6:20-cv-1042

EXHIBIT B

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(12) **United States Patent**   (10) **Patent No.:**   **US 7,421,032 B2**
Jin et al.   (45) **Date of Patent:**   **Sep. 2, 2008**

(54) **SERIAL CONCATENATION OF INTERLEAVED CONVOLUTIONAL CODES FORMING TURBO-LIKE CODES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/542,950**

(22) Filed: **Oct. 3, 2006**

(65) **Prior Publication Data**

US 2007/0025450 A1   Feb. 1, 2007

Related U.S. Application Data

(63) Continuation of application No. 09/861,102, filed on May 18, 2001, now Pat. No. 7,116,710, and a continuation-in-part of application No. 09/922,852, filed on Aug. 18, 2000, now Pat. No. 7,089,477.

(60) Provisional application No. 60/205,095, filed on May 18, 2000.

(51) **Int. Cl.**
H04L 5/12   (2006.01)

(52) **U.S. Cl.** **375/262**; 375/265; 375/348; 714/755; 714/786; 714/792; 341/52; 341/102

(58) **Field of Classification Search** 375/259, 375/262, 265, 285, 296, 341, 346, 348; 714/746, 714/752, 755, 756, 786, 792, 794–796; 341/51, 341/52, 56, 102, 103
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,392,299 A		2/1995	Rhines et al.
5,530,707 A	*	6/1996	Lin 714/792
5,751,739 A		5/1998	Seshadri et al.
5,802,115 A	*	9/1998	Meyer 375/341
5,881,093 A		3/1999	Wang et al.
6,014,411 A		1/2000	Wang
6,023,783 A		2/2000	Divsalar et al.
6,031,874 A		2/2000	Chennakeshu et al.
6,032,284 A		2/2000	Bliss
6,044,116 A		3/2000	Wang
6,094,739 A	*	7/2000	Miller et al. 714/792

(Continued)

OTHER PUBLICATIONS

Appendix A.1 "Structure of Parity Check Matrices of Standardized LDPC Codes," Digital Video Broadcasting (DVB) User guidelines for the second generation system for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2) ETSI TR 102 376 V1.1.1. (Feb. 2005) Technical Report, pp. 64.

(Continued)

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(74) *Attorney, Agent, or Firm*—Fish & Richardson P.C.

(57) **ABSTRACT**

A serial concatenated coder includes an outer coder and an inner coder. The outer coder irregularly repeats bits in a data block according to a degree profile and scrambles the repeated bits. The scrambled and repeated bits are input to an inner coder, which has a rate substantially close to one.

23 Claims, 5 Drawing Sheets
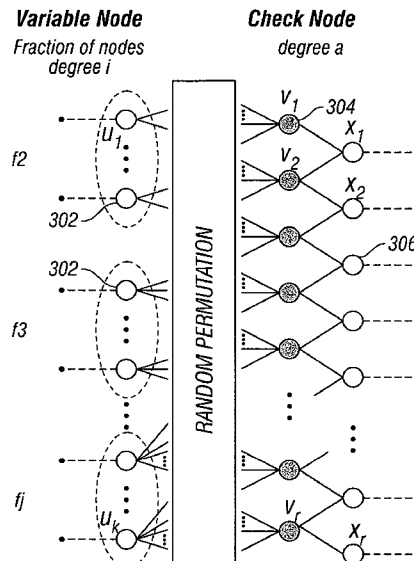
US 7,421,032 B2

Page 2

U.S. PATENT DOCUMENTS

6,396,423	B1	5/2002	Laumen et al.
6,437,714	B1	8/2002	Kim et al.
6,859,906	B2 *	2/2005	Hammons et al. 714/786
2001/0025358	A1	9/2001	Eidson et al.

OTHER PUBLICATIONS

Benedetto et al., "A Soft-Input Soft-Output Maximum A Posteriori (MAP) Module to Decode Parallel and Serial Concatenated Codes," The Telecommunications and Data Acquisition (TDA) Progress Report 42-127 for NASA and California Institute of Technology Jet Propulsion Laboratory, Jospeh H. Yuen, Ed., pp. 1-20 (Nov. 15, 1996).

Benedetto et al., "Bandwidth efficient parallel concatenated coding schemes," Electronics Letters 31(24): 2067-2069 (Nov. 23, 1995).

Benedetto et al., "Design of Serially Concatenated Interleaved Codes," ICC 97, Montreal, Canada, pp. 710-714, (Jun. 1997).

