraints can be combined in to the following expression for □,

$$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lfloor \frac{7\hat{N}+1}{2} \right\rfloor} \right\} \right\rceil \quad (3)$$

Alternatively, non-punctured bits may be increased in P2 and decreased in P1. Figure 1 shows the required SNR for successful decoding of the Turbo coded block when P1/P2 biasing is applied.

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 3GPP2 Turbo Code (CDMA2000) 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.

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.

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.

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.

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 e_minus and e_plus parameters throughout the execution of the rate-matching algorithm.

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. Any permutation (and methods of generating such permutations) of the puncturing pattern is claimed by the invention.

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.

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

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Matching with respect to parity bits}. The output is a rational number that may be compared to a threshold to accept/reject the configuration as providing/not providing acceptable performance. The equation is provided below in (4). 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 (4) is a piecewise linear and continuous function in r1, r2 and is therefore trivial to evaluate.

$$\begin{aligned}\lambda(r1,r2)=\sum_{n=1}^{L-1}\alpha_n\Bigg[&\left(1-\left\lceil\frac{1}{L}\lceil r1\lceil nr2\rceil\rceil-\left\lfloor\frac{1}{L}\lceil r1\lceil nr2\rceil\rceil\right\rfloor\right)(nr2-\lfloor r2\rfloor)(r1\lceil nr2\rceil-\lfloor r1\lceil nr2\rceil\rfloor)+\\&\left(1-\left\lceil\frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor-\left\lfloor\frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor\right\rfloor\right)(nr2-\lfloor nr2\rfloor)(-r1\lceil nr2\rceil-\lfloor r1\lceil nr2\rceil\rfloor+1)+\\&\left(1-\left\lceil\frac{1}{L}\lceil r1\lfloor nr2\rfloor\rceil-\left\lfloor\frac{1}{L}\lceil r1\lfloor nr2\rfloor\rceil\right\rfloor\right)(-nr2+\lfloor nr2\rfloor+1)(r1\lfloor nr2\rfloor-\lfloor r1\lfloor nr2\rfloor\rfloor)+\\&\left(1-\left\lceil\frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor-\left\lfloor\frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor\right\rfloor\right)(-nr2+\lfloor nr2\rfloor+1)(-r1\lfloor nr2\rfloor+\lfloor r1\lfloor nr2\rfloor\rfloor+1)\Bigg]\end{aligned}\tag{4}$$

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.

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Methods of addressing and/or mitigating performance issues with multiple stages of rate matching include those discussed herein and methods described in the following sections.

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.

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.

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.

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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.

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ABSTRACT

According to the present invention there is provided several method embodiments for detecting, avoiding and/or correcting the problematic puncturing patterns in the parity bit streams without having to avoid code rates. When creating codes via puncturing, it is generally wise to distribute, as uniformly as possible, the bits that are punctured. Using this rule, it is inevitable that certain code rates will require the resulting non-punctured bit pattern to be less effective. An algorithm is provided to identify all puncturing patterns with degraded performance. Additionally, methods are described for modification to the puncturing patterns such that performance of the Turbo code is restored.

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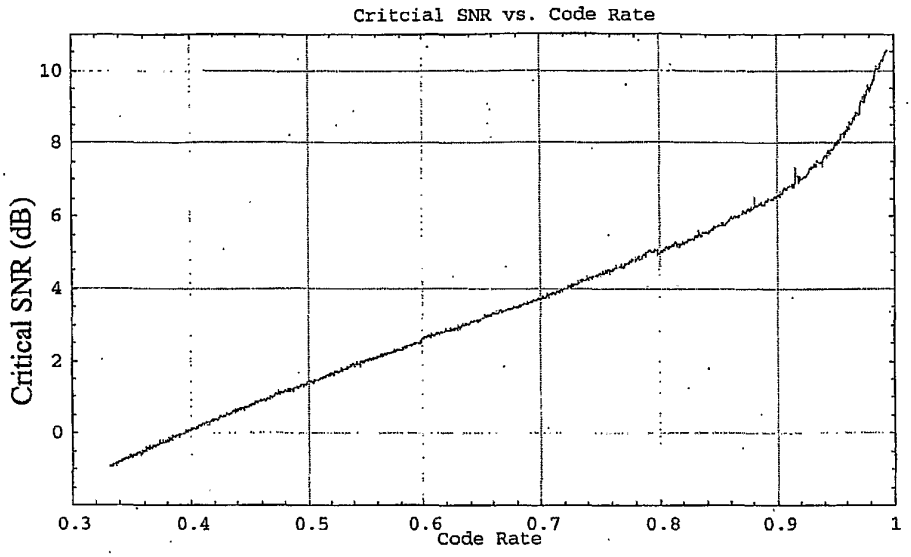

Critcial SNR vs. Code Rate
Critical SNR (dB)
10
8
6
4
2
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Code Rate

FIGURE 1


PCT Application
PCT/US2003/038223

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

60/470921
05/15/03

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[X] *Additional inventors are being named on the* 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

TURBO-CODING AND PUNCTURING INTERACTIONS ON HIGH-SPEED DOWNLINK SHARED CHANNEL (HS-DSCH)

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ENCLOSED APPLICATION PARTS *(check all that apply)*

[X] Specification *Number of Pages* 16 — [ ] CD(s), Number

[X] Drawing(s) *Number of Sheets* 7 — [X] Other (specify) Fee Transmittal

[ ] Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

[ ] Applicant claims small entity status. See 37 CFR 1.27.

[ ] A check or money order is enclosed to cover the filing fees

[X] The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 09-0435

[ ] Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): 160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[X] No.

[ ] Yes, the name of the U.S. Government agency and the Government contract number are: _____

Respectfully submitted,

SIGNATURE _____

TYPED or PRINTED NAME Kimberly S. Chotkowski, Esquire

TELEPHONE 215-568-6400

Date 05 / 15 / 03

REGISTRATION NO. *(if appropriate)* 45,012

Docket Number: 2-526US

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PROVISIONAL APPLICATION COVER SHEET
Additional Page

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Gregory S.	Sternberg	50 Brompton Road, Apt. 2B Great Neck, NY 11021

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FEE TRANSMITTAL for FY 2002

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TOTAL AMOUNT OF PAYMENT	($) 160.00

Complete if Known	
Application Number	Not Yet Known
Filing Date	Not Yet Known
First Named Inventor	Pietraski et al.
Examiner Name	Not Yet Known
Group Art Unit	Not Yet Known
Attorney Docket No.	2-526US

METHOD OF PAYMENT

1. [X] The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number: 09-0435

Deposit Account Name: InterDigital Comm. Corp.

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[ ] Applicant claims small entity status. See 37 CFR 1.27

2. [ ] **Payment Enclosed:**

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	740	201	370	Utility filing fee	
106	330	206	165	Design filing fee	
107	510	207	255	Plant filing fee	
108	740	208	370	Reissue filing fee	
114	160	214	80	Provisional filing fee	160.00

SUBTOTAL (1) ($) 160.00

2. EXTRA CLAIM FEES

	Extra Claims		Fee from below		Fee Paid
Total Claims		- ** =		X =	0
Independent Claims		- ** =		X =	
Multiple Dependent				=	0

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0

**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
105	130	205	65	Surcharge - late filing fee or oath	0
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	740	249	370	For each additional invention to be examined (37 CFR § 1.129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	
Other fee (specify)					

*Reduced by Basic Filing Fee Paid SUBTOTAL (3) ($) 0

SUBMITTED BY				Complete (if applicable)	
Name (Print/Type)	Kimberly S. Chotkowski, Esquire	Registration No. (Attorney/Agent)	45,012	Telephone	215-568-6400
Signature				Date	May 15, 2003

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Practitioner's Docket No. 2-526US ***PATENT***

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: PIETRASKI, Philip J.; STERNBERG, Gregory S.

Application No.: Not Yet Known Group No.: Not Yet Known

Filed: Not Yet Known Examiner: Not Yet Known

For: TURBO-CODING AND PUNCTURING INTERACTIONS ON HIGH-SPEED DOWNLINK SHARED CHANNEL (HS-DSCH)

Mail Stop Provisional Patent Application
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

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Date: May 15, 2003

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TURBO-CODING AND PUNCTURING INTERACTIONS ON HIGH-SPEED DOWNLINK SHARED CHANNEL (HS-DSCH)

FIELD OF THE INVENTION

This invention generally relates to the use of turbo codes, and more particularly to a method for detecting and correcting performance in punctured turbo codes, wherein two or more stages of rate matching are employed.

BACKGROUND OF THE INVENTION

In order to obtain efficient performance, It is necessary to ensure proper detecting, avoiding and /or correcting the problematic puncturing patterns in the parity bit streams without having to avoid code rates. Problematic interactions are known to occur between turbo coder output and puncturing in the rate matching stages. It is desirable to provide a method and an approach to avoid problematic interactions between turbo coder output and puncturing in the rate matching stages, wherein two or more stages are employed.

SUMMARY OF THE INVENTION

The invention provides a method for detecting and correcting performance in punctured turbo codes, where two or more stages are employed, particularly for turbo coding and puncturing interactions on HS-DSCH in R5 HSDPA.

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BRIEF DESCRIPTION OF THE DRAWING

A more detailed understanding of the invention may be had from the following description of a preferred embodiment, given by way of example and to be understood in conjunction with the accompanying drawing wherein:

Figure 1 shows initial BLER for HS-DSCH transport blocks with certain effective coding rates;

Figure 2 shows SNR required to decode a transport block on HS-DSCH as function of effective coding rate;

Figure 3illustrates the structure of rate1/3 turbo coder;

Figure 4 shows simple periodicity of 7 for surviving (i.e., non-punctured) parity bits;

Figure 5 shows an alternating pattern of surviving (i.e., non-punctured) parity bits:

Figure 6 shows problematic puncturing regions as a function of puncturing rates in turbo-coded parity bit streams; and,

Figure 7 illustrates a look up table as a function of the combination indicator *i* and transport block size *ki.*

DETAILED DESCRIPTION OF PREFERRED EMBODIMEDNT

Support for link adaptation by means of Adaptive Modulation and Coding (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 Transport Block Set Size (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.

Discussions on high-speed downlink packet access (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.

The description that follows indicates that the Turbo-coding performance on HS-DSCH is heavily impacted by unfavourable 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 25.222) on HS-DSCH transport blocks (where the problematic interactions originate) are done exactly the same way for both modes.

As a short illustration, figure 1 shows the BLER performance of 3 different

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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 HS-PDSCHs. 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.

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%.

Generalizing the above example and looking on what happens over the range of possible effective coding rates, figure 2 shows the SNR necessary to decode a transport block on HS-DSCH.

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.

In the analyses that follow, a single R99 rate-matching block is assumed,

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however, the concepts apply more generally to R4 (section 4) and R5 with and without Incremental Redundancy (section 5). 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.

Section 6 looks at the implications of the findings in section 4 and 5 into more detail.

