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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/531,772	04/19/2005	Thomas P. McElwain	C108/US

114420
Collision Communications, Inc.
5400 Trinity Road
Suite 303
Raleigh, NC 27607

CONFIRMATION NO. 6021
POA ACCEPTANCE LETTER



Date Mailed: 07/23/2013

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 06/14/2013.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/deelliott/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/531,772	04/19/2005	Thomas P. McElwain	234/8 UTIL

79683
OLIVE LAW GROUP, PLLC
Bentley J Olive
125 EDINBURGH SOUTH DRIVE, SUITE 100
Suite 100
CARY, NC 27511

CONFIRMATION NO. 6021
POWER OF ATTORNEY NOTICE



Date Mailed: 07/23/2013

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 06/14/2013.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/deelliott/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:



Practitioners associated with the Customer Number:

114420

OR



Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:



The address associated with Customer Number:

114420

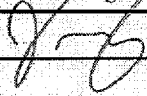
OR

☐ Firm or Individual Name			
Address			
City	State	Zip	
Country			
Telephone			Email

Assignee Name and Address:

Collision Communications, Inc.
20 Depot Street, Suite 2A
Peterborough, NH 03458**A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.****SIGNATURE of Assignee of Record**

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee.

Signature		Date	4/10/2013
Name	Jared Fry	Telephone	(857) 222-0690
Title	Co-Chairman, Collision Communications, Inc.		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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

Electronic Acknowledgement Receipt

EFS ID:	16040617
Application Number:	10531772
International Application Number:	
Confirmation Number:	6021
Title of Invention:	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR
First Named Inventor/Applicant Name:	Thomas P. McElwain
Customer Number:	79683
Filer:	Theodosios Thomas/Jeanine Young
Filer Authorized By:	Theodosios Thomas
Attorney Docket Number:	234/8 UTIL
Receipt Date:	14-JUN-2013
Filing Date:	19-APR-2005
Time Stamp:	11:28:55
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		C108_373_Statement.pdf	408470 4ce569a2eab84a07abdc107dbc0b1b032b8b85d	yes	3

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Assignee showing of ownership per 37 CFR 3.73.	1	2
	Power of Attorney	3	3
Warnings:			
Information:			
Total Files Size (in bytes):		408470	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:

Inventor: Thomas P. McElwain

Application Number: 10/531,772

Filed: 11/25/2003

Customer No.: 114420

Confirmation Number: 6021

Group Art Unit: 2611

Examiner: Temesghen Ghebretinsae

For: Joint Symbol, Amplitude, And Rate Estimator

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

STATEMENT UNDER 37 CFR 3.73(b)

IN ACCORDANCE WITH 37 CFR 3.71(a), PROSECUTION OF THE PRESENT APPLICATION SHALL BE CONDUCTED BY THE ASSIGNEE, TO THE EXCLUSION OF THE INVENTOR(S).

Applicant, **Collision Communications, Inc.**, a Limited Liability Company, states that it is:

1. ☒ the assignee of the entire right, title, and interest; or
2. ☐ an assignee of less than the entire right, title, and interest
(The extent (by percentage) of its ownership interest is _____%)

in the patent application identified above by virtue of an assignment from the inventor(s) to the current assignee as follows:

1. From: **Inventor(s)** To: **BAE Systems Information And Electronic Systems Integration Inc.**
The document was recorded in the United States Patent and Trademark Office at Reel / Frame: **015999 / 0543**, or for which a copy thereof is attached.
2. From: **BAE Systems Information And Electronic Systems Integration Inc.** To: **Collision Technology LLC**
The document was recorded in the United States Patent and Trademark Office at Reel / Frame: **026190 / 0812**, or for which a copy thereof is attached.

Additional documents in the chain of title are listed on a supplemental sheet.

As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to the Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

Signature:  Date: 06/06/13
Theodosios Thomas
Reg. No. 45159, Patent Counsel, Phone No. 919-233-1942 x-203

STATEMENT UNDER 37 CFR 3.73(c)

(Supplemental Sheet)

3. From: **Collision Technology LLC** To: **Collision Communications, Inc.**

The document was recorded in the United States Patent and Trademark Office at Reel / Frame:
028490 / 0285, or for which a copy thereof is attached.



UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/531,772	04/19/2005	Thomas P. McElwain	20030076-US

CONFIRMATION NO. 6021

POWER OF ATTORNEY NOTICE



22500
BAE SYSTEMS
PO BOX 868
NHQ1-719
NASHUA, NH 03061-0868

Date Mailed: 08/22/2011

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 08/15/2011.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/hchristian/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



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CARY, NC 27511

CONFIRMATION NO. 6021
POA ACCEPTANCE LETTER



Date Mailed: 08/22/2011

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 08/15/2011.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/hchristian/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

POWER OF ATTORNEY FOR PATENT APPLICATIONS

Under CFR § 3.73(b), Collision Technology, LLC, a corporation, hereby certifies that it is the Assignee of the entire right, title, and interest in and to the patent applications listed below. Each of the patent applications listed below is assigned to Collision Technology, LLC. As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the Assignee was submitted for recordation pursuant to 37 CFR 3.11 as shown in the Reel/Frame numbers listed below.

Filing Date	Application Serial No.; Patent No. (if issued)	Title	Reel/Frame
10/03/2003	10/678,203; 6,831,574	MULTI-TURBO MULTI- USER DETECTOR	014073/0269 026190/0812
04/05/2004	10/818,536; 6,967,598	REDUCED COMPLEXITY MULTI-TURBO MULTI- USER DETECTOR	014525/0140 026190/0812
03/24/2005	10/529,019; 7,599,346	BANDWIDTH- EFFICIENT WIRELESS NETWORK MODEM	016520/0107 026190/0812 026193/0661
08/27/2009	12/548,502	BANDWIDTH EFFICIENT WIRELESS NETWORK MODEM	026190/0812
02/03/2004	10/486,004; 7,486,722	BANDWIDTH EFFICIENT CABLE NETWORK MODEM	013771/0874 014405/0749 026190/0812 026193/0661
02/11/2004	10/486,871; 7,245,673	WINDOWED MULTIUSER DETECTION	013816/0233 015656/0249 026190/0812 026193/0661
12/21/2004	10/497,556; 7,126,533	DIRECTION-FINDING FOR MULTIPLE COCHANNEL SOURCES	014737/0931 013824/0323 026190/0812 026193/0661
04/19/2005	10/531,772; 7,463,703	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR	015999/0543 026190/0812 026193/0661
10/15/2008	12/251,571; 7,590,203	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR	021690/0566 026190/0812
10/15/2008	12/251,575; 7,583,757	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR	021690/0608 026190/0812
06/25/2009	12/491,332; 7,920,651	JOINT SYMBOL, AMPLITUDE, AND RATE	022879/0419 026190/0812

		ESTIMATOR	
12/23/2003	10/482,599; 7,428,261	CROSS-SYSTEM INTERFERENCE CANCELLATION FOR MULTICARRIER CDMA AND OFDM	013823/0522 014271/0189 026190/0812 026193/0661
12/01/2005	11/291,883; 7,593,473	TREE STRUCTURED MULTICARRIER MULTIPLE ACCESS SYSTEMS	016887/0516 026190/0812
12/01/2005	11/292,233; 7,817,754	M-ALGORITHM WITH PRIORITIZED USER ORDERING	017098/0162 026190/0812
04/10/2006	11/400,922; 7,783,110	SEMICOHERENT CHANNEL ESTIMATOR	017623/0177 026190/0812
08/10/2006	11/463,877; 7,613,228	M-ALGORITHM MULTIUSER DETECTOR WITH CORRELATION BASED PRUNING	018151/0479 026190/0812
09/15/2006	11/532,125; 7,593,492	COMBINATIONAL HYBRID TURBO-MUD	018272/0171 026190/0812
08/12/2009	12/539,691	METHOD FOR SIMULTANEOUS DETECTION OF A PLURALITY OF RFID TAGS USING MULTIUSER DETECTION	023099/0858 026190/0812
05/13/2010	12/742,686	MEDIA ACCESS CONTROL PROTOCOL FOR MULTIUSER DETECTION ENABLED AD-HOC WIRELESS COMMUNICATIONS	025578/0117 024673/0287 026190/0812
07/24/2003	10/626,146; 7,218,690	HYBRID TURBO-MUD FOR MULTIPLE ACCESS SYSTEMS	013859/0734 026190/0812
04/11/2002	10/120,955; 6,947,506	METHOD AND APPARATUS FOR IMPROVED TURBO MULTIUSER DETECTOR	013095/0631 026190/0812
01/23/2002	10/055,155; 6,839,390	VOTING SYSTEM FOR IMPROVING THE PERFORMANCE OF SINGLE-USER	012540/0669 024907/0140 026190/0812

		DECODERS WITHIN AN ITERATIVE MULTI- USER DETECTION SYSTEM	
11/12/2004	10/987,140; 7,350,136	VOTING SYSTEM FOR IMPROVING THE PERFORMANCE OF SINGLE-USER DECODERS WITHIN AN ITERATIVE MULTI- USER DETECTION SYSTEM	026190/0812
07/29/2002	10/208,409; 6,704,376	POWER AND CONFIDENCE ORDERED LOW COMPLEXITY SOFT TURBOMUD WITH VOTING SYSTEM	013020/0053 026190/0812
06/08/2004	10/863,081; 7,092,464	MULTIUSER DETECTION WITH TARGETED ERROR CORRECTION CODING	014778/0014 026190/0812
03/25/2002	10/105,918; 7,110,439	SYSTEM FOR DECREASING PROCESSING TIME IN AN ITERATIVE MULTI- USER DETECTOR SYSTEM	012744/0987 026190/0812
04/25/2003	10/423,695; 7,190,747	FREQUENCY MISMATCH COMPENSATION FOR MULTIUSER DETECTION	013676/0030 026190/0812
04/25/2003	10/423,740; 7,092,452	CO-CHANNEL INTERFERENCE RECEIVER	013674/0904 026190/0812
07/29/2002	10/207,490; 7,190,743	METHOD AND APPARATUS FOR OPTIMIZING TREE PRUNING IN A MULTIUSER DETECTOR	013198/0060 026190/0812
04/16/2003	10/414,738; 7,269,223	SYSTEM AND METHOD FOR INCREASING THROUGHPUT IN A MULTIUSER DETECTION BASED MULTIPLE ACCESS	013633/0069 026190/0812

		COMMUNICATIONS SYSTEM	
02/14/2005	11/057,479; 7,724,851	RECEIVER WITH MULTIPLE COLLECTORS IN A MULTIPLE USER DETECTION SYSTEM	016000/0309 026190/0812
04/29/2002	10/134,330; 6,981,203	METHOD AND APPARATUS FOR RANDOM SHUFFLED TURBO MULTIUSER DETECTOR	012877/0237 013129/0802 026190/0812
04/25/2003	10/423,655; 7,218,665	DEFERRED DECORRELATING DECISION-FEEDBACK DETECTOR FOR SUPERSATURATED COMMUNICATIONS	013633/0393 025710/0043 026190/0812
04/24/2003	10/422,340; 6,954,482	SOFT-DECISION TRELLIS-CODED DIFFERENTIAL FREQUENCY-HOPPED SPREAD SPECTRUM (DFHSS)	013643/0771 026190/0812
04/22/2005	10/482,598; 6,999,498	MULTIUSER DETECTION AIDED MULTIPLE ACCESS DIFFERENTIAL FREQUENCY-HOPPED SPREAD SPECTRUM	013904/0597 014293/0674 026190/0812 026193/0661
04/19/2004	10/827,462; 7,376,171	MULTIUSER DETECTION AIDED MULTIPLE ACCESS DIFFERENTIAL M-ARY CODING APPLICATIONS	014602/0733 026190/0812
09/10/2003	10/659,567; 7,236,546	PIPELINED TURBO MULTIUSER DETECTION	014002/0447 026190/0812
08/07/2001	09/923,709; 7,058,422	METHOD FOR OVERUSING FREQUENCIES TO PERMIT SIMULTANEOUS TRANSMISSION OF SIGNALS FROM TWO OR MORE USERS ON THE	012100/0995 026190/0812

		SAME FREQUENCY AND TIME SLOT	
08/31/2001	09/943,770; 6,947,505	SYSTEM FOR PARAMETER ESTIMATION AND TRACKING OF INTERFERING DIGITALLY MODULATED SIGNALS	012151/0553 026190/0812
04/16/2003	10/414,784; 6,985,699	EFFICIENT AND OPTIMAL CHANNEL ENCODING AND CHANNEL DECODING IN A MULTIPLE ACCESS COMMUNICATIONS SYSTEM	013633/0018 026190/0812
04/18/2002	10/125,241; 7,233,620	BANDWIDTH- EFFICIENT WIRELESS NETWORK MODEM	012670/0320 026190/0812
06/20/2002	10/176,011; 7,200,103	REDUCED ALGORITHM RECEIVER	013191/0058 026190/0812
06/20/2002	10/175,693; 7,139,334	COOPERATIVE CODE- ENHANCED MULTI- USER COMMUNICATIONS SYSTEM	013192/0370 013194/0865 026190/0812
08/26/2002	10/228,787; 6,947,502	PARAMETER ESTIMATOR FOR A MULTIUSER DETECTION RECEIVER	013198/0089 026190/0812
09/20/2002	10/251,187; 6,826,140	MULTICHANNEL DIGITAL RECORDING SYSTEM WITH MULTI- USER DETECTION	013147/0391 026190/0812
06/30/2004	10/497,557; 7,126,890	MULTITRACK READBCK AND MULTIUSER DETECTION FOR DISK DRIVES	014764/0397 014052/0594 026190/0812 026193/0661
08/27/2010	12/869,875	QR-RLS ADAPTIVE DIGITAL FILTER WITH 18-BIT PIPELINE ARCHITECTURE	024974/0911 026190/0812 026193/0661
04/20/2011	13/090,435	DISTRIBUTED SCHEDULER DESIGN FOR MULTIUSER	026155/0754 026190/0812 026193/0661

		DETECTION ENABLED WIRELESS MOBILE AD HOC NETWORKS	
01/31/2011	13/017,819	MULTIUSER DETECTION ENABLED MEDIUM ACCESS CONTROLE IN MOBILE AD HOC NETWORKS	026126/0450 026190/0812 026193/0661
02/23/2011	12/932,318	POWER AWARE SCHEDULING AND POWER CONTROL TECHNIQUES FOR MULTIUSER DETECTION ENABLED WIRELESS AD-HOC NETWORKS	025895/0099 026190/0812 026193/0661

The undersigned, acting as the Assignee, hereby revokes all prior powers of attorney, if applicable, and appoints the practitioners associated with the customer number 79683 as my/our attorney(s) or agent(s) to prosecute the patent(s) and/or patent application(s) and transact all business in the United States Patent and Trademark Office connected therewith.

By:

Jared Fry

Member, Collision Technology, LLC

Date:

8/13/2011

Electronic Acknowledgement Receipt

EFS ID:	10732409
Application Number:	10531772
International Application Number:	
Confirmation Number:	6021
Title of Invention:	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR
First Named Inventor/Applicant Name:	Thomas P. McElwain
Customer Number:	22500
Filer:	Justin Robert Nifong
Filer Authorized By:	
Attorney Docket Number:	20030076-US
Receipt Date:	15-AUG-2011
Filing Date:	19-APR-2005
Time Stamp:	08:05:16
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	POA_Collision_OliveLawGroup_20110812.pdf	3476082 a15fd5b1bebf4103df873fa8db61954b90f35cfba	no	6

Warnings:

Information:

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

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New International Application Filed with the USPTO as a Receiving Office

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,463,703 B2
APPLICATION NO. : 10/531772
DATED : December 9, 2008
INVENTOR(S) : Thomas P. McElwain

Page 1 of 1

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

Column 10

Line 20, delete “ $G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}$ ”; insert -- $G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}$ --

Column 17

Line 20, delete “ $\rho_{j,k}^2(i) = (s_k^H(i) s_j(i))^2$ ”; insert -- $\rho_{j,k}^2(i) = (s_k^H(i) s_j(i))^2$ --

Column 17

Line 28, delete “ $b_i^2 = 1$ ”; insert -- $b_i^2 = 1$ --

Column 17

Line 29, delete “ $b_i^2 \neq 1$ ”; insert -- $b_i^2 \neq 1$ --

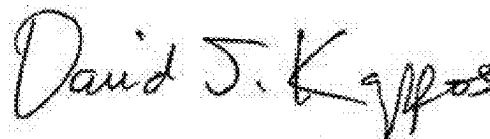
Column 17

Line 40, delete “ $\rho_{j,inactive}^2(i) = (s_{inactive}^H(i) s_j(i))^2$ ”; insert -- $\rho_{j,inactive}^2(i) = (s_{inactive}^H(i) s_j(i))^2$ --

Column 19

Line 10, delete “ $G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}$ ”; insert -- $G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}$ --

Signed and Sealed this
Twenty-fifth Day of January, 2011



David J. Kappos
Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE CERTIFICATE OF CORRECTION

Page 1 of 2

PATENT NO. : 7,463,703 B2

APPLICATION NO.: 10/531772

ISSUE DATE : December 9, 2008

INVENTOR(S) : MCELWAIN, Thomas P.

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

Column 10
Line 20, delete " $G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}$ "; insert -- " $G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}$ --

Column 17
Line 20, delete " $\rho_{j,k}^2(i) = (s_k^H(i) s_j(i))^2$ "; insert -- " $\rho_{j,k}^2(i) = (s_k^H(i) s_j(i))^2$ --

Column 17
Line 28, delete " $b_i^2 = 1$ "; insert -- " $b_i^2 = 1$ --

Column 17
Line 29, delete " $b_i^2 \neq 1$ "; insert -- " $b_i^2 \neq 1$ --

Column 17
Line 40, delete " $\rho_{j,inactive}^2(i) = (s_{inactive}^H(i) s_j(i))^2$ "; insert -- " $\rho_{j,inactive}^2(i) = (s_{inactive}^H(i) s_j(i))^2$ --

MAILING ADDRESS OF SENDER (Please do not use customer number below):

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

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

UNITED STATES PATENT AND TRADEMARK OFFICE CERTIFICATE OF CORRECTION

Page 2 of 2

PATENT NO. : 7,463,703 B2

APPLICATION NO.: 10/531772

ISSUE DATE : December 9, 2008

INVENTOR(S) : MCELWAIN, Thomas P.

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

Column 19

Line 10, delete " $G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}$,"; insert -- $G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}$ --

MAILING ADDRESS OF SENDER (Please do not use customer number below):

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

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

Electronic Acknowledgement Receipt

EFS ID:	9132791
Application Number:	10531772
International Application Number:	
Confirmation Number:	6021
Title of Invention:	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR
First Named Inventor/Applicant Name:	Thomas P. McElwain
Customer Number:	22500
Filer:	Andrew Paul Cernota/Jacqueline Judkins
Filer Authorized By:	Andrew Paul Cernota
Attorney Docket Number:	20030076-US
Receipt Date:	29-DEC-2010
Filing Date:	19-APR-2005
Time Stamp:	14:52:59
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	20030076-US_Transmittal.pdf	72557 f040ac59abf69605b3aaa8863a03df6aec47fe8a	no	1

Warnings:

Information:

2	Request for Certificate of Correction	20030076- US_CertificateOfCorrection.pdf	95440 c41783a9b3b134ec6aeb2390de43ee31d06 87e6c	no	2
Warnings:					
Information:					
Total Files Size (in bytes):				167997	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Patent No.: 7,463,703 B2 Issued: Dec. 9, 2008
Patentee: BAE Systems Information and Electronic Systems Integration, Inc.
Ser. Nr.: 10/531772
Filing or 371 (c) Date: April 19, 2005 Atty Dkt No: 20030076-US
Title: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

To: Commissioner for Patents
Attn: Certificate of Correction Branch
PO Box 1450
Alexandria, VA 22313-1450

Fr:

22500

Commissioner:

REQUEST FOR CERTIFICATE OF CORRECTION
(35 U.S.C. 254)

1. The above patent contains errors, as indicated on the attached Certificate of Correction form (submitted in duplicate), which were not the fault of the Applicant. These errors arose through the fault of the Patent and Trademark Office, and are clearly disclosed by the records of the Office, therefore issuance of the Certificate of Correction, without charge, is respectfully requested.
2. Transmitted herewith is: 2 pages Certificate of Correction.
3. All required fees are intended to be included with this submission. However, the Office is hereby authorized to charge any deficiency or credit any overpayment in the fees to deposit account #190130.

Respectfully submitted,

/Andrew P. Cernota, Reg. No. 52,711/

Cust. No. 22500
BAE SYSTEMS
PO Box 868
Nashua, NH 03061-0868
Tel. No. (603) 886-6100, Fax. No. (603) 886-4796
patents@vernmaine.com

Vernon C. Maine, Reg. No. 37,389
Andrew P. Cernota, Reg. No. 52,711
David A. Rardin, Reg. No. 52,153
Douglas P. Burum, Reg. No. 65,019
Michael J. Albaneze, Reg. No. 66,977
Attorneys/Agents for Applicant



UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	FILE WRAPPER LOCATION
10/531,772	7463703	2611	9200



Correspondence Address/Fee Address Change

The following fields have been set to Customer Number 22500 on 01/13/2009

- Correspondence Address
- Power of Attorney Address

The address of record for Customer Number 22500 is:

22500
BAE SYSTEMS
PO BOX 868
NASHUA, NH 03061-0868



UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/531,772	12/09/2008	7463703	20030076-US	6021

42716 7590 11/19/2008
Vern Maine & Associates
P. O. BOX 3445
NASHUA, NH 03061

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

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

The Patent Term Adjustment is 756 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

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

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

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

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

Thomas P. McElwain, Merrimack, NH;

PART B - FEE(S) TRANSMITTAL

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

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

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

42716 7590 09/04/2008

Vern Maine & Associates
P. O. BOX 3445
NASHUA, NH 03061

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

Certificate of Mailing or Transmission

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

Debra A. Stengel	(Depositor's name)
/Debra A. Stengel/	(Signature)
November 10, 2008	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
-----------------	-------------	----------------------	---------------------	------------------

10/531,772	04/19/2005	Thomas P. McElwain	20030076-US	6021
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TITLE OF INVENTION: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
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nonprovisional	NO	\$1440	\$300	\$0	\$1740	12/04/2008
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EXAMINER	ART UNIT	CLASS-SUBCLASS
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GHEBRETINSAE, TEMESGHEN	2611	375-341000
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1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Vernon C. Maine

2

3

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

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

(A) NAME OF ASSIGNEE

BAE SYSTEMS INFORMATION AND
ELECTRONIC SYSTEMS INTEGRATION INC

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Nashua, NH USA

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

4a. The following fee(s) are submitted:

- ☒ Issue Fee
☒ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 190130 (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

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

Authorized Signature /Andrew P. Cernota, Reg. No. 52,711/

Date November 10, 2008

Typed or printed name Andrew P. Cernota

Registration No. 52,711

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

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

Electronic Patent Application Fee Transmittal

Application Number:	10531772			
Filing Date:	19-Apr-2005			
Title of Invention:	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR			
First Named Inventor/Applicant Name:	Thomas P. McElwain			
Filer:	Andrew Paul Cernota/Debra Stengel			
Attorney Docket Number:	20030076-US			
Filed as Large Entity				
U.S. National Stage under 35 USC 371 Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl issue fee	1501	1	1510	1510
Publ. Fee- early, voluntary, or normal	1504	1	300	300

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				1810

Electronic Acknowledgement Receipt

EFS ID:	4245967
Application Number:	10531772
International Application Number:	
Confirmation Number:	6021
Title of Invention:	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR
First Named Inventor/Applicant Name:	Thomas P. McElwain
Customer Number:	42716
Filer:	Andrew Paul Cernota/Debra Stengel
Filer Authorized By:	Andrew Paul Cernota
Attorney Docket Number:	20030076-US
Receipt Date:	07-NOV-2008
Filing Date:	19-APR-2005
Time Stamp:	08:34:33
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$1810
RAM confirmation Number	7213
Deposit Account	190130
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /Zip	Pages (if appl.)
			Samsung Ex 1002	Page 29 of 242	

1	Miscellaneous Incoming Letter	20030076-US_IssueFeeTransmittal.pdf	91063 e4f00dccc16e2d4f832e0bb9b7567bc5e6ec4b54b	no	1
Warnings:					
Information:					
2	Issue Fee Payment (PTO-85B)	20030076-US_PTOL85b.pdf	141331 32b501248730b3276b16ae4d00b7f296f6dfd8ba	no	1
Warnings:					
Information:					
3	Fee Worksheet (PTO-06)	fee-info.pdf	32056 76d6c55b1e7f2b4638345cdbea3712164d6a26ea	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			264450		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: MCELWAIN, Thomas P. Group Art Unit: 2611
Serial No. 10/531,772 Examiner: GHEBRETINSAE, Temesghen
Filed: 04/19/2005 Atty. Dkt. No: 200300076-US
For: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

To: Mail Stop ISSUE FEE
 Commissioner for Patents
 PO Box 1450
 Alexandria, VA 22313-1450

From:

42716

Commissioner:

LETTER OF TRANSMITTAL

1. Transmitted herewith is 1 page PTOL-85B Issue Fee Transmittal.
2. Drawings: were neither approved or rejected by the Examiner
3. DEPOSIT ACCOUNT **190130** AUTHORIZATION – The Office is hereby authorized to charge the required fee, and any deficiency or credit any overpayment in the fees to the above deposit account, owned by BAE SYSTEMS Information and Electronic Systems Integration Inc. an authorized signator for which is Kevin M. Perkins, V.P. & Company Counsel, and for whom the undersigned are authorized agents.

Respectfully submitted,

/Andrew P. Cernota, Reg. No. 52,711/

Cus. No. 42716
Vern Maine & Associates
PO Box 3445
Nashua, NH 03061-3445
Tel. No. (603) 886-6100, Fax. No. (603) 886-4796
patents@vernmaine.com

Vernon C. Maine, Reg. No. 37,389
Andrew P. Cernota, Reg. No. 52,711
David A. Rardin, Reg. No. 52,153
Attorneys/Agents for Applicant



UNITED STATES PATENT AND TRADEMARK OFFICE

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

NOTICE OF ALLOWANCE AND FEE(S) DUE

42716 7590 09/04/2008

Vern Maine & Associates
P. O. BOX 3445
NASHUA, NH 03061

EXAMINER

GHEBRETINSAE, TEMESGHEN

ART UNIT

PAPER NUMBER

2611

DATE MAILED: 09/04/2008

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
-----------------	-------------	----------------------	---------------------	------------------

10/531,772

04/19/2005

Thomas P. McElwain

20030076-US

6021

TITLE OF INVENTION: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1440	\$300	\$0	\$1740	12/04/2008

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

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

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

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

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

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

If the SMALL ENTITY is shown as NO:

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

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

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

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

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

PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
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INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

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

42716 7590 09/04/2008

Vern Maine & Associates
P. O. BOX 3445
NASHUA, NH 03061

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

Certificate of Mailing or Transmission

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

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

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
-----------------	-------------	----------------------	---------------------	------------------

10/531,772 04/19/2005 Thomas P. McElwain 20030076-US 6021

TITLE OF INVENTION: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
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nonprovisional NO \$1440 \$300 \$0 \$1740 12/04/2008

EXAMINER	ART UNIT	CLASS-SUBCLASS
----------	----------	----------------

GHEBRETSINAE, TEMESGHEN 2611 375-341000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

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

2. For printing on the patent front page, list

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

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

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

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

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

4a. The following fee(s) are submitted:

- ☐ Issue Fee
- ☐ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies _____

4b. Payment of Fee(s); (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

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

Authorized Signature _____

Date _____

Typed or printed name _____

Registration No. _____

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

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/531,772	04/19/2005	Thomas P. McElwain	20030076-US	6021
42716	7590	09/04/2008	EXAMINER	
Vern Maine & Associates P. O. BOX 3445 NASHUA, NH 03061			GHEBRETINSAE, TEMESGHEN	
			ART UNIT	PAPER NUMBER
			2611	
DATE MAILED: 09/04/2008				

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

The Patent Term Adjustment to date is 756 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 756 day(s).

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

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

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

Notice of Allowability	Application No.	Applicant(s)	
	10/531,772	MCELWAIN, THOMAS P.	
	Examiner	Art Unit	
	Temesghen Ghebretinsae	2611	

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

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

1. ☒ This communication is responsive to amendment filed 7/31/08.
2. ☒ The allowed claim(s) is/are 1-5.
3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
 - a) ☐ All b) ☐ Some* c) ☐ None of the:
 1. ☐ Certified copies of the priority documents have been received.
 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).
 - * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.

THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
 - (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
 - 1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
 - (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

- | | |
|--|--|
| 1. ☒ Notice of References Cited (PTO-892) | 5. ☐ Notice of Informal Patent Application |
| 2. ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) | 6. ☐ Interview Summary (PTO-413),
Paper No./Mail Date _____. |
| 3. ☒ Information Disclosure Statements (PTO/SB/08),
Paper No./Mail Date <u>4/26/06,9/8/05</u> | 7. ☐ Examiner's Amendment/Comment |
| 4. ☐ Examiner's Comment Regarding Requirement for Deposit
of Biological Material | 8. ☐ Examiner's Statement of Reasons for Allowance |
| | 9. ☐ Other _____. |

/Temesghen Ghebretinsae/
Primary Examiner, Art Unit 2611

Notice of References Cited	Application/Control No. 10/531,772		Applicant(s)/Patent Under Reexamination MCELWAIN, THOMAS P.	
	Examiner Temesghen Ghebretinsae		Art Unit 2611	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,956,893	10-2005	Frank et al.	375/147
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
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	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
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	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
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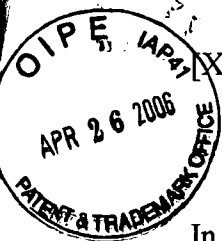
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BIB DATA SHEET

CONFIRMATION NO. 6021

SERIAL NUMBER 10/531,772	FILING or 371(c) DATE 04/19/2005 RULE	CLASS 709	GROUP ART UNIT 2611	ATTORNEY DOCKET NO. 20030076-US	
APPLICANTS Thomas P. McElwain, Merrimack, NH; ** CONTINUING DATA ***** This application is a 371 of PCT/US03/38190 11/25/2003 which claims benefit of 60/462,657 04/14/2003 ** FOREIGN APPLICATIONS ***** ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 10/17/2005					
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☒ No Verified and /TEMESGH GHEBRETINSAE/ Acknowledged Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY NH	SHEETS DRAWINGS 6	TOTAL CLAIMS 30	INDEPENDENT CLAIMS 6
ADDRESS Vern Maine & Associates P. O. BOX 3445 NASHUA, NH 03061 UNITED STATES					
TITLE Joint symbol, amplitude, and rate estimator					
FILING FEE RECEIVED 1700	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		



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2157-TFW

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: MCELWAIN, Thomas P.

Group Art Unit: 2157

Serial No. 10/531,772

Examiner:

Filing or 371 (c) Date: 04/19/2005

Atty. Dkt. No: 20030076-US

For: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

To: Mail Stop Amendment
Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

Fm:

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4/21/06

[X] Dawn M. Case

Commissioner:

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Transmitted herewith is the Applicant's Information Disclosure Statement, 2 sheets form PTO/SB/08A and/or PTO/SB/08B, and 1 references and other information. Pursuant to 37 CFR 1.98 (a)(2)(i) applicant has not transmitted herewith copies of cited U.S. Patents and U.S. patent application publications as the above application was filed after June 30, 2003. Please enter in the above application and communicate in all related matters with the undersigned.

DEPOSIT ACCOUNT 190130 AUTHORIZATION – All necessary fees are intended to be included, however the Office is hereby authorized to charge any deficiency or credit any overpayment in the fees to the above deposit account, owned by BAE SYSTEMS Information and Electronic Systems Integration Inc. an authorized signator for which is Kevin M. Perkins, V.P. & Company Counsel, and for whom the undersigned are authorized agents.

Respectfully submitted,

Scott J. Asmus, Reg. No. 42,269
Andrew P. Cernota, Reg. No. 52,711
Kristina M. Grasso, Reg. No. 39,205
Attorneys/Agents for Applicant

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Info@maineandasmus.com



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Re Application of: MCELWAIN, Thomas P.

Group Art Unit: 2157

Serial No. 10/531,772

Examiner:

Filing or 371 (c) Date: 04/19/2005

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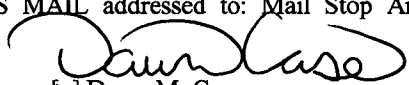
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☒ Dawn M. Case

Commissioner:

INFORMATION DISCLOSURE STATEMENT

Applicants submit this statement and the attached 2 sheet(s) of form PTO/SB/08A and/or PTO/SB/08B and 1 references and other information in accordance to the duty of disclosure under 37 C.F.R. §§1.56, 1.97, and 1.98, and requests consideration hereof. Pursuant to 37 CFR 1.98 (a)(2)(i) applicant has not transmitted herewith copies of cited U.S. Patents and U.S. patent application publications as the above application was filed after June 30, 2003.

Compliance with 37 C.F.R. §1.97: This Information Disclosure Statement is filed within three (3) months of the filing date of a National Application or before the mailing date of a first office action on the merits. No fee or certification is required.

Information Cited: The Applicants hereby make of record in the above-identified application, the information listed on the attached form PTO/SB/08A and/or PTO/SB/08B. The order of presentation of the references should not be construed as an indication of the importance of the reference. As all the references listed on attached Form PTO/SB/08A and/or PTO/SB/08B are in English, no commentary is required.

Remarks: A copy of each reference, together with a listing on Form PTO/SB/08A and/or PTO/SB/08B, is submitted herewith. Applicants respectfully request that:

1. The Examiner consider completely the cited information, along with any other information, in reaching a determination concerning the patentability of the present claims;

2. The enclosed form PTO/SB/08A and/or PTO/SB/08B be signed by the Examiner to evidence that the cited information has been fully considered by the Patent and Trademark Office during the examination of this application; and

3. The citations for the information be printed on any patent which issues from this application.

By submitting this Information Disclosure Statement, the Applicants make no representation that a search has been performed, of the extent of any search performed, or that more relevant information does not exist.

By submitting this Information Disclosure Statement, the Applicants make no representation that the information cited in the Statement is, or is considered to be, material to patentability as defined in 37 C.F.R. §1.56(b).

By submitting this Information Disclosure Statement, the Applicants make no representation that the information cited in the Statement is, or is considered to be, in fact, prior art as defined in 37 C.F.R. §102.

Notwithstanding any statement by the Applicant, the Examiner is urged to form his own conclusion regarding the relevance of the cited information.

An early and favorable action is hereby requested.

Respectfully submitted,



Scott J. Asmus, Reg. No. 42,269
Andrew P. Cernota, Reg. No. 52,711
Kristina M. Grasso, Reg. No. 39,205
Attorneys/Agents for Applicant

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STATEMENT BY APPLICANT**

(Use as many sheets as necessary)

Complete if Known

Application Number	10/531,772
Filing Date	04/19/2005
First Named Inventor	McElwain, Thomas P.
Art Unit	2157
Examiner Name	
Attorney Docket Number	20030076-US

Sheet

2

of

2

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T ²
		PCT International Search Report dated April 5, 2006 of International Application No. PCT/US03/38190 filed November 25, 2003.	

Examiner
Signature

/Temesghen Ghebretinsae/

Date
Considered

08/26/2008

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

¹ Applicant's unique citation designation number (optional). ² Applicant is to place a check mark here if English language Translation is attached.

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2157 *EW*

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor Application of: MCELWAIN, Thomas P.

Group Art Unit: 2157

Serial No. 10/531,772

Examiner:

Filing or 371 (c) Date: 04/19/2005

Atty. Dkt. No: 20030076-US

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[X] Dawn M. Case

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DEPOSIT ACCOUNT **190130** AUTHORIZATION – All necessary fees are intended to be included, however the Office is hereby authorized to charge any deficiency or credit any overpayment in the fees to the above deposit account, owned by BAE SYSTEMS Information and Electronic Systems Integration Inc. an authorized signator for which is Kevin M. Perkins, V.P. & Company Counsel, and for whom the undersigned are authorized agents.

Respectfully submitted,

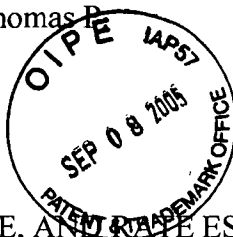
Scott J. Asmus

Scott J. Asmus, Reg. No. 42,269
Andrew P. Cernota, Reg. No. 52,711
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In re Application of: MCELWAIN, Thomas P. Group Art Unit: 2157
Serial No. 10/531,772 Examiner:
Filing or 371 (c) Date: 04/19/2005 Atty. Dkt. No: 20030076-US
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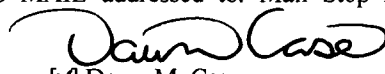
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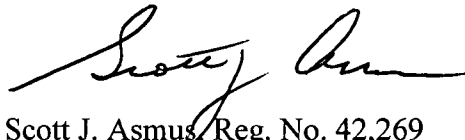
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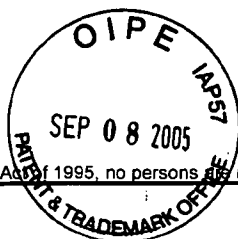
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STATEMENT BY APPLICANT**

(Use as many sheets as necessary)

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First Named Inventor	McElwain, Thomas P.
Art Unit	2157
Examiner Name	
Attorney Docket Number	20030076-US

Sheet 1 of 2

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No. ¹	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		Number-Kind Code ² (if known)			
		US- 6,298,461	10-02-2001	Tong et al.	
		US- 6,373,858 B1	04-16-2002	Soleimani et al.	
		US- 6,473,417 B1	10-29-2002	Herzog	
		US- 6,510,536 B1	01-21-2003	Crozier et al.	
		US- 6,574,291 B2	06-03-2003	Doetsch et al.	
		US- 6,704,376 B2	03-09-2004	Mills et al.	
		US- 6,839,390 B2	01-04-2005	Mills	
		US- 2002/0110206 A1	08-15-2002	Becker et al.	
		US- 2002/0122464 A1	09-05-2002	Dodge	
		US- 2003/0031237 A1	02-13-2003	Bachl et al.	
		US- 2003/0074191 A1	04-17-2003	Byrnes et al.	
		US- 2003/0086512 A1	05-08-2003	Rick et al.	
		US- 2003/0102905 A1	06-05-2003	Ha et al.	
		US- 2003/0125937 A1	07-03-2003	Thomson	
		US- 2003/0128836 A1	07-10-2003	Stephens et al.	
		US- 2003/0138054 A1	07-24-2003	Ha et al.	
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FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No. ¹	Foreign Patent Document	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear	T ⁶
		Country Code ³ Number ⁴ Kind Code ⁵ (if known)				

Examiner
Signature

/Temesghen Ghebretinsae/

Date

Considered

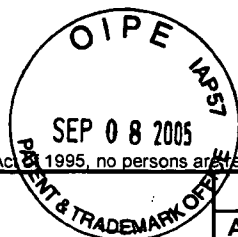
08/26/2008

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. ¹ Applicant's unique citation designation number (optional). ² See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. ³ Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). ⁴ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁵ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁶ Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND

TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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Substitute for form 1449/PTO

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**

(Use as many sheets as necessary)

Complete if Known

Application Number	10/531,772
Filing Date	04/19/2005
First Named Inventor	McElwain, Thomas P.
Art Unit	2157
Examiner Name	
Attorney Docket Number	20030076-US

Sheet 2 of 2

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T ²
		CHAN, ALBERT M. et al., "A CLASS OF ASYMPTOTICALLY OPTIMUM ITERATED-DECISION MULTIUSER DETECTOR", pp. 1-4. .2001.	
		VERDU, SERGIO, "Minimum Probability of Error for Asynchronous Gaussian Multiple-Access Channels", IEEE Transactions on Information Theory, January 1986, pp. 85-96, Vol. IT-32, No. 1.	
		LUPAS, RUXANDRA et al., "Linear Multiuser Detectors for Synchronous Code-Division Multiple-Access Channels", IEEE Transactions on Information Theory, January 1989, pp. 123-136, Vol. 35, No. 1.	
		LUPAS, RUXANDRA et al., "Near-Far Resistance of Multiuser Detectors in Asynchronous Channels", IEEE Transactions on Communications, April 1990, pp. 496-508, Vol. 38, No. 4.	
		ALEXANDER, PAUL D. et al., "Iterative Multiuser Interference Reduction: Turbo CDMA", IEEE Transactions on Communications, July 1999, pp. 1008-1014, Vol. 47, No. 7.	
		VARANASI, MAHESH K. et al., "Near-Optimum Detection in Synchronous Code-Division Multiple-Access Systems", IEEE Transactions on Communications, May 1991, pp. 725-736, Vol. 39, No. 5.	
		DUEL-HALLEN, ALEXANDRA, "Decorrelating Decision-Feedback Multiuser Detector for Synchronous Code-Division Multiple-Access Channel", February 1993, pp. 285-290, Vol. 41, No. 2.	
		WEI, LEI et al., "Synchronous DS-SSMA System with Improved Decorrelating Decision-Feedback Multiuser Detection", IEEE Transactions on Vehicular Technology, August 1994, pp. 767-772, Vol. 43, No. 3.	
		WANG, XIAODONG, et al., "Iterative (Turbo) Soft Interference Cancellation and Decoding for Coded CDMA", IEEE Transactions on Communications, July 1999, pp. 1046-1061, Vol. 47, No. 7.	
		POOR, H. VINCENT, "Turbo Multiuser Detection: An Overview", IEEE 6th Int. Symp. on Spread-Spectrum Tech. & Appl., September 6-8, 2000, pp. 583-587.	