Benedetto et al., "Parallel Concatenated Trellis Coded Modulation," ICC '96, IEEE, pp. 974-978, (Jun. 1996).

Benedetto et al., "Serial Concatenated Trellis Coded Modulation with Iterative Decoding," Proceedings from the IEEE 1997 International Symposium on Information Theory (ISIT), Ulm, Germany, p. 8, Jun. 29-Jul. 4, 1997.

Benedetto et al., "Serial Concatenation of Interleaved Codes: Performance Analysis, Design, and Iterative Decoding," The Telecommunications and Data Acquisition (TDA) Progress Report 42-126 for NASA and California Institute of Technology Jet Propulsion Laboratory, Jospeh H. Yuen, Ed., pp. 1-26 (Aug. 15, 1996).

Benedetto et al., "Serial Concatenation of interleaved codes: performance analysis, design, and iterative decoding," Proceedings from the IEEE 1997 International Symposium on Information Theory (ISIT), Ulm, Germany, p. 106, Jun. 29-Jul. 4, 1997.

Benedetto et al., "Soft-output decoding algorithms in iterative decoding of turbo codes," The Telecommunications and Data Acquisition (TDA) Progress Report 42-124 for NASA and California Institute of Technology Jet Propulsion Laboratory, Jospeh H. Yuen, Ed., pp. 63-87 (Feb. 15, 1996).

Benedetto, S. et al., "A Soft-Input Soft-Output APP Module for Iterative Decoding of Concatenated Codes," IEEE Communications Letters 1(1): 22-24 (Jan. 1997).

Berrou et al., "Near Shannon Limit Error-Correcting Coding and Decoding: Turbo Codes," ICC pp. 1064-1070 (1993).

Digital Video Broadcasting (DVB) User guidelines for the second generation system for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2) ETSI TR 102 376 V1.1.1. (Feb. 2005) Technical Report, pp. 1-104 (Feb. 15, 2005).

Divsalar et al., "Coding Theorems for 'Turbo-Like' Codes," Proceedings of the 36th Annual Allerton Conference on Communication, Control, and Computing, Sep. 23-25, 1998, Allerton House, Monticello, Illinois, pp. 201-210 (1998).

Divsalar et al., "Effective free distance of turbo codes," Electronics Letters 32(5): 445-446 (Feb. 29, 1996).

Divsalar, D. et al., "Hybrid Concatenated Codes and Iterative Decoding," Proceedings from the IEEE 1997 International Symposium on Information Theory (ISIT), Ulm, Germany, p. 10 (Jun. 29-Jul. 4, 1997).

Divsalar, D. et al., "Low-rate turbo codes for Deep Space Communications," Proceedings from the 1995 IEEE International Symposium on Information Theory, Sep. 17-22, 1995, Whistler, British Columbia, Canada, pp. 35.

Divsalar, D. et al., "Multiple Turbo Codes for Deep-Space Communications," The Telecommunications and Data Acquisition (TDA) Progress Report 42-121 for NASA and California Institute of Technology Jet Propulsion Laboratory, Jospeh H. Yuen, Ed., pp. 60-77 (May 15, 1995).

Divsalar, D. et al., "Multiple Turbo Codes," MILCOM 95, San Diego, CA pp. 279-285 (Nov. 5-6, 1995).

Divsalar, D. et al., "On the Design of Turbo Codes," The Telecommunications and Data Acquisition (TDA) Progress Report 42-123 for NASA and California Institute of Technology Jet Propulsion Laboratory, Jospeh H. Yuen, Ed., pp. 99-131 (Nov. 15, 1995).

Divsalar, D. et al., "Serial Turbo Trellis Coded Modulation with Rate-1 Inner Code," Proceedings from the IEEE 2000 International Symposium on Information Theory (ISIT), Italy, pp. 1-14 (Jun. 2000).

Divsalar, D. et al., "Turbo Codes for PCS Applications," ICC 95, IEEE, Seattle, WA, pp. 54-59 (Jun. 1995).

Jin et al., "Irregular Repeat—Accumulate Codes," 2nd International Symposium on Turbo Codes & Related Topics, Sep. 4-7, 2000, Brest, France, 25 slides, (presented on Sep. 4, 2000).

Jin et al., "Irregular Repeat—Accumulate Codes," 2nd International Symposium on Turbo Codes & Related Topics, Sep. 4-7, 2000, Brest, France, pp. 1-8 (2000).

Richardson et al., "Design of capacity approaching irregular low density parity check codes," IEEE Trans. Inform. Theory 47: 619-637 (Feb. 2001).