In particular, we discuss a first approach to simply avoid the setting of critical puncturing rates 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 being our preferred approach in the beginning, the complexity (look-up tables) and imposed restrictions on possible MAC-hs scheduler decisions lead us to also consider a second alternative, which is to investigate slight modifications to the puncturing patterns as generated by the current rate-matching stages for HS-DSCH in 25.212/222. This change would constitute only a small change in the way the rate matching parameters are generated in TS25.212/222, e.g. a modification to the parameters in Table 10 "Parameters for hybrid automatic repeat request (HARQ) second rate matching", and more importantly would not require any additional signaling.

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

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its transparency for the MAC-hs scheduler (simply selects whatever transport block size is desired as outcome of the scheduler decision), we recommend a corresponding change in 25.212/222 to remedy this problem.

Turbo-coding and puncturing periodicities:

The constituent recursive convolutional encoders in the Turbo-coder as by 25.212/222 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. Since every surviving parity bit can be written as a function of all preceding systematic bits, we will look at how much can be learned about the systematic bits from the surviving parity bits.

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).

Note that the constituent recursive convolutional encoder is a Linear Time Invariant (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 Transport Block (TB).

Now consider the following simplistic example to illustrate how 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:

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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.

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 they are linearly independent, the values of the 7 bits may be determined.

However, consider the case where 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.

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.

It is also possible that some distributed information is lost even for non-

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simple periods, e.g., consider the case where the non-puncture pattern alternates between a simple period of three and four (2 surviving parity bits per period with period = 7), such as shown in figure 3.

This results in a period seven 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.

Single Stage Rate Matching:

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.

These degradations correspond to rank-1 and rank-2 scenario respectively as described in section 3. This case corresponds to the rank-1 scenario in section 3. Rank-2 scenarios have less impact on the SNR degradation than rank-1 scenarios as can be seen in figure 2. Since higher rank scenarios (>2) do not significantly contribute to performance degradation, other than rank-1 and rank-2 scenarios are not considered here.

The code rates at the center of these regions are determined by:

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$$CR = \frac{1}{1+\frac{2}{3.5N}} = \frac{3.5N}{3.5N+2} \qquad N = 1,2,... \tag{1}$$

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.

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.

The average 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 (transport block size) and *P* is the total number of surviving parity bits (sum of Turbo-coded parity surviving bits from parity bit streams 1 and 2) at the output of rate matching.

Therefore, the desired code rate will lead to a problematic puncturing pattern if,

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

for $\hat{N} > 0$ where,

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$$\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor. \tag{3}$$

Two Stages of Rate Matching:

When two 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.

A closed form expression based upon similar considerations as above is possible. This expression takes as input either the triplet {Bits Before 1st stage of rate Matching, Bits after 1st Rate Matching, Bits after 2nd Rate matching} or the pair {1st stage parity puncturing rate, 2nd stage parity puncturing rate}.

The output is a rational number that may be compared to a threshold to accept/reject the configuration as being critical or not critical. The parameters *r1* and *r2* represent the 1st and 2nd stage parity puncturing rates. Although complicated, equation (4) is a piecewise linear and continuous function in *r1*, *r2*.

$$\begin{aligned}\lambda(r1,r2) = \sum_{n=1}^{2} \alpha_n \Bigg[& \left(1 - \left\lceil \frac{1}{L}\lceil r1\lceil nr2\rceil\rceil - \left\lfloor \frac{1}{L}\lceil r1\lceil nr2\rceil\rceil \right\rfloor\right)(nr2 - \lfloor r2\rfloor)(r1\lceil nr2\rceil - \lceil r1\lceil nr2\rceil\rceil) + \\ & \left(1 - \left\lceil \frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor - \left\lfloor \frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor \right\rfloor\right)(nr2 - \lfloor nr2\rfloor)(-r1\lceil nr2\rceil - \lceil r1\lceil nr2\rceil\rceil + 1) + \\ & \left(1 - \left\lceil \frac{1}{L}\lceil r1\lfloor nr2\rfloor\rceil - \left\lfloor \frac{1}{L}\lceil r1\lfloor nr2\rfloor\rceil \right\rfloor\right)(-nr2 + \lfloor nr2\rfloor + 1)(r1\lfloor nr2\rfloor - \lfloor r1\lfloor nr2\rfloor\rfloor) + \\ & \left(1 - \left\lceil \frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor - \left\lfloor \frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor \right\rfloor\right)(-nr2 + \lfloor nr2\rfloor + 1)(-r1\lfloor nr2\rfloor + \lfloor r1\lfloor nr2\rfloor\rfloor + 1) \Bigg] \end{aligned} \tag{4}$$

Figure 6 shows a contour plot of equation (4) with contours placed at 1/3 and 2/3 for α = {2/3, 1/3}. The α's are selected so that rank-1 effects have twice

the weight of rank-2 effects. A threshold comparison could then be based on this equation to test whether or not the Code Rate pair will perform adequately.

Alternative solutions

At least 2 approaches exist to avoid the problematic interactions between Turbo-coder output and puncturing in the rate-matching stages. These 2 approaches are further described in the following subsections.

Avoidance of problematic puncturing patterns:

This approach requires that the MAC-hs simply avoids using puncturing patterns that lead to SNR degradation and simply does not use certain combinations for mapping incoming transport blocks sizes to HS-PDSCHs.

Avoidance would either require building lookup tables that identify the problematical configurations or evaluating the predicted degradation expression described in the previous 2 sections in the MAC-hs scheduler.

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.

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,

- transport block set size of HS-DSCH transmission,
- number of soft information bits to be stored at the UE for H-ARQ,

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- number of physical channel bits allocated for the HS-PDSCHs,

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.

A graphical representation of 2 such look-up tables for 9600 soft bits (left) and 160000 soft bits (right) is shown in figure 7. Green regions indicate no significant degradation would be expected, yellow regions correspond to a small degradation (<~1/2 dB), and red regions exhibit degradations as large as ~4dB. The gray regions indicate configurations that would exceed the capabilities of the highest UE category.

Adjustments to the parity stream puncturing scheme:

This approach would allow the 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 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.

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.

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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 of the Turbo-coder (figure 1), although the puncturing pattern "phases" can be adjusted.

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.

If the number of punctured bits in parity bit stream 1 is decreased by □ and accordingly, the number punctured bits in parity bit stream 2 bits is increased by □, 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.

As shown in the previous sections, the desired code rate will lead to a problematic puncturing pattern if,

$$\exists \hat{N} \in \{1,2,...\} s.t. \left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor, \quad (5)$$

The set of code rates that give rise to problematic puncture patterns is a set of unconnected intervals of the real line, one interval per $\hat{N}$. Therefore, only one such $\hat{N}$ needs to be considered, the one that minimizes the left hand side of equation (1):

$$\hat{N} = \left\lfloor \frac{4I}{7P} + \frac{1}{2} \right\rfloor. \qquad (6)$$

In biasing the puncturing rates of the parity bit streams 1 and 2, P1 and P2, two constraints must be met.

First, the number of surviving bits in parity bit stream 1 must be increased sufficiently by an amount □ to avoid the problematic puncturing patterns. Likewise, the number of surviving bits in parity bit stream 2 must be decreased by an equal amount □that is also sufficient to avoid problematic puncturing patterns.

These two constraints can be combined in to the following expression for □,

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

The procedure to determine and apply the necessary P1/P2 bias is as follows:

Step 1) Compute $\hat{N}$ using (6).

Step 2) Determine if the desired code rate results in a problematic puncturing pattern using (5). If it does, continue to Step 3, otherwise set $\Delta = 0$.

Step 3) Compute the bias Δ using (7).

Step 4) Compute rate matching parameters by modifying Table 10 in TS25.212/222.

The foregoing is a description of a preferred embodiment and alternative solutions to providing detecting, avoiding/correcting problematic turbo code puncturing patterns especially on HS-DSCH in R5 HSDPA. 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.

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ABSTRACT

A method for detecting and correcting performance in punctured turbo codes, where two or more stages are employed, particularly for turbo coding and puncturing interactions on HS-DSCH in R5 HSDPA.

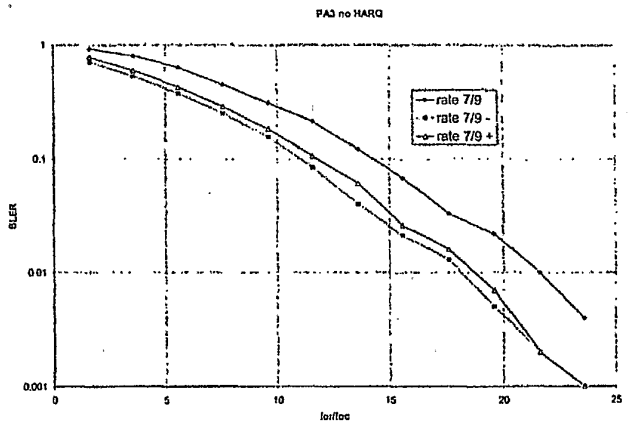

PA3 no HARQ
rate 7/9
rate 7/9 -
rate 7/9 +
BLER
1
0.1
0.01
0.001
0
5
10
15
20
25
Ior/Ioc

Figure 1

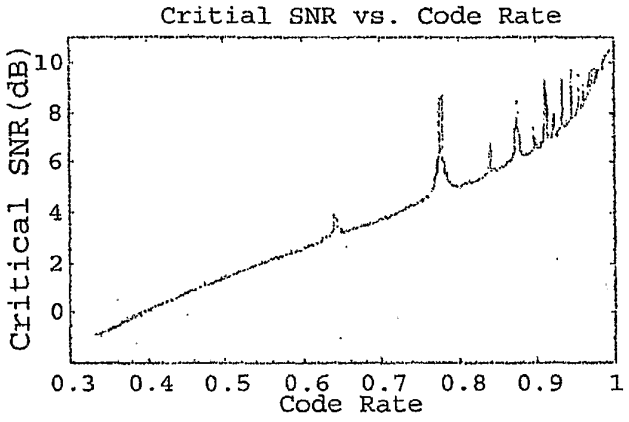

Critial SNR vs. Code Rate
Critical SNR(dB)
10
8
6
4
2
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Code Rate

Figure 2

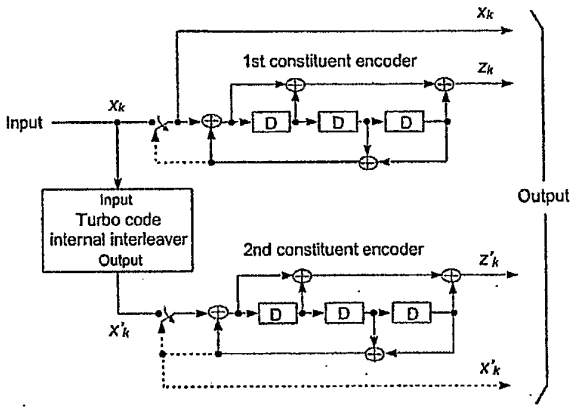

X_k
1st constituent encoder
Z_k
Input
X_k
D
D
D
Input
Turbo code
internal interleaver
Output
Output
2nd constituent encoder
Z'_k
X'_k
D
D
D
X'_k