Examiner Signature	/Temesghen Ghebretinsae/	Date Considered	08/26/2008
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

1 Applicant's unique citation designation number (optional). 2 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /TG/

Search Notes 	Application/Control No. 10531772	Applicant(s)/Patent Under Reexamination MCELWAIN, THOMAS P.
	Examiner Temesghen Ghebretinsae	Art Unit 2611

SEARCHED			
Class	Subclass	Date	Examiner
375	316,320,341,324,340	8/15/08	tg

SEARCH NOTES		
Search Notes	Date	Examiner
EAST, inventor search	8/15/08	tg

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
375	340	8/15/08	tg

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<i>Index of Claims</i> 	Application/Control No. 10531772	Applicant(s)/Patent Under Reexamination MCELWAIN, THOMAS P.
	Examiner Temesghen Ghebretinsae	Art Unit 2611

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant				☐ CPA		☐ T.D.		☐ R.1.47	
CLAIM		DATE							
Final	Original	06/22/2008	08/15/2008						
1	1	=	=						
2	2	=	=						
3	3	=	=						
4	4	=	=						
5	5	=	=						
	6	N	-						
	7	N	-						
	8	N	-						
	9	N	-						
	10	N	-						
	11	N	-						
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	26	N	-						
	27	N	-						
	28	N	-						
	29	N	-						
	30	N	-						

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	10	((THOMAS) near2 (MCELWAIN)).INV.	US-PGPUB; USPAT	OR	OFF	2008/08/15 16:13
L2	10	initial adj amplitude adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:15
L3	3	joint adj amplitude adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:15
L4	1	2004-795942.NRAN.	DERWENT	OR	OFF	2008/08/15 16:15
L5	1386	amplitude adj estimat \$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:17
L6	2534	symbol adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:17
L7	80	5 and 6	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:17
L8	40	soft adj decoders	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:18
L9	263	soft adj decoder\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:18
L10	1	7 and 9	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:18

L11	342147	decoder\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:18
L12	34	7 and 11	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:18
L13	4	joint adj symbol adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:19
L14	6210	rate adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:20
L15	5	7 and 14	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:21
L16	19602	viterbi or maximum adj posteriori	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:24
L17	16	7 and 16	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/08/15 16:24

8/15/08 4:27:16 PM

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: MCELWAIN, Thomas P. Group Art Unit: 2611
Serial No. 10/531,772 Examiner: GHEBRETINSAE, Temesghen
Filed: 04/19/2005 Atty. Dkt. No: 200300076-US
For: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR
To: Mail Stop Amendment Customer No:

42716

 Commissioner for Patents
 PO Box 1450
 Alexandria, VA 22313-1450

Commissioner:

OFFICE ACTION RESPONSE
AMENDMENT

INTRODUCTORY COMMENTS

In response to the Office's *Ex Parte Quayle* Office Action dated 07/14/2008, the Applicant has timely enclosed herein: 7 pages Office Action Response. Please amend the above-identified application as follows:

Amendments to the Specification begin on page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims which begins on page 3 of this paper.

Remarks/Arguments begin on page 5 of this paper.

DEPOSIT ACCOUNT **190130** AUTHORIZATION – The Office is hereby authorized to charge the required fee, and any deficiency or credit any overpayment in the fees to the above deposit account, owned by BAE SYSTEMS Information and Electronic Systems Integration Inc. an authorized signator for which is Kevin M. Perkins, V.P. & Company Counsel, and for whom the undersigned are authorized agents.

AMENDMENTS TO THE SPECIFICATION

Please replace the paragraph [0001] with the following amended paragraph:

-- This application claims priority to PCT Application No. PCT/US2003/038190, filed November 25, 2003, which claims the benefit of U.S. Provisional Application[[s]] No. 60/462657, filed April 14, 2003. This application is also related to U.S. Patent application Serial No. 10/105,918, filed March 25, 2002 entitled "System for Decreasing Processing Time in an Iterative Multi-User Detector System" (D4608); U.S. Patent Application Serial No. 10/414,738 filed April 16, 2003 entitled "System and Method for Increasing Throughput in a Multiuser Detection Based Multiple Access Communications System" (D4615); and U.S. Patent Application Serial No. 10/208409 entitled "Power and Confidence Ordered Low Complexity Soft TurboMUD with Voting System" (D-4627US). Each of these applications is herein incorporated in their entirety by reference. --

AMENDMENTS TO THE CLAIMS

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

Claim 1 (Original): An apparatus for processing a digital data stream from multiple users, comprising:

an initial amplitude estimation unit processing said data stream and producing initial amplitude estimates on a first iteration;

a joint amplitude estimator coupled to said data stream and said initial amplitude estimator, wherein said joint amplitude estimator produces updated amplitude estimates;

a symbol estimator coupled to said data stream, said initial amplitude estimator, and said joint amplitude estimator, wherein said symbol estimator produces a plurality of symbols estimates for each user; and

a bank of decoders coupled to said symbol estimator, producing a plurality of symbol likelihood estimates for each user, wherein said symbol likelihood estimates are iteratively fed back to said symbol estimator and said joint amplitude estimator until a final condition is obtained.

Claim 2 (Original): The apparatus according to claim 1, wherein said final condition is selected from at least one of the group consisting of: bit error rate metric level and fixed number of iterations.

Claim 3 (Currently Amended): The apparatus according to claim 1, wherein said ~~symbol hypothesis testing module~~ symbol estimator is a member selected from at least one member of the group consisting of: Minimum Mean Squared Error (MMSE), maximum likelihood, M-algorithm, T-algorithm, and Q-algorithm, decorrelating decision-feedback detector (DDFD), improved decorrelating decision-feedback detector (IDDFD), successive interference cancellation (SIC), parallel interference cancellation (PIC) and multi-stage detector; block-iterative interference cancellation, and a deferred decorrelating decision-feedback detector.

Claim 4 (Original): The apparatus according to claim 1, further comprising an energy detector coupled to said joint amplitude estimator.

Claim 5 (Currently Amended): The apparatus according to claim 1, wherein said bank of decoders are decoders selected from at least one decoder of the group consisting of: Soft-output Viterbi, Maximum A Posteriori, and ~~BCJR~~-Bahl-Cocke-Jelinek-Raviv.

Claims 6-30 (Canceled)

REMARKS

Priority Claim

Applicant requests that the Office acknowledge the claim of priority under 35 USC Section 119(e). The present application claims priority to PCT Application No. PCT/US2003/038190, filed November 25, 2003, which claims the benefit of U.S. Provisional Application No. 60/462657, filed April 14, 2003.

Drawings

Applicant notes the Office Action Summary did not note the Drawing Office review of the drawings submitted on 04/19/2005.

Election/Restriction

The Examiner has made a restriction requirement in accordance with 35 U.S.C. §121 between:

Group I: Claims 1-5 are, drawn to a receiver, classified in class 375, subclass 316.

Group II: Claims 6-21 are, drawn to amplitude estimation, classified in class 375, subclass 320.

Group III: Claims 22-30 are, drawn to Turbo decoders, classified in class 375, subclass 341.

In response to the Examiner's restriction requirement, election is hereby made without traverse to prosecute the invention of Group I, claims 1-5. Claims 6-30 have been canceled without prejudice.

Substance of Interview (MPEP713.04)

As noted in 37 CFR 1.133, the Applicant is required to make the Substance of the Interview of record in the application file. To ensure compliance therewith, Applicant wishes to note the following:

- 1) A telephonic interview was conducted on June 19, 2008 between Attorney Andrew P. Cernota and Examiner Temesghen Ghebretinsae.
- 2) Claims 1-30 were discussed and it was agreed to provisionally elect, without traverse, Group 1, claims 1-5, and the examiner would withdraw claims 6-30 from further consideration.
- 3) It was agreed that such amendment would place the application in condition for allowance.

Claim Objections

The Office objected to claim 3, noting that 3 lacked antecedent basis for “said symbol hypothesis testing module”. The Applicant herein amends claim 3 deleting “said symbol hypothesis testing module” and inserting the phrase “symbol estimator” used in the specification synonymously with “said symbol hypothesis testing module”.

The Office objected to claim 5, requiring the definition of the acronym “BCJR”. The applicant herein amends “BCJR” to read “Bahl-Cocke-Jelinek-Raviv”.

The applicant respectfully submits that the above amendments cure the Office’s objection and place the application in condition for allowance.

Applicant believes the above amendments and remarks to be fully responsive to the Office Action, thereby placing this application in condition for allowance. No new matter is added. Applicant requests speedy reconsideration, and further requests that Examiner contact its attorney by telephone, facsimile, or email for quickest resolution, if there are any remaining issues.

Respectfully submitted,

/Andrew P. Cernota, Reg. No. 52,711/

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Vernon C. Maine, Reg. No. 37,389
Andrew P. Cernota, Reg. No. 52,711
David A. Rardin, Reg. No. 52,153
Attorneys/Agents for Applicant

Electronic Acknowledgement Receipt

EFS ID:	3700643
Application Number:	10531772
International Application Number:	
Confirmation Number:	6021
Title of Invention:	Joint symbol, amplitude, and rate estimator
First Named Inventor/Applicant Name:	Thomas P. McElwain
Customer Number:	42716
Filer:	Andrew Paul Cernota/Debra Stengel
Filer Authorized By:	Andrew Paul Cernota
Attorney Docket Number:	20030076-US
Receipt Date:	31-JUL-2008
Filing Date:	19-APR-2005
Time Stamp:	07:27:55
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1		20030076-US_OAR.pdf	151033 d3bd57c64980f5888f0df8170fb5bed600373fd6	yes	7

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Response after Ex Parte Quayle Action	1	1
	Specification	2	2
	Claims	3	4
	Applicant Arguments/Remarks Made in an Amendment	5	7

Warnings:

Information:

Total Files Size (in bytes):	151033
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This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 10/531,772		Filing Date 04/19/2005		☐ To be Mailed	
APPLICATION AS FILED – PART I										
(Column 1)			(Column 2)			SMALL ENTITY ☐ OR		OTHER THAN SMALL ENTITY		
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)		RATE (\$)	FEE (\$)			
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A				
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A				
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A				
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$	=		X \$	=			
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$	=		X \$	=			
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))										
* If the difference in column 1 is less than zero, enter "0" in column 2.						TOTAL		TOTAL		
APPLICATION AS AMENDED – PART II										
(Column 1)			(Column 2)			SMALL ENTITY OR		OTHER THAN SMALL ENTITY		
AMENDMENT	07/31/2008	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)		RATE (\$)	ADDITIONAL FEE (\$)
	Total (37 CFR 1.16(i))	* 5	Minus	** 30	= 0	X \$	=		X \$50=	0
	Independent (37 CFR 1.16(h))	* 1	Minus	***6	= 0	X \$	=		X \$210=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))									
						TOTAL ADD'L FEE		TOTAL ADD'L FEE	0	
(Column 1)			(Column 2)			SMALL ENTITY OR		OTHER THAN SMALL ENTITY		
AMENDMENT	Total (37 CFR 1.16(i))	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)		RATE (\$)	ADDITIONAL FEE (\$)
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$	=		X \$	=
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))									
						TOTAL ADD'L FEE		TOTAL ADD'L FEE		
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.										

Legal Instrument Examiner:
/ANTHONY WILLIAMS/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/531,772	04/19/2005	Thomas P. McElwain	20030076-US	6021

42716 7590 07/14/2008
Vern Maine & Associates
P. O. BOX 3445
NASHUA, NH 03061

EXAMINER

GHEBRETINSAE, TEMESGHEN

ART UNIT	PAPER NUMBER
----------	--------------

2611

MAIL DATE	DELIVERY MODE
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07/14/2008

PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 10/531,772	Applicant(s) MCELWAIN, THOMAS P.	
	Examiner Temesghen Ghebretinsae	Art Unit 2611	

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

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 2 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☐ Responsive to communication(s) filed on ____.
- 2a) ☐ This action is **FINAL**. 2b) ☐ This action is non-final.
- 3) ☒ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 1-30 is/are pending in the application.
- 4a) Of the above claim(s) 6-30 is/are withdrawn from consideration.
- 5) ☒ Claim(s) 1-5 is/are allowed.
- 6) ☐ Claim(s) ____ is/are rejected.
- 7) ☐ Claim(s) ____ is/are objected to.
- 8) ☐ Claim(s) ____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on ____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

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

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

- | | |
|--|---|
| 1) ☒ Notice of References Cited (PTO-892) | 4) ☐ Interview Summary (PTO-413) |
| 2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) | Paper No(s)/Mail Date. ____. |
| 3) ☒ Information Disclosure Statement(s) (PTO/SB/08) | 5) ☐ Notice of Informal Patent Application |
| Paper No(s)/Mail Date <u>4/26/06;9/8/05</u> . | 6) ☐ Other: ____. |

DETAILED ACTION

1. Restriction to one of the following inventions is required under 35 U.S.C. 121:
 - I. Claims 1-5 are, drawn to a receiver, classified in class 375, subclass 316.
 - II. Claims 6-21 are, drawn to amplitude estimation, classified in class 375, subclass 320.
 - III. Claims 22-30 are, drawn to Turbo decoders, classified in class 375, subclass 341.

The inventions are distinct, each from the other because of the following reasons:

2. Inventions Group I; Group II and Group III are related as subcombinations disclosed as usable together in a single combination. The subcombinations are distinct if they do not overlap in scope and are not obvious variants, and if it is shown that at least one subcombination is separately usable. In the instant case, subcombination Group II has separate utility such as amplitude estimation and Group III has separate utility such as Turbo decoders. See MPEP § 806.05(d).

The examiner has required restriction between subcombinations usable together. Where applicant elects a subcombination and claims thereto are subsequently found allowable, any claim(s) depending from or otherwise requiring all the limitations of the allowable subcombination will be examined for patentability in accordance with 37 CFR 1.104. See MPEP § 821.04(a). Applicant is advised that if any claim presented in a continuation or divisional application is anticipated by, or includes all the limitations of, a claim that is allowable in the present application, such claim may be subject to

provisional statutory and/or nonstatutory double patenting rejections over the claims of the instant application.

3. Restriction for examination purposes as indicated is proper because all these inventions listed in this action are independent or distinct for the reasons given above and there would be a serious search and examination burden if restriction were not required because one or more of the following reasons apply:

- (a) the inventions have acquired a separate status in the art in view of their different classification;
- (b) the inventions have acquired a separate status in the art due to their recognized divergent subject matter;
- (c) the inventions require a different field of search (for example, searching different classes/subclasses or electronic resources, or employing different search queries);
- (d) the prior art applicable to one invention would not likely be applicable to another invention;
- (e) the inventions are likely to raise different non-prior art issues under 35 U.S.C. 101 and/or 35 U.S.C. 112, first paragraph.

Applicant is advised that the reply to this requirement to be complete must include (i) an election of a invention to be examined even though the requirement may be traversed (37 CFR 1.143) and (ii) identification of the claims encompassing the elected invention.

The election of an invention may be made with or without traverse. To reserve a right to petition, the election must be made with traverse. If the reply does not distinctly and specifically point out supposed errors in the restriction requirement, the election shall be treated as an election without traverse. Traversal must be presented at the time of election in order to be considered timely. Failure to timely traverse the requirement will result in the loss of right to petition under 37 CFR 1.144. If claims are added after the election, applicant must indicate which of these claims are readable on the elected invention.

If claims are added after the election, applicant must indicate which of these claims are readable upon the elected invention.

Should applicant traverse on the ground that the inventions are not patentably distinct, applicant should submit evidence or identify such evidence now of record showing the inventions to be obvious variants or clearly admit on the record that this is the case. In either instance, if the examiner finds one of the inventions unpatentable over the prior art, the evidence or admission may be used in a rejection under 35 U.S.C. 103(a) of the other invention.

4. During a telephone conversation with Mr. Andrew P. Cernota on 6/19/08 a provisional election was made with out traverse to prosecute the invention of Group I, claims 1-5. Affirmation of this election must be made by applicant in replying to this Office action. Claims 6-30 are withdrawn from further consideration by the examiner, 37 CFR 1.142(b), as being drawn to a non-elected invention.

Information Disclosure Statement

5. The IDS filed 4/26/08 and 9/8/05 have been considered by the examiner.

Claim Objections

6. Claims 3 and 5 are objected to because of the following informalities: In claim 3, "said symbol hypothesis testing module" lack clear antecedent basis and in claim 5, "BCJR" should be defined. Appropriate correction is required.

Allowable Subject Matter

7. This application is in condition for allowance except for the following formal matters:

See above objection of claims 3 and 5.

Prosecution on the merits is closed in accordance with the practice under *Ex parte Quayle*, 25 USPQ 74, 453 O.G. 213, (Comm'r Pat. 1935).

A shortened statutory period for reply to this action is set to expire **TWO MONTHS** from the mailing date of this letter.

8. The following is a statement of reasons for the indication of allowable subject matter: the prior art of record fail to anticipate or render obvious the claimed apparatus for processing a digital data stream from multiple users, comprising: an initial amplitude estimation unit processing said data stream and producing initial amplitude estimates on a first iteration; a joint amplitude estimator coupled to said data stream and said initial amplitude estimator, wherein said joint amplitude estimator produces updated amplitude estimates; a symbol estimator coupled to said data stream, said initial amplitude

estimator, and said joint amplitude estimator, wherein said symbol estimator produces a plurality of symbols estimates for each user; and a bank of decoders coupled to said symbol estimator, producing a plurality of symbol likelihood estimates for each user, wherein said symbol likelihood estimates are iteratively fed back to said symbol estimator and said joint amplitude estimator until a final condition is obtained as claimed in claim 1.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Temesghen Ghebretinsae whose telephone number is 571-272-3017. The examiner can normally be reached on Monday-Friday from 8 to 6. The examiner can also be reached on alternate.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ghayour Mohammed, can be reached on 571-272-3021. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Application/Control Number: 10/531,772
Art Unit: 2611

Page 7

Temesghen Ghebretinsae
Primary Examiner
Art Unit 2611

/Temesghen Ghebretinsae/

Primary Examiner, Art Unit 2611 6/22/08

Notice of References Cited	Application/Control No. 10/531,772		Applicant(s)/Patent Under Reexamination MCELWAIN, THOMAS P.	
	Examiner Temesghen Ghebretinsae		Art Unit 2611	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-2003/0189979	10-2003	Li et al.	375/227
*	B	US-2003/0179698	09-2003	Lu, Chun Chian	370/209
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	10	((THOMAS) near2 (MCELWAIN)).INV.	US-PGPUB; USPAT	OR	OFF	2008/06/20 11:15
L2	1353	amplitude adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:19
L3	2469	symbol adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:19
L4	78	2 and 3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:20
L5	337484	decoder\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:20
L6	32	4 and 5	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:20
L7	3	joint adj symbol with amplitude with rate adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:21
L8	1	2004-795942.NRAN.	DERWENT	OR	OFF	2008/06/20 11:21
L9	13389	energy adj detect\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:29
L10	1	7 and 9	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:29

L11	14	amplitude adj estimat \$ with symbol adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:33
L12	3	joint adj amplitude adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:39
L13	10	initial adj amplitude adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:39
L14	15467	multi adj user	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:43
L15	44	4 and 14	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:43
L16	14	5 and 15	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:43
L17	3	mmse adj symbol adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:49
L18	1326	minimum adj mean adj squared adj error	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:50
L19	8	4 and 18	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:50
L20	255	soft adj decoder\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:53

L21	1	4 and 20	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:53
L22	192	inactive adj channel \$ with active adj channel\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:53
L23	1	4 and 22	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:54
L24	3	symbol adj likelihood adj estimat\$	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 11:54
L25	217	joint adj demodulation	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 12:02
L26	5621	4 abd 25	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 12:02
L27	2	4 and 25	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 12:02

6/20/08 12:03:24 PM

<i>Index of Claims</i> 	Application/Control No. 10531772	Applicant(s)/Patent Under Reexamination MCELWAIN, THOMAS P.
	Examiner Temesghen Ghebretinsae	Art Unit 2611

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant			☐ CPA			☐ T.D.			☐ R.1.47		
CLAIM		DATE									
Final	Original	06/22/2008									
	1	=									
	2	=									
	3	=									
	4	=									
	5	=									
	6	N									
	7	N									
	8	N									
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	24	N									
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	26	N									
	27	N									
	28	N									
	29	N									
	30	N									



UNITED STATES PATENT AND TRADEMARK OFFICE

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

BIB DATA SHEET

CONFIRMATION NO. 6021

SERIAL NUMBER 10/531,772	FILING or 371(c) DATE 04/19/2005 RULE	CLASS 709	GROUP ART UNIT 2611	ATTORNEY DOCKET NO. 20030076-US	
APPLICANTS Thomas P. McElwain, Merrimack, NH; ** CONTINUING DATA ***** This application is a 371 of PCT/US03/38190 11/25/2003 which claims benefit of 60/462,657 04/14/2003 ** FOREIGN APPLICATIONS ***** ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 10/17/2005					
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☐ No Verified and /TEMESGH GHEBRETINSAE/ Acknowledged Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY NH	SHEETS DRAWINGS 6	TOTAL CLAIMS 30	INDEPENDENT CLAIMS 6
ADDRESS Vern Maine & Associates P. O. BOX 3445 NASHUA, NH 03061 UNITED STATES					
TITLE Joint symbol, amplitude, and rate estimator					
FILING FEE RECEIVED 1700	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		

Search Notes 	Application/Control No. 10531772	Applicant(s)/Patent Under Reexamination MCELWAIN, THOMAS P.
	Examiner Temesghen Ghebretinsae	Art Unit 2611

SEARCHED			
Class	Subclass	Date	Examiner
375	316,320,341,324	6/22/08	tg

SEARCH NOTES		
Search Notes	Date	Examiner
EAST, inventor search	6/22/08	tg

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

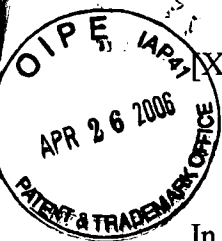
EAST Search History

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L1	10	((THOMAS) near2 (MCELWAIN)).INV.	US-PGPUB; USPAT	OR	OFF	2008/06/20 11:15
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L27	2	4 and 25	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2008/06/20 12:02
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6/ 20/ 08 12:06:55 PM



[X] First Class Mail or [] Express Mail Certificate _____

2157 J. TFW

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: MCELWAIN, Thomas P.

Group Art Unit: 2157

Serial No. 10/531,772

Examiner:

Filing or 371 (c) Date: 04/19/2005

Atty. Dkt. No: 20030076-US

For: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

To: Mail Stop Amendment
Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

Fm:

42716

CERTIFICATE OF MAILING 37 CFR 1.8: I certify that this correspondence is being deposited on the below date with the U.S. Postal Service with sufficient postage as FIRST CLASS MAIL addressed to: Mail Stop Amendment, Commissioner of Patents, PO Box 1450, Alexandria, VA 22313-1450

Date:

4/21/06

[X] Dawn M. Case

Commissioner:

TRANSMITTAL OF INFORMATION DISCLOSURE STATEMENT

Transmitted herewith is the Applicant's Information Disclosure Statement, 2 sheets form PTO/SB/08A and/or PTO/SB/08B, and 1 references and other information. Pursuant to 37 CFR 1.98 (a)(2)(i) applicant has not transmitted herewith copies of cited U.S. Patents and U.S. patent application publications as the above application was filed after June 30, 2003. Please enter in the above application and communicate in all related matters with the undersigned.

DEPOSIT ACCOUNT 190130 AUTHORIZATION – All necessary fees are intended to be included, however the Office is hereby authorized to charge any deficiency or credit any overpayment in the fees to the above deposit account, owned by BAE SYSTEMS Information and Electronic Systems Integration Inc. an authorized signator for which is Kevin M. Perkins, V.P. & Company Counsel, and for whom the undersigned are authorized agents.

Respectfully submitted,

Scott J. Asmus, Reg. No. 42,269
Andrew P. Cernota, Reg. No. 52,711
Kristina M. Grasso, Reg. No. 39,205
Attorneys/Agents for Applicant

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Info@maineandasmus.com



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Re Application of: MCELWAIN, Thomas P.

Group Art Unit: 2157

Serial No. 10/531,772

Examiner:

Filing or 371 (c) Date: 04/19/2005

Atty. Dkt. No: 20030076-US

For: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

To: Mail Stop Amendment
Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

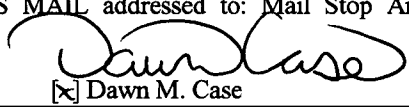
Fm:

42716

CERTIFICATE OF MAILING 37 CFR 1.8: I certify that this correspondence is being deposited on the below date with the U.S. Postal Service with sufficient postage as FIRST CLASS MAIL addressed to: Mail Stop Amendment, Commissioner of Patents, PO Box 1450, Alexandria, VA 22313-1450

Date:

4/21/06


☒ Dawn M. Case

Commissioner:

INFORMATION DISCLOSURE STATEMENT

Applicants submit this statement and the attached 2 sheet(s) of form PTO/SB/08A and/or PTO/SB/08B and 1 references and other information in accordance to the duty of disclosure under 37 C.F.R. §§1.56, 1.97, and 1.98, and requests consideration hereof. Pursuant to 37 CFR 1.98 (a)(2)(i) applicant has not transmitted herewith copies of cited U.S. Patents and U.S. patent application publications as the above application was filed after June 30, 2003.

Compliance with 37 C.F.R. §1.97: This Information Disclosure Statement is filed within three (3) months of the filing date of a National Application or before the mailing date of a first office action on the merits. No fee or certification is required.

Information Cited: The Applicants hereby make of record in the above-identified application, the information listed on the attached form PTO/SB/08A and/or PTO/SB/08B. The order of presentation of the references should not be construed as an indication of the importance of the reference. As all the references listed on attached Form PTO/SB/08A and/or PTO/SB/08B are in English, no commentary is required.

Remarks: A copy of each reference, together with a listing on Form PTO/SB/08A and/or PTO/SB/08B, is submitted herewith. Applicants respectfully request that:

1. The Examiner consider completely the cited information, along with any other information, in reaching a determination concerning the patentability of the present claims;

2. The enclosed form PTO/SB/08A and/or PTO/SB/08B be signed by the Examiner to evidence that the cited information has been fully considered by the Patent and Trademark Office during the examination of this application; and

3. The citations for the information be printed on any patent which issues from this application.

By submitting this Information Disclosure Statement, the Applicants make no representation that a search has been performed, of the extent of any search performed, or that more relevant information does not exist.

By submitting this Information Disclosure Statement, the Applicants make no representation that the information cited in the Statement is, or is considered to be, material to patentability as defined in 37 C.F.R. §1.56(b).

By submitting this Information Disclosure Statement, the Applicants make no representation that the information cited in the Statement is, or is considered to be, in fact, prior art as defined in 37 C.F.R. §102.

Notwithstanding any statement by the Applicant, the Examiner is urged to form his own conclusion regarding the relevance of the cited information.

An early and favorable action is hereby requested.

Respectfully submitted,



Scott J. Asmus, Reg. No. 42,269
Andrew P. Cernota, Reg. No. 52,711
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**Complete if Known**

(Use as many sheets as necessary)

Sheet	1	of	2
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Application Number	10/531,772
Filing Date	04/19/2005
First Named Inventor	McElwain, Thomas P.
Art Unit	2157
Examiner Name	
Attorney Docket Number	20030076-US

[illegible][illegible]

Examiner Signature	/Temesghen Ghebretinsae/	Date Considered	06/19/2008
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Sheet 2 of 2

NON PATENT LITERATURE DOCUMENTS

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/TG/		PCT International Search Report dated April 5, 2006 of International Application No. PCT/US03/38190 filed November 25, 2003.	

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2157 *EW*

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor Application of: MCELWAIN, Thomas P.

Group Art Unit: 2157

Serial No. 10/531,772

Examiner:

Filing or 371 (c) Date: 04/19/2005

Atty. Dkt. No: 20030076-US

For: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

To: Mail Stop Amendment
Commissioner for Patents
PO Box 1450
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[X] Dawn M. Case

Commissioner:

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DEPOSIT ACCOUNT 190130 AUTHORIZATION – All necessary fees are intended to be included, however the Office is hereby authorized to charge any deficiency or credit any overpayment in the fees to the above deposit account, owned by BAE SYSTEMS Information and Electronic Systems Integration Inc. an authorized signator for which is Kevin M. Perkins, V.P. & Company Counsel, and for whom the undersigned are authorized agents.

Respectfully submitted,

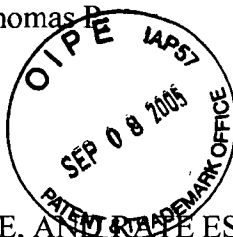


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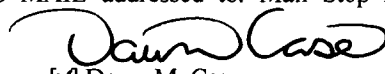
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2. The enclosed form PTO/SB/08A and/or PTO/SB/08B be signed by the Examiner to evidence that the cited information has been fully considered by the Patent and Trademark Office during the examination of this application; and

3. The citations for the information be printed on any patent which issues from this application.

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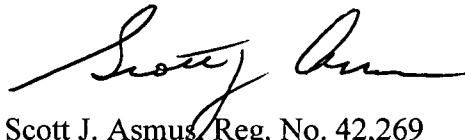
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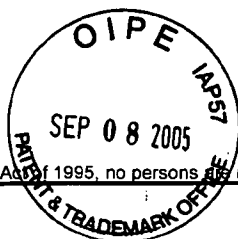
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Art Unit	2157
Examiner Name	
Attorney Docket Number	20030076-US

Sheet 1 of 2

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No. ¹	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		Number-Kind Code ² (if known)			
		US- 6,298,461	10-02-2001	Tong et al.	
		US- 6,373,858 B1	04-16-2002	Soleimani et al.	
		US- 6,473,417 B1	10-29-2002	Herzog	
		US- 6,510,536 B1	01-21-2003	Crozier et al.	
		US- 6,574,291 B2	06-03-2003	Doetsch et al.	
		US- 6,704,376 B2	03-09-2004	Mills et al.	
		US- 6,839,390 B2	01-04-2005	Mills	
		US- 2002/0110206 A1	08-15-2002	Becker et al.	
		US- 2002/0122464 A1	09-05-2002	Dodge	
		US- 2003/0031237 A1	02-13-2003	Bachl et al.	
		US- 2003/0074191 A1	04-17-2003	Byrnes et al.	
		US- 2003/0086512 A1	05-08-2003	Rick et al.	
		US- 2003/0102905 A1	06-05-2003	Ha et al.	
		US- 2003/0125937 A1	07-03-2003	Thomson	
		US- 2003/0128836 A1	07-10-2003	Stephens et al.	
		US- 2003/0138054 A1	07-24-2003	Ha et al.	
		US-			
		US-			
		US-			

FOREIGN PATENT DOCUMENTS

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		Country Code ³ Number ⁴ Kind Code ⁵ (if known)				

Examiner
Signature

/Temesghen Ghebretinsae/

Date
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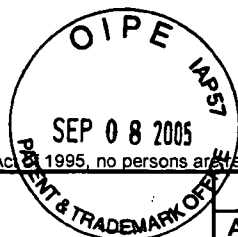
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Sheet 2

of

2

NON PATENT LITERATURE DOCUMENTS

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		CHAN, ALBERT M. et al., "A CLASS OF ASYMPTOTICALLY OPTIMUM ITERATED-DECISION MULTIUSER DETECTOR", pp. 1-4.	
		VERDU, SERGIO, "Minimum Probability of Error for Asynchronous Gaussian Multiple-Access Channels", IEEE Transactions on Information Theory, January 1986, pp. 85-96, Vol. IT-32, No. 1.	
		LUPAS, RUXANDRA et al., "Linear Multiuser Detectors for Synchronous Code-Division Multiple-Access Channels", IEEE Transactions on Information Theory, January 1989, pp. 123-136, Vol. 35, No. 1.	
		LUPAS, RUXANDRA et al., "Near-Far Resistance of Multiuser Detectors in Asynchronous Channels", IEEE Transactions on Communications, April 1990, pp. 496-508, Vol. 38, No. 4.	
		ALEXANDER, PAUL D. et al., "Iterative Multiuser Interference Reduction: Turbo CDMA", IEEE Transactions on Communications, July 1999, pp. 1008-1014, Vol. 47, No. 7.	
		VARANASI, MAHESH K. et al., "Near-Optimum Detection in Synchronous Code-Division Multiple-Access Systems", IEEE Transactions on Communications, May 1991, pp. 725-736, Vol. 39, No. 5.	
		DUEL-HALLEN, ALEXANDRA, "Decorrelating Decision-Feedback Multiuser Detector for Synchronous Code-Division Multiple-Access Channel", February 1993, pp. 285-290, Vol. 41, No. 2.	
		WEI, LEI et al., "Synchronous DS-SSMA System with Improved Decorrelating Decision-Feedback Multiuser Detection", IEEE Transactions on Vehicular Technology, August 1994, pp. 767-772, Vol. 43, No. 3.	
		WANG, XIAODONG, et al., "Iterative (Turbo) Soft Interference Cancellation and Decoding for Coded CDMA", IEEE Transactions on Communications, July 1999, pp. 1046-1061, Vol. 47, No. 7.	
		POOR, H. VINCENT, "Turbo Multiuser Detection: An Overview", IEEE 6th Int. Symp. on Spread-Spectrum Tech. & Appl., September 6-8, 2000, pp. 583-587.	

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: MCELWAIN, Thomas P.

Group Art Unit: 2157

Serial No. 10/531,772

Examiner:

Filing or 371 (c) Date: 04/19/2005

Atty. Dkt. No: 20030076-US

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[X] Dawn M. Case

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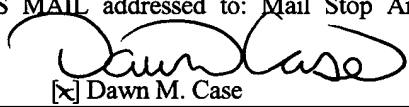
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			Application Number	10/531,772
			Filing Date	04/19/2005
			First Named Inventor	McElwain, Thomas P.
			Art Unit	2157
			Examiner Name	
Sheet 2	of 2	Attorney Docket Number	20030076-US	

[illegible]

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

1 Applicant's unique citation designation number (optional). 2 Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO:**

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

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2157 *EW*

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor Application of: MCELWAIN, Thomas P.

Group Art Unit: 2157

Serial No. 10/531,772

Examiner:

Filing or 371 (c) Date: 04/19/2005

Atty. Dkt. No: 20030076-US

For: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

To: Mail Stop Amendment
Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

Fm:

42716

CERTIFICATE OF MAILING 37 CFR 1.8: I certify that this correspondence is being deposited on the below date with the U.S. Postal Service with sufficient postage as FIRST CLASS MAIL addressed to: Mail Stop Amendment, Commissioner of Patents, PO Box 1450, Alexandria, VA 22313-1450

Date:

9/6/05

Dawn M. Case
[X] Dawn M. Case

Commissioner:

TRANSMITTAL OF INFORMATION DISCLOSURE STATEMENT

Transmitted herewith is the Applicant's Information Disclosure Statement, 2 sheets form PTO/SB/08A and/or PTO/SB/08B, and 10 references and other information. Pursuant to 37 CFR 1.98 (a)(2)(i) applicant has not transmitted herewith copies of cited U.S. Patents and U.S. patent application publications as the above application was filed after June 30, 2003. Please enter in the above application and communicate in all related matters with the undersigned.

DEPOSIT ACCOUNT **190130** AUTHORIZATION – All necessary fees are intended to be included, however the Office is hereby authorized to charge any deficiency or credit any overpayment in the fees to the above deposit account, owned by BAE SYSTEMS Information and Electronic Systems Integration Inc. an authorized signator for which is Kevin M. Perkins, V.P. & Company Counsel, and for whom the undersigned are authorized agents.

Respectfully submitted,

Scott J. Asmus

Scott J. Asmus, Reg. No. 42,269
Andrew P. Cornota, Reg. No. 52,711
Attorneys/Agents for Applicant

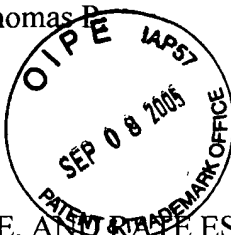
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Tel. No. (603) 886-6100, Fax. No. (603) 886-4796
Info@maineandasmus.com

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: MCELWAIN, Thomas P.

Group Art Unit: 2157

Serial No. 10/531,772



Examiner:

Filing or 371 (c) Date: 04/19/2005

Atty. Dkt. No: 20030076-US

For: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

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PO Box 1450
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CERTIFICATE OF MAILING 37 CFR 1.8: I certify that this correspondence is being deposited on the below date with the U.S. Postal Service with sufficient postage as FIRST CLASS MAIL addressed to: Mail Stop Amendment, Commissioner of Patents, PO Box 1450, Alexandria, VA 22313-1450

Date:

9/6/05


☒ Dawn M. Case

Commissioner:

INFORMATION DISCLOSURE STATEMENT

Applicants submit this statement and the attached 2 sheet(s) of form PTO/SB/08A and/or PTO/SB/08B and 10 references and other information in accordance to the duty of disclosure under 37 C.F.R. §§1.56, 1.97, and 1.98, and requests consideration hereof. Pursuant to 37 CFR 1.98 (a)(2)(i) applicant has not transmitted herewith copies of cited U.S. Patents and U.S. patent application publications as the above application was filed after June 30, 2003.

Compliance with 37 C.F.R. §1.97: This Information Disclosure Statement is filed within three (3) months of the filing date of a National Application or before the mailing date of a first office action on the merits. No fee or certification is required.

Information Cited: The Applicants hereby make of record in the above-identified application, the information listed on the attached form PTO/SB/08A and/or PTO/SB/08B. The order of presentation of the references should not be construed as an indication of the importance of the reference. As all the references listed on attached Form PTO/SB/08A and/or PTO/SB/08B are in English, no commentary is required.

Remarks: A copy of each reference, together with a listing on Form PTO/SB/08A and/or PTO/SB/08B, is submitted herewith. Applicants respectfully request that:

1. The Examiner consider completely the cited information, along with any other information, in reaching a determination concerning the patentability of the present claims;

2. The enclosed form PTO/SB/08A and/or PTO/SB/08B be signed by the Examiner to evidence that the cited information has been fully considered by the Patent and Trademark Office during the examination of this application; and

3. The citations for the information be printed on any patent which issues from this application.

By submitting this Information Disclosure Statement, the Applicants make no representation that a search has been performed, of the extent of any search performed, or that more relevant information does not exist.

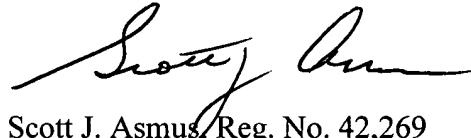
By submitting this Information Disclosure Statement, the Applicants make no representation that the information cited in the Statement is, or is considered to be, material to patentability as defined in 37 C.F.R. §1.56(b).

By submitting this Information Disclosure Statement, the Applicants make no representation that the information cited in the Statement is, or is considered to be, in fact, prior art as defined in 37 C.F.R. §102.

Notwithstanding any statement by the Applicant, the Examiner is urged to form his own conclusion regarding the relevance of the cited information.

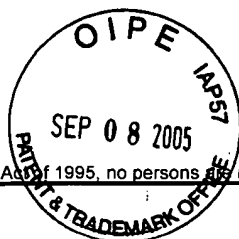
An early and favorable action is hereby requested.

Respectfully submitted,



Scott J. Asmus, Reg. No. 42,269
Andrew P. Cernota, Reg. No. 52,711
Attorneys/Agents for Applicant

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Maine & Asmus
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Info@maineandasmus.com



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Substitute for form 1449/PTO

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**

(Use as many sheets as necessary)

Complete if Known

Application Number	10/531,772
Filing Date	04/19/2005
First Named Inventor	McElwain, Thomas P.
Art Unit	2157
Examiner Name	
Attorney Docket Number	20030076-US

Sheet 1 of 2

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No. ¹	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		Number-Kind Code ² (if known)			
		US- 6,298,461	10-02-2001	Tong et al.	
		US- 6,373,858 B1	04-16-2002	Soleimani et al.	
		US- 6,473,417 B1	10-29-2002	Herzog	
		US- 6,510,536 B1	01-21-2003	Crozier et al.	
		US- 6,574,291 B2	06-03-2003	Doetsch et al.	
		US- 6,704,376 B2	03-09-2004	Mills et al.	
		US- 6,839,390 B2	01-04-2005	Mills	
		US- 2002/0110206 A1	08-15-2002	Becker et al.	
		US- 2002/0122464 A1	09-05-2002	Dodge	
		US- 2003/0031237 A1	02-13-2003	Bachl et al.	
		US- 2003/0074191 A1	04-17-2003	Byrnes et al.	
		US- 2003/0086512 A1	05-08-2003	Rick et al.	
		US- 2003/0102905 A1	06-05-2003	Ha et al.	
		US- 2003/0125937 A1	07-03-2003	Thomson	
		US- 2003/0128836 A1	07-10-2003	Stephens et al.	
		US- 2003/0138054 A1	07-24-2003	Ha et al.	
		US-			
		US-			
		US-			

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No. ¹	Foreign Patent Document	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear	T ⁶
		Country Code ³ Number ⁴ Kind Code ⁵ (if known)				

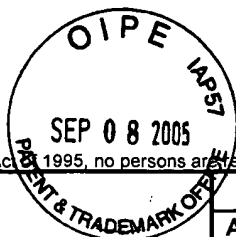
Examiner
SignatureDate
Considered

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. ¹ Applicant's unique citation designation number (optional). ² See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. ³ Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). ⁴ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁵ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁶ Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND

TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.