Richardson, T. and R. Urbanke, "Efficient encoding of low-density parity check codes," IEEE Trans. Inform. Theory 47: 638-656 (Feb. 2001).

Wilberg, et al., "Codes and Iteratie Decoding on General Graphs", 1995 Intl. Symposium on Information Theory, Sep. 1995, p. 468.
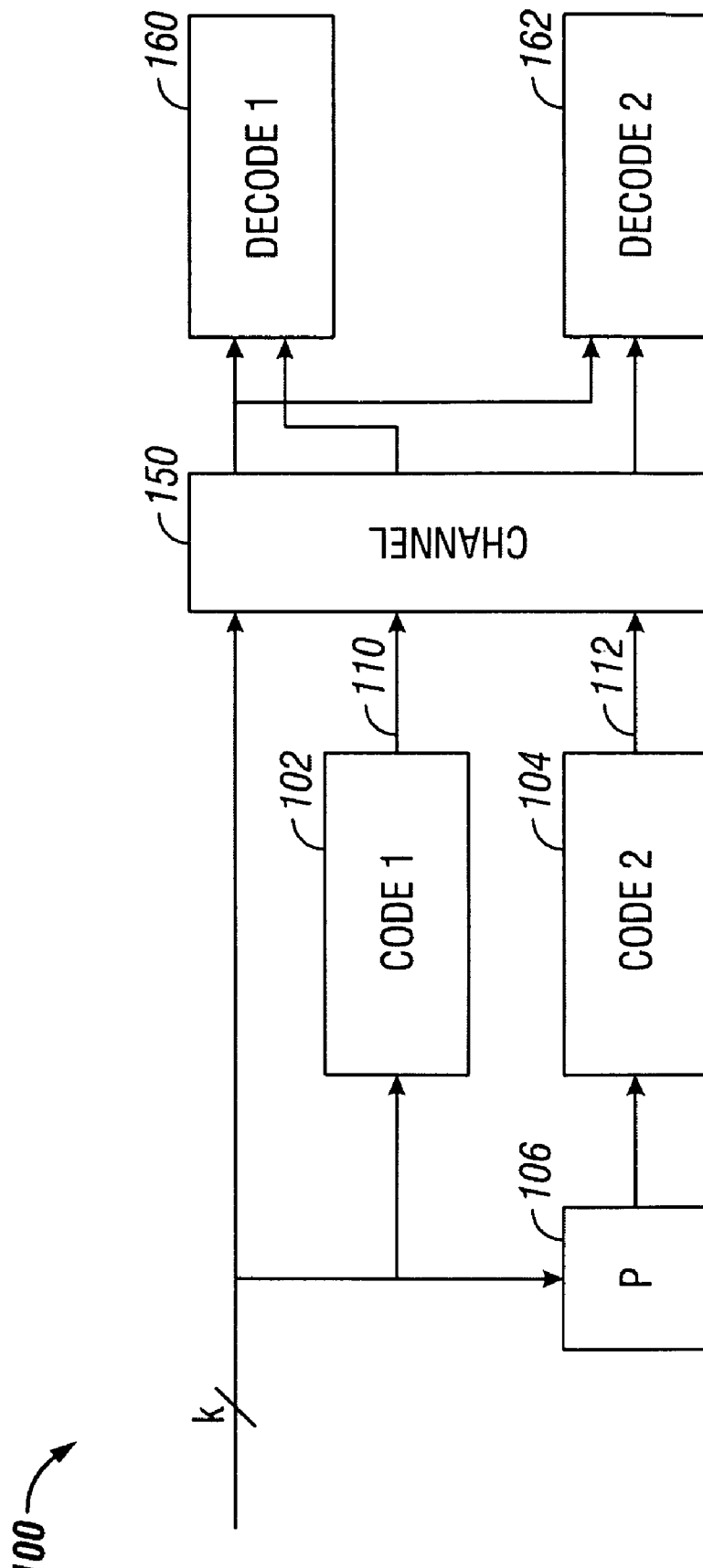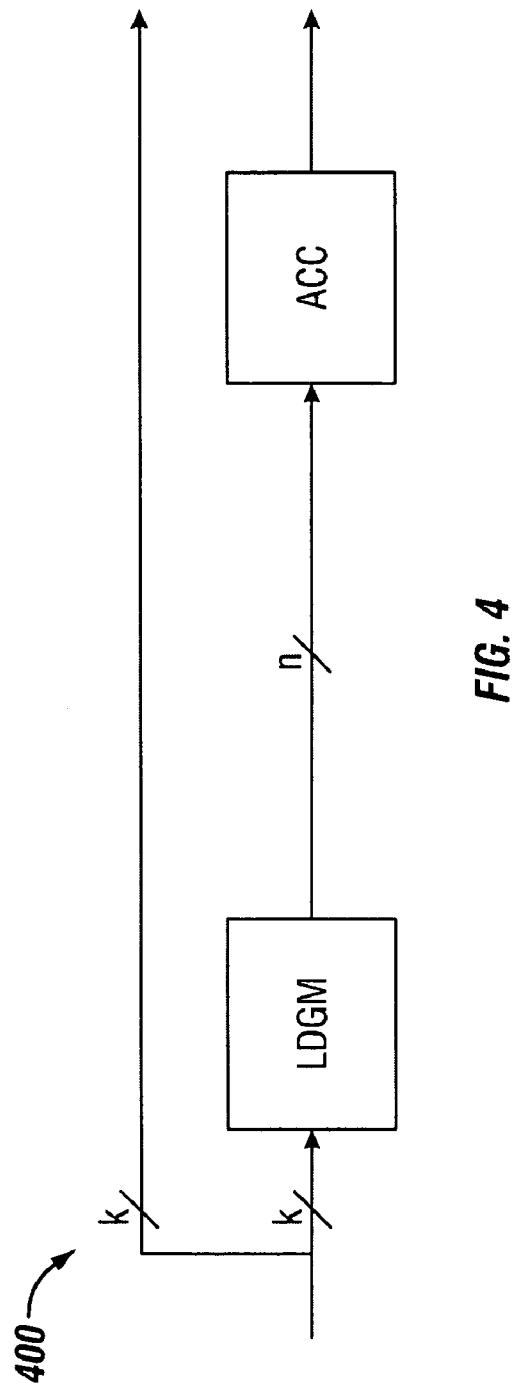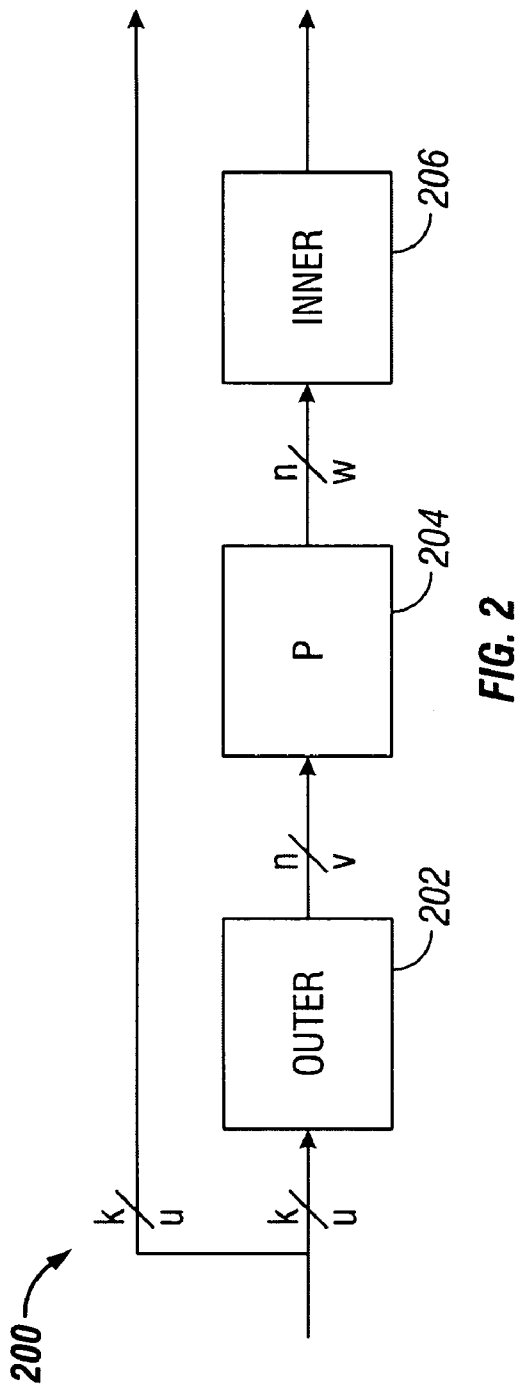
* cited by examiner

FIG. 1
(Prior Art)

FIG. 2

FIG. 4

DOCKET ALARM

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