Figure 3

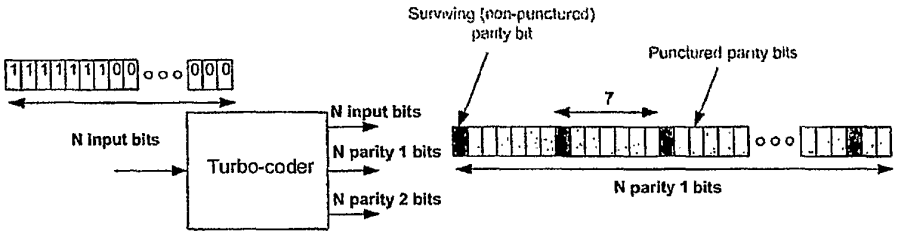

Surviving (non-punctured) parity bit
Punctured parity bits
7
1 1 1 1 1 1 1 0 0 ooo 0 0 0
N input bits
N input bits
Turbo-coder
N parity 1 bits
N parity 2 bits
ooo
N parity 1 bits

Figure 4

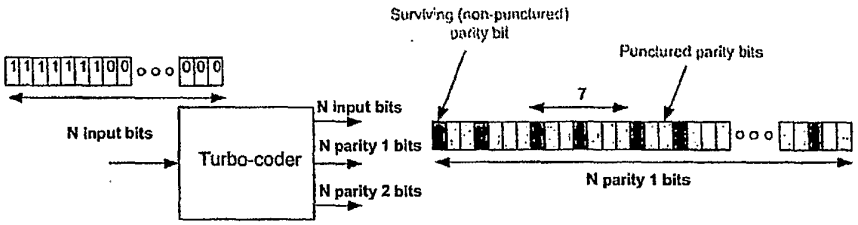

Surviving (non-punctured) parity bit
Punctured parity bits
7
N input bits
N input bits
Turbo-coder
N parity 1 bits
N parity 2 bits
N parity 1 bits

Figure 5

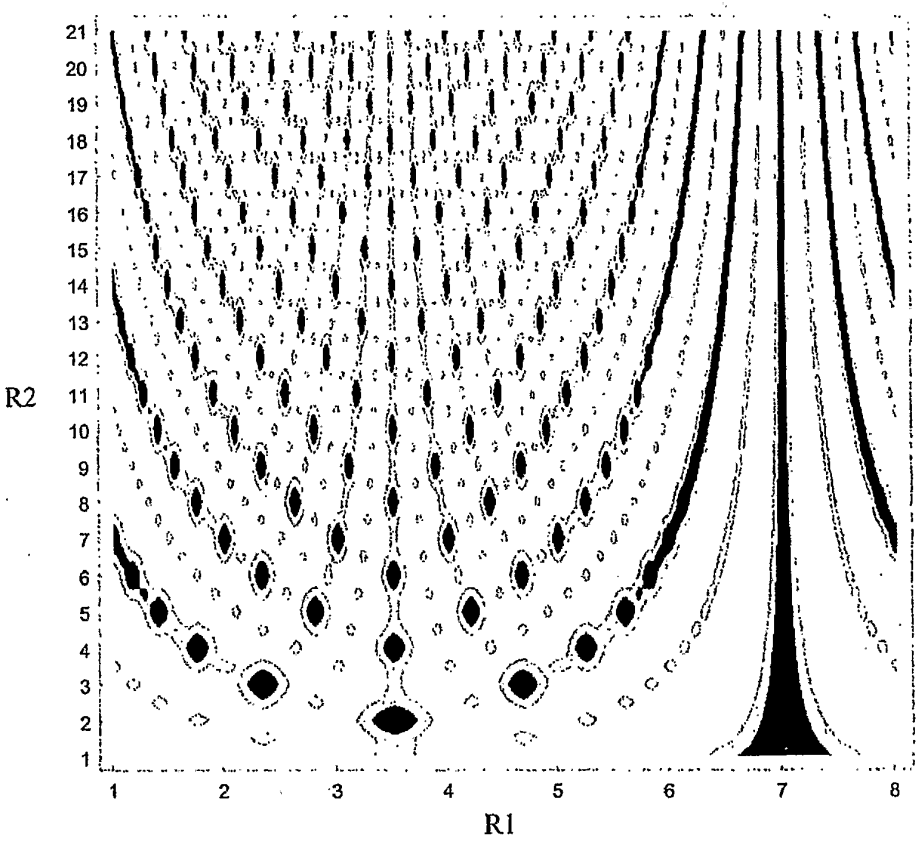


Figure 6

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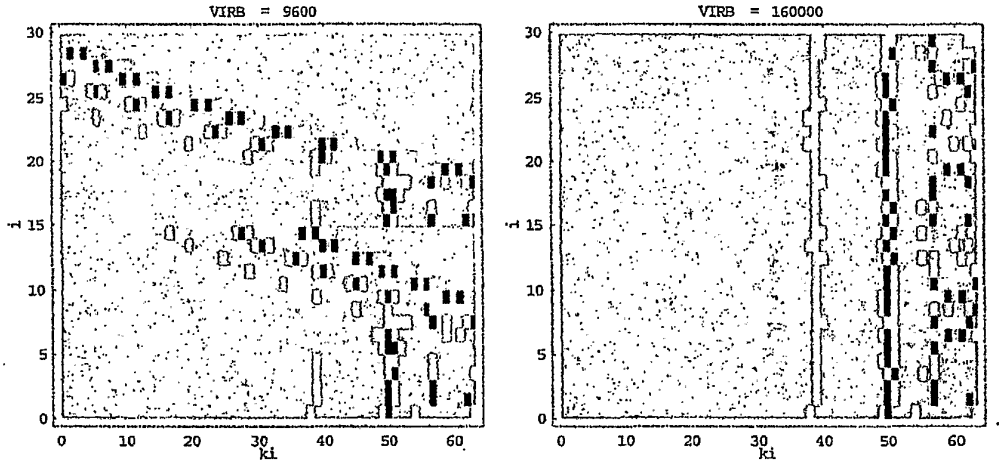


Figure 7


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PCT/US2003/038223

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

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B. FIELDS SEARCHED

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U.S. : 714/786, 790; 375/265

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)
East, IEEE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,370,669 B1 (EROZ et al) 09 April 2002 (09.04.2002), abstract, column 3, lines 1-52.	1, 6, 11, 16, 19, 25, 30, 35, 40, 43
Y,P	US 6,601,214 B1 (HAMMONS, JR.) 29 July 2003 (29.07.2003), abstract, column 5, lines 23-67.	2-5, 7-10, 12-15, 17, 18, 20-24, 26-29, 31-34, 36-39, 41, 42, 44-48

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

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"&" document member of the same patent family

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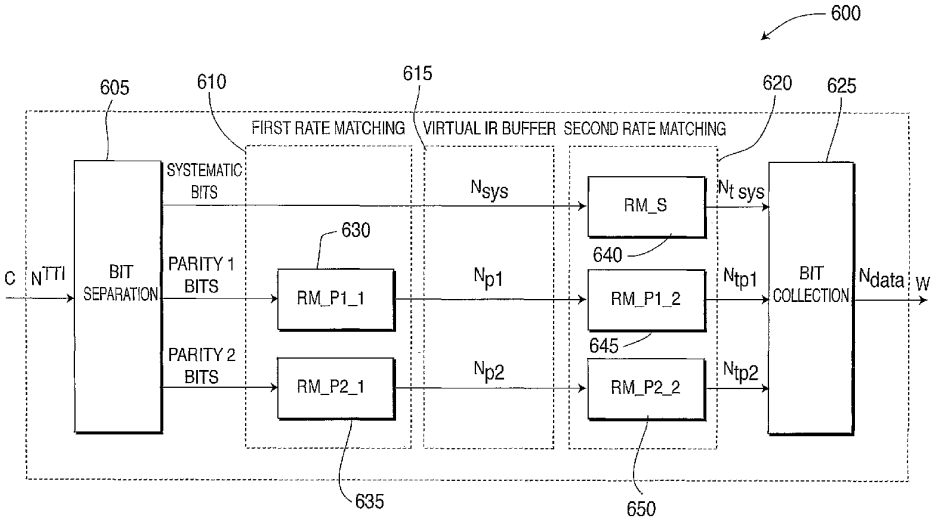
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(54) Title: DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES



(57) 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 (600) 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 (610, 620) are employed.

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[0001] # DETECTION, AVOIDANCE AND/OR CORRECTION OF PROBLEMATIC PUNCTURING PATTERNS IN PARITY BIT STREAMS USED WHEN IMPLEMENTING TURBO CODES

[0002] ## FIELD OF THE INVENTION

[0003] 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.

[0004] ## BACKGROUND

[0005] 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.

[0006] 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.

[0007] 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

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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.

[0008] 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.

[0009] 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).

[0010] 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.

[0011] 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.

[0012] Figures 5A, 5B and 6 are diagrams of channel coding and multiplexing examples in accordance with 3GPP Frequency Division Duplex (FDD) specifications.

[0013] 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.

[0014] 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

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include large block size transfers, which are particularly useful in mobile communications.

[0015] 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.

[0016] 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.

[0017] 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.

[0018] 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.

[0019] Regions where performance of the punctured Turbo code is degraded can be determined by measuring how close the puncturing pattern is to being

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periodic with period related to the period of the semi-periodic impulse response of the recursive encoding blocks of the Turbo encoder.

[0020] 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.

[0021] 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 $t > T$.

[0022] 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

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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.

[0023] 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.

[0024] 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.

[0025] 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.

[0026] It would be desirable to have a method for creating high-rate Turbo codes that avoids problematic interactions by modifying the puncturing patterns.

[0027] SUMMARY OF THE INVENTION

[0028] 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.

[0029] 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.

[0030] 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.

[0031] 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).

[0032] BRIEF DESCRIPTION OF THE DRAWINGS

[0033] 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:

[0034] Figure 1 is a schematic diagram of a typical CDMA system in accordance with current 3GPP specifications;

[0035] Figure 2 is a processing diagram of TrCH data for a CCTrCH in accordance with 3GPP TDD specifications;

[0036] Figures 3 and 4 are diagrams of channel coding and multiplexing examples in accordance with 3GPP TDD specifications;

[0037] Figures 5A, 5B and 6 are diagrams of channel coding and multiplexing examples in accordance with 3GPP FDD specifications;

[0038] 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;

[0039] 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;

[0040] 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;

[0041] Figure 10 is a schematic block diagram showing a circuit for 3GPP rate matching for HSDPA, using a Turbo coded HS-DSCH; and

[0042] Figure 11 graphically depicts initial Block Error Rate (BLER) for HS-DSCH transport blocks with certain effective coding rates.

[0043] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0044] 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.

[0045] 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.

[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 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)

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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.

[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 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.

[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.

[0053] When non-puncturing patterns with period $7\hat{N}/2$ ($\hat{N} = 1, 2, 3...$) 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.

[0054] 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,

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

Equation 1

for $\hat{N} > 0$ where,

$$\hat{N} = \left\lfloor\frac{4I}{7P} + \frac{1}{2}\right\rfloor.$$

Equation 2

[0055] In biasing the puncturing rates of the parity bit streams 1 and 2, P1 and P2, two constraints must be met.

[0056] 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.

[0057] These two constraints can be combined in to the following expression for Δ, where:

[0058] $$\Delta = \left\lceil \max\left\{ \frac{I}{\left\lfloor \frac{7\hat{N}-1}{2} \right\rfloor} - \frac{P}{2}, \frac{P}{2} - \frac{I}{\left\lceil \frac{7\hat{N}+1}{2} \right\rceil} \right\} \right\rceil$$

Equation 3

[0059] 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.