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**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**

(Use as many sheets as necessary)

Complete if Known

Application Number	10/531,772
Filing Date	04/19/2005
First Named Inventor	McElwain, Thomas P.
Art Unit	2157
Examiner Name	
Attorney Docket Number	20030076-US

Sheet 2 of 2

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No. ¹	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T ²
		CHAN, ALBERT M. et al., "A CLASS OF ASYMPTOTICALLY OPTIMUM ITERATED-DECISION MULTIUSER DETECTOR", pp. 1-4.	
		VERDU, SERGIO, "Minimum Probability of Error for Asynchronous Gaussian Multiple-Access Channels", IEEE Transactions on Information Theory, January 1986, pp. 85-96, Vol. IT-32, No. 1.	
		LUPAS, RUXANDRA et al., "Linear Multiuser Detectors for Synchronous Code-Division Multiple-Access Channels", IEEE Transactions on Information Theory, January 1989, pp. 123-136, Vol. 35, No. 1.	
		LUPAS, RUXANDRA et al., "Near-Far Resistance of Multiuser Detectors in Asynchronous Channels", IEEE Transactions on Communications, April 1990, pp. 496-508, Vol. 38, No. 4.	
		ALEXANDER, PAUL D. et al., "Iterative Multiuser Interference Reduction: Turbo CDMA", IEEE Transactions on Communications, July 1999, pp. 1008-1014, Vol. 47, No. 7.	
		VARANASI, MAHESH K. et al., "Near-Optimum Detection in Synchronous Code-Division Multiple-Access Systems", IEEE Transactions on Communications, May 1991, pp. 725-736, Vol. 39, No. 5.	
		DUEL-HALLEN, ALEXANDRA, "Decorrelating Decision-Feedback Multiuser Detector for Synchronous Code-Division Multiple-Access Channel", February 1993, pp. 285-290, Vol. 41, No. 2.	
		WEI, LEI et al., "Synchronous DS-SSMA System with Improved Decorrelating Decision-Feedback Multiuser Detection", IEEE Transactions on Vehicular Technology, August 1994, pp. 767-772, Vol. 43, No. 3.	
		WANG, XIAODONG, et al., "Iterative (Turbo) Soft Interference Cancellation and Decoding for Coded CDMA", IEEE Transactions on Communications, July 1999, pp. 1046-1061, Vol. 47, No. 7.	
		POOR, H. VINCENT, "Turbo Multiuser Detection: An Overview", IEEE 6th Int. Symp. on Spread-Spectrum Tech. & Appl., September 6-8, 2000, pp. 583-587.	

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

1 Applicant's unique citation designation number (optional). 2 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: MCELWAIN, Thomas P. Group Art Unit: 2157
Serial No. 10/531,772 Examiner:
Filed: 04/19/2005 Atty. Dkt. No: 200300076-US

FOR: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

To: Commissioner for Patents
Office of Initial Patent Examination
Customer Service Center
PO Box 1450
Alexandria, VA 22313-1450

Fr:

42716

CERTIFICATE OF FACSIMILE 37 CFR 1.8: I hereby certify that this paper is being transmitted by facsimile to the Commissioner for Patents and Trademarks to the attention of Office of Initial Patent Examination at facsimile # 703-746-9195 and telephone # 703-308-1202 on the date shown below.

Date: August 17, 2005[☒] Debra A. Stengel [☐] Scott J. Asmus, Reg. #42,269

Commissioner:

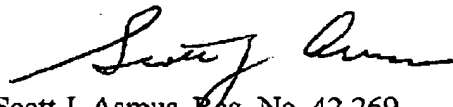
REQUEST FOR CORRECTIONS TO FILING RECEIPT

We are in receipt of a filing receipt, dated 08/05/2005, for the above referenced patent application. There are two errors in the spelling of the Assignee's name. The first word should be capitalized – BAE. The fifth word should be Electronic, not Eletronics. The spelling is correct on the Application Data Sheet, filed with the original application.

Applicant respectfully requests this correction be made and a correct filing receipt issued. A copy of the original filing receipt with the correction made is enclosed herewith.

All necessary fees relating to the attached submittal, if any, are intended to be included. However, the Office is hereby authorized to charge any deficiency or credit any overpayment in the fees to deposit account 500323.

Respectfully submitted,



Scott J. Asmus, Reg. No. 42,269
Andrew P. Cernota, Reg. No. 52,711
Attorneys/Agents for Applicant

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UNITED STATES PATENT AND TRADEMARK OFFICE

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APPL NO.	FILING OR 371 (c) DATE	ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	DRAWINGS	TOT CLMS	IND CLMS
10/531,772	04/19/2005	2157	1700	20030076-US	6	30	6

CONFIRMATION NO. 6021

42716
MAINE & ASMUS
P. O. BOX 3445
NASHUA, NH 03061

FILING RECEIPT



OC00000016685358

Date Mailed: 08/05/2005

Receipt is acknowledged of this regular Patent Application. It will be considered in its order and you will be notified as to the results of the examination. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please mail to the Commissioner for Patents P.O. Box 1450 Alexandria Va 22313-1450. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections (if appropriate).

Applicant(s)

Thomas P. McElwain, Merrimack, NH;

Assignment For Published Patent Application

~~BAE~~ Systems Information and ~~Electronic~~ Systems Integration Inc., Nashua, NH
BAE Electronic

Power of Attorney: The patent practitioners associated with Customer Number 42716.

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/US03/38190 11/25/2003
which claims benefit of 60/462,657 04/14/2003

Foreign Applications

Projected Publication Date: 11/10/2005

Non-Publication Request: No

Early Publication Request: No

Title

Joint symbol, amplitude, and rate estimator

BAE
20030076-US
CVD: 8/12/05
SPBY: _____
CVDDBY: _____
SUM: _____
AL: _____
EXT: _____
NOTICE: _____



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U.S. APPLICATION NUMBER NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
10/531,772	Thomas P. McElwain	20030076-US

INTERNATIONAL APPLICATION NO.
PCT/US03/38190

42716
 MAINE & ASMUS
 P. O. BOX 3445
 NASHUA, NH 03061

I.A. FILING DATE	PRIORITY DATE
11/25/2003	04/14/2003

CONFIRMATION NO. 6021
371 ACCEPTANCE LETTER



Date Mailed: 08/05/2005

NOTICE OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C 371 AND 37 CFR 1.495

The applicant is hereby advised that the United States Patent and Trademark Office in its capacity as a Designated / Elected Office (37 CFR 1.495), has determined that the above identified international application has met the requirements of 35 U.S.C. 371, and is **ACCEPTED** for national patentability examination in the United States Patent and Trademark Office.

The United States Application Number assigned to the application is shown above and the relevant dates are:

<u>04/19/2005</u>	<u>04/19/2005</u>
DATE OF RECEIPT OF 35 U.S.C. 371(c)(1), (c)(2) and (c)(4) REQUIREMENTS	DATE OF COMPLETION OF ALL 35 U.S.C. 371 REQUIREMENTS

A Filing Receipt (PTO-103X) will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE " FILING DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371 (c)(1), (c)(2) and (c)(4) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN ABOVE.** The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363). Once the Filing Receipt has been received, send all correspondence to the Group Art Unit designated thereon.

The following items have been received:

- Copy of the International Application filed on 04/19/2005
- Copy of the International Search Report filed on 04/19/2005
- Oath or Declaration filed on 04/19/2005
- Request for Immediate Examination filed on 04/19/2005
- U.S. Basic National Fees filed on 04/19/2005
- Priority Documents filed on 04/19/2005
- Power of Attorney filed on 04/19/2005
- Specification filed on 04/19/2005
- Claims filed on 04/19/2005
- Abstracts filed on 04/19/2005
- Drawings filed on 04/19/2005

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

LAMONT M HUNTER

Telephone: (703) 308-9140 EXT 201

PART 3 - OFFICE COPY

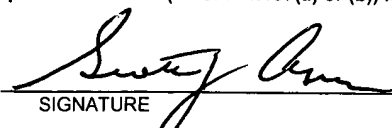
FORM PCT/DO/EO/903 (371 Acceptance Notice)

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TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371		ATTORNEY'S DOCKET NUMBER 20030076-US
INTERNATIONAL APPLICATION NO. PCT/US2003/038190		U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/531772
INTERNATIONAL FILING DATE 25.11.2003 (25 NOV 2003)		PRIORITY DATE CLAIMED 14.04.2003 (14 April 2003)
TITLE OF INVENTION JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR		
APPLICANT(S) FOR DO/EO/US MCELWAIN, Thomas P.		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
1. ☒ This is a FIRST submission of items concerning a submission under 35 U.S.C. 371. 2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a submission under 35 U.S.C. 371. 3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below. 4. ☒ The US has been elected (Article 31). 5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2)) a. ☒ is attached hereto (required only if not communicated by the International Bureau). b. ☒ has been communicated by the International Bureau. c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US). 6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)). a. ☐ is attached hereto. b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4). 7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) a. ☐ are attached hereto (required only if not communicated by the International Bureau). b. ☐ have been communicated by the International Bureau. c. ☐ have not been made; however, the time limit for making such amendments has NOT expired. d. ☒ have not been made and will not be made. 8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)). 9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). 10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).		
Items 11 to 20 below concern document(s) or information included:		
11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98. 12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. ☐ A preliminary amendment. 14. ☒ An Application Data Sheet under 37 CFR 1.76. 3 pages 15. ☐ A substitute specification. 16. ☐ A power of attorney and/or change of address letter. 17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 37 CFR 1.821- 1.825. 18. ☐ A second copy of the published International Application under 35 U.S.C. 154(d)(4). 19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4). 20. ☒ Other items or information: Copy of PCT application no. PCT/US2003/038190 as filed - 66 pages, Form PCT/IB/301 Notification of Receipt of Record Copy - 3 pages		

This collection of information is required by 37 CFR 1.414 and 1.491-1.492. The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 15 minutes to complete, including gathering information, preparing, and submitting the completed 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 PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 10/531772		INTERNATIONAL APPLICATION NO. PCT/US2003/038190		ATTORNEY'S DOCKET NUMBER 20030076-US		
The following fees have been submitted				CALCULATIONS PTO USE ONLY		
21. ☒ Basic national fee..... \$300				\$ 300		
22. ☒ Examination fee If International preliminary examination report prepared by USPTO and all claims satisfy provisions of PCT Article 33(1)-(4)..... \$100 All other situations..... \$200				\$ 200		
23. ☒ Search fee Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority..... \$100 International Search Report prepared and provided to the Office..... \$400 All other situations..... \$500				\$ 100		
TOTAL OF 21, 22 and 23 =				\$ 600		
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing or computer program listing filed in an electronic medium). The fee is \$250 for each additional 50 sheets of paper or fraction thereof.						
Total Sheets	Extra Sheets	Number of each additional 50 or fraction thereof (round up to a whole number)	RATE			
- 100 =	/50 =		x \$250	\$ 0		
Surcharge of \$130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(h)).				\$ 0		
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE			
Total claims	30 - 20 =	10	x \$ 50	\$ 500		
Independent claims	6 - 3 =	3	x \$200	\$ 600		
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$360	\$ 0		
TOTAL OF ABOVE CALCULATIONS =				\$ 1700		
☐ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by 1/2.				0		
SUBTOTAL =				\$ 1700		
Processing fee of \$130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)).				\$ 0		
TOTAL NATIONAL FEE =				\$ 1700		
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				\$ 0		
TOTAL FEES ENCLOSED =				\$ 1700		
				Amount to be refunded:	\$	
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NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status. SEND ALL CORRESPONDENCE TO: Customer No. 42716 Maine & Asmus PO Box 3445 Nashua, NH 03061-3445 United States of America						
				 SIGNATURE Scott J. Asmus NAME 42,269 REGISTRATION NUMBER		

PCT INTERNATIONAL APPLICATION TRANSMITTAL LETTER

TRANSMITTAL DATE: 25 NOVEMBER 2003

REGARDING THE APPLICATION OF: BAE SYSTEMS INFORMATION &
ELECTRONIC SYSTEMS
INTEGRATION INC

INTERNATIONAL APPLICATION NO.

INTERNATIONAL FILING DATE: HEREIN

ATTORNEY DOCKET NO: 20030076-PCT

ENTITLED: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

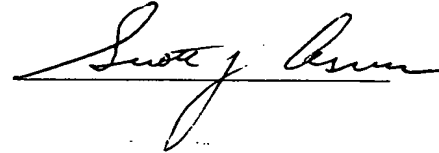
EXPRESS MAIL CERT: EL 962 755 142 US DATE: 25 November 2003

JCB# BAE
90030076-P
 RCVD: 11/25/03
 RSPBY:
 RCVDBY: DAS
 FSUM: ✓
 CAL: ✓
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I certify that this application is being deposited with the U.S. Postal Service EXPRESS MAIL POST OFFICE TO ADDRESSEE under 37 CFR 1.10 on the date indicated above and is addressed to Mail Stop PCT, Commissioner for Patents, PO Box 1450, Alexandria, VA 22313-1450.

☒ Scott J. Asmus, Reg. No. 42,269
☐ Neil F. Maloney, Reg. No. 42,833
☒ Debra A. Stengel

Signed



To the United States Receiving Office (RO/US):

Accompanying this transmittal letter is the above-identified application comprising 6 page PCT Easy Request, 2 page PCT Easy Fee Calc Sheet, 1 floppy disk of PCT Easy application forms, 1 page executed Power of Attorney-Applicant, 1 page executed General Power of Attorney-Applicant/Inventor, 48 pages of Specification and Claims, 6 sheets of Drawings. The following requests are made of the RO/US:

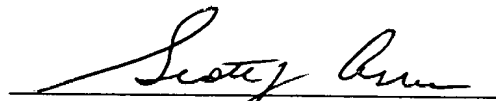
1. ☒ PREPARATION AND TRANSMITTAL OF CERTIFIED COPY OF PRIORITY DOCUMENTS- Please prepare and transmit to the International Bureau a certified copy of the United States origin priority documents identified in Box VI of the Request form (37 CFR 1.451).
2. ☒ DISCLOSURE INFORMATION-- In order to assist in screening the accompanying International application for purposes of determining whether a license for foreign transmittal should and could be granted, the following information is supplied:
 - A. ☐ There is no prior filed application relating to this invention.
 - B. ☒ There is one prior application, US 60/462,657, filed 14 April 2003 which contains subject matter that is
 1. ☐ substantially identical to that of the accompanying International application.
 2. ☐ less than that of the accompanying International application. The additional subject matter of the International application appears on page(s) and line(s) _____
 3. more than that of the accompanying International application.
 - C. ☐ Disclosure information cannot be covered by the language of Points 2A or 2B above due to the involvement of several prior applications or for other reasons. A separate sheet on which the disclosure information is explained is attached to this transmittal letter.

3. [X] REQUEST FOR FOREIGN TRANSMITTAL LICENSE-- According to the provisions of 35 USC 184 and 37 CFR 5.11, a license to transmit the accompanying International application to foreign agencies or international authorities is hereby requested.

4. [X] The Office is hereby authorized to charge deposit account 190130, the amount of \$2,168.00 to cover above filing fees, and any deficiency or credit any overpayment in the fees to the above deposit account, owned by BAE SYSTEMS Information and Electronic Systems Integration Inc. an authorized signator for which is Kevin M. Perkins, V.P. & Company Counsel, and for whom the undersigned are authorized agents.

Date: 25 Nov 2003

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JC13 R PCT/PTO 19 APR 2005

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: MCELWAIN, Thomas P. Group Art Unit:

Serial No.

Examiner:

Filed: Herein

Atty. Dkt. No: 200300076-US

FOR: JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

To: Mail Stop PCT
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Date: April 19, 2005

Debra A. Stengel
☒ Debra A. Stengel or ☐ Andrew P. Cernota, Reg. No. 52,711

Dear Honorable Commissioner:

TRANSMITTAL COVER SHEET

Submitted herewith, pursuant to 35 U.S.C. 371, is a US National Stage Patent
Application of International Application No. PCT/US2003/038190 consisting of:

2 pages Transmittal Letter To The United States Designated/Elected Office Concerning a Filing
Under 35 U.S.C. 371,
3 pages Application Data Sheet,
66 pages copy of PCT application as filed,
3 pages Form PCT/IB/301 Notification of Receipt of Record Copy.

DEPOSIT ACCOUNT **190130** AUTHORIZATION – The Office is hereby authorized to charge the required fee, and any deficiency or credit any overpayment in the fees to the above deposit account, owned by BAE SYSTEMS Information and Electronic Systems Integration Inc. an authorized signator for which is Kevin M. Perkins, V.P. & Company Counsel, and for whom the undersigned are authorized agents.

Respectfully submitted,



Scott J. Asmus, Reg. No. 42,269
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JC13 Rec'd PCT/PTO 19 APR 2005

JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

Inventor:
Thomas P. McElwain

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Applications No. 60/462657, filed April 14, 2003. This application is also related to U.S. Patent application Serial No. 10/105,918, filed March 25, 2002 entitled "System for Decreasing Processing Time in an Iterative Multi-User Detector System" (D4608); U.S. Patent Application Serial No. 10/414,738 filed April 16, 2003 entitled "System and Method for Increasing Throughput in a Multiuser Detection Based Multiple Access Communications System" (D4615); and U.S. Patent Application Serial No. 10/208409 entitled "Power and Confidence Ordered Low Complexity Soft TurboMUD with Voting System" (D-4627US). Each of these applications is herein incorporated in their entirety by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to communications and more particularly to co-channel communications, and more particularly to increasing capacity by allowing interfering channels.

BACKGROUND OF THE INVENTION

[0003] The telecommunications industry has been expanding at an unprecedented growth rate throughout the World. In particular, the wireless sector, including cell phones, PCS, wireless local area networks and Bluetooth such as IS95, GSM, 3G, IEEE 802.11a/b/g, and 802.16 has grown far beyond expectations and at a much higher rate than the fixed telecommunications (wired) counterpart. The ability to access data and communicate anywhere at anytime has enormous potential and commercial value.

[0004] The content of the wireless sector is also changing, with more and more data being transmitted, including Internet connectivity and live feeds. The usage involving personal digital assistants (PDA's) and even smart appliances have created new markets utilizing

wireless data communications. Despite advancements in wireless transmission and reception, there is a growing problem of extracting more information signals within a limited bandwidth.

[0005] Emerging multiple-access receiver processing procedures allow for multiple users to access the same communications medium to transmit or receive information. Multiple access communication systems allow the transmission of multiple digital data streams between multiple transmitting and receiving devices. However, since many users transmit energy on the same communications channel, a number of inherent difficulties arise, particularly when receivers attempt to detect the information associated with a particular user when there is heavy signal interference created by other users of the system at the same time. Typically the signal of interest cannot be received or the quality of reception is significantly degraded.

[0006] For example, a base station that processes a number of cellular devices has to receive and transmit data within a certain frequency range. The ability to extract the correct data from a given user is a difficult task when the effects of interference and multipaths are considered. The problem is further complicated when the number of users exceeds the number of dimensions (e.g. time slots, frequency slots, polarizations, etc), resulting in an overloaded condition.

[0007] In addition to the problems associated with multiple users in a given bandwidth, an additional problem is the inability to process the data in the receivers in real time. Advanced receiver techniques cover several areas, namely interference suppression (also called Multi-User Detection or MUD), multipath combining and space-time processing, equalization, and channel estimation. These various techniques can be mixed and matched depending upon the circumstances.

[0008] One way of alleviating some of the multiple access problems is to separate the interfering transmissions at the receiver using signal processing techniques. However, state of the art receivers are not capable of detecting and decoding the information associated with each user under conditions of heavy interference. Another solution to the co-channel interference problem is to decrease the number of users per channel. This, of course, is not an attractive option for telecommunication companies, since obtaining the

maximum number of users or managing peak volume transmission periods are important business objectives.

[0009] It should be understood that the discussion herein illustrates wireless cellular communications the multiple access topologies are equally applicable to wired cable systems and local area networks, read/write operations of a disc drive, satellite communications and any application that benefits from extracting digital information from among many multiple interfering signals.

[0010] Several techniques are used to improve results in co-channel multiple access communications systems. Frequency-Division Multiple Access (FDMA) assigns a different frequency to each user and parses an allocated band for a communication system wherein a single user's signal transmission power is concentrated into a single narrower radio frequency band. Interference from adjacent channels is limited by the use of band pass filters, however for each channel being assigned a different frequency system the total capacity is limited by the available frequency slots and by physical limitations imposed by frequency reuse. In a cellular telephone configuration this poses problems because all proximate cells must operate on different frequencies. However, frequency bands may be re-used, provided that the same frequency cells are positioned at a certain distance apart. A further drawback with FDMA schemes is that users will pay full-time for their assigned frequency regardless of their actual use of the system.

[0011] Code Division Multiple Access (CDMA) is another multiplexing technique wherein for each communication channel the signals are encoded using a sequence known to the transmitter and the receiver for that specific channel. In CDMA, all users use the same frequency at the same time. However, before transmission, the signal from each user is multiplied by a distinct signature waveform. The signature waveform is a signal that has a larger bandwidth than the information-bearing signal from the user. However, in a CDMA system, the total level of co-channel interference limits the number of active users at any instant of time.

[0012] In Time Division Multiple Access (TDMA) technology, multiple channels of data are temporally interleaved, i.e. each signal is assigned to a different time interval and the signals are transmitted individually, according to their assigned time slot. The TDMA

channel consists of a time slot or frame in a periodic train of time intervals over the same frequency, with a given signal's energy confined to one of these time slots. However, in a TDMA system, all transmitters and receivers must have access to a common clock, as time-synchronization among the users is required. Adjacent channel interference is limited by the use of a time gate or other synchronization element that only passes signal energy received at the proper time. The system capacity is limited by the available time slots (within a given frequency band) as well as by physical limitations imposed by frequency reuse, as each channel is assigned a different time slot within a particular frequency band.

[0013] One of the goals of FDMA and TDMA systems is to try and prevent two potentially interfering signals from occupying the same frequency at the same time. In contrast, Code Division Multiple Access (CDMA) techniques allow signals to overlap in both time and frequency. CDMA signals share the same frequency spectrum at the same time, hence, the CDMA signals appear to overlap one another. The scrambled signal format of CDMA virtually eliminates cross talk between interfering transmitters.

[0014] In a CDMA system, each signal is transmitted using spread spectrum techniques. The transmitted informational data stream is impressed upon a much higher rate data stream termed a signature sequence. The bit stream of the signature sequence data is typically binary, and can be generated using a pseudo-noise (PN) process that appears random, but can be replicated by an authorized receiver. The informational data stream and the high bit rate signature sequence stream are combined by multiplying the two bit streams together, assuming the binary values of the two bit streams are represented by +1 or -1. This combination of the higher bit rate signal with the lower bit rate data stream is called spreading the informational data stream signal. Each informational data stream or channel is allocated a unique signature sequence.

[0015] In operation, a stream of spread information signature signals are modulated by weights corresponding to the information that is to be transmitted. Some modulation examples include binary phase shift keying (BPSK) and quadrature phase shift keying (QPSK). If several transmitters modulate their data onto the signature waveform and modulate again with the carrier tone, a radio frequency (RF) signal comprised of a continuous stream of information modulated signature pulses will be present at the receiver, one corresponding to each transmitter. The plurality of transmitted signals and are

jointly received as a composite signal at the receiver. Each of the spread signals overlaps all of the other spread signals in time and frequency. Moreover, environmental noise as well as receiver electronic noise is also present in the measured received signal. The state of the art receiver correlates the composite noisy signal with one of the unique signature sequences, and the corresponding information signal is isolated and despread while the other signals appear as only small additions to the noise floor.

[0016] A signature sequence is often used to represent one bit of information. Receiving the transmitted sequence or its complement indicates whether the information bit is a +1 or -1, sometimes denoted "0" or "1". The signature sequence usually comprises N pulses, and each pulse is called a "chip". The entire N-chip sequence, or its complement, depending on the information bit to be conveyed, is referred to as a transmitted symbol.

[0017] The receiver correlates the received signal with the complex conjugate of the known signature sequence to produce a correlation value. When a 'large' positive correlation results, a "0" is detected, and when a 'large' negative correlation results, a "1" is detected.

[0018] It should be understood that the information bits could also be coded bits, where the code is a block or convolutional code. Also, the signature sequence can be much longer than a single transmitted symbol, in which case a subsequence of the signature sequence is used to spread the information bit.

[0019] The prior systems do not properly account for the real world mobile communication signals that suffer from signal degradation such as interference and multipath problems. The systems of the state of the art generally tended to make assumptions that all other interferers and multipaths were additive white Gaussian noise. However, this assumption is not accurate for co-channel interference and multipaths.

[0020] Multipath dispersion occurs when a signal proceeds to the receiver along not one but many paths so that the receiver encounters echoes having different and randomly varying delays and amplitudes. The receiver receives a composite signal of multiple versions of the transmitted symbol that have propagated along different paths, called rays, having different relative time. Each distinguishable ray has a certain relative time of arrival, a certain amplitude and phase, and as a result, the correlator outputs several smaller

spikes. RAKE receivers are well known and attempt to 'rake' together all the contributions to detect the transmitted symbol and recover the information bit.

[0021] Conventional RAKE receivers provide satisfactory performance for operation in the presence of multipath under ideal conditions however the signature sequence must be uncorrelated with time shifted versions of itself as well as various shifted versions of the signature sequences of the other CDMA signals. Co-channel interference refers to signals received from other users either directly or reflected. If one received signal corresponding to the signature sequence of interest has a non-negligible cross correlation with the received signal originating from another transmitter (a co-channel interferer), then the value measured at the receiver, e.g. the correlation value for the signal of interest, is corrupted. In other words, the correlation computed at the receiver that would be used to decode a particular signal of interest is overwhelmed by an interfering signal; this is referred to as the near-far problem. The interference caused by an echo of one transmitted symbol overlapping with the next transmitted symbol might also be non-negligible. If this is the case, the transmitted symbols interfere with past and future transmitted symbols. This is commonly referred to as intersymbol interference (ISI). In actuality, performance is degraded both by co-channel interference and ISI.

[0022] There has been much research to address signal interference with known multipath time dispersion. This is termed joint demodulation with no multipath and is further described in S. Verdu, "Minimum Probability of Error For Asynchronous Gaussian Multiple-Access Channels," IEEE Trans. Info. Theory, Vol. IT-32, pp. 85-96, R. Lupas and S. Verdu, "Linear multiuser detectors for synchronous code-division multiple-access channels," IEEE Trans. Inform. Theory, Vol. 35, pp. 123-136, Jan. 1989; and R. Lupas and S. Verdu, "Near-far resistance of multiuser detectors in asynchronous channels," IEEE Trans. Commun., Vol. 38, pp. 496-508, Apr. 1990.

[0023] There are a host of approaches for jointly demodulating any set of interfering digitally modulated signals, including multiple digitally modulated signals. Maximum Likelihood Sequence Estimation determines the most likely set of transmitted information bits for a plurality of digital signals without multipath time dispersion. The maximum likelihood joint demodulator is capable, in theory, of accommodating the largest number of interfering signals, but has a prohibitive computational complexity that makes it

unrealizable in practice. The decorrelation receiver is another, less computationally complex receiver processing approach that zeroes out or decorrelates the different signals so that they no longer interfere with one another. The decorrelator as well as virtually every other lower complexity joint demodulator, is not capable of operation when the number of signals is over a set threshold which falls significantly short of the theoretical maximum.

[0024] In a real world multi-user system, there are a number of independent users simultaneously transmitting signals. These transmissions have the real-time problems of multi-path and co-channel interference, fading, and dispersion that affect the received signals. As described in the prior art, multiple user systems communicate on the same frequency and at the same time by utilizing parameter and channel estimates that are processed by a multi-user detector. The output of the optimal multi-user detector operating within the multiuser capacity limits of the channel is an accurate estimation as to the individual bits for an individual user.

[0025] Moreover, in an article by Paul D. Alexander, Mark C. Reed, John A. Asenstorfer and Christian B. Schlager in IEEE Transactions on Communications, vol. 47, number 7, July 1999, entitled "Iterative Multi-User Interference Reduction: Turbo CDMA," a system is described in which multiple users can transmit coded information on the same frequency at the same time, with the multi-user detection system separating the scrambled result into interference-free voice or data streams.

[0026] Low complexity multiuser detector have been contemplated that use linear multiuser detectors to achieve optimal near-far resistance. (Near-Far Resistance of Multiuser Detectors for Coherent Multiuser Communications, R. Lupas, S. Verdu, IEEE Trans. Commun. Vol. 38, no. 4, pp 495-508, April 1990). While providing certain advantages, the performance has not been demonstrably improved. Varanasi and Aazhang proposed a multistage technique as described in the article Near-Optimum Detection in Synchronous Code-Division Multiple Access Systems, IEEE Trans. Commun., Vol. 39, No. 5, May 1991.

[0027] Decorrelating decision feedback detectors (DDFD) have been described by A. Duel-Hallen in Decorrelating Decision-Feedback Multiuser Detector for Synchronous Code-division Multiple Access Channel, IEEE Trans. Commun., Vol. 41, pp 285-290, Feb.

1993. Wei and Schlegel proposed soft-decision feedback to suppress error propagation of the DDFD in Synchronous DS-SSMA with Improved Decorrelating Decision-Feedback Multiuser Detection, IEEE Trans. Veh. Technol., Vol. 43, pp 767-772, Aug. 1994. Tree-type maximum-likelihood sequence detectors were also proposed for multiuser systems as were breadth-first algorithms and sequential detection including using the M-algorithm tree-search scheme with a matched filter (MF). The prior references also reveal schemes that include some form of decorrelating noise whitening filter (WF).

[0028] However, one of the primary disadvantages of the prior references implementations is the inability to accommodate overloaded conditions. Decision feedback techniques are limited in that they are incapable of working in supersaturated environments. Although the MMSE-based decision feedback detector can work in a supersaturated environment, it has been demonstrated to be too aggressive with hypothesis testing to produce accurate results.

[0029] Multi-user detection (MUD) refers to the detection of data in non-orthogonal multiplexes. MUD processing increases the number of bits available per chip or signaling dimension for systems having interference limited systems. A MUD receiver jointly demodulates co-channel interfering digital signals. Multiuser detection systems take full advantage of all information available at the receiver, by making use of any "knowledge" that the receiver has about the interfering signals. Because the number of users that can be packed into a MUD-based multiple access (MA) system is a function of the number of independent dimensions over which the set of signals is spread (the dimension of the span of the set of signals), the total number of users in the system can be increased if more dimensions are used for transmitting the signals and the same dimensions are accessible at the receiver.

[0030] In addition to expanding the number of dimensions, favorably "spreading" the received signals out over those dimensions can also allow for increases in the number of users a MUD-based system can accommodate. For example, typical signaling sets for multiuser communications do not include as a free parameter the reference amplitude of each user. In the IS95 code division protocol, amplitude is controlled completely for purposes of power control to meet a signal-to-noise specification (all users ideally being received with the same signal-to-noise ratio (SNR)). Therefore the advantages offered to

the MUD are not exploited and the aggregate throughput of a multiple access system is limited if amplitude is not exploited.

[0031] There are various multiuser detectors in the art, including optimal or maximum likelihood MUD, maximum likelihood sequence estimator for multiple interfering users, successive interference cancellation, TurboMUD or iterative MUD, and various linear algebra based multi-user detectors such as all of those detailed in the well-known text "Multiuser Detection" by Sergio Verdu. In the state of the art, algebraic means are used to compute linear operators for the entire set of users (communications channels) simultaneously. This is done by utilizing prior information, or knowledge of the likely value of each user's bit of information, each at a particular instant in time. This multiuser detection processing is described in the text S. Verdu, Multiuser Detection, Cambridge Press, 1998. However, this suffers from a significant disadvantage in that it requires knowledge of all parameters to perform the processing.

[0032] Optimal MUD based on the maximum likelihood sequence estimator operates by comparing the received signal with the entire number of possibilities that could have resulted, one for each bit or symbol epoch. The number of possible measured levels for the received signal is exponentially related to the number of users and the duration of the ISI. Hence, the optimal processing is a computationally complex and it is not possible to accomplish in a real-time environment. Thus for those multi-user detectors that examine the entire space, real-time operation is often elusive.

[0033] In general, optimal MUD units function by examining a number of possibilities for each bit. However, for multi-user detectors that examine a larger capacity of signal, the computations are complex and time-consuming, thus making real-time operation impossible. Numerous attempts at reliable pruning of the optimal MUD decision process or the use of linear approximation to replace the optimal MUD have still not produced a workable solution for the real world environment.

[0034] There are several suboptimal multiuser detectors that are less computationally complex and known in the art. One example of suboptimal detectors, called linear detectors, includes decorrelators, minimum mean square error or MMSE detectors, and zero-forcing block linear equalizers. The conventional Minimum Mean Squared Error (MMSE) Multiuser detector utilizing prior information is described by Wang and Poor in

“Iterative (Turbo) Soft Interference Cancellation and Decoding for Coded CDMA”, in the Transactions on Communications, July 1999. See also Alexander, Reed, Asenstorfer, and Schlegel, “Iterative Multiuser Interference Reduction: Turbo CDMA,” IEEE Trans on Comm, July 1999; and Poor, “Turbo Multiuser Detection: An Overview” ISSSTA 2000. But, linear algebra based MUD (non-iterative) and successive interference cancellation fails for cases of overloaded multiple access systems.

[0035] One example of overloading is where the number of simultaneous users is doubled or tripled relative to existing state of the art. Even for underloaded multiple access systems, the performance of non-iterative MUD and successive interference cancellation degrades significantly as the number of users increases, while the computation complexity of the optimal MUD increases significantly as the number of users increases. The computing problems are so extreme that even the most expensive hardware unbound by size and weight can often to keep up with this overwhelming complex processing requirement of optimal MUD. Moreover, an unreasonable delay would be required to decode each bit or symbol rendering such a system useless in practice.

[0036] Reduced complexity approaches based on tree-pruning help to some extent to eliminate the improper bit combination from consideration where, ideally, such a procedure should prune out many ‘bad’ paths in the decision tree but maintain the proper path. Thus, the entire tree does not need to be traversed to make the final decision.

[0037] The M-algorithm is a pruning process that limits the number of hypotheses extended to each stage to a fixed tree width and prunes based on ranking metrics for all hypotheses and retaining only the M most likely hypotheses. The T-algorithm prunes hypotheses by comparing the metrics representing all active hypotheses to a threshold based on the metric corresponding to the most-likely candidate. Performance of M-algorithm based MUD degrades as the parameter M is decreased, but M governs the number of computations required. Similar effects are seen for other tree-pruning based MUD (T- algorithm, etc). To combat improper pruning, basic tree-pruning must ensure that M is “large enough”, and therefore still encounters increased complexity for acceptable performance levels when the number of interfering signals and/or ISI lengths are moderate to large.

[0038] As an illustration of the M-algorithm as a tree-pruning algorithm, consider a tree made up of nodes and branches. Each branch has a weight or metric, and a complete path is sequences of nodes connected by branches between the root of the tree and its branches. When applied as a short cut to the optimal MUD, each branch weight is a function of the signature signal of a certain transmitter, the possible bit or symbol value associated with that transmitter at that point in time, and the actual received signal which includes all the signals from all the interfering transmissions. The weight of each path is the sum of the branch metrics in a complete path. The goal of a tree searching algorithm is to try to find the complete path through a tree with the lowest metric. With the present invention the metrics of multiple complete paths are not calculated. Rather, the metrics of individual branches in a tree are calculated in the process of locating one complete path through the tree and thereby defines one unknown characteristic of each of the co-channel, interfering signals needed to decode the signals.

[0039] A MUD algorithm within the TurboMUD system determines discrete estimates of the transmitted channel symbols, with the estimates then provided to a bank of single-user decoders (one decoder for each user) to recover the input bit streams of all transmitted signals. Two general types of multi-user detectors within the TurboMUD system are possible, namely those that provide hard outputs, which are discrete values, and those that provide soft outputs, which indicate both the discrete estimate and the probability that the estimate is correct. In basic terms, turbodecoding refers to breaking a large processing process into smaller pieces and performing iterative processing on the smaller pieces until the larger processing is completed, and this basic principle was applied to the MUD.

[0040] However, single-user decoders operating on hard values, or discrete integers, have unacceptable error rates when there is a large amount of interference or noise in the received signal. The reason is that discrete integers do not provide adequate confidence values on which the single-user decoder can operate. These decoders operate better on so-called soft inputs in which confidence values can range from -1 to 1, such as for instance 0.75 as opposed to being either -1 or +1. To provide soft values that can then be utilized by a single-user decoder, the multi-user detector chosen for the TurboMUD can generate these soft values. The invention described below will work with soft output or a hard output MUDs, or a combination of the two.

[0041] In general, soft or hard output versions of the optimum maximum likelihood multi-user detector (Verdu, Multiuser Detection, Cambridge University Press, 1998) or an M algorithm (as described, for instance, in Schlegel, Trellis Coding, IEEE Press, 1997) with a moderate to high value of M causes the Turbo MUD to require too many computations to keep up with real time transmissions. Using a fast, but inferior, multiuser detection scheme such as a linear-based detector or those detailed in the text "Multiuser Detection" by Sergio Verdu causes poor quality output when there are many interferers or users.

[0042] Moreover, when dealing with hand-held communications units such as wireless handsets, the amount of processing within the device is limited, directly limiting the amount of computational complexity that is allowed. In order to provide real-time performance both at a cell site and the handset, it therefore becomes important to be able to reduce the amount of computational complexity and processing time so as to achieve real-time performance.

[0043] A great number of communications and data transfer systems operate at or near a full capacity. Conventional receiver performance is unsatisfactory in the presence of co-channel interference. Furthermore, many receivers require prior knowledge of signal parameters such as phase and amplitude of the channel to perform processing functions without co-channel interference. What is needed is a means to increase the number of available channels, by reassigning channels to be perhaps slightly interfering, thereby increasing the overall throughput without increasing bandwidth. Such a system should provide an efficient means of jointly estimating symbols, channel amplitude, and data rate transmitted in a super-saturated communications channel. And, any such invention should have the ability to estimate the symbols and data rate, blindly without prior knowledge of channel amplitudes and phase.

BRIEF SUMMARY OF THE INVENTION

[0044] While adaptable in many forms, one embodiment of the invention is an apparatus for processing a digital data stream from multiple users, comprising an initial amplitude estimation unit processing the data stream and producing initial amplitude estimates on a first iteration. There is a joint amplitude estimator coupled to the data stream and the initial amplitude estimator, wherein the joint amplitude estimator produces updated

amplitude estimates. A symbol estimator is coupled to the data stream, the initial amplitude estimator, and the joint amplitude estimator, wherein the symbol estimator produces a plurality of symbols estimates for each user. There is a bank of decoders coupled to the symbol estimator, producing a plurality of symbol likelihood estimates for each user, wherein the symbol likelihood estimates are iteratively fed back to the symbol estimator and the joint amplitude estimator until a final condition is obtained.

[0045] Further variations of the invention include wherein the final condition is selected from at least one of the group consisting of: bit error rate metric level and fixed number of iterations.

[0046] The symbol hypothesis testing module can generally be any module that is a member selected from at least one of the group consisting Minimum Mean Squared Error (MMSE), maximum likelihood, M-algorithm, T-algorithm, and Q-algorithm, decorrelating decision-feedback detector (DDFD), improved decorrelating decision-feedback detector (IDDFD), successive interference cancellation (SIC), parallel interference cancellation (PIC) and multi-stage detector; block-iterative interference cancellation; and a deferred decorrelating decision-feedback detector.

[0047] The apparatus can further comprise an energy detector coupled to the joint amplitude estimator which can determine activity on a channel, such as code, time slot or frequency channel.

[0048] The bank of decoders can be selected from at least one decoder of the group consisting of: Soft-output Viterbi , Maximum A Posteriori , and BCJR.

[0049] Another embodiment includes a method for providing initial amplitude estimation for a plurality of user channels, comprising separating the user channels into active channels and inactive channels. Processing the inactive channels is according to the sub-steps comprising applying a bank of filters to the inactive channels for each inactive user, squaring an output from the filters, summing an output from the squaring operation, and calculating an average bias estimate from an output of the summing. Processing the active channels is according to the sub-steps comprising applying a bank of filters to the user data of the active channels, squaring an output from the bank of filters, summing an output from the squaring, and removing the average bias estimate from an output from the summing.