[0060] 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.

[0061] 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

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degraded performance can now be identified using the above equation, it is a simple matter to avoid them.

[0062] 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.

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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.

[0068] 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.

[0069] 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.

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[0070] 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.

[0071] 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.

[0072] 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.

[0073] 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.

[0074] 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.

[0075] 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

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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.

[0076] 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.

[0077] The code rates at the center of these regions are determined by:

[0078] $$CR = \frac{1}{1+\frac{2}{3.5N}} = \frac{3.5N}{3.5N+2} \qquad N = 1,2,...$$

Equation 4

[0079] 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,....

[0080] 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.

[0081] 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.

[0082] 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

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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.

$$\lambda(r1,r2)=\sum_{n=1}^{L-1}\alpha_n\left[\left(1-\left\lceil\frac{1}{L}\lceil r1\lceil nr2\rceil\rceil-\left\lfloor\frac{1}{L}\lceil r1\lceil nr2\rceil\rceil\right\rfloor\right\rceil\right)(nr2-\lfloor r2\rfloor)(r1\lceil nr2\rceil-\lfloor r1\lceil nr2\rceil\rfloor)+\right.$$
$$\left(1-\left\lceil\frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor-\left\lfloor\frac{1}{L}\lfloor r1\lceil nr2\rceil\rfloor\right\rfloor\right\rceil\right)(nr2-\lfloor nr2\rfloor)(-r1\lceil nr2\rceil-\lfloor r1\lceil nr2\rceil\rfloor+1)+$$
$$\left(1-\left\lceil\frac{1}{L}\lceil r1\lfloor nr2\rfloor\rceil-\left\lfloor\frac{1}{L}\lceil r1\lfloor nr2\rfloor\rceil\right\rfloor\right\rceil\right)(-nr2+\lfloor nr2\rfloor+1)(r1\lfloor nr2\rfloor-\lfloor r1\lfloor nr2\rfloor\rfloor)+$$
$$\left.\left(1-\left\lceil\frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor-\left\lfloor\frac{1}{L}\lfloor r1\lfloor nr2\rfloor\rfloor\right\rfloor\right\rceil\right)(-nr2+\lfloor nr2\rfloor+1)(-r1\lfloor nr2\rfloor+\lfloor r1\lfloor nr2\rfloor\rfloor+1)\right]$$

Equation 5

[0083] 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.

[0084] 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.

[0085] 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.

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[0086] 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.

[0087] 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.

[0088] 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.

[0089] 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

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implies a modification to the individual puncturing rates of each of the stages such that a desirable overall puncturing pattern results.

[0090] 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.

[0091] 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.

[0092] 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.

[0093] 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.

[0094] 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

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Turbo encoder. An algorithm may used to identify all puncturing patterns with degraded performance.

[0095] 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.

[0096] 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.

[0097] 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.

[0098] The present invention is particularly useful for 3GPP-coding, and can be used for low chip rate TDD, high chip rate TDD and FDD.

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[0099] 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.

[0100] 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.

[0101] 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.

[0102] 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.

[0103] 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

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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.

[0104] 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.

[0105] 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.

[0106] 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.

[0107] 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%.

[0108] 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.

[0109] 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.

[0110] 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.

[0111] 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.

[0112] 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.

[0113] 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.

[0114] 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).

[0115] 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.

[0116] 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.

[0117] 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.

[0118] 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.

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[0119] 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.

[0120] 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).

[0121] 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.

[0122] At least two alternative approaches exist to avoid the problematic interactions between Turbo-coder output and puncturing in the rate-matching stages.

[0123] 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.

[0124] 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.

[0125] 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.

[0126] 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.

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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.

[0127] 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.

[0128] Described below is one embodiment of the present invention that includes a combination of previously described techniques.

[0129] 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.

[0130] The hybrid ARQ functionality consists of two rate-matching stages and a virtual buffer.

[0131] 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.

[0132] 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.

[0133] Definitions of notations used:

N^{TTI}: Number of bits in a transmission time interval before rate matching.

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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.

[0134] The HARQ bit separation function shall be performed in the same way as bit separation for turbo encoded TrCHs.

[0135] HARQ first stage rate matching for the HS-DSCH transport channel shall be performed using the method described below with the following specific parameters.

[0136] 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.

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[0137] 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.

[0138] 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.

[0139] 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

$$X_i = \lfloor N^{TTI}/3 \rfloor; \quad PR = \frac{\lfloor -\Delta N_{il}^{TTI}/2 \rfloor}{X_i}; \quad \Delta N_{PARITY} = 0; \quad \delta_{PR} = 49; \quad \alpha = 1$$

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

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$$\Delta N_{PARITY} = \left\| \left\lfloor -\Delta N_{il}^{TTI}/2 \right\rfloor - X_i \cdot \left(round - \frac{1}{\delta_{PR}} \right) \right\|$$

$\alpha = 5$

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

[0140] 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.

[0141] For each radio frame, the rate-matching pattern shall be calculated, where:

X_i is as above,

$e_{ini} = X_i$

e_{plus} = a×X_i

e_{minus} = a×$|\Delta N_i|$

[0142] HARQ second stage rate matching for the HS-DSCH transport channel shall be done using one of two possible methods.

[0143] 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.

[0144] Composite Puncturing Ratio, $CPR = \begin{cases} \dfrac{\lfloor N^{TTI}/3 \rfloor - N_{t,p1}}{N^{TTI}/3}, b = 2 \\ \dfrac{\lfloor N^{TTI}/3 \rfloor - N_{t,p2}}{N^{TTI}/3}, b = 3 \end{cases}$

[0145] 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.

[0146] 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.

[0147] 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 $N_{data}=P\times3\times N_{data1}$. The rate matching parameters are determined as follows.

[0148] 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.

[0149] 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 $N_{t,sys} = \left\lfloor N_{sys} \cdot \frac{N_{data}}{N_{sys} + 2N_{p1}} \right\rfloor$.

[0150] 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 $N_{t,p2} = N_{data} - \left(N_{t,sys} + N_{t,p1}\right)$ 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

[0151] 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
$e_{ini}(r) = \left\{\left(X_i - \left\lfloor r \cdot e_{plus} / r_{\max} \right\rfloor - 1\right) \bmod e_{plus}\right\} + 1$ in the case of puncturing , i.e., $N_{data} \le N_{sys} + N_{p1} + N_{p2}$, and
$e_{ini}(r) = \left\{\left(X_i - \left\lfloor (s + 2 \cdot r) \cdot e_{plus} / (2 \cdot r_{\max}) \right\rfloor - 1\right) \bmod e_{plus}\right\} + 1$ for repetition, i.e., $N_{data} > N_{sys} + N_{p1} + N_{p2}$. Where $r \in \{0,1,\text{L}\ ,r_{\max} - 1\}$ 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.

[0152] 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).

[0153] 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.

[0154] 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.

[0155] 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 $X_{seg1} = 42 \cdot \lfloor X_i / 98 \rfloor, X_{seg2} = 56 \cdot \lfloor X_i / 98 \rfloor, X_{seg3} = X_i \bmod 98$

[0156] 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.

[0157] Additional parameters for HARQ Second Rate Matching Stage for problematic puncturing rates

[0158] Parameters P, N_{data}, N_{sys}, N_{p1}, N_{p2}, $N_{p,t1}$, and $N_{p,t2}$ are calculated, additional parameters are defined below.

[0159] 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.

[0160] For $N_{data} \le N_{sys} + N_{p1} + N_{p2}$, puncturing is performed in the second rate matching stage.

[0161] The number of parity bits after segmentation is

$$N_{pb,seg1} = 42 \cdot \lfloor N_{pb} / 98 \rfloor$$
$$N_{pb,seg2} = 56 \cdot \lfloor N_{pb} / 98 \rfloor$$

$$N_{pb,seg3} = N_{pb} \bmod 98$$

[0162] The number of parity bits in each segment for parity 1 bits (b=2), and parity 2bits (b=3) is:

$$N_{t,pb,seg1} = \left\lfloor \frac{49 \cdot N_{t,pb} \cdot \lfloor N_{pb}/98 \rfloor}{N_{pb}} + \frac{1}{2} \right\rfloor;$$
$$N_{t,pb,seg2} = \left\lfloor \frac{49 \cdot N_{t,pb} \cdot \lfloor N_{pb}/98 \rfloor}{N_{pb}} + \frac{1}{2} \right\rfloor;$$
$$N_{t,pb,seg3} = N_{t,pb} - \left(N_{t,pb,seg1} + N_{t,pb,seg2}\right)$$

[0163] The parameters X_i, e_{plus} and e_{minus} are calculated as per table 2 below.

Stream	***Segment***	***Xi***	***eplus***	***eminus***
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

[0164] 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 $r \in \{0,1,\mathrm{L}\ , r_{\max} - 1\}$ 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 $r_{max} = 4$.

[0165] 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.

[0166]

[0167] 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.

[0168] The re-concatenated bit stream is denoted by:

$$x_{o,seg1,1}, x_{o,seg1,2}, \ldots x_{o,seg1,N_{t,p1,seg1}}, x_{o,seg2,1}, x_{o,seg2,2}, \ldots x_{o,seg2,N_{t,p1,seg2}}, x_{o,seg3,1}, x_{o,seg3,2}, \ldots x_{o,seg3,N_{t,p1,seg3}}$$

[0169] 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.

[0170] Data is written into the interleaver column by column, and read out of the interleaver column by column starting from the first column.

[0171] $N_{t,sys}$ is the number of transmitted systematic bits. Intermediate values N_r and N_c are calculated using:

$$N_r = \left\lfloor \frac{N_{t,sys}}{N_{col}} \right\rfloor \text{ and } N_c = N_{t,sys} - N_r \cdot N_{col}.$$

[0172] If N_c=0 and $N_r > 0$, the systematic bits are written into rows 1...N_r.

[0173] 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.

[0174] 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

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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.

[0175] 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.

[0176] 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.

[0177] 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.

[0178] 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.

[0179] In order to avoid either of these puncturing mechanisms that cause a performance degradation, the following methodology has been adopted:

[0180] 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.

[0181] 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.

[0182] 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.

[0183] 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.

[0184] 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.

[0185] 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.

[0186] 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.

[0187] 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

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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

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(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

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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

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

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 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

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

$$\left| \frac{I}{(P/2)} - \frac{7\hat{N}}{2} \right| < 1 - \frac{\hat{N}}{2} + \left\lfloor \frac{\hat{N}}{2} \right\rfloor ; \text{ and}$$

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

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.

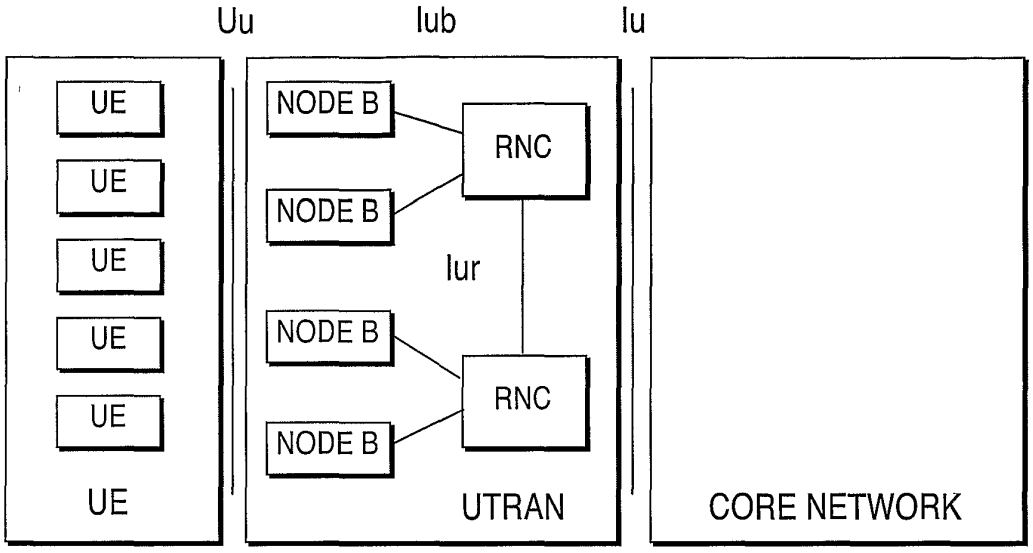


FIG. 1
PRIOR ART

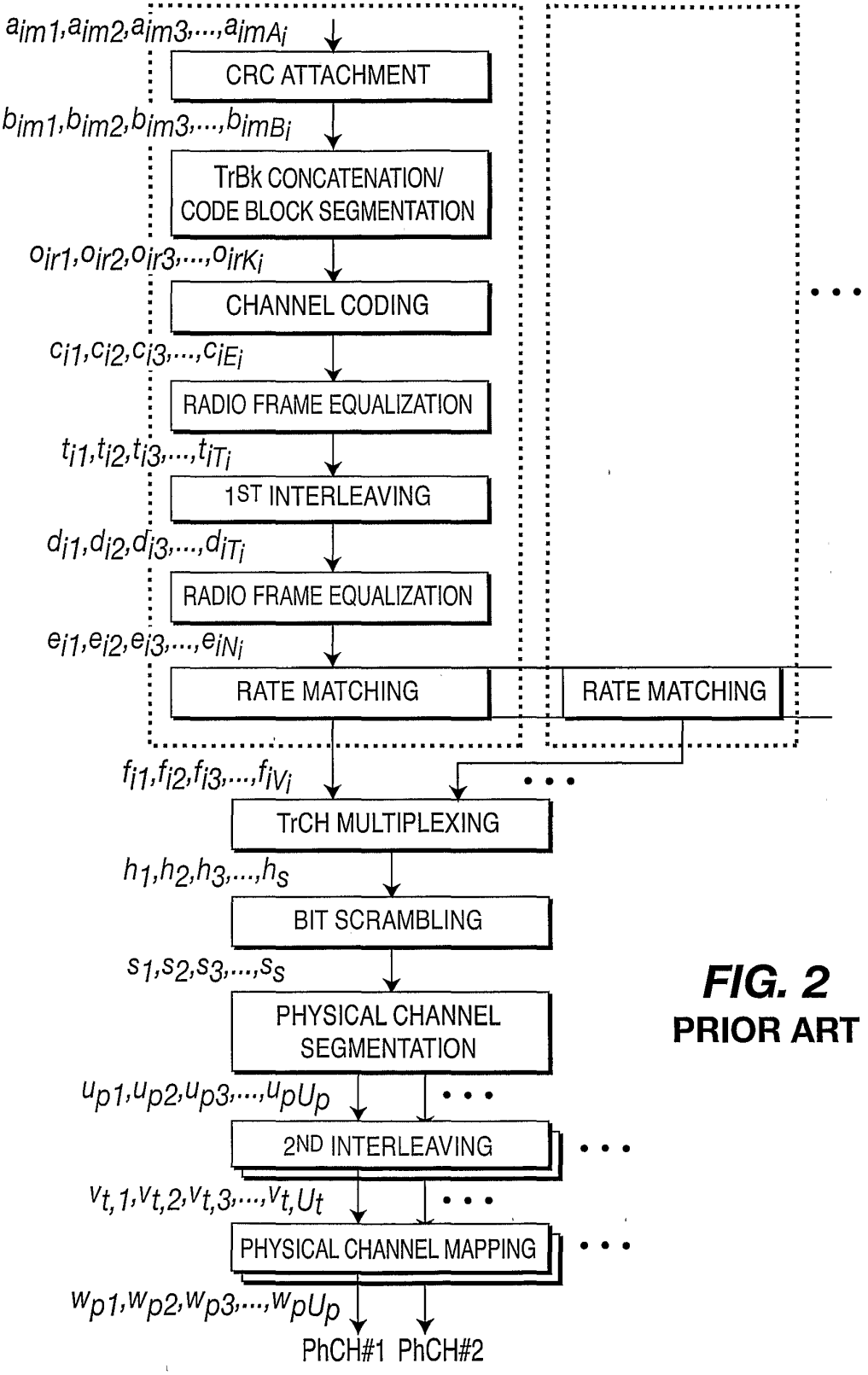


FIG. 2
PRIOR ART

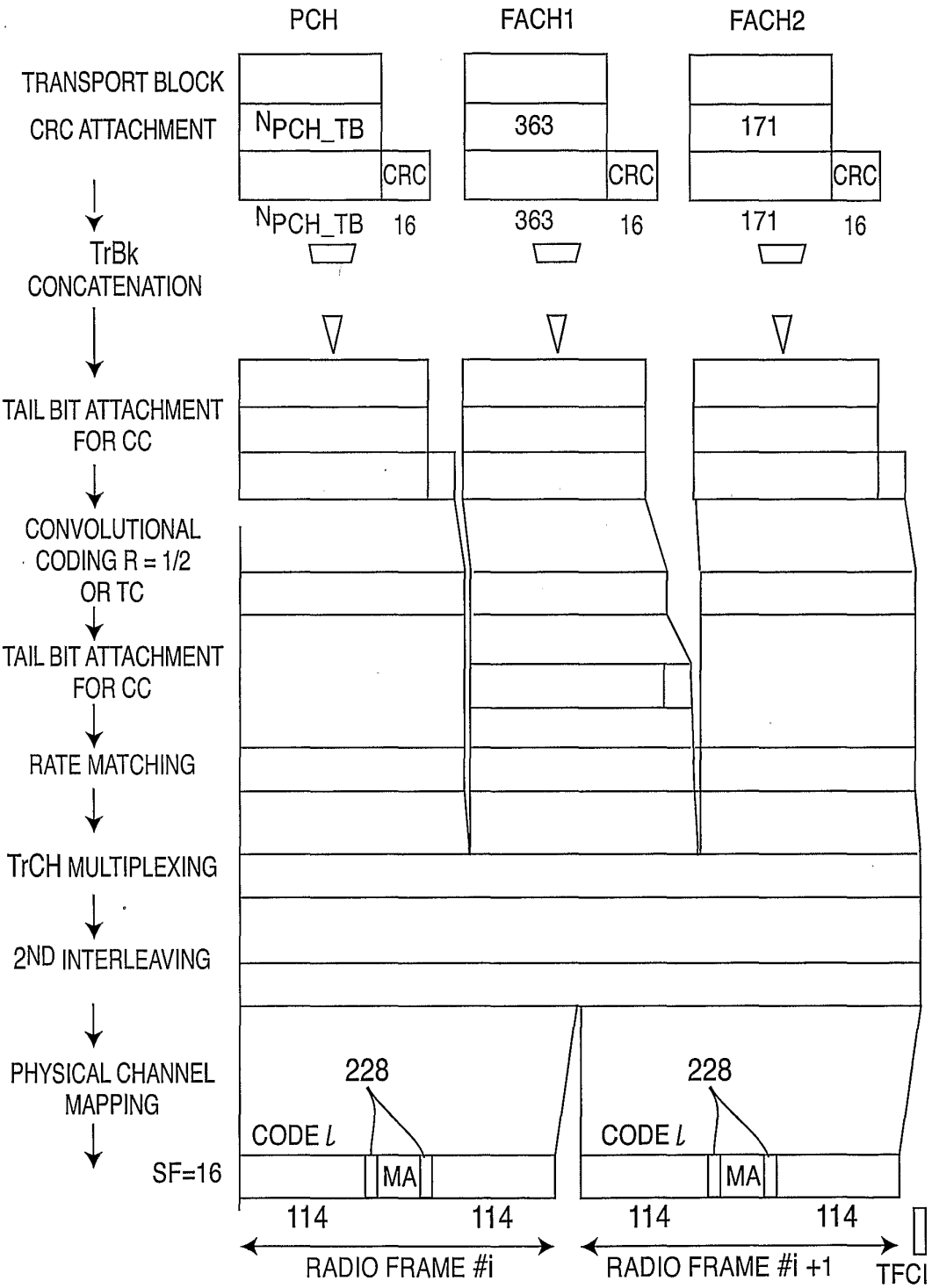


FIG. 3
PRIOR ART

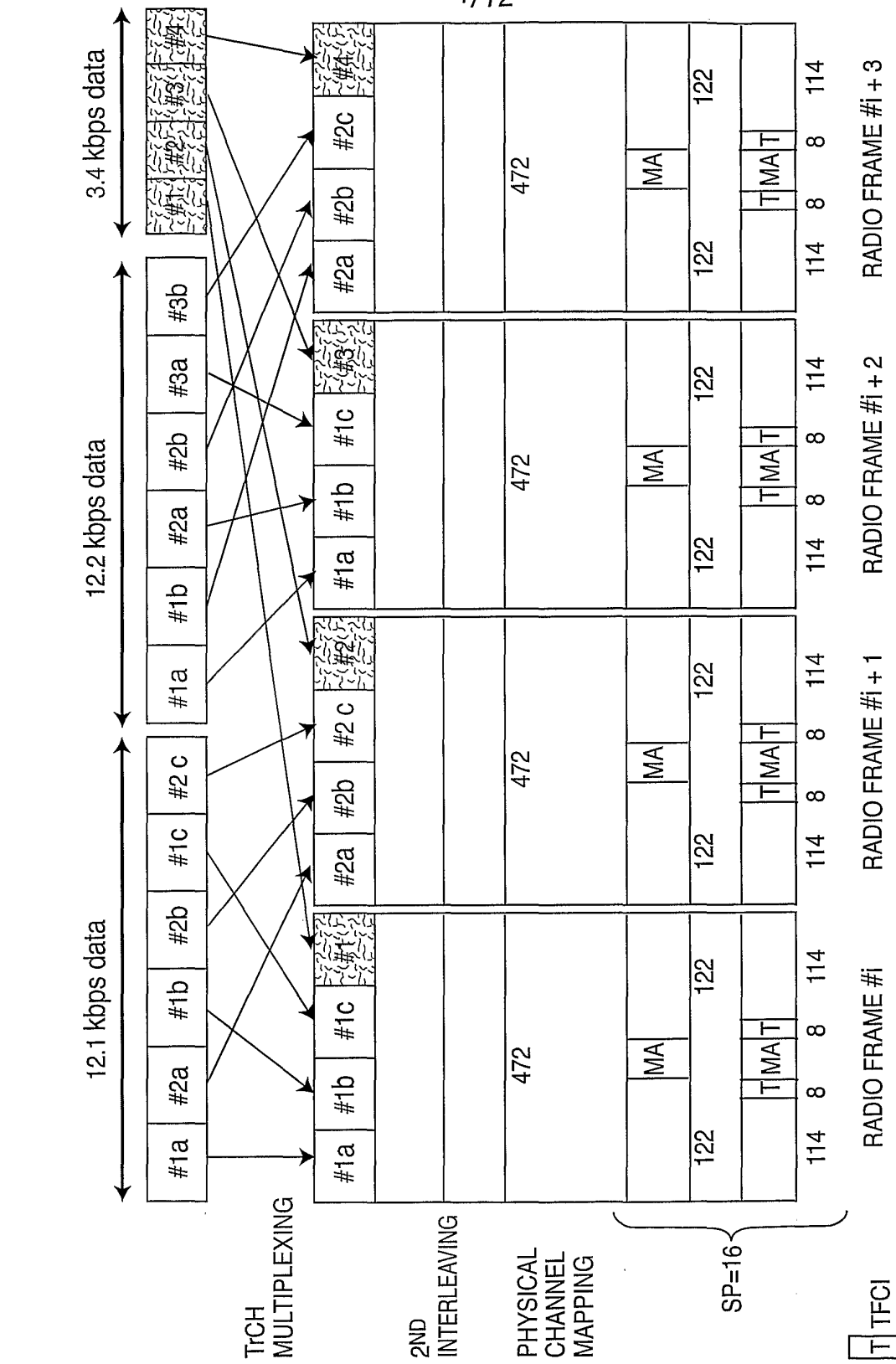


FIG. 4 PRIOR ART

FIG. 5
PRIOR ART
FIG. 5a
FIG. 5b

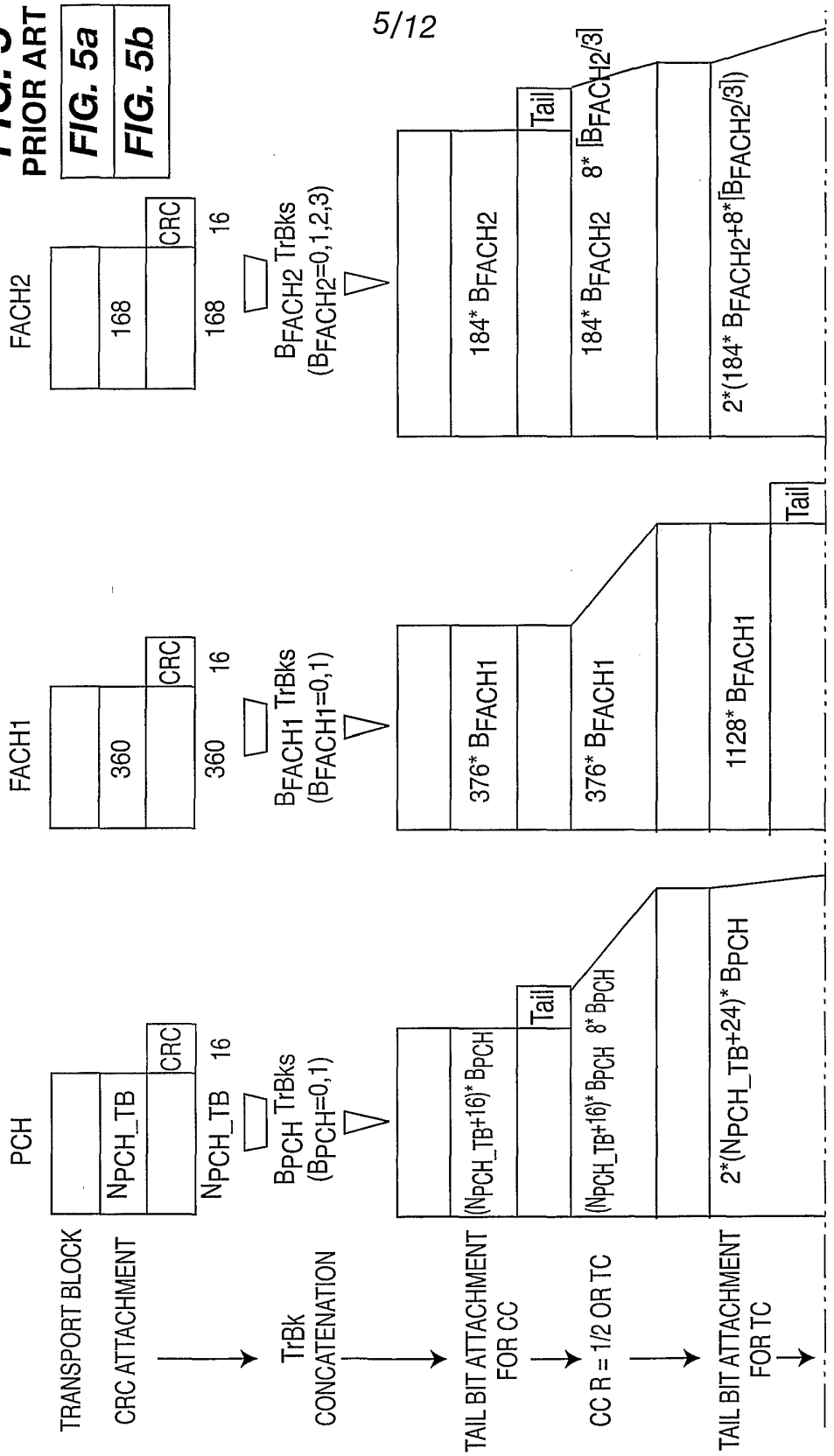


FIG. 5a

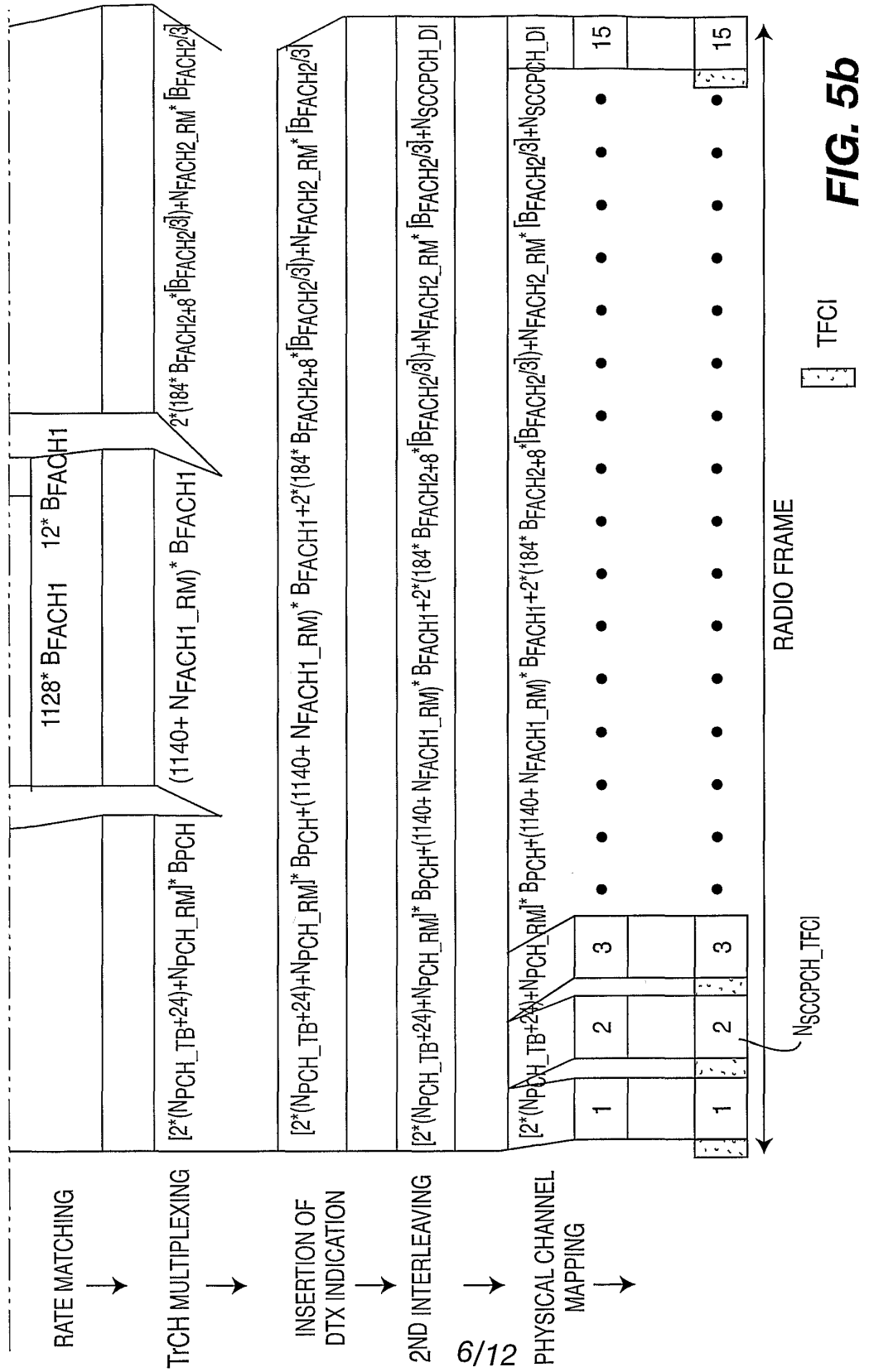

RATE MATCHING
TrCH MULTIPLEXING
INSERTION OF DTX INDICATION
2ND INTERLEAVING
PHYSICAL CHANNEL MAPPING
1128* BFACH1
12* BFACH1
(1140+ NFACH1_RM)* BFACH1
2*(184* BFACH2+8*⌈BFACH2/3⌉)+NFACH2_RM* ⌈BFACH2/3⌉
[2*(NPCH_TB+24)+NPCH_RM]* BPCH
[2*(NPCH_TB+24)+NPCH_RM]* BPCH+(1140+ NFACH1_RM)* BFACH1+2*(184* BFACH2+8*⌈BFACH2/3⌉)+NFACH2_RM* ⌈BFACH2/3⌉
[2*(NPCH_TB+24)+NPCH_RM]* BPCH+(1140+ NFACH1_RM)* BFACH1+2*(184* BFACH2+8*⌈BFACH2/3⌉)+NFACH2_RM* ⌈BFACH2/3⌉+NSCCPCH_DI
[2*(NPCH_TB+24)+NPCH_RM]* BPCH+(1140+ NFACH1_RM)* BFACH1+2*(184* BFACH2+8*⌈BFACH2/3⌉)+NFACH2_RM* ⌈BFACH2/3⌉+NSCCPCH_DI
1
2
3
15
NSCCPCH_TFCI
RADIO FRAME
TFCI