[0050] The method can include processing the inactive channels by dividing the inactive channels into groups and calculating at least one group average bias estimate. It can also include processing the active channels by dividing the active channels into groups and respectively removing the at least one group average bias estimate.

[0051] A further variation includes scaling by the summers and may include an energy detector for separating the active channel from the inactive channels.

[0052] Another embodiment of the invention is an apparatus for processing initial amplitude estimates from a data stream of multiple users, comprising an energy detector measuring an energy level of the data stream, wherein the energy detector separates a plurality of active channels from a plurality of inactive channels. There is a bank of filters coupled to the inactive channels, a bank of squaring operators coupled to the bank of filters, a bank of inactive summers coupled to the squaring operators, and an average bias estimator coupled to the inactive summers calculating an average bias estimate. There is also a bank of filters coupled to the active channels, a bank of squaring operators coupled to the bank of filters, a bank of active summers coupled to the squaring operators, and a bias removal section coupled to the active summers and the average bias estimator.

[0053] Another embodiment includes a joint amplitude estimator for a data stream from multiple users, comprising a data stream from the multiple users divided into a plurality of observation intervals. There are a plurality of processing modules coupled to the observation intervals, wherein the processing modules calculates interference cancellation values for each of the users and computes a filter for each of the observation intervals. The filter being applied to the data within the observation interval is used to compute individual amplitude estimates. There is an amplitude estimation unit that processes the individual amplitude estimates and calculates new amplitude estimates, wherein the new amplitude estimates are iteratively passed back to the processing modules until a final condition is obtained.

[0054] One aspect includes where the amplitude estimation unit sums and weighs the individual estimates such that the new amplitude estimate is a weighted average of individual amplitude estimates.

[0055] It should be understood that the observation intervals may be based on distinguishing attributes selected from at least one of the group consisting of: time, code, and frequency.

[0056] The filter may be calculated for an arbitrary observation interval m by the equation:

$$G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}.$$

[0057] Yet a further embodiment includes a method for processing amplitude estimates for a multiuser data stream divided into a plurality of observation intervals, comprising computing a filter for each observation interval of the data stream, applying interference cancellation to the data stream for each observation interval, applying the filter to the data stream for each observation interval from the interference cancellation to produce individual amplitude estimates for each observation interval, computing new amplitude estimates using the individual amplitude estimates; and passing the new amplitude estimates back to the filter for iterative processing until a final condition is obtained.

[0058] One embodiment is a turbo-decoding system for joint signal demodulation, comprising a data stream from a plurality of users divided into a plurality of observation intervals. There is a plurality of symbol processing nodes processing the observation intervals to compute symbol estimates for the data stream within the observation interval. A plurality of decoder nodes is present for processing the symbol estimates and producing a plurality of symbol likelihoods. There is a plurality of amplitude update nodes processing the symbol likelihoods and calculating a plurality of amplitude update vectors. And, there is an amplitude estimator node processing the amplitude update vectors and producing an amplitude estimate update, wherein the amplitude estimate update is passed back to the processing nodes for iterative processing between the symbol processing nodes, the decoder nodes, the amplitude update nodes, and the amplitude estimator node until a final condition is obtained.

[0059] The turbo-decoding system can encompass a plurality of memory units, wherein at least one memory unit is coupled to each of the processing nodes and to each of the amplitude estimation nodes. There can also be a first system area network (SAN) coupling

the processing nodes and the decoder nodes, a second system area network (SAN) coupling the decoder nodes and the amplitude estimation nodes, a third system area network coupling the amplitude estimation nodes and the amplitude estimator, and a fourth system area network coupling the amplitude estimator and the processing nodes. The processing nodes, the decoder nodes and the amplitude estimation nodes can even be one set of nodes. A set of nodes can also be comprised of at least one processor.

[0060] A further embodiment of the system includes wherein the likelihood symbols from the decoders are accessible at any time for post-processing. The processing nodes can further comprise a thresholder to convert the symbol estimates to symbol bits. And, the bank of decoder can also perform de-interleaving, rate identification, de-puncturing and de-scrambling.

[0061] The features and advantages described herein are not all-inclusive and, in particular, many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims. Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes, and not to limit the scope of the inventive subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0062] **Figure 1** illustrates a basic diagrammatic processing perspective for the prior art transmitter end and receiver end with iterative multiuser detection processing;

[0063] **Figure 2** is a block diagram perspective showing joint symbol amplitude and data rate estimator for one embodiment of the invention;

[0064] **Figure 3** is a schematic block diagram showing initial amplitude estimation;

[0065] **Figure 4** is a schematic block diagram showing joint amplitude estimator;

[0066] **Figure 5** is a schematic block diagram showing parallelization of joint symbol amplitude and data rate estimator; and

[0067] **Figure 6** is a schematic block diagram showing hardware conceptualization according to one embodiment of the present invention with nodes used to depict the processing.

DETAILED DESCRIPTION OF THE INVENTION

[0068] The methods and embodiments of the joint symbol, amplitude and rate estimator disclosed herein enable implementations of advanced receiver processing providing high quality real-time processing for multiple access systems, including overloaded situations. One embodiment illustrates the signal processing technique applicable to many variations that are all within the scope of the invention. It should be understood that the reference to a data stream of multiple users is understood to represent digital data from a number of references and not necessarily multiple users in communications.

[0069] In order to fully appreciate the processing of the present invention, it is useful to consider a description of the processing known in the art. Referring to **Figure 1**, prior art transmitter section **5** and receiver section **10** is depicted with MUD processing. There are K users with data $d_1 - d_k$ as the input to the channel encoders **20** where the data is convolutionally encoded at a code rate R_k . The interleaver **25** performs the interleaving of the data, which is then symbol mapped by the symbol mapper **30**, such as BPSK symbol mapped with data symbols having a duration T . Each data symbol is then modulated by a spreading waveform from the spreader **35**, and the signal data $s_k(t)$ is output from the transmitter end with a number of data symbols per user per frame. In the typical wireless communication application presented herein, a number of users $(1-K)$ generate signals that are transmitted by antennas **40** into free space. The transmission on hard-wire or fixed wire systems is also known in the art, however the present example is directed towards the wireless communications systems. Noise $n(t)$, such as white Gaussian noise, is an inherent component of most transmission signals and some random noise components are generally present in transmitted data signals $r(t)$.

[0070] On the receiving end **10**, antenna(s) **42** receive the transmitted signals $r(t)$ as well as the various interfering signals, such as $n(t)$. There is normally a noise component $n(t)$ that is introduced from the environment of a random nature in the received signal. While any noise that has a repeatable or non-random nature can be eliminated through processing, random noise elements are reduced in other manners such as filtering but are inherent conditions. The various signals are received at antennas **42** wherein there is typically one

signal for each polarization feed. The received signals represent directly received signals, as well as multi-path signals from the same user, and interfering signals from other users.

[0071] The input signals of raw non-manipulated data at the receiver **10** is comprised of the aggregate of many signals from many different transmitters/users, where each signal is generally assigned a channel (frequency, timeslot, and/or spreading code) from a finite set of channels. The interference from these various users generally requires complex processing and associated processing time. The input data represents a vector of data, transferred at some rate (e.g., the symbol rate), and this data is typically transmitted to a matched filter (not shown).

[0072] The plurality of signals from each antenna **42** is processed in a RF front end unit **44**. The front end unit **44** generally downconverts the higher frequency signals into baseband signals and provide processing and filtering as is known in the art. The baseband signals are also digitized by analog to digital converters (ADC). The front end **44** cooperates with the parameter estimation unit **46** to retrieve needed information for the signals such as relative received timing offsets, carrier phase, frequency offsets, received amplitudes, and multipath structure for each of the interfering signals present in the received signal.

[0073] A parameter estimation unit **46** is coupled to the front end **44** and processes the various parameters for the received vector data. A parameter estimator **46**, as known in the art, is a broad description for a unit that provides information to the MUD **50** such as convolutional code, signatures, and multiplexing format. While the term parameter estimator is used herein, the term is intended to be interpreted in the broader sense as known in the joint demodulation field. The parameter estimation module **46** generally tries to estimate timing, signal amplitudes, phases, polarization, and identification of transmission channels.

[0074] The MUD element **50** consists of functional blocks that process the digital data and extract the user symbol streams. The MUD **50** performs pre-processing and converts the baseband digital data into the proper format for further processing according to the detection scheme. The format is often one measurement per 'dimension' per symbol. The

MUD unit **50** outputs a bit (or symbol) stream associated with each interfering signals present on the channel for one data block.

[0075] Turbo MUD processing assumes knowledge of various parameters such as relative received timing offsets, carrier phase, frequency offsets, received amplitudes, and multipath structure for each of the interfering signals present in the received signal. This input data represents raw data after some front end processing such as downconversion, amplification, and analog-to-digital conversion. MUD **50** needs some raw data parameters in order to establish accurate decision trees for processing.

[0076] There is an iterative processing topology with a MUD section **50** that interacts with the K number of channel decoders **65** for the received signal $r(t)$ for each user. The multiuser detector **50** is generally a SISO detector, receiving and outputting soft values, although hard value processing is known in the art. The MUD section **50** utilizes a priori information and delivers values such as a posteriori log-likelihood ratio (LLR) data of a transmitted '+1' or '-1' for each bit of every user. Certain a priori information is computed by the channel decoder **65** from a previous iteration which is interleaved and fed back to the MUD section **50**. The interleaver **60** and deinterleaver **75** perform the interleaving and deinterleaving functions respectfully for the encoding schema. Likewise, the summers **55**, **70** perform the summations for the data. Once the processing is complete the channel decoders **65** produce the output data stream (d_k) representing the best estimate of the transmitted signal (d_k) .

[0077] Various schemes for TurboMUD processing are well known in the art and utilize a priori information about the received signals wherein the processing continues through a number of iterations until certain conditional parameters are satisfied. The basic TurboMud procedure is presented in published literature such as Poor, "Turbo Multiuser Detection: An overview," IEEE 6th Int. Symp. On Spread-Spectrum Tech. And Appli., NJIT, New Jersey, Sept. 6-8, 2000 and Alexander, Reed, Asenstorfer, and Schlegel, "Iterative Multiuser Interference Reduction: Turbo CDMA," IEEE Trans. On Comms., v41, n7, July 1999. The iterative MUD algorithm such as representative of the approaches used to incorporate turbo decoding methods into joint MUD/FEC (Forward Error Correction) decoding and to then reduce the complexity of the system are known in the art.

[0078] The bit streams from the MUD 50 are passed to a bank of error correction decoders unit 65. The decoders 65 calculate conditional probabilities, one for each decoded symbol of each user, and output them as confidence values back to the MUD 50. In one embodiment, there is a bank of error correction decoders 65 such as Viterbi decoders or MAP.

[0079] Soft outputs for each bit of each user from the bank of decoders 65 is fed back to the multiuser detector 50 for each iteration, one stream of outputs for each interfering user present in the received signal. These soft outputs are passed back to the MUD 50 to produce an improved stream of soft bit (or symbol) decisions that fed into the decoder 65 for another iteration of improvement. The information between the MUD 50 and the decoders 65 repeats in subsequent iterations until an asymptote is reached or the desired performance level is attained. At that point, estimates of the data sequences for all active users are output. Operation then commences for the next block of data, repeating the process described above. The multiuser detector 50 takes these soft inputs along with the original raw input signal to calculate an improved, less corrupted bit stream for each user. This iterative process continues until a desired metric is reached or a fixed number is reached. At that point, estimates of the data sequences for all active users are output. Operation then commences for the next block of data, repeating the process described above.

[0080] The number of iterations for processing between the MUD 50 and the decoders 65 can be set to a fixed counter or by checking if there were significant changes to the data from the last iteration. Once the data is no longer being altered or reaches a certain iteration counter limit, the data from the decoder 65 can be output as final estimates of what the user sent, $(dk)'$. A fixed number of iterations can be stored and used and processed by the decision block. Alternatively, the information between the multiuser detector 50 and the decoders 65 repeats in subsequent iterations until an asymptote is reached or the desired performance level is attained. A buffer can store the previous values and compare them to the latter processed values during the iterative process.

[0081] MMSE detectors with prior information are usually described in a turbo or iterative application, but also function in non-iterative operations. As described herein, a

complete solution to the problem is computed, and one approximate (low complexity) method is described. Furthermore, prior schemes are generally inferior for overloaded systems, and this is alleviated by the present invention.

[0082] The apparatus in **Figure 2** is now described in more detail. A Data Stream **100**, potentially complex, is received from some source. For the case of Code Division Multiple Access (CDMA) communications schemes, the data stream is sampled by some multiple of the chip rate. For TDMA communication schemes, the data stream is sampled at some multiple of the symbol rate. The received signal can effectively be modeled as the linear combination of many co-channel signals, mathematically illustrated by

$$r[n] = \sum_{i=1}^F \sum_{k=1}^K b_k[i] a_k s_k(nT_n - iT_i) + n_w(nT_n). \quad \text{Equation 1}$$

[0083] The term $b_k[i]$ represents the symbol for user k at time index i . The term $s_k(nT_n - iT_i)$ represents the user's signal characteristic for sample index n for the symbol period i for the user k . The characteristic waveform, $s_k(\cdot)$, is normalized such that the amplitude of the transmitted signal for user k is represented by a_k . The symbol period is defined by T_i and the sample period is represented by T_n . The linear model represents a summation of K separate users and over F symbols. The received signal can represent a collection from multiple sources. For example, the collection may consist of multiple antennas, not necessarily co-located, with potentially different polarizations.

[0084] The user's signal characteristic, $s_k(nT_n - iT_i)$, combines a sequence of signal transformations: pulse shaping filter, signal delays, receiver filters, code channels (for CDMA) and multipath. It should be understood that the characteristic waveform is not restricted to a sample or symbol interval.

[0085] The multiple access interference model in Equation 1 is represented concisely using matrix notation in Equation 2. The KF symbols, corresponding to the KF simultaneous users, is represented by the KF -element vector, $\mathbf{b}[i]$ at time i . A linear model is used to represent the received signal at time index i by

$$\mathbf{r}[i] = \mathbf{S}\mathbf{A}\mathbf{b}[i] + \mathbf{n}_w[i], \quad \text{Equation 2}$$

where $\mathbf{b}[i]$ represents the KF symbols at time index i . The term $\mathbf{S}$ is a $N \times KF$ matrix representing the combination of the spreading code, channel codes, pulse shaping filter, and propagation effects

$$\mathbf{S} = \begin{bmatrix} s_1[1,i] & s_2[1,i] & \cdots & s_{KF}[1,i] \\ s_1[2,i] & s_2[2,i] & \cdots & s_{KF}[2,i] \\ \vdots & \vdots & \ddots & \vdots \\ s_1[N,i] & s_2[N,i] & \cdots & s_{KF}[N,i] \end{bmatrix} \quad \text{Equation 3}$$

[0086] The matrix entries, $s_k[n,i]$, represents the n^{th} sample of the signal characteristic waveform for user k at time i . The term $\mathbf{A}$ is a $KF \times KF$ diagonal matrix that represents the complex signal amplitudes, which can include phase and polarization weighting. The term $\mathbf{n}_w[i]$ is a $N \times 1$ vector that represents additive white Gaussian noise (AWGN).

[0087] Referring again to **Figure 2**, the data stream **100** represents a vector of data, representing the received signal. This data is communicated to the symbol hypothesis testing module **105** which is indicated in this implementation as Minimum Mean Squared Error (MMSE) based symbol estimator. The MMSE implementation for symbol hypothesis testing **105** is better for computational efficiency however other forms of symbol estimators such as the maximum likelihood detector are within the scope of the invention. The maximum likelihood detector is a brute force approach which performs an exhaustive evaluation of the Euclidean distances between the received samples and the linear model of the samples using every possible hypothesis of the bit sequence. Instead of the optimal detector for the symbol estimation testing module **105**, more computationally efficient forms of symbol hypothesis testing includes, the M-algorithm, T-algorithm, etc. Although the most efficient approach appears to be the MMSE-based symbol estimator, another efficient implementation for symbol estimation is referred to as the Q-algorithm, disclosed in U.S. Patent application Serial No. 10/105,918, filed March 25, 2002 entitled "System for Decreasing Processing Time in an Iterative Multi-User Detector System". The Q-

algorithm used for the MMSE-symbol estimator cancels interference based on symbol estimates obtained from thresholding the symbol likelihoods.

[0088] The computational efficiency utilizing the MMSE based symbol estimation is described in further details for the MMSE-based joint amplitude estimation and the parallelization of the algorithm. It should be noted that the symbol hypothesis testing is performed following completion of the initial amplitude estimate.

[0089] The same data vector 100 is passed to the initial amplitude estimation module 110. As indicated by the name, the purpose of initial amplitude estimation module 110 is to provide an initial estimate of the amplitude for each interfering signal. The approach implemented in initial amplitude estimation module 110 consists of incoherently integrating the energy out of a properly normalized matched filter for all users determined to be active. Note these users can be transmitted over code, temporal, and/or frequency channels and this estimation procedure are appropriate for these modes of digital communication. Part of the function performed in the initial amplitude estimation module 110, is the identification of which users are active. User identification can be easily obtained via an energy detector based on some sufficiently long observation interval that can determine activity on a channel: code, time slot, or frequency channel. The energy detector is generally integrated within the initial amplitude estimation module 110.

[0090] The initial amplitudes from the estimator 110 are passed to the MMSE-based symbol estimator 105 and the MMSE-based Joint Amplitude Estimator 120. The MMSE-based symbol estimator 105 uses the initial amplitude estimate only on the first iteration, for all other iterations it uses the amplitude estimates from the MMSE-based Joint Amplitude Estimator 120. This module may implement any type of symbol hypothesis testing procedure however an MMSE-based approach is used because of computational efficiency. It should be understood that other linear detectors, such as the decorrelator, may also be used for computational efficiency. While the linear detectors are efficient, the performance is sacrificed through BER performance and loading capacity.

[0091] There are numerous non-linear symbol-hypothesis testing procedures adaptable to the present invention, including the M-algorithm/T-algorithm; maximum likelihood; decorrelating decision-feedback detector (DDFD) and improved decorrelating decision-

feedback detector (IDDFD); successive interference cancellation (SIC), parallel interference cancellation (PIC) or multi-stage detector; block-iterative interference cancellation. A further symbol-hypothesis testing implementation is described in the commonly owned application entitled "Deferred Decorrelating Decision-Feedback Detector for Supersaturated Communications", U.S. Patent Application Serial No. 10/423655, filed April 25, 2003.

[0092] The MMSE-based symbol estimator **105** provides symbols estimates to a bank of single user decoders **130**. The symbols estimates from the symbol estimator **105** are routed to the decoders **130** based on user number. For example, all symbol likelihoods corresponding to the first user are passed to the decoder dedicated to the first user. This mapping is repeated for all users. The single user decoders consist of a bank of K decoders that may consist of Soft-output Viterbi or Maximum A Posteriori based techniques such as BCJR. Soft-input, soft-output (SISO) decoders are used in one embodiment for this implementation, but hard values can be processed as is known in the art.

[0093] Inherent in most processing is a de-interleaving, rate identification, de-puncturing and de-scrambling processing depicted merely as deinterleaving **125** for illustrative purposes. The symbol estimates and their respective likelihoods are output from the bank of decoders **130** for one of the most-likely data rates. In addition, symbol likelihood estimates from the decoders **130** are also fed back around to both the MMSE-based symbol estimator **105** and MMSE-based amplitude estimator **120** respectively. However, prior to feedback the symbol likelihoods are processed by an interleaving section **135** performing re-interleaving, re-puncturing, re-scrambling and symbol repeating (for low rate frames). The purpose of this re-coding task is to properly emulate the interference.

[0094] As referenced herein, the term 'data rate' refers to the rate at which the information bits are transmitted over the channel, defined in terms of bits per second. Sometime the data can be transmitted at one of a number of different rates. The likelihoods of the bits are maximized when the data rate is known. However, if the receiver is non-cooperative, the 'most likely' data rate must be identified. One approach

for determining the most likely data rate is through joint maximization of the bit likelihoods and data rate.

[0095] The new symbol likelihoods from the decoders 130 are used to update previous amplitude estimates in the joint amplitude estimator 120. The procedure for processing the MMSE-based amplitude estimator is described in further detail herein. The new amplitude estimates from the joint amplitude estimator 120 are passed to the MMSE-based Symbol Estimator 105 that re-estimates the symbols based on prior information on the symbols and the updated parameter estimates. These updated symbol estimates from the symbol estimator 105 are then re-routed to the bank of decoders 130. This process is repeated for either some fixed number of iterations or until the estimates of the bit error rate or frame error rate achieve some desired level.

[0096] Figure 3 illustrates the system and processing for calculating initial amplitude estimates with the Initial Amplitude Estimator 110 of Figure 2. Referring to Figure 2 and Figure 3, the initial amplitude estimate obtained from the Initial Amplitude Estimator 110 is based on the incoherent integration of the matched filter output of the Active Channel 180 over some observation interval. The procedure consists of applying a bank of matched filters 205, 230, 255 for all users K and all symbols F to the received data vector 100. The $KF \times 1$ vector representing the matched filter outputs is represented by

$$\mathbf{y} = \mathbf{S}^H \mathbf{r} = \mathbf{S}^H \mathbf{S} \mathbf{a} + \mathbf{S}^H \mathbf{n}_w \quad \text{Equation 4}$$

[0097] The estimate of the amplitude for a user k is based on summing the squared outputs of the matched filter for that user k , summed over an observation interval of F symbols. An estimate of the amplitude squared is represented by

$$\hat{a}_k^2 = \frac{1}{F} \sum_{i=1}^F |y_{i,k}|^2 \quad \text{Equation 5}$$

[0098] The summation over F is performed for all K users to obtain K initial amplitude estimates for the K users. Since the estimate is based on incoherent integration,

the estimate is biased which is illustrated by the expected value of the initial amplitude estimate for an arbitrary users k ,

$$E[\hat{a}_k^2] = a_k^2 + \frac{1}{F} \sum_{i=1}^F \sum_{\substack{j=1 \\ j \neq k}}^K \rho_{j,k}^2(i) a_j^2 \quad \text{Equation 6}$$

where the bias is represented by the last term in Equation 6 and $\rho_{j,k}^2(i) = (\mathbf{s}_k^H(i) \mathbf{s}_j(i))^2$.

Note that the bias in Equation 6 is based on the expected values of the bits in the vector $\mathbf{b}$, in Equation 4, equaling zero. This is mathematically represented by

$$E[\underline{\mathbf{b}}] = 0$$

In addition, Equation 6 assumes the symbols are defined such that $b_i^2 = 1$. A generalization of Equation 6 for the case of non-zero mean bit values and $b_i^2 \neq 1$ is obvious.

[0099] An inactive user 190 is defined as a signature signal that is not present. The expected value of the amplitude estimate for an arbitrary inactive channel is defined as

$$E[\hat{a}_{inactive}^2] = \frac{1}{F} \sum_{i=1}^F \sum_{j=1}^K \rho_{j,inactive}^2(i) a_j^2 \quad \text{Equation 7}$$

where $\rho_{j,inactive}^2(i) = (\mathbf{s}_{inactive}^H(i) \mathbf{s}_j(i))^2$. Since no signal is present for inactive users, a nonzero value for the expected value of the estimate for amplitude squared for inactive signature vectors is due to the presence of other active channels. Comparing Equations 6 and 7 reveals that examination of the estimate of squared amplitudes for non-active users can be used to estimate the bias relative to active users. Thus the Initial Amplitude Estimation concept is based on Equations 5 through 7 is illustrated in **Figure 3**.

[00100] A data stream 200 representing the received signal, potentially complex, is received from some source. A bank of filters 205, 230, 255, 280 and 300 is applied to the data stream 100. The Active Channel 180 set of filters 205, 230, 255 consists of filters matched to users that have been determined to be active based on an energy detector.

Filter 205 corresponds to a filter matched to the signature signal for user 1. Similarly, filter 230 corresponds to a filter matched to the signature signal for user 2. It should be noted that the size of the bank of matched filters is based on the number of users determined to be active and represented by the term K .

[00101] The output data from each matched filter (1- K) 205, 230, 255 is then processed by a squaring operation 210, 235, 260 for all K users. The outputs from the squaring operations 210, 235, 260 for each active channel user (1- K) are then passed to a bank of summers 215, 240, 265 which performs the incoherent integration. The bank of summer 215, 240, 265 for each user 1- K used to implement Equation 5, accumulates energy in each of their respective processing chains. The proper scaling required for averaging is included in the output of the summers. As previously mentioned these estimates of squared amplitude are biased, therefore, the bias removal component must be implemented to minimize the bias.

[00102] A set of filters 280, 300 for the Inactive Channel 190 representing those channels that were determined to be inactive based on an energy detector. The bank of filters 280, 300 matched to the inactive user's signature signals is applied to the data stream 200 and processed. The size of the bank of filters 280, 300 is based on the number of users determined to be inactive, defined herein as the number J .

[00103] Following the processing of the inactive filters 280, 300 for the users 1- J , the user data is further processed by a squaring operation 285, 305 for all J users. The outputs from the squaring operations 285, 305 for each inactive channel user (1- J) are then passed to a bank of summers 290, 310. The bank of summer 290, 310 for each user 1- J accumulates energy in each of their respective processing chains. The proper scaling required for averaging is included in the output of the summers 290, 310, wherein the output is then processed by the Average Bias Estimator 295.

[00104] Following the computation of the amplitude bias by the Average Bias Estimator 295, the bias is passed to Bias Removal 220, 245, 270 that is applied to each of the Active Channel Users 1- K . The illustration in **Figure 3** shows the output from the active channel summers 215, 240, 265 going to all bias removal modules 220, 245, 270. The initial amplitude squared estimate obtained for the active channels has an estimate of the bias

removed in modules 220, 245, 270. Following the bias removal, the initial amplitude squared estimates 225, 250, 275 for each user 1- K are passed out to the remaining processing shown in Figure 2.

[00105] Figure 3 shows the computation of one amplitude bias in module 295, which is then applied to all bias-removal modules 220, 245, and 270, for all active channels. The processing configuration of Figure 3 is also extendable to other embodiments in which different biases are computed for different sets of active channels, which are obvious extensions and within the scope of the present invention. For example, in a wireless communications system the bias removal could be restricted to channels within certain sectors. More specifically, for all non-active channels identified in a sector, a bias estimate is computed and then applied to all active channels in the same sector. Therefore, active channels identified in a different sector will only use a bias based on non-active channels in this same sector.

[00106] Referring to Figure 2, the initial amplitude squared estimates are updated in the MMSE-based Joint Amplitude Estimator 120. The apparatus for updating these amplitude squared estimates is described in Figure 4. The solution described in Figure 4 is based on the assumption that the amplitude is nearly constant over some observation window. Since this solution is based on the MMSE criteria, this approach is easily extended to time-varying amplitudes, however, only the windowed based estimator is detailed herein for illustrative purposes. For example, when the amplitude fluctuates by rate, the amplitudes over multiple frames are linked based upon the data rate. Incorporating data rate into the amplitude estimator, the module described in Figure 4 actually evolves into an energy-per-bit estimator. When the amplitude fluctuates based on temporal instability, then this implementation is extended into a Kalman filter framework by using a temporal model of the channel variation. The Kalman filter equation itself is well known to those in the art.

[00107] Referring to Figure 2 and Figure 4, the stream of data representing the received signal 100 is passed to the MMSE-based Joint Amplitude Estimator 120. This data stream 100 is divided up into M observation intervals as illustrated by r_1 , r_2 , through r_M 400, 405, 410. These intervals can be based on distinguishing attributes such as time, code, or frequency. For the example presented herein, the observation interval refers to time.

These observation intervals each enter a different processing section 415, 420, 430, representing 1 to M observation intervals. In each processing module, 415, 420, 430, an MMSE filter is computed which is defined for an arbitrary observation interval m as:

$$G_m = \mathbf{B}_m \mathbf{S}_m^H (\mathbf{S}_m \chi_m \mathbf{S}_m^H + \sigma_n^2 \mathbf{I})^{-1}. \quad \text{Equation 8}$$

[00108] The term $\mathbf{B}_m$ refers to a diagonal matrix representing the expected bit or symbol value in interval m for all K users. For example,

$$\mathbf{B}_m = \begin{bmatrix} \hat{b}_1 & 0 & \cdots & 0 \\ 0 & \hat{b}_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \hat{b}_K \end{bmatrix}, \quad \text{Equation 9}$$

where $\hat{b}_k$ represents the expected value of the symbol for user k . For illustrative purposes, for BPSK systems, $\hat{b}_k = 2p_k - 1$, where p_k equals the probability that the symbol equals 1. The term $\mathbf{S}_m$, is similar to that presented in Equation 2, except here $\mathbf{S}_m$ represents the “S-matrix” defined over a single observation interval, while $\mathbf{S}$ in Equation 2 is defined over F observation intervals. Therefore, $\mathbf{S}$ in Equation 2 contains the $\mathbf{S}_m$ defined herein. The term χ_m represents the amplitude uncertainty and is rewritten as:

$$\chi_m = (\Omega + \mathbf{A}^2) \Lambda_m \quad \text{Equation 10}$$

which more clearly defined the amplitude uncertainty in terms of the bit uncertainty, Λ_m , the initial amplitude uncertainty, Ω , and the expected value of the amplitude $\mathbf{A}$. The terms, Λ_m , Ω , and $\mathbf{A}$ are all diagonal matrices, and each element along the diagonal corresponding to a different active user, therefore, χ_m is a diagonal matrix. This formulation assumes the amplitudes and corresponding uncertainties are constant for the M observation intervals.

[00109] Following the computation of M different MMSE filters in each of the $1-M$ modules 415, 420, 430, each MMSE filter is applied to components of the respective data stream 400, 405, 410 corresponding to the same observation interval.

[00110] Prior to application of the MMSE filter, interference cancellation is performed based on the expected value of the bits, represented by $\mathbf{B}_m$ and prior estimates of the amplitude for all K users, represented by the $K \times 1$ vector $\underline{a}^{l-1}$. The interference cancellation is represented by

$$\tilde{\underline{r}}_m = \underline{r}_m - \mathbf{S}_m \mathbf{B}_m \underline{a}^{l-1}. \quad \text{Equation 11}$$

And, each MMSE processor cancels out different interference.

[00111] Therefore, application of the MMSE filter following interference cancellation is represented by

$$\Delta \underline{a}_m = G_m \left(\underline{r}_m - \mathbf{S}_m \mathbf{B}_m \underline{a}^{l-1} \right) \quad \text{Equation 12.}$$

[00112] The amplitude estimator is defined in module 435 of **Figure 4**. It is an iterative formulation that updates previous estimates, represented by $\underline{a}^{l-1}$, with information based on new estimates of the users' bits and data rate. These new estimates are represented by $\underline{a}^l$. The MMSE-based joint amplitude estimator 435 combines the individual estimates, $\Delta \underline{a}_m$, in a weighted manner. The weighted combination in this embodiment is expressed by:

$$\underline{a}^l = \underline{a}^{l-1} + \left(\Omega^{1/2} (Q + I)^{-1} \Omega^{1/2} \right) \sum_{m=1}^M \Delta \underline{a}_m \quad \text{Equation 13}$$

where

$$Q = \sum_{m=1}^M Q_m \quad \text{Equation 14}$$

[00113] As indicated by Equation 13 and illustrated in **Figure 4**, the individual estimates from the filter modules **415**, **420**, **430** are passed to the Amplitude Estimator **435** for each interval 1-M. These individual estimates, $\Delta \underline{a}_m$, are $K \times 1$ vectors which are then summed together in Amplitude Estimator **435**. These estimates are then weighted by $\left(\Omega^{1/2} (\underline{Q} + I)^{-1} \Omega^{1/2} \right)$ where $\Omega^{1/2}$ is a diagonal matrix containing the standard deviation of the amplitude estimates and $\underline{Q}$ is represented in Equation 14. The term $\underline{Q}$ is a summation of quadratics computed in the filter modules **415**, **420**, **430**. Each quadratic is computed by

$$\underline{Q}_m = G_m \underline{S}_m \underline{B}_m \quad \text{Equation 15}$$

which is shown to be based on the MMSE filter for the respective observation region defined in interval m . Therefore each filter module **415**, **420**, **430** responsible for an observation interval must compute: the MMSE filter (see Equation 8); apply interference cancellation to the section of the data stream corresponding to the observation interval (see Equation 11); apply the MMSE filter to the interference mitigated data vector (see Equation 12); and computed the quadratic (see Equation 15).

[00114] In this embodiment the outputs of each module **415**, **420**, **430** is a $K \times 1$ vector $\Delta \underline{a}_m$ and a hermitian matrix $\underline{Q}_m$ which is a $K \times K$ matrix with $K(K+1)/2$ unique elements. These two outputs are passed to the Amplitude Estimator **435** for each interval 1-M. The prior amplitude estimates, $\underline{a}^{l-1}$ are updated to $\underline{a}^l$ and passed out from the Amplitude Estimator **435** back to the individual filter modules **415**, **420**, **430** defined for the observation intervals. This feedback is part of the iterative implementation inherent in this MMSE formulation.

[00115] Referring again to **Figure 2**, it should be understood that the amplitude estimates are not updated until the bits (or symbols) have been updated in the bank of decoders **130**. Following the processing by the MMSE-based symbol estimator **105** and the decoders **130** in **Figure 2**, the symbols are fed back to the MMSE-based joint amplitude estimator **120** where prior amplitude estimates are updated as detailed herein. As previously described,

the number of iterations is typically dictated by the user which is defined for either a fixed iteration number or until the frame error rate or estimate bit error rate metric reaches some desired level.

[00116] Once processing is completed, the updated amplitude estimate vector **440** is transmitted from the MMSE-based Joint Amplitude Estimator **120** to the MMSE-based symbol estimator **105**. Since for this particular implementation, the amplitudes are constant over the observation interval described for M smaller observation intervals, the same amplitude estimate **440** is reported to each MMSE-based symbol estimator **105**. This approach is easily modified for a variable amplitude estimate which varies over the entire observation interval.

[00117] The apparatus in **Figure 5** is one embodiment of a hardware implementation that provides a more detailed characterization of the processing shown in **Figure 2**. It should be noted that **Figure 5** shows an implementation that parallels the joint estimation based on M observation intervals. The data stream in **100** of **Figure 2** is partitioned into M observation intervals as the data vectors **500**, **502**, **504**, **506** representing intervals 1 - M . As in previous diagrams, the number of observation intervals is generalized to M intervals. The observation intervals may overlap (not necessarily disjoint) to account for asynchronous reception and multipath signals.

[00118] These data vectors **500**, **502**, **504**, **506** are processed immediately by a bank of MMSE filters which are implemented on the M processors, **520**, **522**, **524**, **526**, for all M observation intervals and each processor simultaneously estimates symbols for all K users. The filter processing can be considered a node, wherein a node is a generic processing component as is known in the art, such as a microprocessor chip or processing board, and wherein it should be readily apparent that there can be more than one processor per node.

[00119] In addition, these data vectors **500**, **502**, **504**, **506** are read into local memory **510**, **512**, **514**, **516** on the processors, because they are used repeatedly for the multiple iterations in this iterative approach to symbol, amplitude, and rate estimation. Any of the forms of memory known in the art are applicable.

[00120] Each symbol estimation MMSE processor, 520, 522, 524, 526 outputs $\underline{b}_m$, which is a vector of K symbol likelihoods or symbol bits for observation interval m . Recall that K corresponds to the number of users and therefore $\underline{b}_m$ represents the collection of symbol estimates for K users in observation interval m . Symbol bits are provided on the output if thresholding is performed within the MMSE processor 520, 522, 524, 526. The output from each MMSE processor, 520, 522, 524, 526, is intended to represent M $K \times 1$ vectors passed to the system area network (SAN) 530 which will then pass K $M \times 1$ frames of likelihoods (or symbols) to a bank of decoders 532, 534, 536, 538 for each user 1- K . The benefit of supplying likelihoods to the decoders 532, 534, 536, 538 is the improved performance when using soft-decoders. It should be noted that the same processing nodes used for implementing the bank of MMSE filters for symbol estimation for processors 520, 522, 524, 526 can be used to implement the K decoders, 532, 534, 536, 538 which are partitioned between the compute nodes. However, this embodiment also covers an implementation for hardware dedicated to MMSE processing and separate hardware for decoding.

[00121] The following discussion describes one embodiment for an implementation when a bank of processing nodes is used for both MMSE processing and decoding. Symbol likelihoods are routed over the SAN 530 based on the assignment of decoders 532, 534, 536, 538 to processing components for decoding. The SAN 530 routes the M $K \times 1$ vectors of symbol likelihoods from the symbol estimation processing previously used to perform MMSE-based symbol estimation on processors 520, 522, 524, 526 to the same set of processing nodes that now perform the decoder processing on the bank of decoders 532, 534, 536, 538. The SAN 530 passes K frames of $M \times 1$ symbol estimates to the K decoders 532, 534, 536, 538, wherein the frames of symbols are represented by $\underline{f}_k$ for the K users. The frames, $\underline{f}_k$, represent a frame for each user that contains M symbols.

[00122] The number of decoders 532, 534, 536, 538 corresponds to the number of users, 1- K . The bank of decoders 532, 534, 536, 538 may implement hard-in, soft-out (HISO) or soft-in, soft-out (SISO) decoders. In addition to decoding, the bank of decoders 532, 534, 536, 538 performs descrambling, de-interleaving, de-puncturing, and rate identification. The output of each decoder 532, 534, 536, 538 is, $\underline{f}_k$, which is

a $M \times 1$ vector representing an update of M likelihoods in the frame following the implementation of the decoders. In addition, the decoders 532, 534, 536, 538 supply likelihoods of the information bits values d_k' for the same collection of symbols. These information bits are passed out as output 540, 542, 544, and 546. The number of bits per user is dependent on the data rate, and there bit likelihoods are available at any time in the iterative scheme for post-processing such as a cyclic reduction check, which is used to determine frame errors. The number of information bits transmitted per second is less than the number of symbols per second. Therefore, the number of information bits will be less than M , which defines the number of symbols per frame.

[00123] The updated likelihoods of the symbols $K M \times 1$ vectors of likelihoods, $\underline{f}_k'$, are fed-back through SAN 550 and processed by a bank of MMSE filters which are implemented on the M processor nodes, 560, 562, 564, 566. The $K M \times 1$ vectors of likelihoods, $\underline{f}_k'$, prior to the SAN 550 are sent to the MMSE filters as $M K \times 1$ vectors of likelihoods, $\underline{b}_m'$. However, now the bank of MMSE filters is used for amplitude estimation 575.

[00124] The same bank of $1 - M$ symbol estimation processors 520, 522, 524, 526 used to implement the initial MMSE filters for symbol estimation can be used for the further MMSE filter implementation for amplitude estimation, illustrated by processing modules 560, 562, 564, 566. The MMSE processing modules 560, 562, 564, 566 in amplitude updating focus on the same observation intervals analyzed during the symbol estimation. The MMSE processors 560, 562, 564, 566 at this stage implement the functionality of the filter module 415, 420, 430 of Figure 4. This bank of MMSE filters implemented by MMSE processors 560, 562, 564, 566 draw from local memory 552, 554, 556, 558 to retrieve prior amplitude estimates, updated symbol estimates, S-matrices, and the received data vector corresponding to the observation interval m .

[00125] Referring back to Figure 4, each amplitude processing module 415, 420, 430 computes an amplitude update vector, $\Delta \underline{a}_m$, which is $K \times 1$ vectors. Each amplitude update vector is passed to a central node that implements the functionality of the Amplitude Estimator 435. In Figure 5, all individual update vectors from the amplitude estimation processors 560, 562, 564, 566 are passed to a central processing node 575 via

the SAN 570. As detailed herein, the amplitude estimate is updated by weighting the sum of all amplitude updating vectors, wherein the weighting is based on quadratic terms reflecting the uncertainty in the update, Q_m . These quadratic terms are also passed to the central node 575 to provide the necessary weighting.

[00126] The SAN 570 passes all $\Delta \underline{a}_m$ vectors (M vectors of size $K \times 1$) and Q_m matrices, (M hermitian $K \times K$ matrices with $K(K+1)/2$ unique elements) from the MMSE processors 560, 562, 564, 566 to the central processing node, 575. The Amplitude Estimator 575 computes the functionality described for the Amplitude Estimator 435 of Figure 4 and the updated estimate gets distributed to all M processors used for the next MMSE-based symbol estimation. Therefore, Amplitude Estimator 575 passes the updated amplitude estimate to SAN 580 that fan out these estimates for all K users to the M processors 520, 522, 524, 526 for the symbol estimation processing.

[00127] The updated amplitude estimates refreshes the amplitude estimates stored in the local memory 510, 512, 514, 516 coupled to the MMSE processors 520, 522, 524, 526. Following the receipt of the updated amplitude estimates, the next iteration of the MMSE-based symbol estimator is implemented. Therefore, the MMSE modules 510, 512, 514, 516 perform the symbol estimation processing and repeat the symbol estimation on the next iteration using the new amplitude estimates. As described herein, the iterative processing continues until estimates of the bit error rate metric achieves a certain level or until a fixed number of iterations have been executed.