FIG. 5b

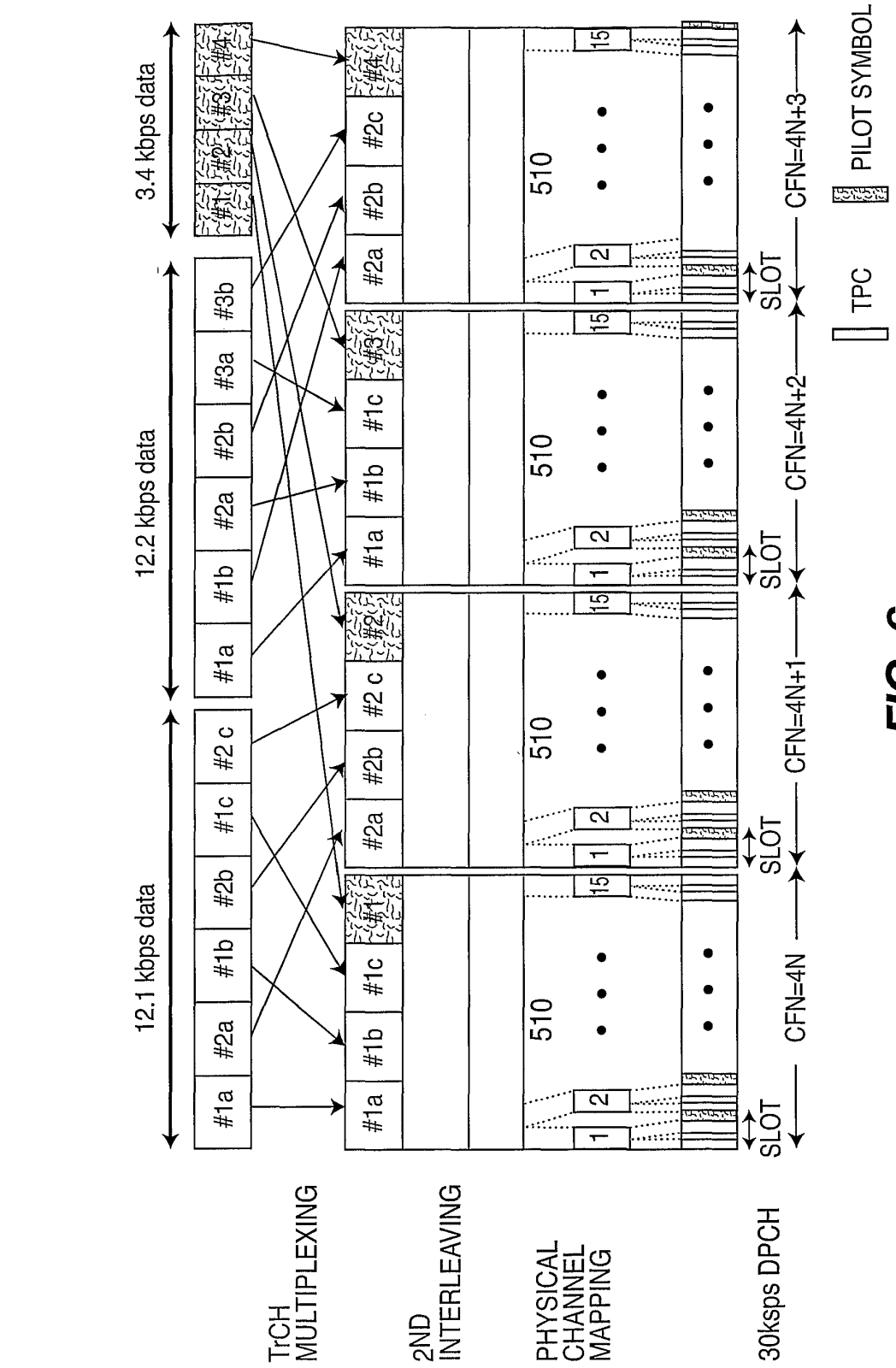


FIG. 6
PRIOR ART

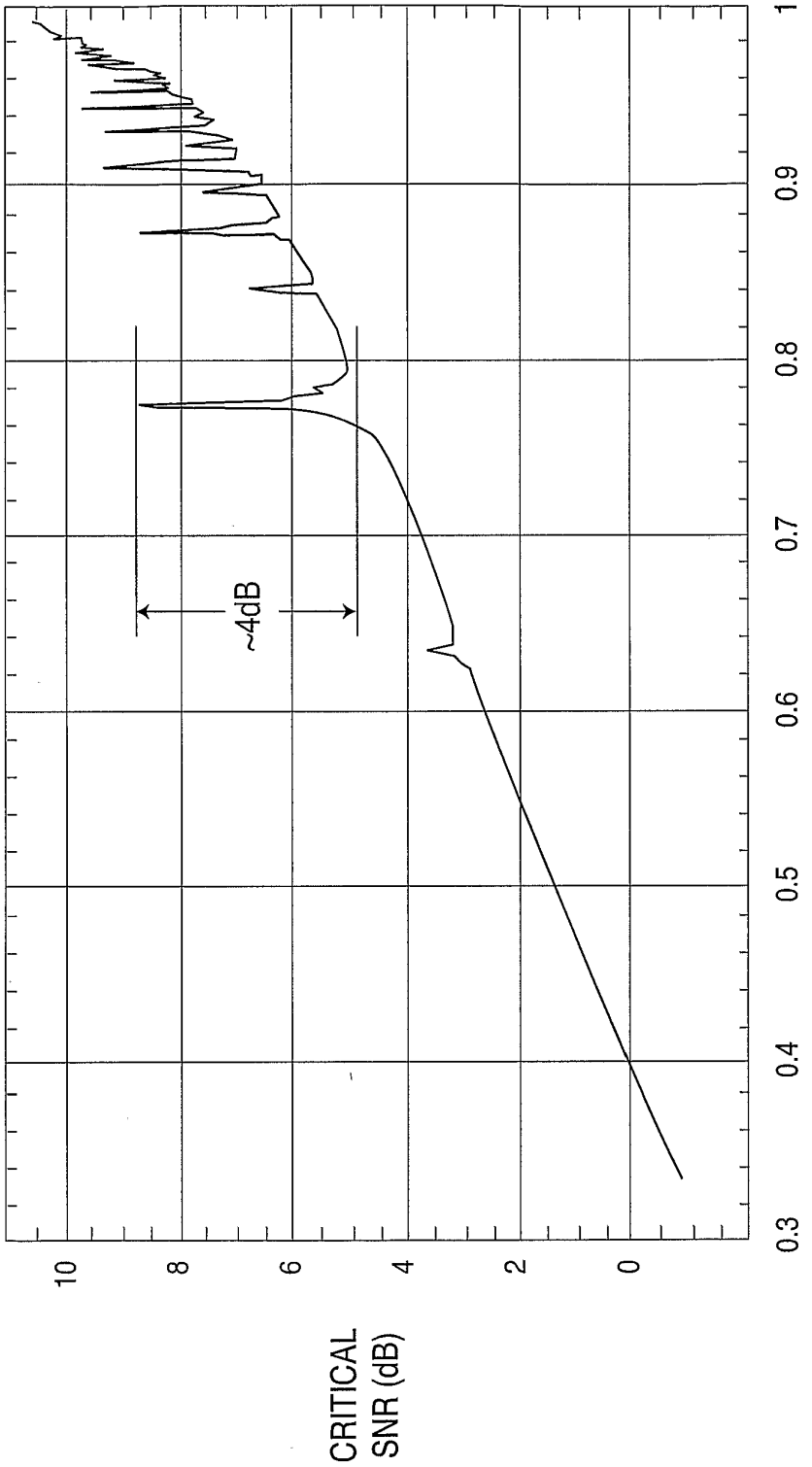


FIG. 7
PRIOR ART

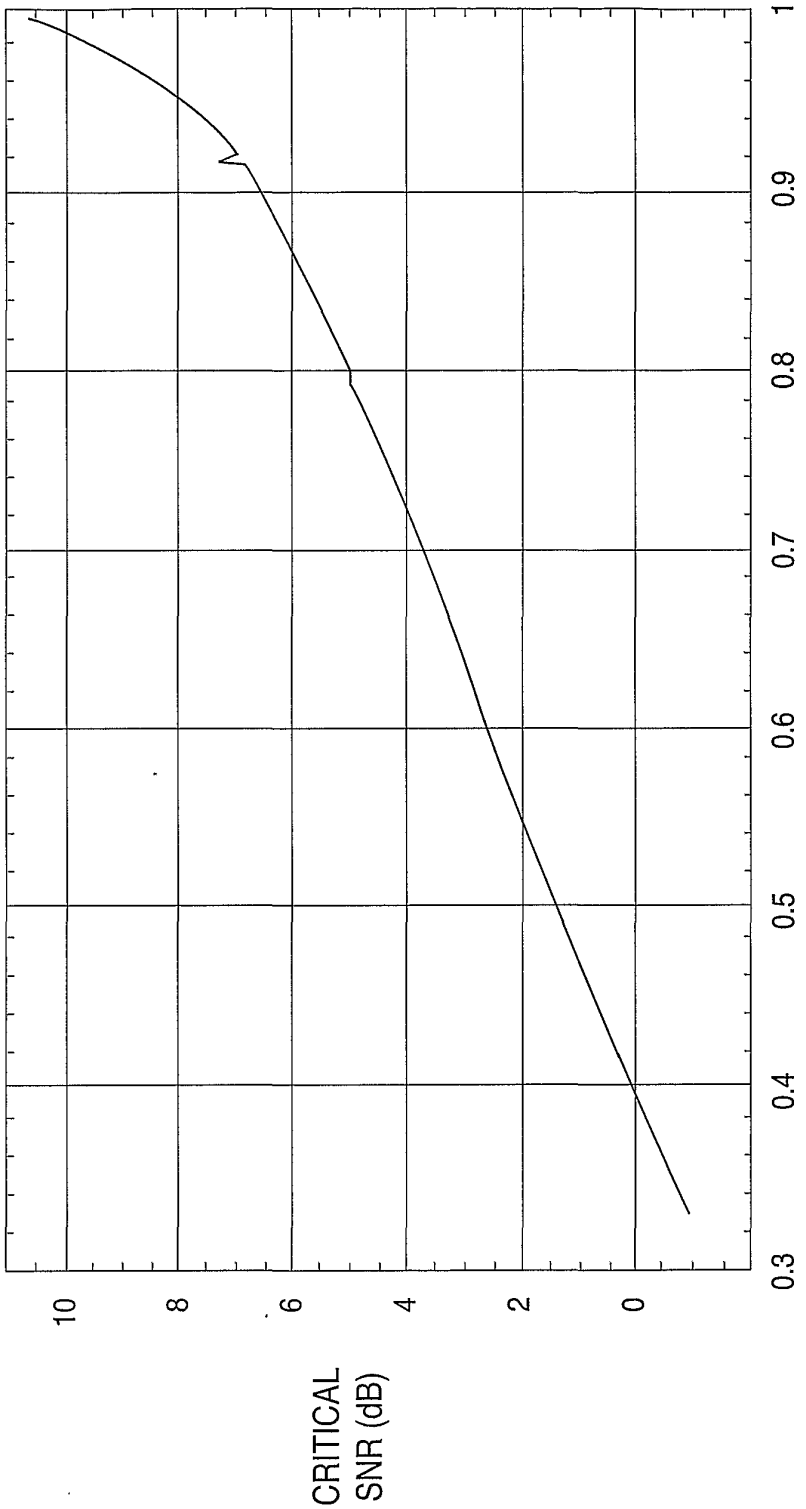


FIG. 8

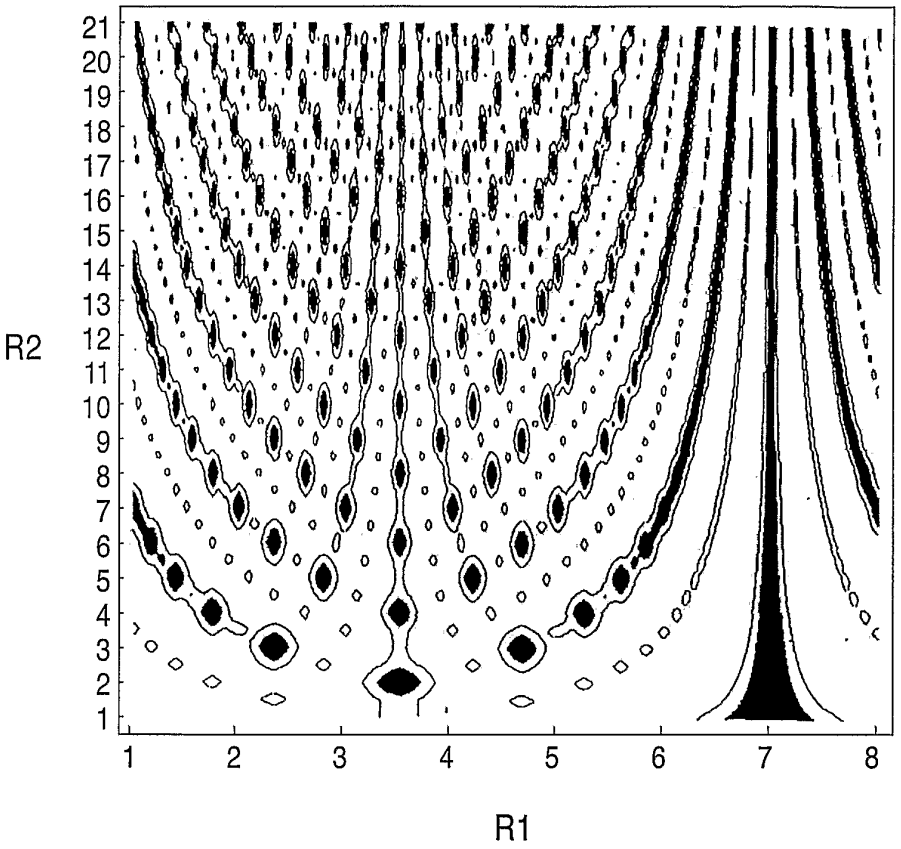


FIG. 9

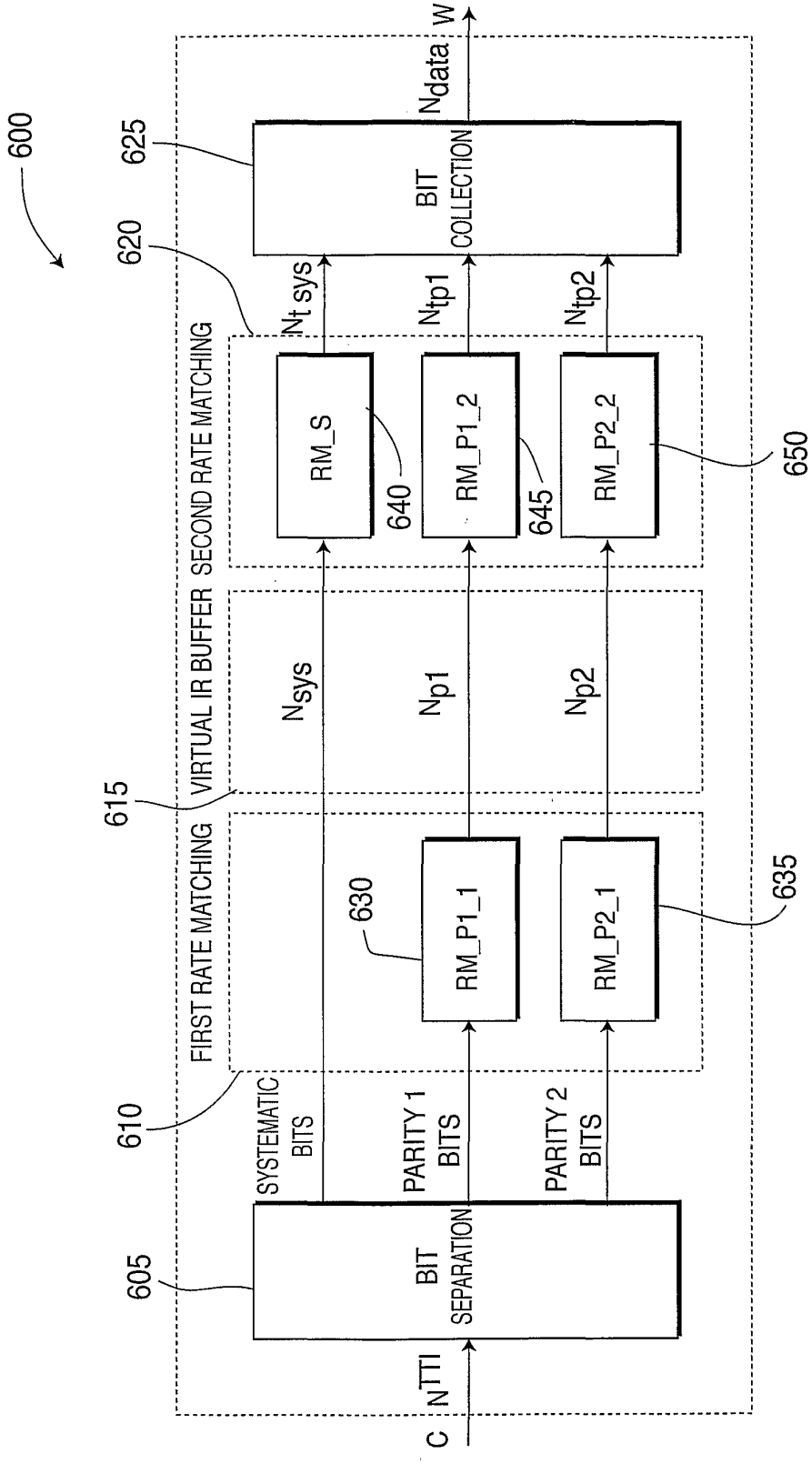

600
625
620
615
610
605
630
640
645
650
635
Ndata : W
BIT COLLECTION
Nt sys
Ntp1
Ntp2
RM_S
RM_P1_2
RM_P2_2
SECOND RATE MATCHING
VIRTUAL IR BUFFER
FIRST RATE MATCHING
Nsys
Np1
Np2
RM_P1_1
RM_P2_1
SYSTEMATIC BITS
PARITY 1 BITS
PARITY 2 BITS
BIT SEPARATION
NTTI
C

FIG. 10

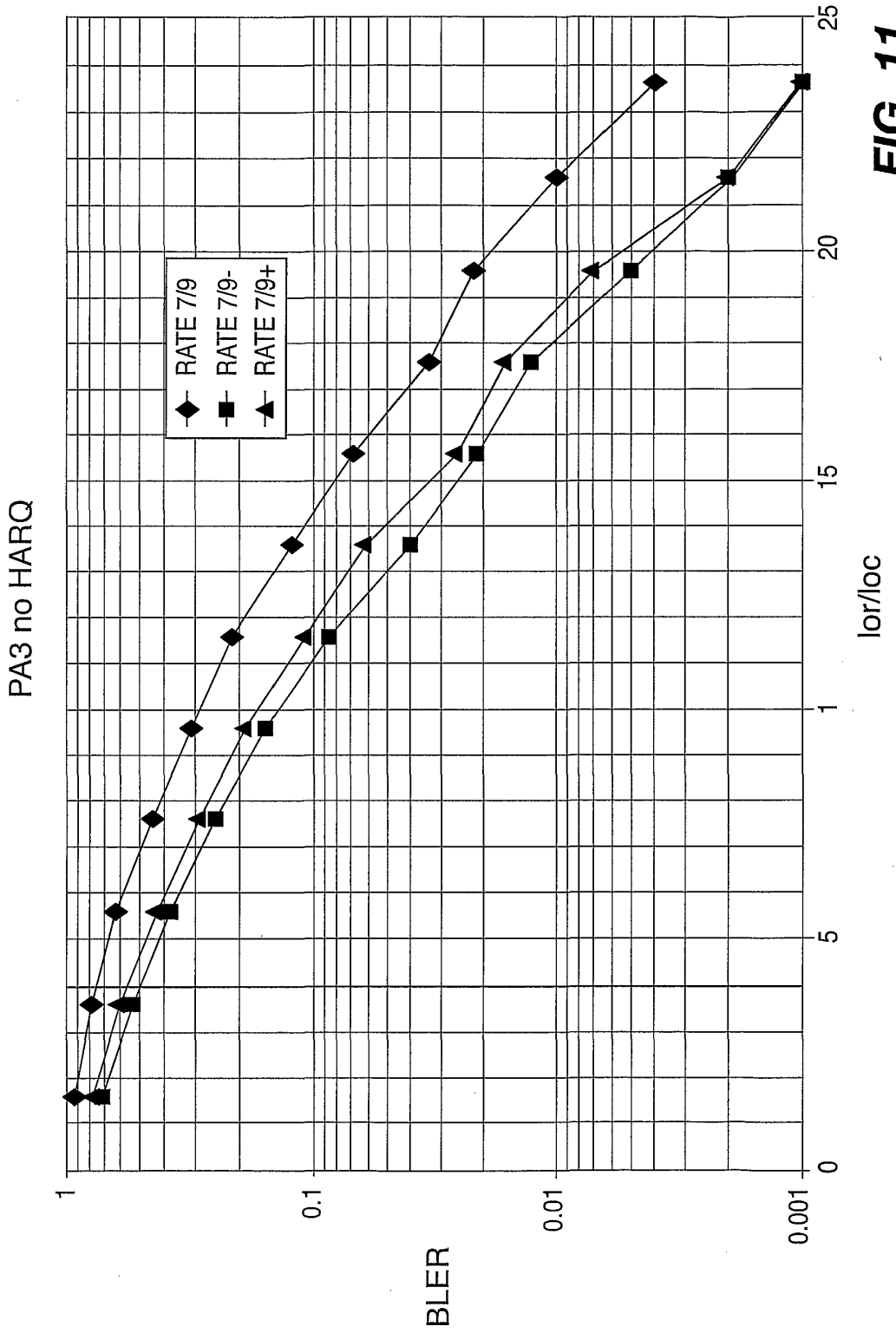

PA3 no HARQ
RATE 7/9
RATE 7/9-
RATE 7/9+
BLER
1
0.1
0.01
0.001
0
5
1
15
20
25
Ior/Ioc

FIG. 11