[00128] The hardware configuration presented in Figure 5 is an attractive implementation because bandwidth requirements are minimized by passing a total of only $K \cdot M$ floating point numbers over the SAN 530, except during amplitude updating when the matrices Q_m are passed over the SAN 570 to a central node 575. Bandwidth can be further minimized during the amplitude testing by approximating Q_m as a diagonal and therefore pass a total of $2K \cdot M$ floating point numbers during amplitude updating. Since the MMSE operations, both symbol and amplitude, occur at the same processing nodes on processors, 520, 522, 524, 526 and 552, 554, 556, 558, less data is processed and efficient techniques can be used to exploit previous MMSE filter weights.

[00129] The communications configuration described in **Figure 5**, is more easily recognized in **Figure 6**, which shows $1 - L$ nodes responsible for all processing. These L nodes pass data between themselves using a high speed interconnect **625** for the system area network (SAN). The modules **600** correspond to the time when the nodes $1 - L$ are used to implement the bank of M MMSE filters for symbol estimation in M observation intervals. The symbol estimation processing at node **600** is comparable to processing performed on MMSE processors **520, 522, 524, 526** shown in **Figure 5**.

[00130] The number of L nodes depends upon the size of the problem, typically the number of K users, and the available hardware. For example, if K is small, then more than one MMSE filter operation can be performed per node in which case $L < M$. If K is large such that more than one node is required per MMSE filter operation, then $L > M$. The capability of the node is based on processing speed, local memory, design constraints, and concept of operation.

[00131] The data from symbol estimation processing nodes **600** is passed by the high speed interconnect **625** to the decoder processing nodes **605**. The decoder processing nodes **605** are L nodes used to implement a bank of decoders such as SISO decoders, wherein the decoders for K users are distributed among the L nodes. This decoder processing corresponds to the bank of decoders **532, 534, 536, 538** of **Figure 5**. While **Figure 6** illustrates an implementation using common hardware, for the implementation where the hardware for MMSE and decoders are different, the L nodes **605** could refer to dedicated decoder hardware.

[00132] The communication between nodes from the MMSE symbol estimation processing stage to the nodes for the decoding stage of the algorithm is illustrated by the following example. For illustrative purposes, let the number of nodes equal the number of observation intervals, $L = M$. This simplification is not an architecture restriction, but simply a convenient way to illustrate the communication between nodes. Based on this simplification, the output of each node **600** in the symbol estimation section is a $K \times 1$ vector representing symbol estimates for the K users. Each node **605** in the decoder section is responsible for decoding a subset of the number of users. To further simplify the discussion, let each node **605** in the decoder section execute two decoders. In other words,

each node 605 performs the processing for two processors of the bank of decoders 532, 534, 536, 538 from **Figure 5** so that the number of nodes L in this example would be one half the number of users K ($L = \frac{1}{2} K$).

[00133] Therefore, based on these simplifications, for purposes of explanation only, the symbols from the symbol estimation nodes 600 that correspond to users 1 and 2 in the first observation interval are two of the K symbol estimates determined in Node 1. The symbols from Node 1 of the symbol estimation section 600 are transmitted to the Node 1 of the decoder section nodes 605, wherein Node 1 of the decoders nodes 605 represents the decoding of users 1 and 2 for the first time interval. The symbols for the users 1 and 2 in the second observation interval, Node 2, from the symbol estimations section 600 are passed over the high-speed interconnect 625 to Node 1 in the decoder section 605. Similarly, the symbols for the same two users, users 1 and 2, in the third observation interval, Node 3, from the symbol estimation section 600 are passed via 625 to Node 1 in the decoder section 605. This procedure continues for the M observation intervals for the symbols corresponding to the first 2 users, user 1 and user 2.

[00134] As should be readily apparent from this example, Node 2 of the decoder section 605 processes user 3 and user 4 for all the L observation nodes 600; Node 3 of the decoder section 605 processes user 5 and user 6 for all the L observation nodes. By way of further explanation, Node 4 in the decoder section 605 is responsible for decoding users 7 and 8, and receives two symbols corresponding to users 7 and 8 from all the L observation nodes 600. For example, Node 1 of the symbol estimation section 600 passes the symbol estimates of users 7 and 8 to Node 4 of decoder section 605. Similarly, Node 2 of the symbol estimation section 600 passes the symbol estimates for users 7 and 8 for the 2nd observation interval to Node 4 of decoder section 605. This procedure continues for all L nodes in the decoder section 605. Therefore, symbol estimates out of the MMSE symbol estimators 600 are routed from the M observation intervals to the K decoders of the decoder section 605 based on the mapping of the K decoders to the L available processing nodes.

[00135] The next section is the amplitude estimation section 610 for nodes 1 – L . The amplitude estimation section 610 represents L nodes implementing the MMSE stage of

the amplitude estimator, as shown by modules 560, 562, 564, 566 in **Figure 5**. Prior to implementing amplitude estimation, the amplitude estimation nodes 610 receives all symbol likelihoods via the high speed interconnect 630 following the execution of the nodes from the decoders 605. As described in **Figure 5**, the likelihoods of the symbols out of the K decoders 532, 534, 536, 538 are routed back to M MMSE filters 560, 562, 564, 566 for the amplitude estimation stage of the algorithm. For this example, two decoders are implemented per node in the decoder section 605 and one MMSE filter processor in the amplitude estimation section 610 is executed per node. The output of Node 1 in the decoder section is a $M \times 2$ array of likelihoods corresponding to the M symbol likelihoods for the first two users after implementing the decoder processing 605, descrambler, de-interleaver, and rate identification. Node 1 in the amplitude estimation section 610 retains the symbol likelihoods for the first two users, user 1 and user 2, in the first observation interval. Node 2 in the amplitude estimation section 610 is responsible for the MMSE implementation over the second observation interval. Therefore, the second set of bits in the $M \times 2$ array is passed from Node 1 in the decoder section 605 to Node 2 in the amplitude estimation section 610. This is repeated for all M observation intervals. Therefore, the outputs of the decoder section 605 are passed to all nodes 610 computing the amplitude updating vector in the M observation intervals.

[00136] The next set of nodes is the amplitude weighing section 615 responsible for updating the amplitude estimate and which implements the functionality of the amplitude estimator 575 of **Figure 5**. This processing is performed at a single node, and for illustrative purposes Node 3 is depicted and described herein. It should be noted that the other nodes of this section 615 of the algorithm remain idle while the amplitude estimation is completed. Therefore the high-speed interconnect 635 passes the amplitude updating vector and quadratics from the L nodes in the amplitude estimation section 610 Node 3 of the amplitude weighing section 615.

[00137] The functionality of the Amplitude Estimator 435 of **Figure 4** provides a more detailed explanation concerning the weighing implementation. The amplitude estimate calculated by Node 3 of the amplitude weighing section 615 is “fanned-out” to all the L processing nodes for further processing of symbol estimation at the next iteration ($I+1$). Thus, the new amplitude estimate for all K users is distributed via the high speed

interconnect 640 to all the L nodes of the next iteration symbol estimation section 620 for the $I+1$ iteration. The L nodes in the next iteration symbol estimation section 620 recompute the symbol estimates, using the new amplitude estimates, for the K users in the M observation intervals. The stages and data routing are repeated until the maximum number of iterations is achieved or the desired bit error rate is reached.

[00138] One aspect of the present invention is that it solves the previously described problem of tightly integrating parameter estimation, symbol hypothesis testing, decoding, and rate identification. The approach in one embodiment assumes a modulation scheme (e.g. CDMA) has been utilized. The solution presented herein in one embodiment is a windowed-based Minimum Mean Squared Error (MMSE) approach to Turbo-decoding for joint signal demodulation, which is easily extended to time-varying channels. The invention is based on an iterative decoding solution that exploits error correction codes. In addition, the approach of the present invention is suitable for symbol asynchronous as well as symbol synchronous. Also, the algorithm used is suitable for a variety of signaling schemes such as M-ary Phase Shift Keying (MPSK).

[00139] It will be appreciated that implementation of the present invention solves the problem of the unknown channel parameters in state of the art detectors. The present invention works with many varieties of multiuser detectors and is easily implemented into different multiuser detecting systems. Specifically, the MMSE symbol estimators in modules 600 and 620 of Figure 6 can be substituted with any of the known or referenced MUD algorithms.

[00140] The present invention dramatically reduces the number of computations needed in a blind approach to joint signal demodulation and without pilot tones or training sequences, so that reliable operation can be achieved in a real-time implementation. It will also be appreciated that since the present technique does not require knowledge of training sequences or existence of a pilot signal, it is considered a blind approach to symbol and data rate estimation. The efficient implementation of blind estimation is realized because of the high degree of parallelism. This provides an efficient implementation because of reduced number of operations associated with updating MMSE filter tap weights.

[00141] Further efficiency is realized because the number of iterations required to achieve a certain bit-error-rate for case of unknown amplitudes is typically similar to the case when the amplitudes are completely known. The present efficiency occurs because the degradation in bit-error-rate for the case of unknown amplitudes is manageable relative to the case of known amplitudes. Thus, the present approach represents a new method to estimate channel amplitudes and extension to time-varying channels is obvious to those in the art. The present approach also represents a new method to reduce biases in amplitude estimates based on incoherent integration.

[00142] The foregoing description of the embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of this disclosure. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

CLAIMS

What is claimed is:

1. An apparatus for processing a digital data stream from multiple users, comprising:
 - an initial amplitude estimation unit processing said data stream and producing initial amplitude estimates on a first iteration;
 - a joint amplitude estimator coupled to said data stream and said initial amplitude estimator, wherein said joint amplitude estimator produces updated amplitude estimates;
 - a symbol estimator coupled to said data stream, said initial amplitude estimator, and said joint amplitude estimator, wherein said symbol estimator produces a plurality of symbols estimates for each user; and
 - a bank of decoders coupled to said symbol estimator, producing a plurality of symbol likelihood estimates for each user, wherein said symbol likelihood estimates are iteratively fed back to said symbol estimator and said joint amplitude estimator until a final condition is obtained.
2. The apparatus according to claim 1, wherein said final condition is selected from at least one of the group consisting of: bit error rate metric level and fixed number of iterations.
3. The apparatus according to claim 1, wherein said symbol hypothesis testing module is a member selected from at least one member of the group consisting of: Minimum Mean Squared Error (MMSE), maximum likelihood, M-algorithm, T-algorithm, and Q-algorithm, decorrelating decision-feedback detector (DDFD), improved decorrelating decision-feedback detector (IDDFD), successive interference cancellation (SIC), parallel interference cancellation (PIC) and multi-stage detector; block-iterative interference cancellation, and a deferred decorrelating decision-feedback detector.

4. The apparatus according to claim 1, further comprising an energy detector coupled to said joint amplitude estimator.

5. The apparatus according to claim 1, wherein said bank of decoders are decoders selected from at least one decoder of the group consisting of: Soft-output Viterbi , Maximum A Posteriori , and BCJR.

6. A method for providing initial amplitude estimation for a plurality of user channels, comprising:

separating said user channels into active channels and inactive channels;
processing said inactive channels according to the sub-steps comprising:
 applying a bank of filters to said inactive channels for each inactive user;
 squaring an output from said bank of filters;
 summing an output from said squaring operation; and
 calculating an average bias estimate from an output of said summing; and
processing said active channels according to the sub-steps comprising:
 applying a bank of filters to said user data of said active channels;
 squaring an output from said bank of filters ;
 summing an output from said squaring; and
 removing said average bias estimate from an output from said summing.

7. The method according to claim 6, said processing said inactive channels further comprising dividing said inactive channels into groups and calculating at least one group average bias estimate.

1 8. The method according to claim 7, said processing said active channels
2 further comprising dividing said active channels into groups and
3 respectively removing said at least one group average bias estimate.
4

1 9. The method according to claim 6, wherein said summers further comprises
2 scaling.
3

1 10. The apparatus according to claim 6, wherein said separating said active
2 channel from said inactive channels is performed by an energy detector.
3

1 11. An apparatus for processing initial amplitude estimates from a data stream
2 of multiple users, comprising:

3 an energy detector measuring an energy level of said data stream, wherein
4 said energy detector separates a plurality of active channels from a plurality of
5 inactive channels;

6 a bank of filters coupled to said inactive channels;

7 a bank of squaring operators coupled to said bank of filters;

8 a bank of inactive summers coupled to said squaring operators;

9 an average bias estimator coupled to said inactive summers calculating an
10 average bias estimate;

11 a bank of filters coupled to said active channels;

12 a bank of squaring operators coupled to said bank of filters;

13 a bank of active summers coupled to said squaring operators; and

14 a bias removal section coupled to said active summers and said average bias
15 estimator.
16

1 12. The apparatus according to claim 11, wherein said inactive channels are
2 divided into groups calculating said average bias estimate for each said
3 group.
4

1 13. The apparatus according to claim 12, wherein said active channels are
2 divided into said groups and wherein said bias removal section for each said
3 group removes said average bias estimate for each said corresponding
4 group.

5
1 14. A joint amplitude estimator for a data stream from multiple users,
2 comprising:
3 a data stream from said multiple users divided into a plurality of
4 observation intervals;
5 a plurality of processing modules coupled to said observation intervals,
6 wherein said processing modules calculates interference cancellation values
7 for each of said users and computes a filter for each of said observation
8 intervals, said filter being applied to said data within said observation
9 interval to compute individual amplitude estimates; and
10 an amplitude estimation unit which processes said individual amplitude
11 estimates and calculates new amplitude estimates, wherein said new
12 amplitude estimates are iteratively passed back to said processing modules
13 until a final condition is obtained.
14

1 15. The joint amplitude estimator according to claim 14, wherein said final
2 condition is selected from at least one of the group consisting of: bit error
3 rate metric level and fixed number of iterations.
4

1 16. The joint amplitude estimator according to claim 14, wherein said
2 amplitude estimation unit sums and weighs said individual estimates.
3

1 17. The joint amplitude estimator according to claim 14, wherein said
2 observation intervals are based on distinguishing attributes selected from at
3 least one of the group consisting of: time, code, and frequency.
4

1 18. The joint amplitude estimator according to claim 14, wherein said filter is
2 calculated for an arbitrary observation interval m as:

3
$$G_m = \mathbf{B}_m \mathbf{S}_m^H (\mathbf{S}_m \chi_m \mathbf{S}_m^H + \sigma_n^2 \mathbf{I})^{-1}.$$

4

1 19. A method for processing amplitude estimates for a multiuser data stream
2 divided into a plurality of observation intervals, comprising:

3 computing a filter for each said observation interval of said data stream;

4 applying interference cancellation to said data stream for each said
5 observation interval;

6 applying said filter to said data stream for each said observation interval
7 from said interference cancellation to produce individual amplitude
8 estimates for each said observation interval;

9 computing new amplitude estimates using said individual amplitude
10 estimates; and

11 passing said new amplitude estimates back to said filter for iterative
12 processing until a final condition is obtained.

13
1 20. The method according to claim 19, wherein said computing further
2 comprises summing said individual amplitude estimates and weighing.

3
1 21. The method according to claim 19, wherein said final condition is selected
2 from at least from the group consisting of: bit error rate metric level and
3 fixed number of iterations.
4

1 22. A turbo-decoding system for joint signal demodulation, comprising:
2 a data stream from a plurality of users divided into a plurality of observation
3 intervals;

a plurality of symbol processing nodes processing said observation intervals to compute symbol estimates for said data stream within said observation interval;

a plurality of decoder nodes processing said symbol estimates and producing a plurality of symbol likelihoods;

a plurality of amplitude update nodes processing said symbol likelihoods and calculating a plurality of amplitude update vectors; and

an amplitude estimator node processing said amplitude update vectors and producing an amplitude estimate update, wherein said amplitude estimate update is passed back to said processing nodes for iterative processing between said symbol processing nodes, said decoder nodes, said amplitude update nodes, and said amplitude estimator node until a final condition is obtained.

23. The system according to claim 22, further comprising a plurality of memory units, wherein at least one memory unit is coupled to each of said processing nodes and to each of said amplitude estimation nodes.

24. The system according to claim 22, further comprising a first system area network (SAN) coupling said processing nodes and said decoder nodes, a second system area network (SAN) coupling said decoder nodes and said amplitude estimation nodes, a third system area network (SAN) coupling said amplitude estimation nodes and said amplitude estimator, and a fourth system area network (SAN) coupling said amplitude estimator and said processing nodes.

25. The system according to claim 22, wherein said final condition is selected from at least one of the group consisting of: bit error rate metric level and fixed number of iterations.

- 1 26. The system according to claim 22, wherein said processing nodes, said
2 decoder nodes and said amplitude estimation nodes are one set of nodes.
3
- 1 27. The system according to claim 26, wherein said one set of nodes are each
2 comprised of at least one processor.
3
- 1 28. The system according to claim 22, wherein said likelihood symbols from
2 said decoder nodes are accessible at any time for post-processing.
3
- 1 29. The system according to claim 22, wherein said processing nodes further
2 comprises a thresholder to convert said symbol estimates to symbol bits.
3
- 1 30. The system according to claim 22, wherein said decoder nodes performs de-
2 interleaving, rate identification, de-puncturing and de-scrambling.
3

JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

ABSTRACT OF THE DISCLOSURE

[00143] The system in one embodiment relates to tightly integrating parameter estimation, symbol hypothesis testing, decoding, and rate identification. The present invention provides Turbo-decoding for joint signal demodulation based on an iterative decoding solution that exploits error correction codes. The system iteratively couples an initial amplitude estimator, a symbol estimator, a bank of decoders, and a joint amplitude estimator to produce the symbol estimates.

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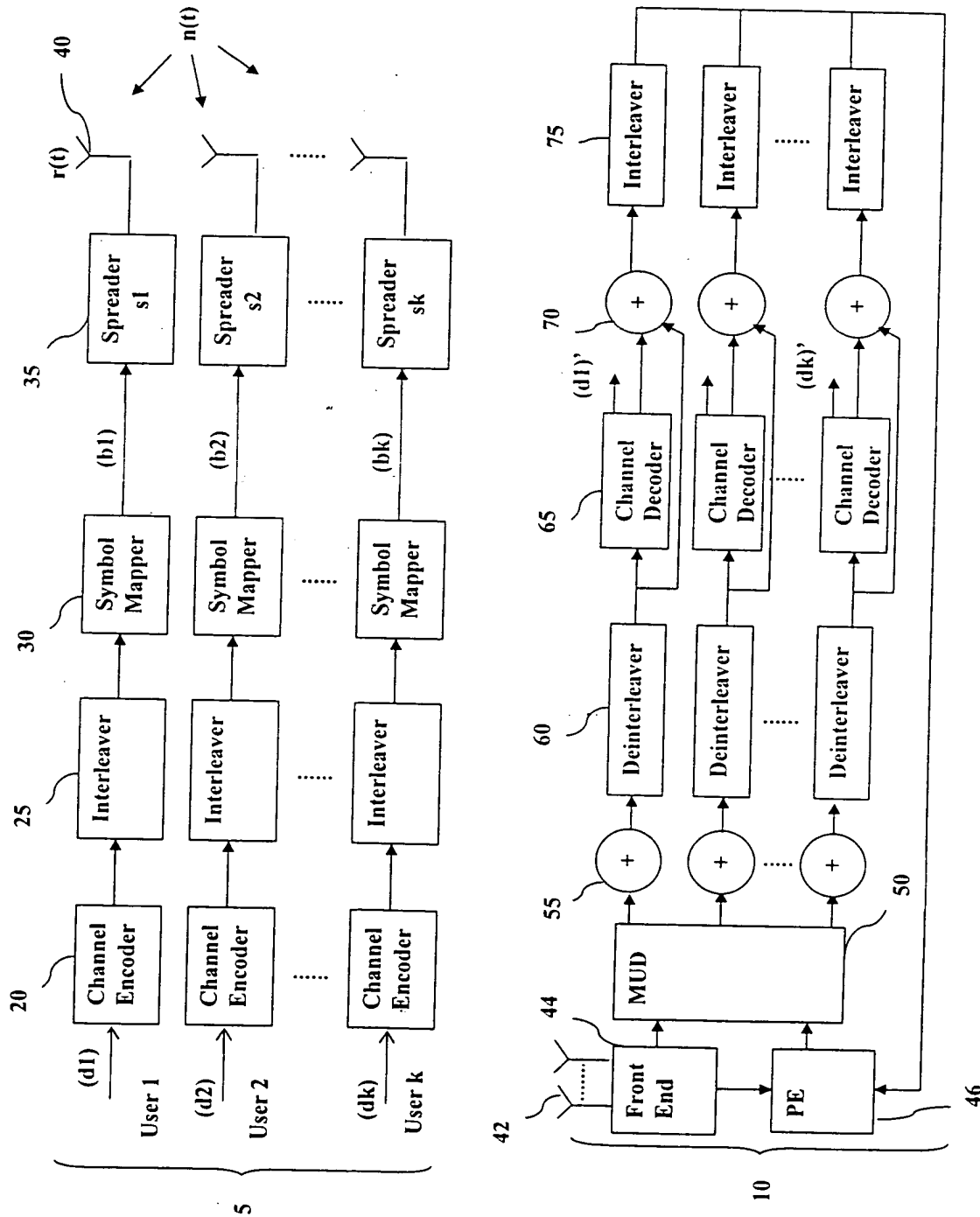


Figure 1
(Prior Art)

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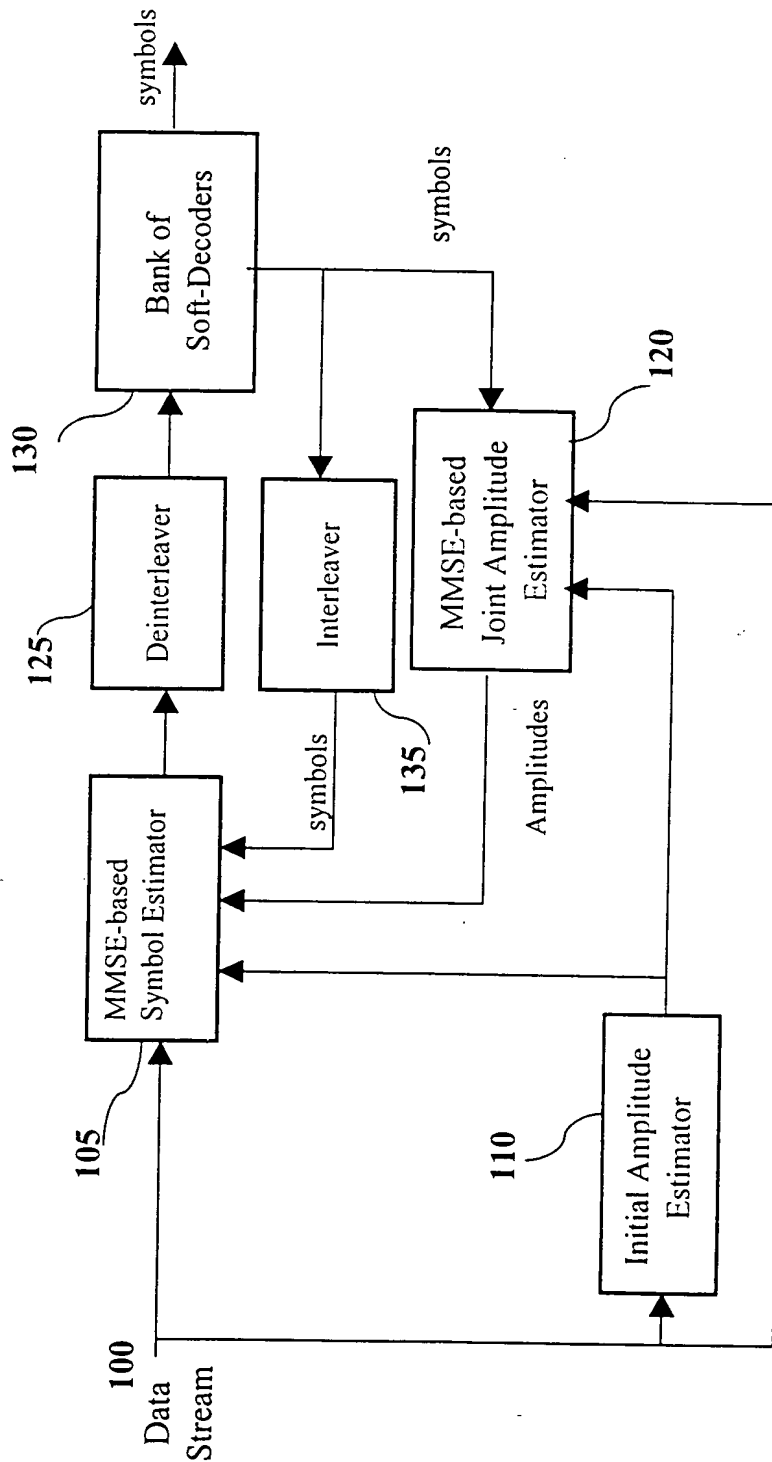


Figure 2

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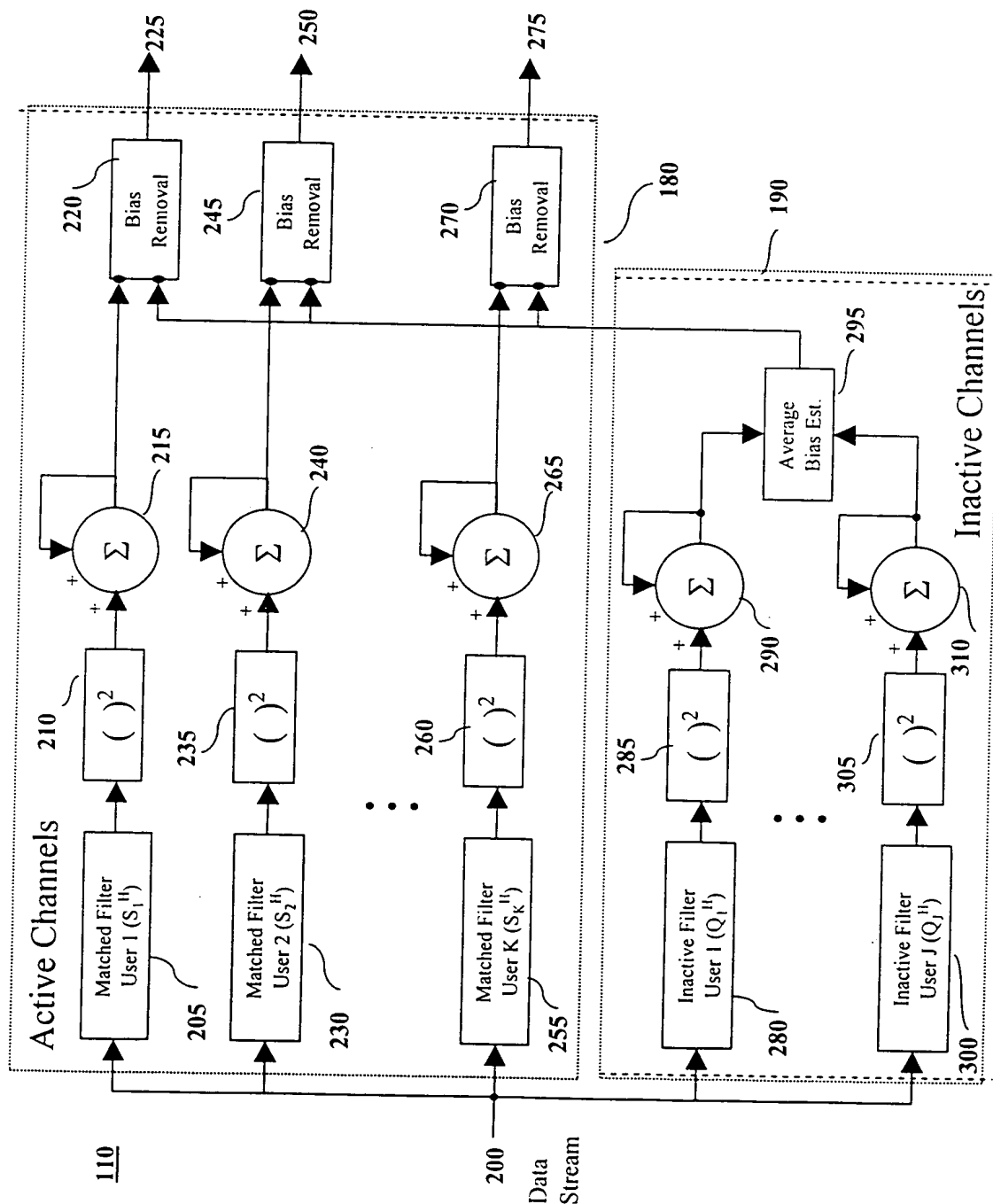


Figure 3

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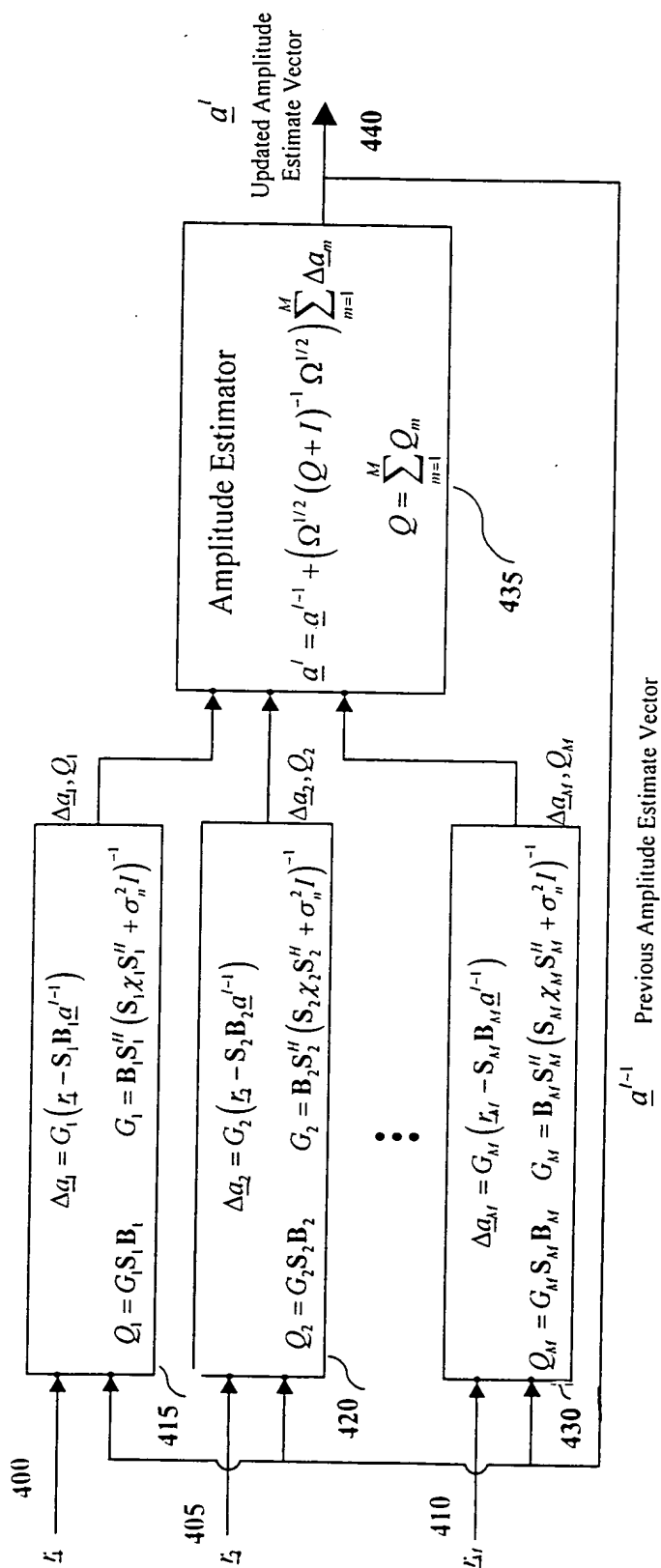


Figure 4

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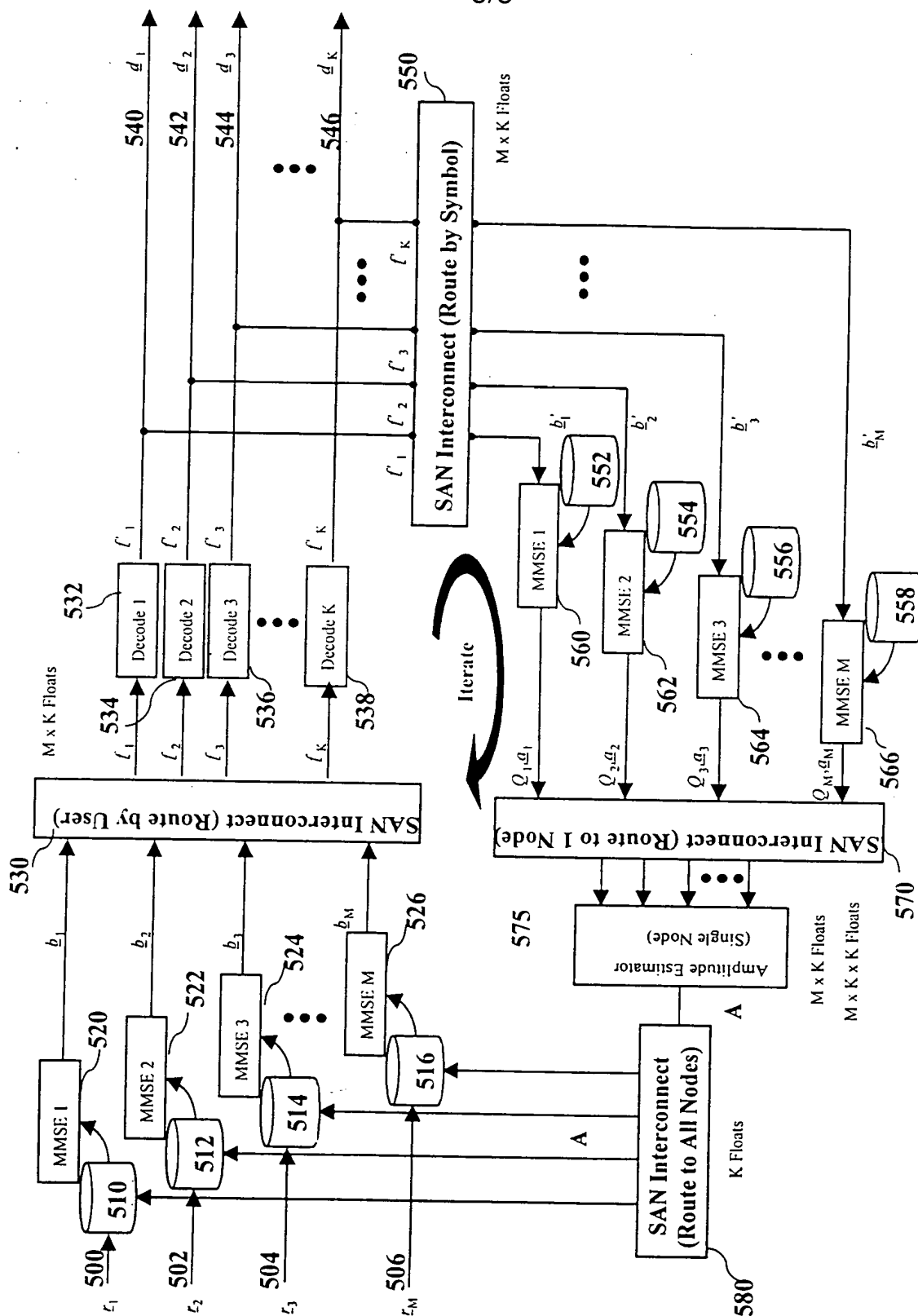


Figure 5

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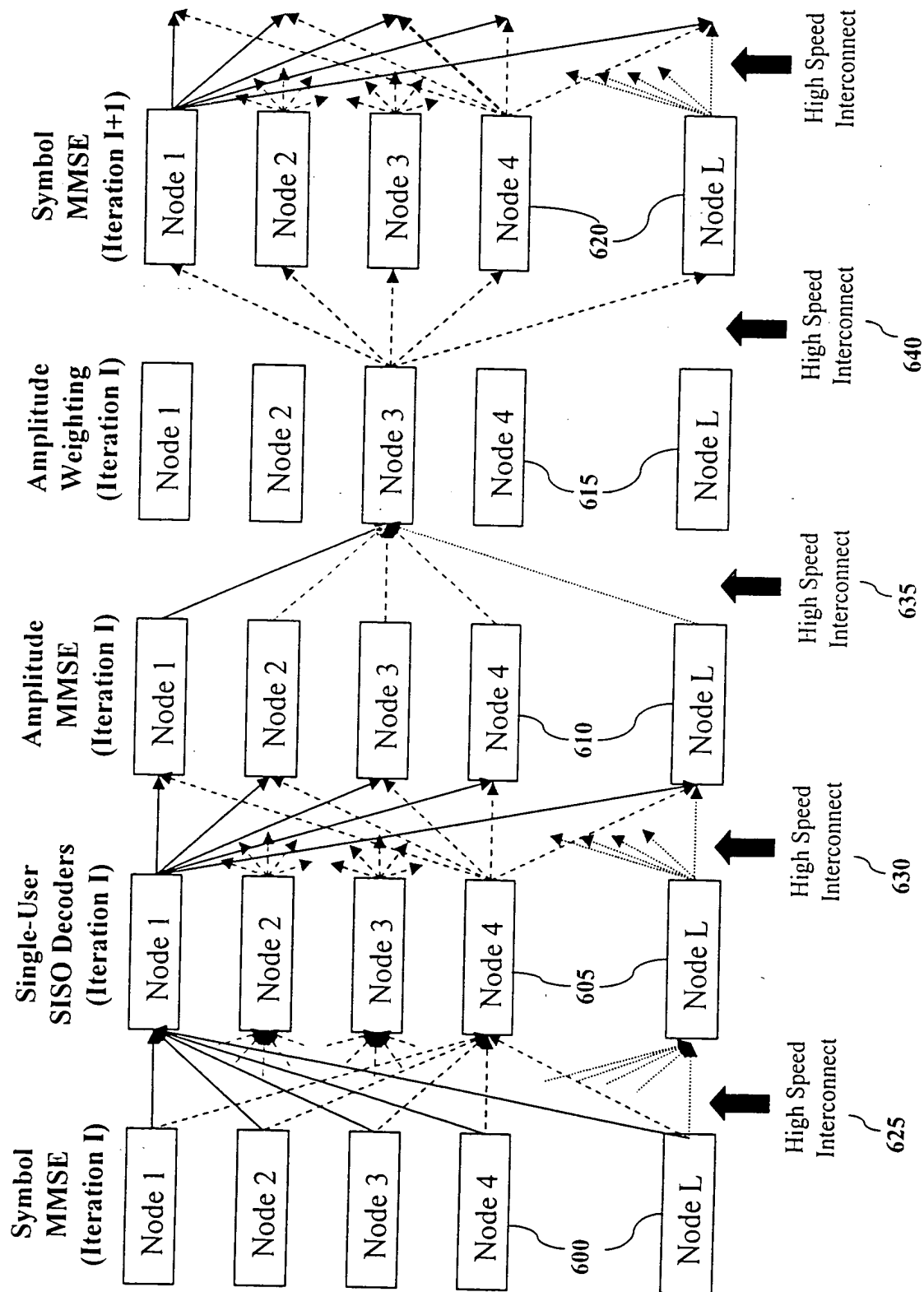


Figure 6

PCT/US03/38190

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Sheet No. 6/6

Box No. VII (iv) **DECLARATION: INVENTORSHIP** (only for the purposes of the designation of the United States of America)
The declaration must conform to the following standardized wording provided for in Section 214; see Notes to Boxes Nos. VIII, VIII (i) to (v)
(In general) and the specific Notes to Box No. VIII (iv). If this Box is not used, this sheet should not be included in the request.

**Declaration of inventorship (Rules 4.17(iv) and 51bis.1(u)(iv))
for the purposes of the designation of the United States of America:**

I hereby declare that I believe I am the original, first and sole (if only one inventor is listed below) or joint (if more than one inventor is listed below) inventor of the subject matter which is claimed and for which a patent is sought.

This declaration is directed to the international application of which it forms a part (if filing declaration with application).

This declaration is directed to international application No. PCT/..... (if furnishing declaration pursuant to Rule 26ter).

I hereby declare that my residence, mailing address, and citizenship are as stated next to my name.

I hereby state that I have reviewed and understand the contents of the above-identified international application, including the claims of said application. I have identified in the request of said application, in compliance with PCT Rule 4.10, any claim to foreign priority, and I have identified below, under the heading "Prior Applications," by application number, country or Member of the World Trade Organization, day, month and year of filing, any application for a patent or inventor's certificate filed in a country other than the United States of America, including any PCT international application designating at least one country other than the United States of America, having a filing date before that of the application on which foreign priority is claimed.

Prior Applications:

I hereby acknowledge the duty to disclose information that is known by me to be material to patentability as defined by 37 C.F.R. § 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the PCT international filing date of the continuation-in-part application.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Mailing Address: 21 Sarah Drive, Merrimack, NH 03054

Citizenship: USA

Inventor's Signature:
(if not contained in the request, or if declaration is corrected or added under Rule 26ter after the filing of the international application. The signature must be that of the inventor, not that of the agent)

Date:
(of signature which is not contained in the request, or of the declaration that is corrected or added under Rule 26ter after the filing of the international application)

Name:

Residence:
(city and either US state, if applicable, or country)

Mailing Address:

Citizenship:

Inventor's Signature:
(if not contained in the request, or if declaration is corrected or added under Rule 26ter after the filing of the international application. The signature must be that of the inventor, not that of the agent)

Date:
(of signature which is not contained in the request, or of the declaration that is corrected or added under Rule 26ter after the filing of the international application)

☐ This declaration is continued on the following sheet, "Continuation of Box No. VIII (iv)".

PCT

GENERAL POWER OF ATTORNEY

(for several international applications filed under the Patent Cooperation Treaty)

(PCT Rule 90.5)

The undersigned person(s) :

(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

BAE SYSTEMS Information and Electronic Systems Integration Inc.

65 Spit Brook Road

Nashua, NH 03061

United States of America

hereby appoint(s) the following person as:

☒ agent

☐ common representative

Name and address

(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

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MALONEY, Neil F., USPTO Reg. No. 42,833

LONG, Daniel J., USPTO Reg. No. 29,404

CERNOTA, Andrew P., USPTO Reg. No. 52,711

Maine & Asmus

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United States of America

to represent the undersigned before

☒ all the competent International Authorities

☐ the International Searching Authority only

☐ the International Preliminary Examining Authority only

in connection with any and all international applications filed by the undersigned with the following Office

US

and to make or receive payments on behalf of the undersigned. _____ as receiving Office

Signature(s) (where there are several persons, each of them must sign; next to each signature, indicate the name of the person signing and the capacity in which the person signs, if such capacity is not obvious from reading this power):


Kevin M. Perkins

Vice President and Secretary

Date:

 3 June 2003

PCT

GENERAL POWER OF ATTORNEY

(for several international applications filed under the Patent Cooperation Treaty)

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United States of America

hereby appoint(s) the following person us:

☐

agent

☒

common representative

Name and address

(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

BAE SYSTEMS Information and Electronic Systems Integration Inc.
65 Spit Brook Road
Nashua, NH 03061
United States of America

to represent the undersigned before

☒

all the competent International Authorities

☐

the International Searching Authority only

☐

the International Preliminary Examining Authority only

in connection with any and all international applications filed by the undersigned with the following Office

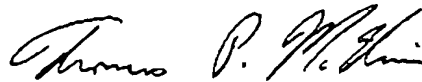
US

as receiving Office

and to make or receive payments on behalf of the undersigned.

Signature(s) (where there are several persons, each of them must sign; next to each signature, indicate the name of the person signing and the capacity in which the person signs, if such capacity is not obvious from reading this power):

Thomas P. McElwain



11/25/2003

Date:

11/25/2003

PATENT APPLICATION SERIAL NO. 10/531772

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

04/25/2005 MKAYPAGH 00000030 10531772

01 FC:1631	300.00 DA
02 FC:1641	100.00 DA
03 FC:1633	200.00 DA
04 FC:1615	500.00 DA
05 FC:1614	600.00 DA

PTO-1556
(5/87)

PATENT APPLICATION FEE DETERMINATION RECORD

Effective December 8, 2004

Application or Docket Number

10/531772

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
U.S. NATIONAL STAGE FEES		
BASIC FEE	SMALL ENT. = \$ 150	LARGE ENT. = \$ 300
EXAMINATION FEE	Satisfies PCT Article 33(1)-(4) = \$ 50 / \$ 100	All other situations = \$ 100 / \$ 200
SEARCH FEE	U.S. is ISA = \$ 50 / \$ 100 ALL other countries = \$ 200 / \$ 400	All other situations = \$ 250 / \$ 500
FEE FOR EXTRA SPEC. PGS.	minus 100 =	/ 50 =
TOTAL CHARGEABLE CLAIMS	30 minus 20 =	10
INDEPENDENT CLAIMS	6 minus 3 =	3
MULTIPLE DEPENDENT CLAIM PRESENT ☐		

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐

OR

OTHER THAN SMALL ENTITY

RATE	FEE		RATE	FEE
BASIC FEE		OR	BASIC FEE	300
EXAM. FEE			EXAM. FEE	200
SEARCH FEE			SEARCH FEE	400
X \$ 125 =			X \$ 250 =	
X \$ 25 =		OR	X \$ 50 =	500
X \$ 100 =		OR	X \$ 200 =	600
+ \$ 180 =		OR	+ \$ 360 =	
TOTAL		OR	TOTAL	

CLAIMS AS AMENDED - PART II

	(Column 1)	(Column 2)	(Column 3)
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	*	Minus	**
Independent	*	Minus	***
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM ☐			

SMALL ENTITY

OR

OTHER THAN SMALL ENTITY

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X \$ 25 =		OR	X \$ 50 =	
X \$ 100 =		OR	X \$ 200 =	
+ \$ 180 =		OR	+ \$ 360 =	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

	(Column 1)	(Column 2)	(Column 3)
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	*	Minus	**
Independent	*	Minus	***
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM ☐			

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X \$ 25 =		OR	X \$ 50 =	
X \$ 100 =		OR	X \$ 200 =	
+ \$ 180 =		OR	+ \$ 360 =	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than "20", enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than "3", enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

APPLICATION DATA SHEET JC13 Rec'd PCT/PTO 19 APR 2005

Electronic Version v14

Stylesheet Version v14.1

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Country of Mailing Address:	US
Phone:	
Fax:	
E-mail:	

Correspondence Information:

Customer Number:	42716	*42716*
------------------	-------	---------

Application Information:

Title of Invention:	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR
Application Type:	regular, utility
Attorney Docket Number:	20030076-US

Botanic Information:

Publication Information:

Suggested Figure for Publication - 2

Suggested Classification -
Suggested Technology Center -
Total Number of Drawing Sheets - 6

Representative Information:

practitioner(s) at Customer Number:

42716

42716

as my attorney(s) or agent(s) to prosecute the application identified above, and to transact all business in the United States Patent and Trademark Office connected therewith.

Domestic Priority Information:

This is a National Stage of US application number PCT/US2003/038190, filed 2003-11-25, now Pending.

US application number PCT/US2003/038190, filed 2003-11-25 is a Non-Provisional of US application number 60/462,657, filed 2003-04-14, now Expired.

*Foreign Priority Information:**Assignee Information:*Assignee 1:

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Bib Data Sheet

CONFIRMATION NO. 6021

SERIAL NUMBER 10/531,772	FILING OR 371(c) DATE 04/19/2005 RULE	CLASS 709	GROUP ART UNIT 2157	ATTORNEY DOCKET NO. 20030076-US	
APPLICANTS Thomas P. McElwain, Merrimack, NH;					
** CONTINUING DATA ***** This application is a 371 of PCT/US03/38190 11/25/2003 which claims benefit of 60/462,657 04/14/2003 ** FOREIGN APPLICATIONS *****					
Foreign Priority claimed ☐ yes ☐ no 35 USC 119 (a-d) conditions ☐ yes ☐ no ☐ Met after Allowance Verified and Acknowledged _____ Examiner's Signature _____ Initials _____		STATE OR COUNTRY NH	SHEETS DRAWING 6	TOTAL CLAIMS 30	INDEPENDENT CLAIMS 6
ADDRESS 42716					
TITLE Joint symbol, amplitude, and rate estimator					
FILING FEE RECEIVED 1700	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		

**MULTIPLE DEPENDENT CLAIM
FEE CALCULATION SHEET**
(FOR USE WITH FORM PTO-875)

SERIAL NO.

10/531772

FILING DATE

APPLICANT(S)

CLAIMS

	AS FILED		AFTER 1 st AMENDMENT		AFTER 2 nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
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TOTAL IND.	6					
TOTAL DEP.	24					
TOTAL CLAIMS	30					

	AS FILED		AFTER 1 st AMENDMENT		AFTER 2 nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
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TOTAL DEP.						
TOTAL CLAIMS						

DO/ EO WORKSHEET

Paralegal/ National Stage Division

U.S. Appl. No. 10/531722International Appl. No. 052003/038190Application filed by : ☐ 20 months ☒ 30 months

WIPO PUBLICATION INFORMATION :

Publication No.: WO2004/095713Publication Language : ☒ English ☐ German ☐ Japanese ☐ Chinese ☐ Korean
☐ French ☐ Spanish ☐ Russian ☐ Other : _____Publication Date : 04.10.04Not Published : ☐ U.S. only designated ☐ EP requestPublished : ☐ EP request

INTERNATIONAL APPLICATION PAPERS IN THE APPLICATION FILE :

☒ International Application (RECORD COPY)☐ PCT/IB/331☐ Article 19 Amendments☒ Request form PCT/RO/101☐ PCT/IPEA/409 IPER : ☐ EP ☐ JP ☐ SE ☐ AU☒ PCT/ISA/210 - Search Report : ☐ EP ☐ JP ☐ SE ☐ AU☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ _____☒ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ _____☐ Annexes to 409☐ Search Report References☒ Priority Document (s) No. 1☐ Other : _____

RECEIPTS FROM THE APPLICANT (other than checked above) :

☒ Basic National Fee (or authorization to charge)☐ Preliminary Amendment(s) Filed on :☒ Description ☒ Claims ☒ Abstract☐ Information Disclosure Statement(s) Filed on :☒ Drawing Figure(s) - (# of drwgs. 6)☐ Assignment Document (forwarded to Assignment Branch)☐ Translation of Article 19 Amendments☐ Assignee PG Publication Notice☐ entered ☐ not entered :☐ Substitute Specification Filed on :☐ not a page for page substitution
☐ replaced by Article 34 Amendment

1. _____ 2. _____

☐ Annexes to 409☐ Verified Small Status Statement☐ entered ☐ not entered :☒ Oath/ Declaration (executed)☐ not a page for page substitution
☐ other : _____☐ DNA Diskette ☐ Sequence Listing☐ Application Data Sheet☐ Other : _____☒ Power of Attorney/ Change of Address

NOTES :

☐ I.A. used as Specification ☐ Other :

35 U.S.C. 371 - Receipt of Request (PTO-1390)

Date Acceptable Oath/ Declaration Received.

Date of Completion of requirements under 35 U.S.C. 371

Date of Completion of ALL requirements (no EP requested)

Date of Completion of DO/ EO 903 - Notification of Acceptance

Date of Completion of DO/ EO 905 - Notification of Missing Requirements

Date of Completion of DO/ EO 909 - Notification of Abandonment

Date of Completion of DO/ EO 916 - Notification of Defective Response

Date of Completion of DO/ EO 922

Date of Completion of DO/ EO 923

PCT REQUEST

1/8 b

20030076-PCT

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0	For receiving Office use only	
0-1	International Application No.	
0-2	International Filing Date	
0-3	Name of receiving Office and "PCT International Application"	
0-4	Form - PCT/RO/101 PCT Request	
0-4-1	Prepared using	PCT-EASY Version 2.92 (updated 01.11.2003)
0-5	Petition The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	Receiving Office (specified by the applicant)	United States Patent and Trademark Office (USPTO) (RO/US)
0-7	Applicant's or agent's file reference	20030076-PCT
I	Title of invention	JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR
II	Applicant	
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II-5	Address:	65 Spit Brook Road Nashua, NH 03061 United States of America
II-6	State of nationality	US
II-7	State of residence	US
II-8	Telephone No.	603-885-3751
II-9	Facsimile No.	603-885-2167
III-1	Applicant and/or inventor	
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III-1-4	Name (LAST, First)	MCELWAIN, Thomas, P.
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III-1-7	State of residence	US

PCT REQUEST

2/56

20030076-PCT

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IV-1	Agent or common representative; or address for correspondence The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
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IV-1-5	Agent's registration No.	42,269
IV-2	Additional agent(s)	additional agent(s) with same address as first named agent
IV-2-1	Name(s)	MAINE, Vernon, C. (37,389); MALONEY, Neil, F. (42,833); CERNOTA, Andrew, P. (52,711)
V	Designation of States	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	AP: BW GH GM KE LS MW MZ SD SL SZ TZ UG ZM ZW and any other State which is a Contracting State of the Harare Protocol and of the PCT EA: AM AZ BY KG KZ MD RU TJ TM and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT EP: AT BE BG CH&LI CY CZ DE DK EE ES FI FR GB GR HU IE IT LU MC NL PT RO SE SI SK TR and any other State which is a Contracting State of the European Patent Convention and of the PCT OA: BF BJ CF CG CI CM GA GN GQ GW ML MR NE SN TD TG and any other State which is a member State of OAPI and a Contracting State of the PCT

PCT REQUEST

3/56

20030076-PCT

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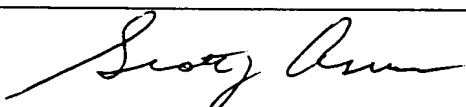
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	AE AG AL AM AT (patent and utility model) AU AZ BA BB BG BR BW BY BZ CA CH&LI CN CO CR CU CZ (patent and utility model) DE (patent and utility model) DK (patent and utility model) DM DZ EC EE (patent and utility model) EG ES FI (patent and utility model) GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX MZ NI NO NZ OM PG PH PL PT (patent and utility model) RO RU SC SD SE SG SK (patent and utility model) SL SY TJ TM TN TR TT TZ UA UG US UZ VC VN YU ZA ZM ZW
V-5	Precautionary Designation Statement In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.	
V-6	Exclusion(s) from precautionary designations	NONE
VI-1	Priority claim of earlier national application	
VI-1-1	Filing date	14 April 2003 (14.04.2003)
VI-1-2	Number	60/462,657
VI-1-3	Country	US
VI-2	Priority document request The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	VI-1
VII-1	International Searching Authority Chosen	United States Patent and Trademark Office (USPTO) (ISA/US)

PCT REQUEST

4/56

20030076-PCT

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VIII	Declarations	Number of declarations	
VIII-1	Declaration as to the identity of the inventor	-	
VIII-2	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent	-	
VIII-3	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application	-	
VIII-4	Declaration of inventorship (only for the purposes of the designation of the United States of America)	-	
VIII-5	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty	-	
IX	Check list	number of sheets	electronic file(s) attached
IX-1	Request (including declaration sheets)	56	-
IX-2	Description	40	-
IX-3	Claims	7	-
IX-4	Abstract	1	EZABST00.TXT
IX-5	Drawings	6	-
IX-7	TOTAL	5260	
	Accompanying items	paper document(s) attached	electronic file(s) attached
IX-8	Fee calculation sheet	✓	-
IX-17	PCT-EASY diskette	-	Diskette
IX-19	Figure of the drawings which should accompany the abstract	2	
IX-20	Language of filing of the international application	English	
X-1	Signature of applicant, agent or common representative		
X-1-1	Name (LAST, First)	ASMUS, Scott, J.	

FOR RECEIVING OFFICE USE ONLY

10-1	Date of actual receipt of the purported international application	
10-2	Drawings:	
10-2-1	Received	
10-2-2	Not received	
10-3	Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application	
10-4	Date of timely receipt of the required corrections under PCT Article 11(2)	
10-5	International Searching Authority	ISA/US
10-6	Transmittal of search copy delayed until search fee is paid	

PCT REQUEST

5/5b

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20030076-PCT

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11-1	Date of receipt of the record copy by the International Bureau	
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Box No. VIII (iv) DECLARATION: INVENTORSHIP (only for the purposes of the designation of the United States of America)
 The declaration must conform to the following standardized wording provided for in Section 214; see Notes to Boxes Nos. VIII, VIII (i) to (v) (in general) and the specific Notes to Box No. VIII (iv). If this Box is not used, this sheet should not be included in the request.

**Declaration of inventorship (Rules 4.17(iv) and 51bis.1(u)(iv))
 for the purposes of the designation of the United States of America:**

I hereby declare that I believe I am the original, first and sole (if only one inventor is listed below) or joint (if more than one inventor is listed below) inventor of the subject matter which is claimed and for which a patent is sought.

This declaration is directed to the international application of which it forms a part (if filing declaration with application).

This declaration is directed to international application No. PCT/..... (if furnishing declaration pursuant to Rule 26ter).

I hereby declare that my residence, mailing address, and citizenship are as stated next to my name.

I hereby state that I have reviewed and understand the contents of the above-identified international application, including the claims of said application. I have identified in the request of said application, in compliance with PCT Rule 4.10, any claim to foreign priority, and I have identified below, under the heading "Prior Applications," by application number, country or Member of the World Trade Organization, day, month and year of filing, any application for a patent or inventor's certificate filed in a country other than the United States of America, including any PCT international application designating at least one country other than the United States of America, having a filing date before that of the application on which foreign priority is claimed.

Prior Applications:

I hereby acknowledge the duty to disclose information that is known by me to be material to patentability as defined by 37 C.F.R. § 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the PCT international filing date of the continuation-in-part application.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name: Thomas P. McElwain *Thomas P. McElwain* 11/25/2003

Residence: 21 Sarah Drive, Merrimack, NH 03054
 (city and either US state, if applicable, or country)

Mailing Address: 21 Sarah Drive, Merrimack, NH 03054

Citizenship: USA

Inventor's Signature:
 (if not contained in the request, or if declaration is corrected or added under Rule 26ter after the filing of the international application. The signature must be that of the inventor, not that of the agent)

Date:
 (of signature which is not contained in the request, or of the declaration that is corrected or added under Rule 26ter after the filing of the international application)

Name:

Residence:
 (city and either US state, if applicable, or country)

Mailing Address:

Citizenship:

Inventor's Signature:
 (if not contained in the request, or if declaration is corrected or added under Rule 26ter after the filing of the international application. The signature must be that of the inventor, not that of the agent)

Date:
 (of signature which is not contained in the request, or of the declaration that is corrected or added under Rule 26ter after the filing of the international application)

☐ This declaration is continued on the following sheet, "Continuation of Box No. VIII (iv)".

PCT (ANNEX - FEE CALCULATION SHEET)

20030076-PCT

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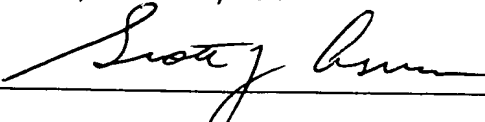
(This sheet is not part of and does not count as a sheet of the international application)

0	For receiving Office use only	
0-1	International Application No.	
0-2	Date stamp of the receiving Office	
0-4	Form - PCT/RO/101 (Annex) PCT Fee Calculation Sheet	
0-4-1	Prepared using	PCT-EASY Version 2.92 (updated 01.11.2003)
0-9	Applicant's or agent's file reference	20030076-PCT
2	Applicant	BAE SYSTEMS INFORMATION AND ELECTRONIC SYSTEMS INTEGRATION INC., et al.
12	Calculation of prescribed fees	fee amount/multiplier Total amounts (USD)
12-1	Transmittal fee T	⇒ 240
12-2-1	Search fee S	⇒ 700
12-2-2	International search to be carried out by	US
12-3	International fee	
	Basic fee (first 30 sheets) b1	476
12-4	Remaining sheets	2930
12-5	Additional amount (X)	12
12-6	Total additional amount b2	360 348
12-7	b1 + b2 = B	836 824
12-8	Designation fees	
	Number of designations contained in international application	99
12-9	Number of designation fees payable (maximum 5)	5
12-10	Amount of designation fee (X)	104
12-11	Total designation fees D	520
12-12	PCT-EASY fee reduction R	-148
12-13	Total International fee (B+D-R) I	⇒ 1,208 ~~1,196~~
12-14	Fee for priority document	
	Number of priority documents requested	1
12-15	Fee per document (X)	20
12-16	Total priority document fee P	⇒ 20
12-17	TOTAL FEES PAYABLE (T+S+I+P)	⇒ 2,156 2,168
12-19	Mode of payment	authorization to charge deposit account
12-20	Deposit account instructions The receiving Office:	United States Patent and Trademark Office (USPTO) (RO/US)
12-20-1	Authorization to charge the total fees indicated above.	✓

PCT (ANNEX - FEE CALCULATION SHEET)

20030076-PCT

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12-20-2	Authorization to charge any deficiency or credit any overpayment in the total fees indicated above.	✓
12-20-3	Authorization to charge the fee for priority document.	✓
12-21	Deposit account No.	190130
12-22	Date	25 November 2003 (25.11.2003)
12-23	Name and signature	ASMUS, Scott, J. 

VALIDATION LOG AND REMARKS

13-2-7	Validation messages Contents	Yellow! The power of attorney or a copy of the general power of attorney will need to be furnished unless all applicants sign the request form.
13-2-9	Validation messages Payment	Green? Please ensure that you have a valid deposit account with the receiving Office selected.

PCT COOPERATION TREATY

PCT

NOTIFICATION OF RECEIPT OF
RECORD COPY

(PCT Rule 24.2(a))

From the INTERNATIONAL BUREAU

To:

ASMUS, Scott, J.
PO Box 3445
Nashua, NH 03061-3445
United States of America

CLIENT:

JOB#

RCVD

RSPBY:

RCVDBY:

FSUM:

CAL:

DKT:

NOTICE:

T/S

Date of mailing (day/month/year)

16 February 2004 (16.02.2004)

IMPORTANT NOTIFICATION

Applicant's or agent's file reference

20030076-PCT

International application No.

PCT/US2003/038190

The applicant is hereby **notified** that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

BAE SYSTEMS INFORMATION AND ELECTRONIC SYSTEMS INTEGRATION INC. (for all
designated States except US)
MCELWAIN, Thomas, P. (for US)

International filing date : 25 November 2003 (25.11.2003)

Priority date(s) claimed : 14 April 2003 (14.04.2003)

Date of receipt of the record copy
by the International Bureau : 09 February 2004 (09.02.2004)

List of designated Offices :

AP : BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW

EA : AM, AZ, BY, KG, KZ, MD, RU, TJ, TM

EP : AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR

OA : BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG

National : AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS,
LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL,
SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 338.71.40

Authorized officer:

Fanny AGRATI

Telephone No. (41-22) 338 9644

Continuation of Form PCT/IB/301

NOTIFICATION OF RECEIPT OF RECORD COPY

Date of mailing (day/month/year) 16 February 2004 (16.02.2004)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference 20030076-PCT	International application No. PCT/US2003/038190

ATTENTION

The applicant should carefully check the data appearing in this Notification. In case of any discrepancy between these data and the indications in the international application, the applicant should immediately inform the International Bureau.

In addition, the applicant's attention is drawn to the information contained in the Annex, relating to:

- ☒ time limits for entry into the national phase - **see updated important information (as of April 2002)**
- ☐ confirmation of precautionary designations (if applicable)
- ☐ requirements regarding priority documents (if applicable)

A copy of this Notification is being sent to the receiving Office and to the International Searching Authority.

INFORMATION ON TIME LIMITS FOR ENTERING THE NATIONAL PHASE

The applicant is reminded that the **"national phase"** must be entered before each of the designated Offices indicated on the cover sheet of this Notification by paying national fees and furnishing translations, as prescribed by Articles 22 and 39 and the applicable national laws. In addition, the applicant may also have to comply with other special requirements applicable in certain Offices. It is the applicant's responsibility to ensure the necessary steps to enter the national phase are taken in a timely fashion. Most Offices do not issue reminders to applicants in connection with the entry into the national phase.

The applicable time limit for entering the national phase will, subject to what is said in the following paragraph, be **30 MONTHS** from the priority date, not only in respect of any elected Office where a demand for international preliminary examination is filed before the expiration of 19 months from the priority date (see Article 39(1)), but also in respect of any designated Office, in the absence of filing of such demand, where Article 22(1) as modified with effect from 1 April 2002 applies in respect of that designated Office. For further details, see PCT Gazette No. 44/2001 of 1 November 2001, pages 19926, 19932 and 19934, as well as the PCT Newsletter, October and November 2001 and February 2002 issues.

In practice, time limits other than the 30-month time limit will continue to apply, for various periods of time, in respect of certain designated or elected Offices. For regular updates on the applicable time limits (20, 21, 30 or 31 months, or other time limit), Office by Office, refer to the PCT Gazette ("Section IV" part published on a weekly basis), to the PCT Newsletter (on a monthly basis) and to the relevant National Chapters in Volume II of the PCT Applicant's Guide (the paper version of which is updated usually twice a year and the Internet version of which is updated usually on a weekly basis). Finally, a cumulative table of all applicable time limits for entering the national phase is available from WIPO's Internet site, via links from various pages the site including those of the Gazette, Newsletter and Guide, at <http://www.wipo.int/pct/en/index.html>.

Information about the requirements for filing a demand for international preliminary examination is set out in the PCT Applicant's Guide, Volume I/A, Chapter IX. Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination (at present, all PCT Contracting States are bound by Chapter II).

CONFIRMATION OF PRECAUTIONARY DESIGNATIONS

This notification lists only specific designations made under Rule 4.9(a) in the request. It is important to check that these designations are correct. Errors in designations can be corrected where precautionary designations have been made under Rule 4.9(b). The applicant is hereby reminded that any precautionary designations may be confirmed according to Rule 4.9(c) before the expiration of 15 months from the priority date (this time limit may not be extended). If it is not confirmed, it will automatically be regarded as withdrawn by the applicant. There will be no reminder and no invitation. Confirmation of a designation consists of the filing of a notice specifying the designated State concerned (with indication of the kind of protection or treatment desired) and the payment of the designation and confirmation fees. The Notice of confirmation and payment must reach the receiving Office within the 15-month time limit.

REQUIREMENTS REGARDING PRIORITY DOCUMENTS

For applicants who have not yet complied with the requirements regarding priority documents, the following is recalled.

Where the priority of an earlier national, regional or international application is claimed, the applicant must submit a copy of the said earlier application, certified by the authority with which it was filed ("the priority document") to the receiving Office (which will transmit it to the International Bureau) or directly to the International Bureau, before the expiration of 16 months from the priority date, provided that any such priority document may still be submitted to the International Bureau before that date of international publication of the international application, in which case that document will be considered to have been received by the International Bureau on the last day of the 16-month time limit (Rule 17.1(a)).

Where the priority document is issued by the receiving Office, the applicant may, instead of submitting the priority document, request the receiving Office to prepare and transmit the priority document to the International Bureau. Such request must be made before the expiration of the 16-month time limit and may be subjected by the receiving Office to the payment of a fee (Rule 17.1(b)).

If the priority document concerned is not submitted to the International Bureau or if the request to the receiving Office to prepare and transmit the priority document has not been made (and the corresponding fee, if any, paid) within the applicable time limit indicated under the preceding paragraphs, any designated State may disregard the priority claim, provided that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within the time limit which is reasonable under the circumstances.

Where several priorities are claimed, the priority date to be considered for the purposes of computing the 16-month time limit is the filing date of the earliest application whose priority is claimed.

531, 772
10/531772

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
4 November 2004 (04.11.2004)

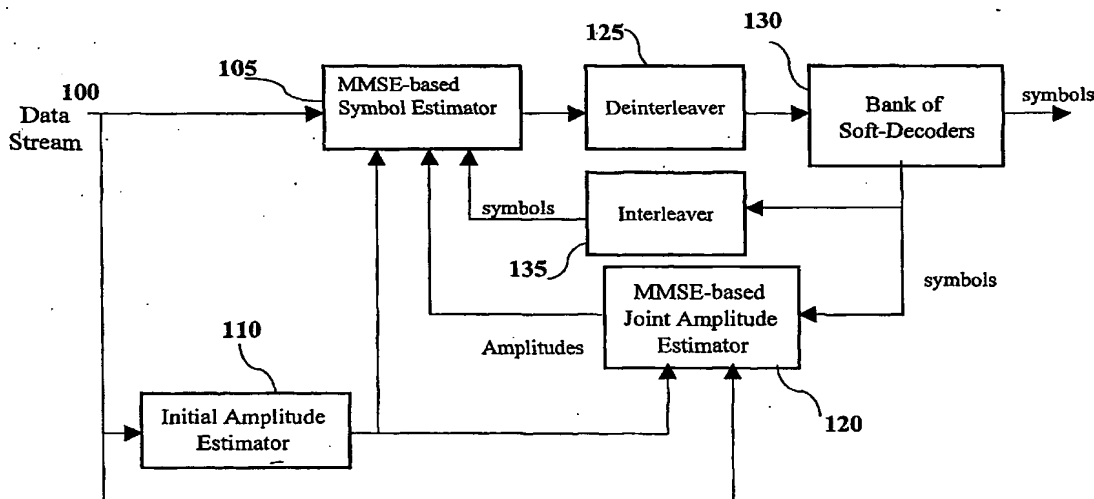
PCT

(10) International Publication Number
WO 2004/095713 A2

- (51) International Patent Classification?: **H04B**
- (21) International Application Number:
PCT/US2003/038190
- (22) International Filing Date:
25 November 2003 (25.11.2003)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
60/462,657 14 April 2003 (14.04.2003) US
- (71) Applicant (for all designated States except US): **BAE SYSTEMS INFORMATION AND ELECTRONIC SYSTEMS INTEGRATION INC.** [US/US]; 65 Spit Brook Road, Nashua, NH 03061 (US).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): **MCELWAIN, Thomas, P.** [US/US]; 21 Sarah Drive, Merrimack, NH 03054 (US).
- (74) Agents: **ASMUS, Scott, J. et al.**; PO Box 3445, Nashua, NH 03061-3445 (US).
- (81) Designated States (*national*): AE, AG, AL, AM, AT (utility model), AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ (utility model), CZ, DE (utility model), DE, DK (utility model), DK, DM, DZ, EC, EE (utility model), EE, EG, ES, FI (utility model), FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT (utility model), PT, RO, RU, SC, SD, SE, SG, SK (utility model), SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (*regional*): ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Declaration under Rule 4.17:**
— of inventorship (Rule 4.17(iv)) for US only
- Published:**
— without international search report and to be republished upon receipt of that report

[Continued on next page]

(54) Title: **JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR**



(57) Abstract: The system in one embodiment relates to tightly integrating parameter estimation, symbol hypothesis testing, decoding, and rate identification. The present invention provides Turbo-decoding for joint signal demodulation based on an iterative decoding solution that exploits error correction codes. The system iteratively couples an initial amplitude estimator, a symbol estimator, a bank of decoders, and a joint amplitude estimator to produce the symbol estimates.



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

JOINT SYMBOL, AMPLITUDE, AND RATE ESTIMATOR

Inventor:
Thomas P. McElwain

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Applications No. 60/462657, filed April 14, 2003. This application is also related to U.S. Patent application Serial No. 10/105,918, filed March 25, 2002 entitled "System for Decreasing Processing Time in an Iterative Multi-User Detector System" (D4608); U.S. Patent Application Serial No. 10/414,738 filed April 16, 2003 entitled "System and Method for Increasing Throughput in a Multiuser Detection Based Multiple Access Communications System" (D4615); and U.S. Patent Application Serial No. 10/208409 entitled "Power and Confidence Ordered Low Complexity Soft TurboMUD with Voting System" (D-4627US). Each of these applications is herein incorporated in their entirety by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to communications and more particularly to co-channel communications, and more particularly to increasing capacity by allowing interfering channels.

BACKGROUND OF THE INVENTION

[0003] The telecommunications industry has been expanding at an unprecedented growth rate throughout the World. In particular, the wireless sector, including cell phones, PCS, wireless local area networks and Bluetooth such as IS95, GSM, 3G, IEEE 802.11a/b/g, and 802.16 has grown far beyond expectations and at a much higher rate than the fixed telecommunications (wired) counterpart. The ability to access data and communicate anywhere at anytime has enormous potential and commercial value.

[0004] The content of the wireless sector is also changing, with more and more data being transmitted, including Internet connectivity and live feeds. The usage involving personal digital assistants (PDA's) and even smart appliances have created new markets utilizing

wireless data communications. Despite advancements in wireless transmission and reception, there is a growing problem of extracting more information signals within a limited bandwidth.

[0005] Emerging multiple-access receiver processing procedures allow for multiple users to access the same communications medium to transmit or receive information. Multiple access communication systems allow the transmission of multiple digital data streams between multiple transmitting and receiving devices. However, since many users transmit energy on the same communications channel, a number of inherent difficulties arise, particularly when receivers attempt to detect the information associated with a particular user when there is heavy signal interference created by other users of the system at the same time. Typically the signal of interest cannot be received or the quality of reception is significantly degraded.

[0006] For example, a base station that processes a number of cellular devices has to receive and transmit data within a certain frequency range. The ability to extract the correct data from a given user is a difficult task when the effects of interference and multipaths are considered. The problem is further complicated when the number of users exceeds the number of dimensions (e.g. time slots, frequency slots, polarizations, etc), resulting in an overloaded condition.

[0007] In addition to the problems associated with multiple users in a given bandwidth, an additional problem is the inability to process the data in the receivers in real time. Advanced receiver techniques cover several areas, namely interference suppression (also called Multi-User Detection or MUD), multipath combining and space-time processing, equalization, and channel estimation. These various techniques can be mixed and matched depending upon the circumstances.

[0008] One way of alleviating some of the multiple access problems is to separate the interfering transmissions at the receiver using signal processing techniques. However, state of the art receivers are not capable of detecting and decoding the information associated with each user under conditions of heavy interference. Another solution to the co-channel interference problem is to decrease the number of users per channel. This, of course, is not an attractive option for telecommunication companies, since obtaining the

maximum number of users or managing peak volume transmission periods are important business objectives.

[0009] It should be understood that the discussion herein illustrates wireless cellular communications the multiple access topologies are equally applicable to wired cable systems and local area networks, read/write operations of a disc drive, satellite communications and any application that benefits from extracting digital information from among many multiple interfering signals.

[0010] Several techniques are used to improve results in co-channel multiple access communications systems. Frequency-Division Multiple Access (FDMA) assigns a different frequency to each user and parses an allocated band for a communication system wherein a single user's signal transmission power is concentrated into a single narrower radio frequency band. Interference from adjacent channels is limited by the use of band pass filters, however for each channel being assigned a different frequency system the total capacity is limited by the available frequency slots and by physical limitations imposed by frequency reuse. In a cellular telephone configuration this poses problems because all proximate cells must operate on different frequencies. However, frequency bands may be re-used, provided that the same frequency cells are positioned at a certain distance apart. A further drawback with FDMA schemes is that users will pay full-time for their assigned frequency regardless of their actual use of the system.

[0011] Code Division Multiple Access (CDMA) is another multiplexing technique wherein for each communication channel the signals are encoded using a sequence known to the transmitter and the receiver for that specific channel. In CDMA, all users use the same frequency at the same time. However, before transmission, the signal from each user is multiplied by a distinct signature waveform. The signature waveform is a signal that has a larger bandwidth than the information-bearing signal from the user. However, in a CDMA system, the total level of co-channel interference limits the number of active users at any instant of time.

[0012] In Time Division Multiple Access (TDMA) technology, multiple channels of data are temporally interleaved, i.e. each signal is assigned to a different time interval and the signals are transmitted individually, according to their assigned time slot. The TDMA

channel consists of a time slot or frame in a periodic train of time intervals over the same frequency, with a given signal's energy confined to one of these time slots. However, in a TDMA system, all transmitters and receivers must have access to a common clock, as time-synchronization among the users is required. Adjacent channel interference is limited by the use of a time gate or other synchronization element that only passes signal energy received at the proper time. The system capacity is limited by the available time slots (within a given frequency band) as well as by physical limitations imposed by frequency reuse, as each channel is assigned a different time slot within a particular frequency band.

[0013] One of the goals of FDMA and TDMA systems is to try and prevent two potentially interfering signals from occupying the same frequency at the same time. In contrast, Code Division Multiple Access (CDMA) techniques allow signals to overlap in both time and frequency. CDMA signals share the same frequency spectrum at the same time, hence, the CDMA signals appear to overlap one another. The scrambled signal format of CDMA virtually eliminates cross talk between interfering transmitters.

[0014] In a CDMA system, each signal is transmitted using spread spectrum techniques. The transmitted informational data stream is impressed upon a much higher rate data stream termed a signature sequence. The bit stream of the signature sequence data is typically binary, and can be generated using a pseudo-noise (PN) process that appears random, but can be replicated by an authorized receiver. The informational data stream and the high bit rate signature sequence stream are combined by multiplying the two bit streams together, assuming the binary values of the two bit streams are represented by +1 or -1. This combination of the higher bit rate signal with the lower bit rate data stream is called spreading the informational data stream signal. Each informational data stream or channel is allocated a unique signature sequence.

[0015] In operation, a stream of spread information signature signals are modulated by weights corresponding to the information that is to be transmitted. Some modulation examples include binary phase shift keying (BPSK) and quadrature phase shift keying (QPSK). If several transmitters modulate their data onto the signature waveform and modulate again with the carrier tone, a radio frequency (RF) signal comprised of a continuous stream of information modulated signature pulses will be present at the receiver, one corresponding to each transmitter. The plurality of transmitted signals and are

jointly received as a composite signal at the receiver. Each of the spread signals overlaps all of the other spread signals in time and frequency. Moreover, environmental noise as well as receiver electronic noise is also present in the measured received signal. The state of the art receiver correlates the composite noisy signal with one of the unique signature sequences, and the corresponding information signal is isolated and despread while the other signals appear as only small additions to the noise floor.

[0016] A signature sequence is often used to represent one bit of information. Receiving the transmitted sequence or its complement indicates whether the information bit is a +1 or -1, sometimes denoted "0" or "1". The signature sequence usually comprises N pulses, and each pulse is called a "chip". The entire N-chip sequence, or its complement, depending on the information bit to be conveyed, is referred to as a transmitted symbol.

[0017] The receiver correlates the received signal with the complex conjugate of the known signature sequence to produce a correlation value. When a 'large' positive correlation results, a "0" is detected, and when a 'large' negative correlation results, a "1" is detected.

[0018] It should be understood that the information bits could also be coded bits, where the code is a block or convolutional code. Also, the signature sequence can be much longer than a single transmitted symbol, in which case a subsequence of the signature sequence is used to spread the information bit.

[0019] The prior systems do not properly account for the real world mobile communication signals that suffer from signal degradation such as interference and multipath problems. The systems of the state of the art generally tended to make assumptions that all other interferers and multipaths were additive white Gaussian noise. However, this assumption is not accurate for co-channel interference and multipaths.

[0020] Multipath dispersion occurs when a signal proceeds to the receiver along not one but many paths so that the receiver encounters echoes having different and randomly varying delays and amplitudes. The receiver receives a composite signal of multiple versions of the transmitted symbol that have propagated along different paths, called rays, having different relative time. Each distinguishable ray has a certain relative time of arrival, a certain amplitude and phase, and as a result, the correlator outputs several smaller

spikes. RAKE receivers are well known and attempt to 'rake' together all the contributions to detect the transmitted symbol and recover the information bit.

[0021] Conventional RAKE receivers provide satisfactory performance for operation in the presence of multipath under ideal conditions however the signature sequence must be uncorrelated with time shifted versions of itself as well as various shifted versions of the signature sequences of the other CDMA signals. Co-channel interference refers to signals received from other users either directly or reflected. If one received signal corresponding to the signature sequence of interest has a non-negligible cross correlation with the received signal originating from another transmitter (a co-channel interferer), then the value measured at the receiver, e.g. the correlation value for the signal of interest, is corrupted. In other words, the correlation computed at the receiver that would be used to decode a particular signal of interest is overwhelmed by an interfering signal; this is referred to as the near-far problem. The interference caused by an echo of one transmitted symbol overlapping with the next transmitted symbol might also be non-negligible. If this is the case, the transmitted symbols interfere with past and future transmitted symbols. This is commonly referred to as intersymbol interference (ISI). In actuality, performance is degraded both by co-channel interference and ISI.

[0022] There has been much research to address signal interference with known multipath time dispersion. This is termed joint demodulation with no multipath and is further described in S. Verdu, "Minimum Probability of Error For Asynchronous Gaussian Multiple-Access Channels," IEEE Trans. Info. Theory, Vol. IT-32, pp. 85-96, R. Lupas and S. Verdu, "Linear multiuser detectors for synchronous code-division multiple-access channels," IEEE Trans. Inform. Theory, Vol. 35, pp. 123-136, Jan. 1989; and R. Lupas and S. Verdu, "Near-far resistance of multiuser detectors in asynchronous channels," IEEE Trans. Commun., Vol. 38, pp. 496-508, Apr. 1990.

[0023] There are a host of approaches for jointly demodulating any set of interfering digitally modulated signals, including multiple digitally modulated signals. Maximum Likelihood Sequence Estimation determines the most likely set of transmitted information bits for a plurality of digital signals without multipath time dispersion. The maximum likelihood joint demodulator is capable, in theory, of accommodating the largest number of interfering signals, but has a prohibitive computational complexity that makes it

unrealizable in practice. The decorrelation receiver is another, less computationally complex receiver processing approach that zeroes out or decorrelates the different signals so that they no longer interfere with one another. The decorrelator as well as virtually every other lower complexity joint demodulator, is not capable of operation when the number of signals is over a set threshold which falls significantly short of the theoretical maximum.

[0024] In a real world multi-user system, there are a number of independent users simultaneously transmitting signals. These transmissions have the real-time problems of multi-path and co-channel interference, fading, and dispersion that affect the received signals. As described in the prior art, multiple user systems communicate on the same frequency and at the same time by utilizing parameter and channel estimates that are processed by a multi-user detector. The output of the optimal multi-user detector operating within the multiuser capacity limits of the channel is an accurate estimation as to the individual bits for an individual user.

[0025] Moreover, in an article by Paul D. Alexander, Mark C. Reed, John A. Asenstorfer and Christian B. Schlager in IEEE Transactions on Communications, vol. 47, number 7, July 1999, entitled "Iterative Multi-User Interference Reduction: Turbo CDMA," a system is described in which multiple users can transmit coded information on the same frequency at the same time, with the multi-user detection system separating the scrambled result into interference-free voice or data streams.

[0026] Low complexity multiuser detector have been contemplated that use linear multiuser detectors to achieve optimal near-far resistance. (Near-Far Resistance of Multiuser Detectors for Coherent Multiuser Communications, R. Lupas, S. Verdu, IEEE Trans. Commun. Vol. 38, no. 4, pp 495-508, April 1990). While providing certain advantages, the performance has not been demonstrably improved. Varanasi and Aazhang proposed a multistage technique as described in the article Near-Optimum Detection in Synchronous Code-Division Multiple Access Systems, IEEE Trans. Commun., Vol. 39, No. 5, May 1991.

[0027] Decorrelating decision feedback detectors (DDFD) have been described by A. Duel-Hallen in Decorrelating Decision-Feedback Multiuser Detector for Synchronous Code-division Multiple Access Channel, IEEE Trans. Commun., Vol. 41, pp 285-290, Feb.

1993. Wei and Schlegel proposed soft-decision feedback to suppress error propagation of the DDFD in Synchronous DS-SSMA with Improved Decorrelating Decision-Feedback Multiuser Detection, IEEE Trans. Veh. Technol., Vol. 43, pp 767-772, Aug. 1994. Tree-type maximum-likelihood sequence detectors were also proposed for multiuser systems as were breadth-first algorithms and sequential detection including using the M-algorithm tree-search scheme with a matched filter (MF). The prior references also reveal schemes that include some form of decorrelating noise whitening filter (WF).

[0028] However, one of the primary disadvantages of the prior references implementations is the inability to accommodate overloaded conditions. Decision feedback techniques are limited in that they are incapable of working in supersaturated environments. Although the MMSE-based decision feedback detector can work in a supersaturated environment, it has been demonstrated to be too aggressive with hypothesis testing to produce accurate results.

[0029] Multi-user detection (MUD) refers to the detection of data in non-orthogonal multiplexes. MUD processing increases the number of bits available per chip or signaling dimension for systems having interference limited systems. A MUD receiver jointly demodulates co-channel interfering digital signals. Multiuser detection systems take full advantage of all information available at the receiver, by making use of any "knowledge" that the receiver has about the interfering signals. Because the number of users that can be packed into a MUD-based multiple access (MA) system is a function of the number of independent dimensions over which the set of signals is spread (the dimension of the span of the set of signals), the total number of users in the system can be increased if more dimensions are used for transmitting the signals and the same dimensions are accessible at the receiver.

[0030] In addition to expanding the number of dimensions, favorably "spreading" the received signals out over those dimensions can also allow for increases in the number of users a MUD-based system can accommodate. For example, typical signaling sets for multiuser communications do not include as a free parameter the reference amplitude of each user. In the IS95 code division protocol, amplitude is controlled completely for purposes of power control to meet a signal-to-noise specification (all users ideally being received with the same signal-to-noise ratio (SNR)). Therefore the advantages offered to

the MUD are not exploited and the aggregate throughput of a multiple access system is limited if amplitude is not exploited.

[0031] There are various multiuser detectors in the art, including optimal or maximum likelihood MUD, maximum likelihood sequence estimator for multiple interfering users, successive interference cancellation, TurboMUD or iterative MUD, and various linear algebra based multi-user detectors such as all of those detailed in the well-known text "Multiuser Detection" by Sergio Verdu. In the state of the art, algebraic means are used to compute linear operators for the entire set of users (communications channels) simultaneously. This is done by utilizing prior information, or knowledge of the likely value of each user's bit of information, each at a particular instant in time. This multiuser detection processing is described in the text S. Verdu, Multiuser Detection, Cambridge Press, 1998. However, this suffers from a significant disadvantage in that it requires knowledge of all parameters to perform the processing.

[0032] Optimal MUD based on the maximum likelihood sequence estimator operates by comparing the received signal with the entire number of possibilities that could have resulted, one for each bit or symbol epoch. The number of possible measured levels for the received signal is exponentially related to the number of users and the duration of the ISI. Hence, the optimal processing is a computationally complex, and it is not possible to accomplish in a real-time environment. Thus for those multi-user detectors that examine the entire space, real-time operation is often elusive.

[0033] In general, optimal MUD units function by examining a number of possibilities for each bit. However, for multi-user detectors that examine a larger capacity of signal, the computations are complex and time-consuming, thus making real-time operation impossible. Numerous attempts at reliable pruning of the optimal MUD decision process or the use of linear approximation to replace the optimal MUD have still not produced a workable solution for the real world environment.

[0034] There are several suboptimal multiuser detectors that are less computationally complex and known in the art. One example of suboptimal detectors, called linear detectors, includes decorrelators, minimum mean square error or MMSE detectors, and zero-forcing block linear equalizers. The conventional Minimum Mean Squared Error (MMSE) Multiuser detector utilizing prior information is described by Wang and Poor in

"Iterative (Turbo) Soft Interference Cancellation and Decoding for Coded CDMA", in the Transactions on Communications, July 1999. See also Alexander, Reed, Asenstorfer, and Schlegel, "Iterative Multiuser Interference Reduction: Turbo CDMA," IEEE Trans on Comm, July 1999; and Poor, "Turbo Multiuser Detection: An Overview" ISSSTA 2000. But, linear algebra based MUD (non-iterative) and successive interference cancellation fails for cases of overloaded multiple access systems.

[0035] One example of overloading is where the number of simultaneous users is doubled or tripled relative to existing state of the art. Even for underloaded multiple access systems, the performance of non-iterative MUD and successive interference cancellation degrades significantly as the number of users increases, while the computation complexity of the optimal MUD increases significantly as the number of users increases. The computing problems are so extreme that even the most expensive hardware unbound by size and weight can often to keep up with this overwhelming complex processing requirement of optimal MUD. Moreover, an unreasonable delay would be required to decode each bit or symbol rendering such a system useless in practice.

[0036] Reduced complexity approaches based on tree-pruning help to some extent to eliminate the improper bit combination from consideration where, ideally, such a procedure should prune out many 'bad' paths in the decision tree but maintain the proper path. Thus, the entire tree does not need to be traversed to make the final decision.

[0037] The M-algorithm is a pruning process that limits the number of hypotheses extended to each stage to a fixed tree width and prunes based on ranking metrics for all hypotheses and retaining only the M most likely hypotheses. The T-algorithm prunes hypotheses by comparing the metrics representing all active hypotheses to a threshold based on the metric corresponding to the most-likely candidate. Performance of M-algorithm based MUD degrades as the parameter M is decreased, but M governs the number of computations required. Similar effects are seen for other tree-pruning based MUD (T- algorithm, etc). To combat improper pruning, basic tree-pruning must ensure that M is "large enough", and therefore still encounters increased complexity for acceptable performance levels when the number of interfering signals and/or ISI lengths are moderate to large.

[0038] As an illustration of the M-algorithm as a tree-pruning algorithm, consider a tree made up of nodes and branches. Each branch has a weight or metric, and a complete path is sequences of nodes connected by branches between the root of the tree and its branches. When applied as a short cut to the optimal MUD, each branch weight is a function of the signature signal of a certain transmitter, the possible bit or symbol value associated with that transmitter at that point in time, and the actual received signal which includes all the signals from all the interfering transmissions. The weight of each path is the sum of the branch metrics in a complete path. The goal of a tree searching algorithm is to try to find the complete path through a tree with the lowest metric. With the present invention the metrics of multiple complete paths are not calculated. Rather, the metrics of individual branches in a tree are calculated in the process of locating one complete path through the tree and thereby defines one unknown characteristic of each of the co-channel, interfering signals needed to decode the signals.

[0039] A MUD algorithm within the TurboMUD system determines discrete estimates of the transmitted channel symbols, with the estimates then provided to a bank of single-user decoders (one decoder for each user) to recover the input bit streams of all transmitted signals. Two general types of multi-user detectors within the TurboMUD system are possible, namely those that provide hard outputs, which are discrete values, and those that provide soft outputs, which indicate both the discrete estimate and the probability that the estimate is correct. In basic terms, turbodecoding refers to breaking a large processing process into smaller pieces and performing iterative processing on the smaller pieces until the larger processing is completed, and this basic principle was applied to the MUD.

[0040] However, single-user decoders operating on hard values, or discrete integers, have unacceptable error rates when there is a large amount of interference or noise in the received signal. The reason is that discrete integers do not provide adequate confidence values on which the single-user decoder can operate. These decoders operate better on so-called soft inputs in which confidence values can range from -1 to 1, such as for instance 0.75 as opposed to being either -1 or +1. To provide soft values that can then be utilized by a single-user decoder, the multi-user detector chosen for the TurboMUD can generate these soft values. The invention described below will work with soft output or a hard output MUDs, or a combination of the two.

[0041] In general, soft or hard output versions of the optimum maximum likelihood multi-user detector (Verdu, Multiuser Detection, Cambridge University Press, 1998) or an M algorithm (as described, for instance, in Schlegel, Trellis Coding, IEEE Press, 1997) with a moderate to high value of M causes the Turbo MUD to require too many computations to keep up with real time transmissions. Using a fast, but inferior, multiuser detection scheme such as a linear-based detector or those detailed in the text "Multiuser Detection" by Sergio Verdu causes poor quality output when there are many interferers or users.

[0042] Moreover, when dealing with hand-held communications units such as wireless handsets, the amount of processing within the device is limited, directly limiting the amount of computational complexity that is allowed. In order to provide real-time performance both at a cell site and the handset, it therefore becomes important to be able to reduce the amount of computational complexity and processing time so as to achieve real-time performance.

[0043] A great number of communications and data transfer systems operate at or near a full capacity. Conventional receiver performance is unsatisfactory in the presence of co-channel interference. Furthermore, many receivers require prior knowledge of signal parameters such as phase and amplitude of the channel to perform processing functions without co-channel interference. What is needed is a means to increase the number of available channels, by reassigning channels to be perhaps slightly interfering, thereby increasing the overall throughput without increasing bandwidth. Such a system should provide an efficient means of jointly estimating symbols, channel amplitude, and data rate transmitted in a super-saturated communications channel. And, any such invention should have the ability to estimate the symbols and data rate, blindly without prior knowledge of channel amplitudes and phase.

BRIEF SUMMARY OF THE INVENTION

[0044] While adaptable in many forms, one embodiment of the invention is an apparatus for processing a digital data stream from multiple users, comprising an initial amplitude estimation unit processing the data stream and producing initial amplitude estimates on a first iteration. There is a joint amplitude estimator coupled to the data stream and the initial amplitude estimator, wherein the joint amplitude estimator produces updated

amplitude estimates. A symbol estimator is coupled to the data stream, the initial amplitude estimator, and the joint amplitude estimator, wherein the symbol estimator produces a plurality of symbols estimates for each user. There is a bank of decoders coupled to the symbol estimator, producing a plurality of symbol likelihood estimates for each user, wherein the symbol likelihood estimates are iteratively fed back to the symbol estimator and the joint amplitude estimator until a final condition is obtained.

[0045] Further variations of the invention include wherein the final condition is selected from at least one of the group consisting of: bit error rate metric level and fixed number of iterations.

[0046] The symbol hypothesis testing module can generally be any module that is a member selected from at least one of the group consisting Minimum Mean Squared Error (MMSE), maximum likelihood, M-algorithm, T-algorithm, and Q-algorithm, decorrelating decision-feedback detector (DDFD), improved decorrelating decision-feedback detector (IDDFD), successive interference cancellation (SIC), parallel interference cancellation (PIC) and multi-stage detector; block-iterative interference cancellation; and a deferred decorrelating decision-feedback detector.

[0047] The apparatus can further comprise an energy detector coupled to the joint amplitude estimator which can determine activity on a channel, such as code, time slot or frequency channel.

[0048] The bank of decoders can be selected from at least one decoder of the group consisting of: Soft-output Viterbi, Maximum A Posteriori, and BCJR.

[0049] Another embodiment includes a method for providing initial amplitude estimation for a plurality of user channels, comprising separating the user channels into active channels and inactive channels. Processing the inactive channels is according to the sub-steps comprising applying a bank of filters to the inactive channels for each inactive user, squaring an output from the filters, summing an output from the squaring operation, and calculating an average bias estimate from an output of the summing. Processing the active channels is according to the sub-steps comprising applying a bank of filters to the user data of the active channels, squaring an output from the bank of filters, summing an output from the squaring, and removing the average bias estimate from an output from the summing.

[0050] The method can include processing the inactive channels by dividing the inactive channels into groups and calculating at least one group average bias estimate. It can also include processing the active channels by dividing the active channels into groups and respectively removing the at least one group average bias estimate.

[0051] A further variation includes scaling by the summers and may include an energy detector for separating the active channel from the inactive channels.

[0052] Another embodiment of the invention is an apparatus for processing initial amplitude estimates from a data stream of multiple users, comprising an energy detector measuring an energy level of the data stream, wherein the energy detector separates a plurality of active channels from a plurality of inactive channels. There is a bank of filters coupled to the inactive channels, a bank of squaring operators coupled to the bank of filters, a bank of inactive summers coupled to the squaring operators, and an average bias estimator coupled to the inactive summers calculating an average bias estimate. There is also a bank of filters coupled to the active channels, a bank of squaring operators coupled to the bank of filters, a bank of active summers coupled to the squaring operators, and a bias removal section coupled to the active summers and the average bias estimator.

[0053] Another embodiment includes a joint amplitude estimator for a data stream from multiple users, comprising a data stream from the multiple users divided into a plurality of observation intervals. There are a plurality of processing modules coupled to the observation intervals, wherein the processing modules calculates interference cancellation values for each of the users and computes a filter for each of the observation intervals. The filter being applied to the data within the observation interval is used to compute individual amplitude estimates. There is an amplitude estimation unit that processes the individual amplitude estimates and calculates new amplitude estimates, wherein the new amplitude estimates are iteratively passed back to the processing modules until a final condition is obtained.

[0054] One aspect includes where the amplitude estimation unit sums and weighs the individual estimates such that the new amplitude estimate is a weighted average of individual amplitude estimates.

[0055] It should be understood that the observation intervals may be based on distinguishing attributes selected from at least one of the group consisting of: time, code, and frequency.

[0056] The filter may be calculated for an arbitrary observation interval m by the equation:

$$G_m = B_m S_m^H (S_m \chi_m S_m^H + \sigma_n^2 I)^{-1}.$$

[0057] Yet a further embodiment includes a method for processing amplitude estimates for a multiuser data stream divided into a plurality of observation intervals, comprising computing a filter for each observation interval of the data stream, applying interference cancellation to the data stream for each observation interval, applying the filter to the data stream for each observation interval from the interference cancellation to produce individual amplitude estimates for each observation interval, computing new amplitude estimates using the individual amplitude estimates; and passing the new amplitude estimates back to the filter for iterative processing until a final condition is obtained.

[0058] One embodiment is a turbo-decoding system for joint signal demodulation, comprising a data stream from a plurality of users divided into a plurality of observation intervals. There is a plurality of symbol processing nodes processing the observation intervals to compute symbol estimates for the data stream within the observation interval. A plurality of decoder nodes is present for processing the symbol estimates and producing a plurality of symbol likelihoods. There is a plurality of amplitude update nodes processing the symbol likelihoods and calculating a plurality of amplitude update vectors. And, there is an amplitude estimator node processing the amplitude update vectors and producing an amplitude estimate update, wherein the amplitude estimate update is passed back to the processing nodes for iterative processing between the symbol processing nodes, the decoder nodes, the amplitude update nodes, and the amplitude estimator node until a final condition is obtained.

[0059] The turbo-decoding system can encompass a plurality of memory units, wherein at least one memory unit is coupled to each of the processing nodes and to each of the amplitude estimation nodes. There can also be a first system area network (SAN) coupling

the processing nodes and the decoder nodes, a second system area network (SAN) coupling the decoder nodes and the amplitude estimation nodes, a third system area network coupling the amplitude estimation nodes and the amplitude estimator, and a fourth system area network coupling the amplitude estimator and the processing nodes. The processing nodes, the decoder nodes and the amplitude estimation nodes can even be one set of nodes. A set of nodes can also be comprised of at least one processor.

[0060] A further embodiment of the system includes wherein the likelihood symbols from the decoders are accessible at any time for post-processing. The processing nodes can further comprise a thresholder to convert the symbol estimates to symbol bits. And, the bank of decoder can also perform de-interleaving, rate identification, de-puncturing and de-scrambling.

[0061] The features and advantages described herein are not all-inclusive and, in particular, many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims. Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes, and not to limit the scope of the inventive subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0062] Figure 1 illustrates a basic diagrammatic processing perspective for the prior art transmitter end and receiver end with iterative multiuser detection processing;

[0063] Figure 2 is a block diagram perspective showing joint symbol amplitude and data rate estimator for one embodiment of the invention;

[0064] Figure 3 is a schematic block diagram showing initial amplitude estimation;

[0065] Figure 4 is a schematic block diagram showing joint amplitude estimator;

[0066] Figure 5 is a schematic block diagram showing parallelization of joint symbol amplitude and data rate estimator; and

[0067] Figure 6 is a schematic block diagram showing hardware conceptualization according to one embodiment of the present invention with nodes used to depict the processing.

DETAILED DESCRIPTION OF THE INVENTION

[0068] The methods and embodiments of the joint symbol, amplitude and rate estimator disclosed herein enable implementations of advanced receiver processing providing high quality real-time processing for multiple access systems, including overloaded situations. One embodiment illustrates the signal processing technique applicable to many variations that are all within the scope of the invention. It should be understood that the reference to a data stream of multiple users is understood to represent digital data from a number of references and not necessarily multiple users in communications.

[0069] In order to fully appreciate the processing of the present invention, it is useful to consider a description of the processing known in the art. Referring to **Figure 1**, prior art transmitter section **5** and receiver section **10** is depicted with MUD processing. There are K users with data $d_1 - d_k$ as the input to the channel encoders **20** where the data is convolutionally encoded at a code rate R_k . The interleaver **25** performs the interleaving of the data, which is then symbol mapped by the symbol mapper **30**, such as BPSK symbol mapped with data symbols having a duration T . Each data symbol is then modulated by a spreading waveform from the spreader **35**, and the signal data $s_k(t)$ is output from the transmitter end with a number of data symbols per user per frame. In the typical wireless communication application presented herein, a number of users $(1-K)$ generate signals that are transmitted by antennas **40** into free space. The transmission on hard-wire or fixed wire systems is also known in the art, however the present example is directed towards the wireless communications systems. Noise $n(t)$, such as white Gaussian noise, is an inherent component of most transmission signals and some random noise components are generally present in transmitted data signals $r(t)$.

[0070] On the receiving end **10**, antenna(s) **42** receive the transmitted signals $r(t)$ as well as the various interfering signals, such as $n(t)$. There is normally a noise component $n(t)$ that is introduced from the environment of a random nature in the received signal. While any noise that has a repeatable or non-random nature can be eliminated through processing, random noise elements are reduced in other manners such as filtering but are inherent conditions. The various signals are received at antennas **42** wherein there is typically one

signal for each polarization feed. The received signals represent directly received signals, as well as multi-path signals from the same user, and interfering signals from other users.

[0071] The input signals of raw non-manipulated data at the receiver 10 is comprised of the aggregate of many signals from many different transmitters/users, where each signal is generally assigned a channel (frequency, timeslot, and/or spreading code) from a finite set of channels. The interference from these various users generally requires complex processing and associated processing time. The input data represents a vector of data, transferred at some rate (e.g., the symbol rate), and this data is typically transmitted to a matched filter (not shown).

[0072] The plurality of signals from each antenna 42 is processed in a RF front end unit 44. The front end unit 44 generally downconverts the higher frequency signals into baseband signals and provide processing and filtering as is known in the art. The baseband signals are also digitized by analog to digital converters (ADC). The front end 44 cooperates with the parameter estimation unit 46 to retrieve needed information for the signals such as relative received timing offsets, carrier phase, frequency offsets, received amplitudes, and multipath structure for each of the interfering signals present in the received signal.

[0073] A parameter estimation unit 46 is coupled to the front end 44 and processes the various parameters for the received vector data. A parameter estimator 46, as known in the art, is a broad description for a unit that provides information to the MUD 50 such as convolutional code, signatures, and multiplexing format. While the term parameter estimator is used herein, the term is intended to be interpreted in the broader sense as known in the joint demodulation field. The parameter estimation module 46 generally tries to estimate timing, signal amplitudes, phases, polarization, and identification of transmission channels.

[0074] The MUD element 50 consists of functional blocks that process the digital data and extract the user symbol streams. The MUD 50 performs pre-processing and converts the baseband digital data into the proper format for further processing according to the detection scheme. The format is often one measurement per 'dimension' per symbol. The

MUD unit 50 outputs a bit (or symbol) stream associated with each interfering signals present on the channel for one data block.

[0075] Turbo MUD processing assumes knowledge of various parameters such as relative received timing offsets, carrier phase, frequency offsets, received amplitudes, and multipath structure for each of the interfering signals present in the received signal. This input data represents raw data after some front end processing such as downconversion, amplification, and analog-to-digital conversion. MUD 50 needs some raw data parameters in order to establish accurate decision trees for processing.

[0076] There is an iterative processing topology with a MUD section 50 that interacts with the K number of channel decoders 65 for the received signal $r(t)$ for each user. The multiuser detector 50 is generally a SISO detector, receiving and outputting soft values, although hard value processing is known in the art. The MUD section 50 utilizes a priori information and delivers values such as a posteriori log-likelihood ratio (LLR) data of a transmitted '+1' or '-1' for each bit of every user. Certain a priori information is computed by the channel decoder 65 from a previous iteration which is interleaved and fed back to the MUD section 50. The interleaver 60 and deinterleaver 75 perform the interleaving and deinterleaving functions respectfully for the encoding schema. Likewise, the summers 55, 70 perform the summations for the data. Once the processing is complete the channel decoders 65 produce the output data stream (d_k) representing the best estimate of the transmitted signal (d_k) .

[0077] Various schemes for TurboMUD processing are well known in the art and utilize a priori information about the received signals wherein the processing continues through a number of iterations until certain conditional parameters are satisfied. The basic TurboMud procedure is presented in published literature such as Poor, "Turbo Multiuser Detection: An overview," IEEE 6th Int. Symp. On Spread-Spectrum Tech. And Appli., NJIT, New Jersey, Sept. 6-8, 2000 and Alexander, Reed, Asenstorfer, and Schlegel, "Iterative Multiuser Interference Reduction: Turbo CDMA," IEEE Trans. On Comms., v41, n7, July 1999. The iterative MUD algorithm such as representative of the approaches used to incorporate turbo decoding methods into joint MUD/FEC (Forward Error Correction) decoding and to then reduce the complexity of the system are known in the art.

[0078] The bit streams from the MUD 50 are passed to a bank of error correction decoders unit 65. The decoders 65 calculate conditional probabilities, one for each decoded symbol of each user, and output them as confidence values back to the MUD 50. In one embodiment, there is a bank of error correction decoders 65 such as Viterbi decoders or MAP.

[0079] Soft outputs for each bit of each user from the bank of decoders 65 is fed back to the multiuser detector 50 for each iteration, one stream of outputs for each interfering user present in the received signal. These soft outputs are passed back to the MUD 50 to produce an improved stream of soft bit (or symbol) decisions that fed into the decoder 65 for another iteration of improvement. The information between the MUD 50 and the decoders 65 repeats in subsequent iterations until an asymptote is reached or the desired performance level is attained. At that point, estimates of the data sequences for all active users are output. Operation then commences for the next block of data, repeating the process described above. The multiuser detector 50 takes these soft inputs along with the original raw input signal to calculate an improved, less corrupted bit stream for each user. This iterative process continues until a desired metric is reached or a fixed number is reached. At that point, estimates of the data sequences for all active users are output. Operation then commences for the next block of data, repeating the process described above.

[0080] The number of iterations for processing between the MUD 50 and the decoders 65 can be set to a fixed counter or by checking if there were significant changes to the data from the last iteration. Once the data is no longer being altered or reaches a certain iteration counter limit, the data from the decoder 65 can be output as final estimates of what the user sent, (dk)'. A fixed number of iterations can be stored and used and processed by the decision block. Alternatively, the information between the multiuser detector 50 and the decoders 65 repeats in subsequent iterations until an asymptote is reached or the desired performance level is attained. A buffer can store the previous values and compare them to the latter processed values during the iterative process.

[0081] MMSE detectors with prior information are usually described in a turbo or iterative application, but also function in non-iterative operations. As described herein, a

complete solution to the problem is computed, and one approximate (low complexity) method is described. Furthermore, prior schemes are generally inferior for overloaded systems, and this is alleviated by the present invention.

[0082] The apparatus in **Figure 2** is now described in more detail. A Data Stream 100, potentially complex, is received from some source. For the case of Code Division Multiple Access (CDMA) communications schemes, the data stream is sampled by some multiple of the chip rate. For TDMA communication schemes, the data stream is sampled at some multiple of the symbol rate. The received signal can effectively be modeled as the linear combination of many co-channel signals, mathematically illustrated by

$$r[n] = \sum_{l=1}^F \sum_{k=1}^K b_k[i] a_k s_k(nT_n - iT_l) + n_w(nT_n). \quad \text{Equation 1}$$

[0083] The term $b_k[i]$ represents the symbol for user k at time index i . The term $s_k(nT_n - iT_l)$ represents the user's signal characteristic for sample index n for the symbol period i for the user k . The characteristic waveform, $s_k(\cdot)$, is normalized such that the amplitude of the transmitted signal for user k is represented by a_k . The symbol period is defined by T_l and the sample period is represented by T_n . The linear model represents a summation of K separate users and over F symbols. The received signal can represent a collection from multiple sources. For example, the collection may consist of multiple antennas, not necessarily co-located, with potentially different polarizations.

[0084] The user's signal characteristic, $s_k(nT_n - iT_l)$, combines a sequence of signal transformations: pulse shaping filter, signal delays, receiver filters, code channels (for CDMA) and multipath. It should be understood that the characteristic waveform is not restricted to a sample or symbol interval.

[0085] The multiple access interference model in Equation 1 is represented concisely using matrix notation in Equation 2. The KF symbols, corresponding to the KF simultaneous users, is represented by the KF -element vector, $\mathbf{b}[i]$ at time i . A linear model is used to represent the received signal at time index i by

$$\mathbf{r}[i] = \mathbf{S}\mathbf{A}\mathbf{b}[i] + \mathbf{n}_w[i], \quad \text{Equation 2}$$

where $\mathbf{b}[i]$ represents the KF symbols at time index i . The term $\mathbf{S}$ is a $N \times KF$ matrix representing the combination of the spreading code, channel codes, pulse shaping filter, and propagation effects

$$\mathbf{S} = \begin{bmatrix} s_1[1,i] & s_2[1,i] & \cdots & s_{KF}[1,i] \\ s_1[2,i] & s_2[2,i] & \cdots & s_{KF}[2,i] \\ \vdots & \vdots & \ddots & \vdots \\ s_1[N,i] & s_2[N,i] & \cdots & s_{KF}[N,i] \end{bmatrix} \quad \text{Equation 3}$$

[0086] The matrix entries, $s_k[n,i]$, represents the n^{th} sample of the signal characteristic waveform for user k at time i . The term $\mathbf{A}$ is a $KF \times KF$ diagonal matrix that represents the complex signal amplitudes, which can include phase and polarization weighting. The term $\mathbf{n}_w[i]$ is a $N \times 1$ vector that represents additive white Gaussian noise (AWGN).

[0087] Referring again to Figure 2, the data stream 100 represents a vector of data, representing the received signal. This data is communicated to the symbol hypothesis testing module 105 which is indicated in this implementation as Minimum Mean Squared Error (MMSE) based symbol estimator. The MMSE implementation for symbol hypothesis testing 105 is better for computational efficiency however other forms of symbol estimators such as the maximum likelihood detector are within the scope of the invention. The maximum likelihood detector is a brute force approach which performs an exhaustive evaluation of the Euclidean distances between the received samples and the linear model of the samples using every possible hypothesis of the bit sequence. Instead of the optimal detector for the symbol estimation testing module 105, more computationally efficient forms of symbol hypothesis testing includes, the M-algorithm, T-algorithm, etc. Although the most efficient approach appears to be the MMSE-based symbol estimator, another efficient implementation for symbol estimation is referred to as the Q-algorithm, disclosed in U.S. Patent application Serial No. 10/105,918, filed March 25, 2002 entitled "System for Decreasing Processing Time in an Iterative Multi-User Detector System". The Q-

algorithm used for the MMSE-symbol estimator cancels interference based on symbol estimates obtained from thresholding the symbol likelihoods.

[0088] The computational efficiency utilizing the MMSE based symbol estimation is described in further details for the MMSE-based joint amplitude estimation and the parallelization of the algorithm. It should be noted that the symbol hypothesis testing is performed following completion of the initial amplitude estimate.

[0089] The same data vector 100 is passed to the initial amplitude estimation module 110. As indicated by the name, the purpose of initial amplitude estimation module 110 is to provide an initial estimate of the amplitude for each interfering signal. The approach implemented in initial amplitude estimation module 110 consists of incoherently integrating the energy out of a properly normalized matched filter for all users determined to be active. Note these users can be transmitted over code, temporal, and/or frequency channels and this estimation procedure are appropriate for these modes of digital communication. Part of the function performed in the initial amplitude estimation module 110, is the identification of which users are active. User identification can be easily obtained via an energy detector based on some sufficiently long observation interval that can determine activity on a channel: code, time slot, or frequency channel. The energy detector is generally integrated within the initial amplitude estimation module 110.

[0090] The initial amplitudes from the estimator 110 are passed to the MMSE-based symbol estimator 105 and the MMSE-based Joint Amplitude Estimator 120. The MMSE-based symbol estimator 105 uses the initial amplitude estimate only on the first iteration, for all other iterations it uses the amplitude estimates from the MMSE-based Joint Amplitude Estimator 120. This module may implement any type of symbol hypothesis testing procedure however an MMSE-based approach is used because of computational efficiency. It should be understood that other linear detectors, such as the decorrelator, may also be used for computational efficiency. While the linear detectors are efficient, the performance is sacrificed through BER performance and loading capacity.

[0091] There are numerous non-linear symbol-hypothesis testing procedures adaptable to the present invention, including the M-algorithm/T-algorithm; maximum likelihood; decorrelating decision-feedback detector (DDFD) and improved decorrelating decision-

feedback detector (IDDFD); successive interference cancellation (SIC), parallel interference cancellation (PIC) or multi-stage detector; block-iterative interference cancellation. A further symbol-hypothesis testing implementation is described in the commonly owned application entitled "Deferred Decorrelating Decision-Feedback Detector for Supersaturated Communications", U.S. Patent Application Serial No. 10/423655, filed April 25, 2003.

[0092] The MMSE-based symbol estimator 105 provides symbols estimates to a bank of single user decoders 130. The symbols estimates from the symbol estimator 105 are routed to the decoders 130 based on user number. For example, all symbol likelihoods corresponding to the first user are passed to the decoder dedicated to the first user. This mapping is repeated for all users. The single user decoders consist of a bank of K decoders that may consist of Soft-output Viterbi or Maximum A Posteriori based techniques such as BCJR. Soft-input, soft-output (SISO) decoders are used in one embodiment for this implementation, but hard values can be processed as is known in the art.

[0093] Inherent in most processing is a de-interleaving, rate identification, de-puncturing and de-scrambling processing depicted merely as deinterleaving 125 for illustrative purposes. The symbol estimates and their respective likelihoods are output from the bank of decoders 130 for one of the most-likely data rates. In addition, symbol likelihood estimates from the decoders 130 are also fed back around to both the MMSE-based symbol estimator 105 and MMSE-based amplitude estimator 120 respectively. However, prior to feedback the symbol likelihoods are processed by an interleaving section 135 performing re-interleaving, re-puncturing, re-scrambling and symbol repeating (for low rate frames). The purpose of this re-coding task is to properly emulate the interference.

[0094] As referenced herein, the term 'data rate' refers to the rate at which the information bits are transmitted over the channel, defined in terms of bits per second. Sometime the data can be transmitted at one of a number of different rates. The likelihoods of the bits are maximized when the data rate is known. However, if the receiver is non-cooperative, the 'most likely' data rate must be identified. One approach

for determining the most likely data rate is through joint maximization of the bit likelihoods and data rate.

[0095] The new symbol likelihoods from the decoders 130 are used to update previous amplitude estimates in the joint amplitude estimator 120. The procedure for processing the MMSE-based amplitude estimator is described in further detail herein. The new amplitude estimates from the joint amplitude estimator 120 are passed to the MMSE-based Symbol Estimator 105 that re-estimates the symbols based on prior information on the symbols and the updated parameter estimates. These updated symbol estimates from the symbol estimator 105 are then re-routed to the bank of decoders 130. This process is repeated for either some fixed number of iterations or until the estimates of the bit error rate or frame error rate achieve some desired level.

[0096] Figure 3 illustrates the system and processing for calculating initial amplitude estimates with the Initial Amplitude Estimator 110 of Figure 2. Referring to Figure 2 and Figure 3, the initial amplitude estimate obtained from the Initial Amplitude Estimator 110 is based on the incoherent integration of the matched filter output of the Active Channel 180 over some observation interval. The procedure consists of applying a bank of matched filters 205, 230, 255 for all users K and all symbols F to the received data vector 100. The $KF \times 1$ vector representing the matched filter outputs is represented by

$$\mathbf{y} = \mathbf{S}^H \mathbf{r} = \mathbf{S}^H \mathbf{S} \mathbf{a} \mathbf{b} + \mathbf{S}^H \mathbf{n}_w. \quad \text{Equation 4}$$

[0097] The estimate of the amplitude for a user k is based on summing the squared outputs of the matched filter for that user k , summed over an observation interval of F symbols. An estimate of the amplitude squared is represented by

$$\hat{a}_k^2 = \frac{1}{F} \sum_{l=1}^F |y_{l,k}|^2 \quad \text{Equation 5}$$

[0098] The summation over F is performed for all K users to obtain K initial amplitude estimates for the K users. Since the estimate is based on incoherent integration,

the estimate is biased which is illustrated by the expected value of the initial amplitude estimate for an arbitrary users k ,

$$E[\hat{a}_k^2] = a_k^2 + \frac{1}{F} \sum_{i=1}^F \sum_{\substack{j=1 \\ j \neq k}}^K \rho_{j,k}^2(i) a_j^2 \quad \text{Equation 6}$$

where the bias is represented by the last term in Equation 6 and $\rho_{j,k}^2(i) = (\mathbf{s}_k^H(i) \mathbf{s}_j(i))^2$.

Note that the bias in Equation 6 is based on the expected values of the bits in the vector $\mathbf{b}$, in Equation 4, equaling zero. This is mathematically represented by

$$E[\mathbf{b}] = 0$$

In addition, Equation 6 assumes the symbols are defined such that $b_i^2 = 1$. A generalization of Equation 6 for the case of non-zero mean bit values and $b_i^2 \neq 1$ is obvious.

[0099] An inactive user 190 is defined as a signature signal that is not present. The expected value of the amplitude estimate for an arbitrary inactive channel is defined as

$$E[\hat{a}_{inactive}^2] = \frac{1}{F} \sum_{i=1}^F \sum_{j=1}^K \rho_{j,inactive}^2(i) a_j^2 \quad \text{Equation 7}$$

where $\rho_{j,inactive}^2(i) = (\mathbf{s}_{inactive}^H(i) \mathbf{s}_j(i))^2$. Since no signal is present for inactive users, a nonzero value for the expected value of the estimate for amplitude squared for inactive signature vectors is due to the presence of other active channels. Comparing Equations 6 and 7 reveals that examination of the estimate of squared amplitudes for non-active users can be used to estimate the bias relative to active users. Thus the Initial Amplitude Estimation concept is based on Equations 5 through 7 is illustrated in **Figure 3**.

[00100] A data stream 200 representing the received signal, potentially complex, is received from some source. A bank of filters 205, 230, 255, 280 and 300 is applied to the data stream 100. The Active Channel 180 set of filters 205, 230, 255 consists of filters matched to users that have been determined to be active based on an energy detector.

Filter 205 corresponds to a filter matched to the signature signal for user 1. Similarly, filter 230 corresponds to a filter matched to the signature signal for user 2. It should be noted that the size of the bank of matched filters is based on the number of users determined to be active and represented by the term K .

[00101] The output data from each matched filter (1- K) 205, 230, 255 is then processed by a squaring operation 210, 235, 260 for all K users. The outputs from the squaring operations 210, 235, 260 for each active channel user (1- K) are then passed to a bank of summers 215, 240, 265 which performs the incoherent integration. The bank of summer 215, 240, 265 for each user 1- K used to implement Equation 5, accumulates energy in each of their respective processing chains. The proper scaling required for averaging is included in the output of the summers. As previously mentioned these estimates of squared amplitude are biased, therefore, the bias removal component must be implemented to minimize the bias.

[00102] A set of filters 280, 300 for the Inactive Channel 190 representing those channels that were determined to be inactive based on an energy detector. The bank of filters 280, 300 matched to the inactive user's signature signals is applied to the data stream 200 and processed. The size of the bank of filters 280, 300 is based on the number of users determined to be inactive, defined herein as the number J .

[00103] Following the processing of the inactive filters 280, 300 for the users 1- J , the user data is further processed by a squaring operation 285, 305 for all J users. The outputs from the squaring operations 285, 305 for each inactive channel user (1- J) are then passed to a bank of summers 290, 310. The bank of summer 290, 310 for each user 1- J accumulates energy in each of their respective processing chains. The proper scaling required for averaging is included in the output of the summers 290, 310, wherein the output is then processed by the Average Bias Estimator 295.

[00104] Following the computation of the amplitude bias by the Average Bias Estimator 295, the bias is passed to Bias Removal 220, 245, 270 that is applied to each of the Active Channel Users 1- K . The illustration in Figure 3 shows the output from the active channel summers 215, 240, 265 going to all bias removal modules 220, 245, 270. The initial amplitude squared estimate obtained for the active channels has an estimate of the bias

removed in modules 220, 245, 270. Following the bias removal, the initial amplitude squared estimates 225, 250, 275 for each user 1-K are passed out to the remaining processing shown in Figure 2.

[00105] Figure 3 shows the computation of one amplitude bias in module 295, which is then applied to all bias-removal modules 220, 245, and 270, for all active channels. The processing configuration of Figure 3 is also extendable to other embodiments in which different biases are computed for different sets of active channels, which are obvious extensions and within the scope of the present invention. For example, in a wireless communications system the bias removal could be restricted to channels within certain sectors. More specifically, for all non-active channels identified in a sector, a bias estimate is computed and then applied to all active channels in the same sector. Therefore, active channels identified in a different sector will only use a bias based on non-active channels in this same sector.

[00106] Referring to Figure 2, the initial amplitude squared estimates are updated in the MMSE-based Joint Amplitude Estimator 120. The apparatus for updating these amplitude squared estimates is described in Figure 4. The solution described in Figure 4 is based on the assumption that the amplitude is nearly constant over some observation window. Since this solution is based on the MMSE criteria, this approach is easily extended to time-varying amplitudes, however, only the windowed based estimator is detailed herein for illustrative purposes. For example, when the amplitude fluctuates by rate, the amplitudes over multiple frames are linked based upon the data rate. Incorporating data rate into the amplitude estimator, the module described in Figure 4 actually evolves into an energy-per-bit estimator. When the amplitude fluctuates based on temporal instability, then this implementation is extended into a Kalman filter framework by using a temporal model of the channel variation. The Kalman filter equation itself is well known to those in the art.

[00107] Referring to Figure 2 and Figure 4, the stream of data representing the received signal 100 is passed to the MMSE-based Joint Amplitude Estimator 120. This data stream 100 is divided up into M observation intervals as illustrated by r_1 , r_2 , through r_M 400, 405, 410. These intervals can be based on distinguishing attributes such as time, code, or frequency. For the example presented herein, the observation interval refers to time.

These observation intervals each enter a different processing section 415, 420, 430, representing 1 to M observation intervals. In each processing module, 415, 420, 430, an MMSE filter is computed which is defined for an arbitrary observation interval m as:

$$G_m = \mathbf{B}_m \mathbf{S}_m^H (\mathbf{S}_m \chi_m \mathbf{S}_m^H + \sigma_n^2 \mathbf{I})^{-1}. \quad \text{Equation 8}$$

[00108] The term $\mathbf{B}_m$ refers to a diagonal matrix representing the expected bit or symbol value in interval m for all K users. For example,

$$\mathbf{B}_m = \begin{bmatrix} \hat{b}_1 & 0 & \dots & 0 \\ 0 & \hat{b}_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \hat{b}_K \end{bmatrix}, \quad \text{Equation 9}$$

where $\hat{b}_k$ represents the expected value of the symbol for user k . For illustrative purposes, for BPSK systems, $\hat{b}_k = 2p_k - 1$, where p_k equals the probability that the symbol equals 1. The term $\mathbf{S}_m$, is similar to that presented in Equation 2, except here $\mathbf{S}_m$ represents the "S-matrix" defined over a single observation interval, while $\mathbf{S}$ in Equation 2 is defined over F observation intervals. Therefore, $\mathbf{S}$ in Equation 2 contains the $\mathbf{S}_m$ defined herein. The term χ_m represents the amplitude uncertainty and is rewritten as:

$$\chi_m = (\Omega + \mathbf{A}^2) \Lambda_m \quad \text{Equation 10}$$

which more clearly defined the amplitude uncertainty in terms of the bit uncertainty, Λ_m , the initial amplitude uncertainty, Ω , and the expected value of the amplitude $\mathbf{A}$. The terms, Λ_m , Ω , and $\mathbf{A}$ are all diagonal matrices, and each element along the diagonal corresponding to a different active user, therefore, χ_m is a diagonal matrix. This formulation assumes the amplitudes and corresponding uncertainties are constant for the M observation intervals.

[00109] Following the computation of M different MMSE filters in each of the 1- M modules 415, 420, 430, each MMSE filter is applied to components of the respective data stream 400, 405, 410 corresponding to the same observation interval.

[00110] Prior to application of the MMSE filter, interference cancellation is performed based on the expected value of the bits, represented by $\mathbf{B}_m$ and prior estimates of the amplitude for all K users, represented by the $K \times 1$ vector $\underline{a}^{l-1}$. The interference cancellation is represented by

$$\tilde{r}_m = r_m - \mathbf{S}_m \mathbf{B}_m \underline{a}^{l-1}. \quad \text{Equation 11}$$

And, each MMSE processor cancels out different interference.

[00111] Therefore, application of the MMSE filter following interference cancellation is represented by

$$\Delta \underline{a}_m = G_m (r_m - \mathbf{S}_m \mathbf{B}_m \underline{a}^{l-1}) \quad \text{Equation 12.}$$

[00112] The amplitude estimator is defined in module 435 of Figure 4. It is an iterative formulation that updates previous estimates, represented by $\underline{a}^{l-1}$, with information based on new estimates of the users' bits and data rate. These new estimates are represented by $\underline{a}^l$. The MMSE-based joint amplitude estimator 435 combines the individual estimates, $\Delta \underline{a}_m$, in a weighted manner. The weighted combination in this embodiment is expressed by:

$$\underline{a}^l = \underline{a}^{l-1} + \left(\Omega^{1/2} (\mathbf{Q} + \mathbf{I})^{-1} \Omega^{1/2} \right) \sum_{m=1}^M \Delta \underline{a}_m \quad \text{Equation 13}$$

where

$$\mathbf{Q} = \sum_{m=1}^M \mathbf{Q}_m \quad \text{Equation 14}$$

[00113] As indicated by Equation 13 and illustrated in **Figure 4**, the individual estimates from the filter modules **415**, **420**, **430** are passed to the Amplitude Estimator **435** for each interval 1-M. These individual estimates, $\Delta \underline{a}_m$, are $K \times 1$ vectors which are then summed together in Amplitude Estimator **435**. These estimates are then weighted by $(\Omega^{1/2} (Q + I)^{-1} \Omega^{1/2})$ where $\Omega^{1/2}$ is a diagonal matrix containing the standard deviation of the amplitude estimates and Q is represented in Equation 14. The term Q is a summation of quadratics computed in the filter modules **415**, **420**, **430**. Each quadratic is computed by

$$Q_m = G_m S_m B_m \quad \text{Equation 15}$$

which is shown to be based on the MMSE filter for the respective observation region defined in interval m . Therefore each filter module **415**, **420**, **430** responsible for an observation interval must compute: the MMSE filter (see Equation 8); apply interference cancellation to the section of the data stream corresponding to the observation interval (see Equation 11); apply the MMSE filter to the interference mitigated data vector (see Equation 12); and computed the quadratic (see Equation 15).

[00114] In this embodiment the outputs of each module **415**, **420**, **430** is a $K \times 1$ vector $\Delta \underline{a}_m$ and a hermitian matrix Q_m which is a $K \times K$ matrix with $K(K+1)/2$ unique elements. These two outputs are passed to the Amplitude Estimator **435** for each interval 1-M. The prior amplitude estimates, $\underline{a}^{l-1}$ are updated to $\underline{a}^l$ and passed out from the Amplitude Estimator **435** back to the individual filter modules **415**, **420**, **430** defined for the observation intervals. This feedback is part of the iterative implementation inherent in this MMSE formulation.

[00115] Referring again to **Figure 2**, it should be understood that the amplitude estimates are not updated until the bits (or symbols) have been updated in the bank of decoders **130**. Following the processing by the MMSE-based symbol estimator **105** and the decoders **130** in **Figure 2**, the symbols are fed back to the MMSE-based joint amplitude estimator **120** where prior amplitude estimates are updated as detailed herein. As previously described,

the number of iterations is typically dictated by the user which is defined for either a fixed iteration number or until the frame error rate or estimate bit error rate metric reaches some desired level.

[00116] Once processing is completed, the updated amplitude estimate vector 440 is transmitted from the MMSE-based Joint Amplitude Estimator 120 to the MMSE-based symbol estimator 105. Since for this particular implementation, the amplitudes are constant over the observation interval described for M smaller observation intervals, the same amplitude estimate 440 is reported to each MMSE-based symbol estimator 105. This approach is easily modified for a variable amplitude estimate which varies over the entire observation interval.

[00117] The apparatus in Figure 5 is one embodiment of a hardware implementation that provides a more detailed characterization of the processing shown in Figure 2. It should be noted that Figure 5 shows an implementation that parallels the joint estimation based on M observation intervals. The data stream in 100 of Figure 2 is partitioned into M observation intervals as the data vectors 500, 502, 504, 506 representing intervals 1 - M . As in previous diagrams, the number of observation intervals is generalized to M intervals. The observation intervals may overlap (not necessarily disjoint) to account for asynchronous reception and multipath signals.

[00118] These data vectors 500, 502, 504, 506 are processed immediately by a bank of MMSE filters which are implemented on the M processors, 520, 522, 524, 526, for all M observation intervals and each processor simultaneously estimates symbols for all K users. The filter processing can be considered a node, wherein a node is a generic processing component as is known in the art, such as a microprocessor chip or processing board, and wherein it should be readily apparent that there can be more than one processor per node.

[00119] In addition, these data vectors 500, 502, 504, 506 are read into local memory 510, 512, 514, 516 on the processors, because they are used repeatedly for the multiple iterations in this iterative approach to symbol, amplitude, and rate estimation. Any of the forms of memory known in the art are applicable.

[00120] Each symbol estimation MMSE processor, 520, 522, 524, 526 outputs $\underline{b}_m$, which is a vector of K symbol likelihoods or symbol bits for observation interval m . Recall that K corresponds to the number of users and therefore $\underline{b}_m$ represents the collection of symbol estimates for K users in observation interval m . Symbol bits are provided on the output if thresholding is performed within the MMSE processor 520, 522, 524, 526. The output from each MMSE processor, 520, 522, 524, 526, is intended to represent $M K \times 1$ vectors passed to the system area network (SAN) 530 which will then pass $K M \times 1$ frames of likelihoods (or symbols) to a bank of decoders 532, 534, 536, 538 for each user 1- K . The benefit of supplying likelihoods to the decoders 532, 534, 536, 538 is the improved performance when using soft-decoders. It should be noted that the same processing nodes used for implementing the bank of MMSE filters for symbol estimation for processors 520, 522, 524, 526 can be used to implement the K decoders, 532, 534, 536, 538 which are partitioned between the compute nodes. However, this embodiment also covers an implementation for hardware dedicated to MMSE processing and separate hardware for decoding.

[00121] The following discussion describes one embodiment for an implementation when a bank of processing nodes is used for both MMSE processing and decoding. Symbol likelihoods are routed over the SAN 530 based on the assignment of decoders 532, 534, 536, 538 to processing components for decoding. The SAN 530 routes the $M K \times 1$ vectors of symbol likelihoods from the symbol estimation processing previously used to perform MMSE-based symbol estimation on processors 520, 522, 524, 526 to the same set of processing nodes that now perform the decoder processing on the bank of decoders 532, 534, 536, 538. The SAN 530 passes K frames of $M \times 1$ symbol estimates to the K decoders 532, 534, 536, 538, wherein the frames of symbols are represented by $\underline{f}_k$ for the K users. The frames, $\underline{f}_k$, represent a frame for each user that contains M symbols.

[00122] The number of decoders 532, 534, 536, 538 corresponds to the number of users, 1- K . The bank of decoders 532, 534, 536, 538 may implement hard-in, soft-out (HISO) or soft-in, soft-out (SISO) decoders. In addition to decoding, the bank of decoders 532, 534, 536, 538 performs descrambling, de-interleaving, de-puncturing, and rate identification. The output of each decoder 532, 534, 536, 538 is, $\underline{f}_k'$, which is

a $M \times 1$ vector representing an update of M likelihoods in the frame following the implementation of the decoders. In addition, the decoders 532, 534, 536, 538 supply likelihoods of the information bits values d_k' for the same collection of symbols. These information bits are passed out as output 540, 542, 544, and 546. The number of bits per user is dependent on the data rate, and there bit likelihoods are available at any time in the iterative scheme for post-processing such as a cyclic reduction check, which is used to determine frame errors. The number of information bits transmitted per second is less than the number of symbols per second. Therefore, the number of information bits will be less than M , which defines the number of symbols per frame.

[00123] The updated likelihoods of the symbols $K M \times 1$ vectors of likelihoods, $\underline{f}_k'$, are fed-back through SAN 550 and processed by a bank of MMSE filters which are implemented on the M processor nodes, 560, 562, 564, 566. The $K M \times 1$ vectors of likelihoods, $\underline{f}_k'$, prior to the SAN 550 are sent to the MMSE filters as $M K \times 1$ vectors of likelihoods, $\underline{b}_m'$. However, now the bank of MMSE filters is used for amplitude estimation 575.

[00124] The same bank of $1 - M$ symbol estimation processors 520, 522, 524, 526 used to implement the initial MMSE filters for symbol estimation can be used for the further MMSE filter implementation for amplitude estimation, illustrated by processing modules 560, 562, 564, 566. The MMSE processing modules 560, 562, 564, 566 in amplitude updating focus on the same observation intervals analyzed during the symbol estimation. The MMSE processors 560, 562, 564, 566 at this stage implement the functionality of the filter module 415, 420, 430 of Figure 4. This bank of MMSE filters implemented by MMSE processors 560, 562, 564, 566 draw from local memory 552, 554, 556, 558 to retrieve prior amplitude estimates, updated symbol estimates, S-matrices, and the received data vector corresponding to the observation interval m .

[00125] Referring back to Figure 4, each amplitude processing module 415, 420, 430 computes an amplitude update vector, $\Delta \underline{a}_m$, which is $K \times 1$ vectors. Each amplitude update vector is passed to a central node that implements the functionality of the Amplitude Estimator 435. In Figure 5, all individual update vectors from the amplitude estimation processors 560, 562, 564, 566 are passed to a central processing node 575 via

the SAN 570. As detailed herein, the amplitude estimate is updated by weighting the sum of all amplitude updating vectors, wherein the weighting is based on quadratic terms reflecting the uncertainty in the update, Q_m . These quadratic terms are also passed to the central node 575 to provide the necessary weighting.

[00126] The SAN 570 passes all $\Delta \underline{a}_m$ vectors (M vectors of size $K \times 1$) and Q_m matrices, (M hermitian $K \times K$ matrices with $K(K+1)/2$ unique elements) from the MMSE processors 560, 562, 564, 566 to the central processing node, 575. The Amplitude Estimator 575 computes the functionality described for the Amplitude Estimator 435 of Figure 4 and the updated estimate gets distributed to all M processors used for the next MMSE-based symbol estimation. Therefore, Amplitude Estimator 575 passes the updated amplitude estimate to SAN 580 that fan out these estimates for all K users to the M processors 520, 522, 524, 526 for the symbol estimation processing.

[00127] The updated amplitude estimates refreshes the amplitude estimates stored in the local memory 510, 512, 514, 516 coupled to the MMSE processors 520, 522, 524, 526. Following the receipt of the updated amplitude estimates, the next iteration of the MMSE-based symbol estimator is implemented. Therefore, the MMSE modules 510, 512, 514, 516 perform the symbol estimation processing and repeat the symbol estimation on the next iteration using the new amplitude estimates. As described herein, the iterative processing continues until estimates of the bit error rate metric achieves a certain level or until a fixed number of iterations have been executed.

[00128] The hardware configuration presented in Figure 5 is an attractive implementation because bandwidth requirements are minimized by passing a total of only $K \cdot M$ floating point numbers over the SAN 530, except during amplitude updating when the matrices Q_m are passed over the SAN 570 to a central node 575. Bandwidth can be further minimized during the amplitude testing by approximating Q_m as a diagonal and therefore pass a total of $2K \cdot M$ floating point numbers during amplitude updating. Since the MMSE operations, both symbol and amplitude, occur at the same processing nodes on processors, 520, 522, 524, 526 and 552, 554, 556, 558, less data is processed and efficient techniques can be used to exploit previous MMSE filter weights.

[00129] The communications configuration described in **Figure 5**, is more easily recognized in **Figure 6**, which shows $1 - L$ nodes responsible for all processing. These L nodes pass data between themselves using a high speed interconnect **625** for the system area network (SAN). The modules **600** correspond to the time when the nodes $1 - L$ are used to implement the bank of M MMSE filters for symbol estimation in M observation intervals. The symbol estimation processing at node **600** is comparable to processing performed on MMSE processors **520, 522, 524, 526** shown in **Figure 5**.

[00130] The number of L nodes depends upon the size of the problem, typically the number of K users, and the available hardware. For example, if K is small, then more than one MMSE filter operation can be performed per node in which case $L < M$. If K is large such that more than one node is required per MMSE filter operation, then $L > M$. The capability of the node is based on processing speed, local memory, design constraints, and concept of operation.

[00131] The data from symbol estimation processing nodes **600** is passed by the high speed interconnect **625** to the decoder processing nodes **605**. The decoder processing nodes **605** are L nodes used to implement a bank of decoders such as SISO decoders, wherein the decoders for K users are distributed among the L nodes. This decoder processing corresponds to the bank of decoders **532, 534, 536, 538** of **Figure 5**. While **Figure 6** illustrates an implementation using common hardware, for the implementation where the hardware for MMSE and decoders are different, the L nodes **605** could refer to dedicated decoder hardware.

[00132] The communication between nodes from the MMSE symbol estimation processing stage to the nodes for the decoding stage of the algorithm is illustrated by the following example. For illustrative purposes, let the number of nodes equal the number of observation intervals, $L = M$. This simplification is not an architecture restriction, but simply a convenient way to illustrate the communication between nodes. Based on this simplification, the output of each node **600** in the symbol estimation section is a $K \times 1$ vector representing symbol estimates for the K users. Each node **605** in the decoder section is responsible for decoding a subset of the number of users. To further simplify the discussion, let each node **605** in the decoder section execute two decoders. In other words,

each node 605 performs the processing for two processors of the bank of decoders 532, 534, 536, 538 from Figure 5 so that the number of nodes L in this example would be one half the number of users K ($L = \frac{1}{2} K$).

[00133] Therefore, based on these simplifications, for purposes of explanation only, the symbols from the symbol estimation nodes 600 that correspond to users 1 and 2 in the first observation interval are two of the K symbol estimates determined in Node 1. The symbols from Node 1 of the symbol estimation section 600 are transmitted to the Node 1 of the decoder section nodes 605, wherein Node 1 of the decoders nodes 605 represents the decoding of users 1 and 2 for the first time interval. The symbols for the users 1 and 2 in the second observation interval, Node 2, from the symbol estimations section 600 are passed over the high-speed interconnect 625 to Node 1 in the decoder section 605. Similarly, the symbols for the same two users, users 1 and 2, in the third observation interval, Node 3, from the symbol estimation section 600 are passed via 625 to Node 1 in the decoder section 605. This procedure continues for the M observation intervals for the symbols corresponding to the first 2 users, user 1 and user 2.

[00134] As should be readily apparent from this example, Node 2 of the decoder section 605 processes user 3 and user 4 for all the L observation nodes 600; Node 3 of the decoder section 605 processes user 5 and user 6 for all the L observation nodes. By way of further explanation, Node 4 in the decoder section 605 is responsible for decoding users 7 and 8, and receives two symbols corresponding to users 7 and 8 from all the L observation nodes 600. For example, Node 1 of the symbol estimation section 600 passes the symbol estimates of users 7 and 8 to Node 4 of decoder section 605. Similarly, Node 2 of the symbol estimation section 600 passes the symbol estimates for users 7 and 8 for the 2nd observation interval to Node 4 of decoder section 605. This procedure continues for all L nodes in the decoder section 605. Therefore, symbol estimates out of the MMSE symbol estimators 600 are routed from the M observation intervals to the K decoders of the decoder section 605 based on the mapping of the K decoders to the L available processing nodes.

[00135] The next section is the amplitude estimation section 610 for nodes 1 – L . The amplitude estimation section 610 represents L nodes implementing the MMSE stage of

the amplitude estimator, as shown by modules 560, 562, 564, 566 in Figure 5. Prior to implementing amplitude estimation, the amplitude estimation nodes 610 receives all symbol likelihoods via the high speed interconnect 630 following the execution of the nodes from the decoders 605. As described in Figure 5, the likelihoods of the symbols out of the K decoders 532, 534, 536, 538 are routed back to M MMSE filters 560, 562, 564, 566 for the amplitude estimation stage of the algorithm. For this example, two decoders are implemented per node in the decoder section 605 and one MMSE filter processor in the amplitude estimation section 610 is executed per node. The output of Node 1 in the decoder section is a $M \times 2$ array of likelihoods corresponding to the M symbol likelihoods for the first two users after implementing the decoder processing 605, descrambler, de-interleaver, and rate identification. Node 1 in the amplitude estimation section 610 retains the symbol likelihoods for the first two users, user 1 and user 2, in the first observation interval. Node 2 in the amplitude estimation section 610 is responsible for the MMSE implementation over the second observation interval. Therefore, the second set of bits in the $M \times 2$ array is passed from Node 1 in the decoder section 605 to Node 2 in the amplitude estimation section 610. This is repeated for all M observation intervals. Therefore, the outputs of the decoder section 605 are passed to all nodes 610 computing the amplitude updating vector in the M observation intervals.

[00136] The next set of nodes is the amplitude weighing section 615 responsible for updating the amplitude estimate and which implements the functionality of the amplitude estimator 575 of Figure 5. This processing is performed at a single node, and for illustrative purposes Node 3 is depicted and described herein. It should be noted that the other nodes of this section 615 of the algorithm remain idle while the amplitude estimation is completed. Therefore the high-speed interconnect 635 passes the amplitude updating vector and quadratics from the L nodes in the amplitude estimation section 610 Node 3 of the amplitude weighing section 615.

[00137] The functionality of the Amplitude Estimator 435 of Figure 4 provides a more detailed explanation concerning the weighing implementation. The amplitude estimate calculated by Node 3 of the amplitude weighing section 615 is "fanned-out" to all the L processing nodes for further processing of symbol estimation at the next iteration ($I+1$). Thus, the new amplitude estimate for all K users is distributed via the high speed

interconnect 640 to all the L nodes of the next iteration symbol estimation section 620 for the $I+1$ iteration. The L nodes in the next iteration symbol estimation section 620 recompute the symbol estimates, using the new amplitude estimates, for the K users in the M observation intervals. The stages and data routing are repeated until the maximum number of iterations is achieved or the desired bit error rate is reached.

[00138] One aspect of the present invention is that it solves the previously described problem of tightly integrating parameter estimation, symbol hypothesis testing, decoding, and rate identification. The approach in one embodiment assumes a modulation scheme (e.g. CDMA) has been utilized. The solution presented herein in one embodiment is a windowed-based Minimum Mean Squared Error (MMSE) approach to Turbo-decoding for joint signal demodulation, which is easily extended to time-varying channels. The invention is based on an iterative decoding solution that exploits error correction codes. In addition, the approach of the present invention is suitable for symbol asynchronous as well as symbol synchronous. Also, the algorithm used is suitable for a variety of signaling schemes such as M-ary Phase Shift Keying (MPSK).

[00139] It will be appreciated that implementation of the present invention solves the problem of the unknown channel parameters in state of the art detectors. The present invention works with many varieties of multiuser detectors and is easily implemented into different multiuser detecting systems. Specifically, the MMSE symbol estimators in modules 600 and 620 of Figure 6 can be substituted with any of the known or referenced MUD algorithms.

[00140] The present invention dramatically reduces the number of computations needed in a blind approach to joint signal demodulation and without pilot tones or training sequences, so that reliable operation can be achieved in a real-time implementation. It will also be appreciated that since the present technique does not require knowledge of training sequences or existence of a pilot signal, it is considered a blind approach to symbol and data rate estimation. The efficient implementation of blind estimation is realized because of the high degree of parallelism. This provides an efficient implementation because of reduced number of operations associated with updating MMSE filter tap weights.

[00141] Further efficiency is realized because the number of iterations required to achieve a certain bit-error-rate for case of unknown amplitudes is typically similar to the case when the amplitudes are completely known. The present efficiency occurs because the degradation in bit-error-rate for the case of unknown amplitudes is manageable relative to the case of known amplitudes. Thus, the present approach represents a new method to estimate channel amplitudes and extension to time-varying channels is obvious to those in the art. The present approach also represents a new method to reduce biases in amplitude estimates based on incoherent integration.

[00142] The foregoing description of the embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of this disclosure. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

CLAIMS

What is claimed is:

1. An apparatus for processing a digital data stream from multiple users, comprising:

an initial amplitude estimation unit processing said data stream and producing initial amplitude estimates on a first iteration;

a joint amplitude estimator coupled to said data stream and said initial amplitude estimator, wherein said joint amplitude estimator produces updated amplitude estimates;

a symbol estimator coupled to said data stream, said initial amplitude estimator, and said joint amplitude estimator, wherein said symbol estimator produces a plurality of symbols estimates for each user; and

a bank of decoders coupled to said symbol estimator, producing a plurality of symbol likelihood estimates for each user, wherein said symbol likelihood estimates are iteratively fed back to said symbol estimator and said joint amplitude estimator until a final condition is obtained.

2. The apparatus according to claim 1, wherein said final condition is selected from at least one of the group consisting of: bit error rate metric level and fixed number of iterations.

3. The apparatus according to claim 1, wherein said symbol hypothesis testing module is a member selected from at least one member of the group consisting of: Minimum Mean Squared Error (MMSE), maximum likelihood, M-algorithm, T-algorithm, and Q-algorithm, decorrelating decision-feedback detector (DDFD), improved decorrelating decision-feedback detector (IDDFD), successive interference cancellation (SIC), parallel interference cancellation (PIC) and multi-stage detector; block-iterative interference cancellation, and a deferred decorrelating decision-feedback detector.

- 10
- 1 4. The apparatus according to claim 1, further comprising an energy detector
2 coupled to said joint amplitude estimator.
3
- 1 5. The apparatus according to claim 1, wherein said bank of decoders are
2 decoders selected from at least one decoder of the group consisting of: Soft-
3 output Viterbi , Maximum A Posteriori , and BCJR.
4
- 1 6. A method for providing initial amplitude estimation for a plurality of user
2 channels, comprising:
3 separating said user channels into active channels and inactive channels;
4 processing said inactive channels according to the sub-steps comprising:
5 applying a bank of filters to said inactive channels for each inactive
6 user;
7 squaring an output from said bank of filters;
8 summing an output from said squaring operation; and
9 calculating an average bias estimate from an output of said
10 summing; and
11 processing said active channels according to the sub-steps comprising:
12 applying a bank of filters to said user data of said active channels;
13 squaring an output from said bank of filters ;
14 summing an output from said squaring; and
15 removing said average bias estimate from an output from said
16 summing.
17
- 1 7. The method according to claim 6, said processing said inactive channels
2 further comprising dividing said inactive channels into groups and
3 calculating at least one group average bias estimate.
4

1 8. The method according to claim 7, said processing said active channels
2 further comprising dividing said active channels into groups and
3 respectively removing said at least one group average bias estimate.
4

1 9. The method according to claim 6, wherein said summers further comprises
2 scaling.
3

1 10. The apparatus according to claim 6, wherein said separating said active
2 channel from said inactive channels is performed by an energy detector.
3

1 11. An apparatus for processing initial amplitude estimates from a data stream
2 of multiple users, comprising:

3 an energy detector measuring an energy level of said data stream, wherein
4 said energy detector separates a plurality of active channels from a plurality of
5 inactive channels;

6 a bank of filters coupled to said inactive channels;

7 a bank of squaring operators coupled to said bank of filters;

8 a bank of inactive summers coupled to said squaring operators;

9 an average bias estimator coupled to said inactive summers calculating an
10 average bias estimate;

11 a bank of filters coupled to said active channels;

12 a bank of squaring operators coupled to said bank of filters;

13 a bank of active summers coupled to said squaring operators; and

14 a bias removal section coupled to said active summers and said average bias
15 estimator.
16

1 12. The apparatus according to claim 11, wherein said inactive channels are
2 divided into groups calculating said average bias estimate for each said
3 group.
4

1 13. The apparatus according to claim 12, wherein said active channels are
2 divided into said groups and wherein said bias removal section for each said
3 group removes said average bias estimate for each said corresponding
4 group.

5
1 14. A joint amplitude estimator for a data stream from multiple users,
2 comprising:
3 a data stream from said multiple users divided into a plurality of
4 observation intervals;
5 a plurality of processing modules coupled to said observation intervals,
6 wherein said processing modules calculates interference cancellation values
7 for each of said users and computes a filter for each of said observation
8 intervals, said filter being applied to said data within said observation
9 interval to compute individual amplitude estimates; and
10 an amplitude estimation unit which processes said individual amplitude
11 estimates and calculates new amplitude estimates, wherein said new
12 amplitude estimates are iteratively passed back to said processing modules
13 until a final condition is obtained.
14

1 15. The joint amplitude estimator according to claim 14, wherein said final
2 condition is selected from at least one of the group consisting of: bit error
3 rate metric level and fixed number of iterations.
4

1 16. The joint amplitude estimator according to claim 14, wherein said
2 amplitude estimation unit sums and weighs said individual estimates.
3

1 17. The joint amplitude estimator according to claim 14, wherein said
2 observation intervals are based on distinguishing attributes selected from at
3 least one of the group consisting of: time, code, and frequency.
4

- 1 18. The joint amplitude estimator according to claim 14, wherein said filter is
2 calculated for an arbitrary observation interval m as:

3
$$G_m = B_m S_m^H (S_m X_m S_m^H + \sigma_n^2 I)^{-1}.$$

4

- 1 19. A method for processing amplitude estimates for a multiuser data stream
2 divided into a plurality of observation intervals, comprising:
3 computing a filter for each said observation interval of said data stream;
4 applying interference cancellation to said data stream for each said
5 observation interval;
6 applying said filter to said data stream for each said observation interval
7 from said interference cancellation to produce individual amplitude
8 estimates for each said observation interval;
9 computing new amplitude estimates using said individual amplitude
10 estimates; and
11 passing said new amplitude estimates back to said filter for iterative
12 processing until a final condition is obtained.
- 13

- 1 20. The method according to claim 19, wherein said computing further
2 comprises summing said individual amplitude estimates and weighing.
- 3

- 1 21. The method according to claim 19, wherein said final condition is selected
2 from at least from the group consisting of: bit error rate metric level and
3 fixed number of iterations.
- 4

- 1 22. A turbo-decoding system for joint signal demodulation, comprising:
2 a data stream from a plurality of users divided into a plurality of observation
3 intervals;

4 a plurality of symbol processing nodes processing said observation intervals
5 to compute symbol estimates for said data stream within said observation
6 interval;
7 a plurality of decoder nodes processing said symbol estimates and
8 producing a plurality of symbol likelihoods;
9 a plurality of amplitude update nodes processing said symbol likelihoods
10 and calculating a plurality of amplitude update vectors; and
11 an amplitude estimator node processing said amplitude update vectors and
12 producing an amplitude estimate update, wherein said amplitude estimate
13 update is passed back to said processing nodes for iterative processing
14 between said symbol processing nodes, said decoder nodes, said amplitude
15 update nodes, and said amplitude estimator node until a final condition is
16 obtained.

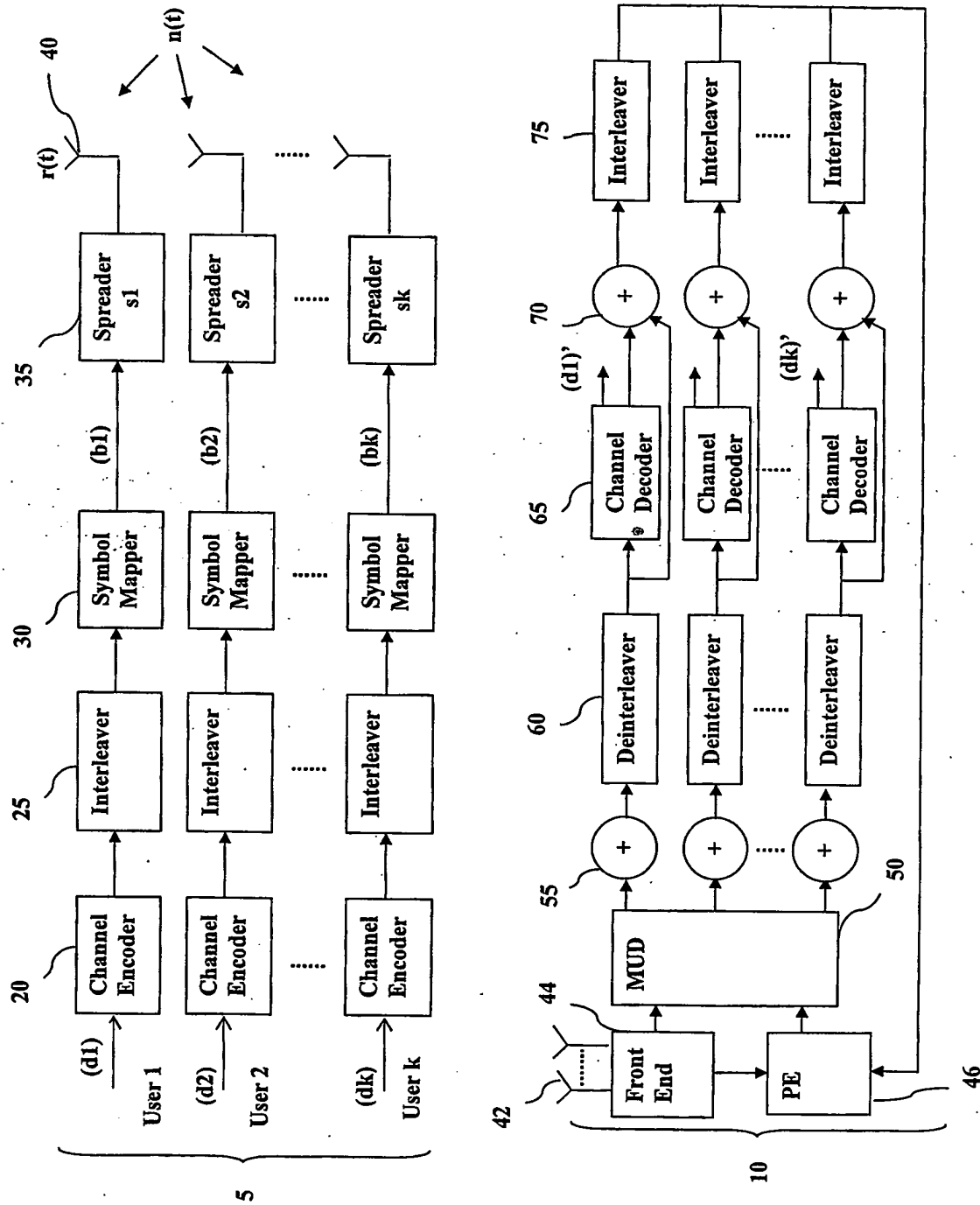
17
1 23. The system according to claim 22, further comprising a plurality of memory
2 units, wherein at least one memory unit is coupled to each of said
3 processing nodes and to each of said amplitude estimation nodes.
4

1 24. The system according to claim 22, further comprising a first system area
2 network (SAN) coupling said processing nodes and said decoder nodes, a
3 second system area network (SAN) coupling said decoder nodes and said
4 amplitude estimation nodes, a third system area network (SAN) coupling
5 said amplitude estimation nodes and said amplitude estimator, and a fourth
6 system area network (SAN) coupling said amplitude estimator and said
7 processing nodes.
8

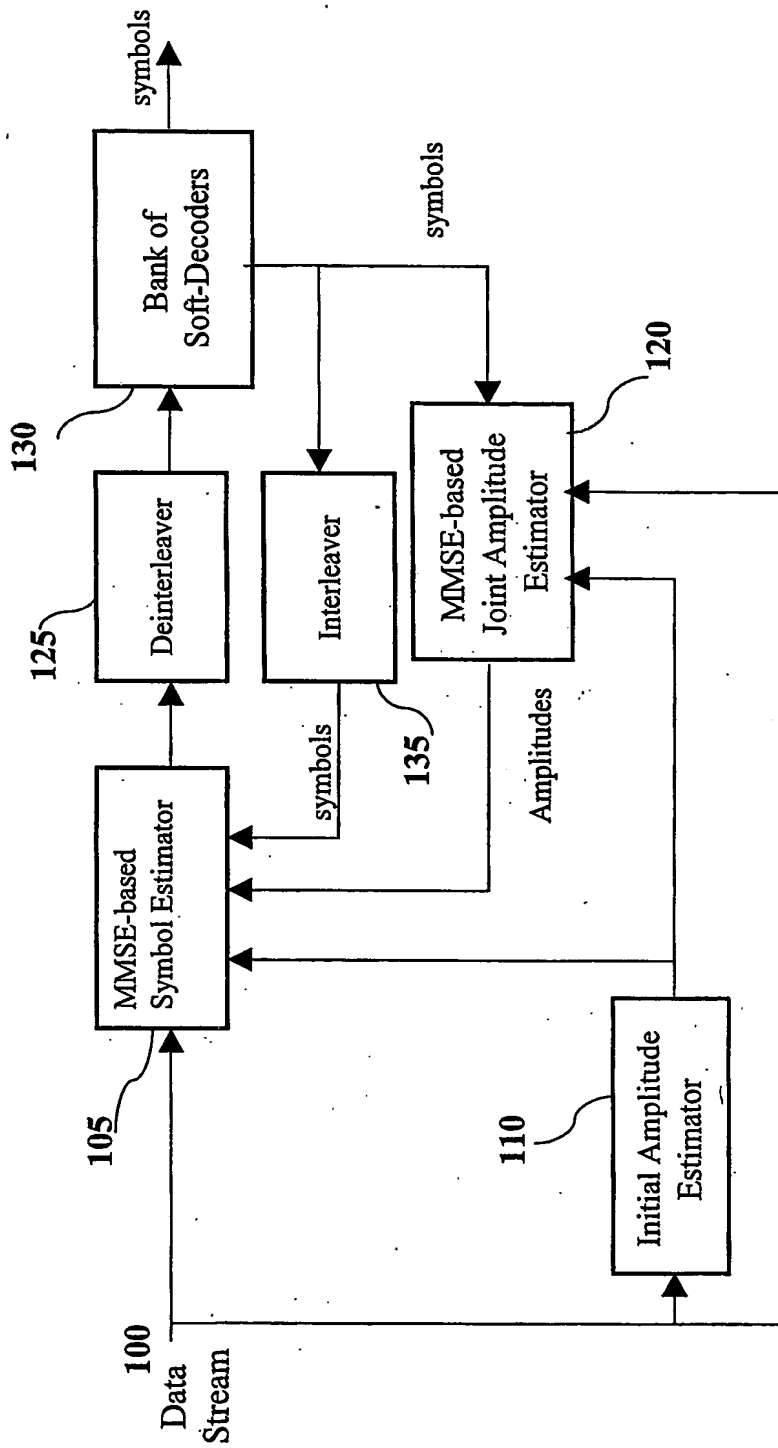
1 25. The system according to claim 22, wherein said final condition is selected
2 from at least one of the group consisting of: bit error rate metric level and
3 fixed number of iterations.
4

- 1 26. The system according to claim 22, wherein said processing nodes, said
2 decoder nodes and said amplitude estimation nodes are one set of nodes.
3
- 1 27. The system according to claim 26, wherein said one set of nodes are each
2 comprised of at least one processor.
3
- 1 28. The system according to claim 22, wherein said likelihood symbols from
2 said decoder nodes are accessible at any time for post-processing.
3
- 1 29. The system according to claim 22, wherein said processing nodes further
2 comprises a thresholder to convert said symbol estimates to symbol bits.
3
- 1 30. The system according to claim 22, wherein said decoder nodes performs de-
2 interleaving, rate identification, de-puncturing and de-scrambling.
3

1/6

Figure 1
(Prior Art)

2/6

**Figure 2**

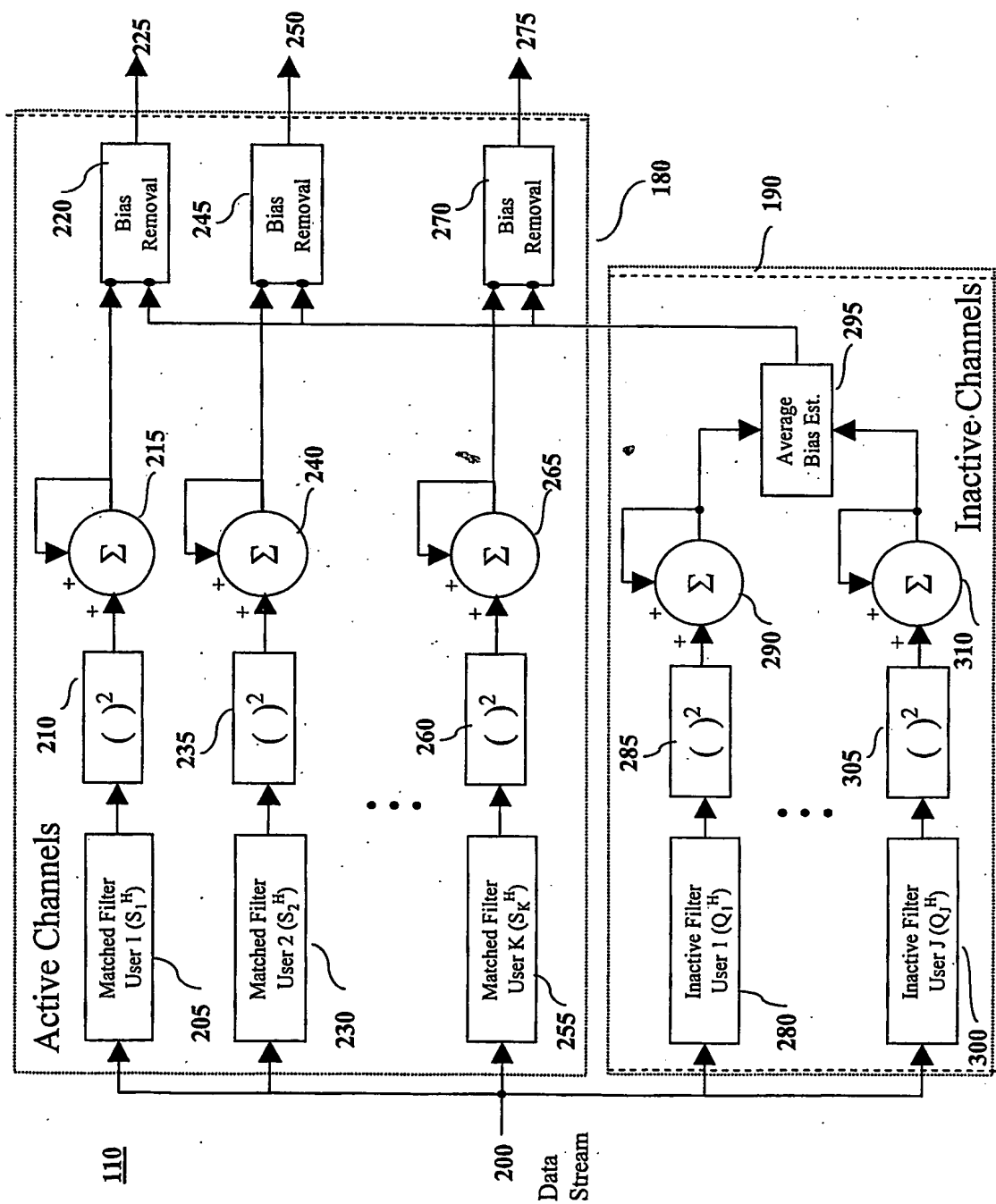


Figure 3

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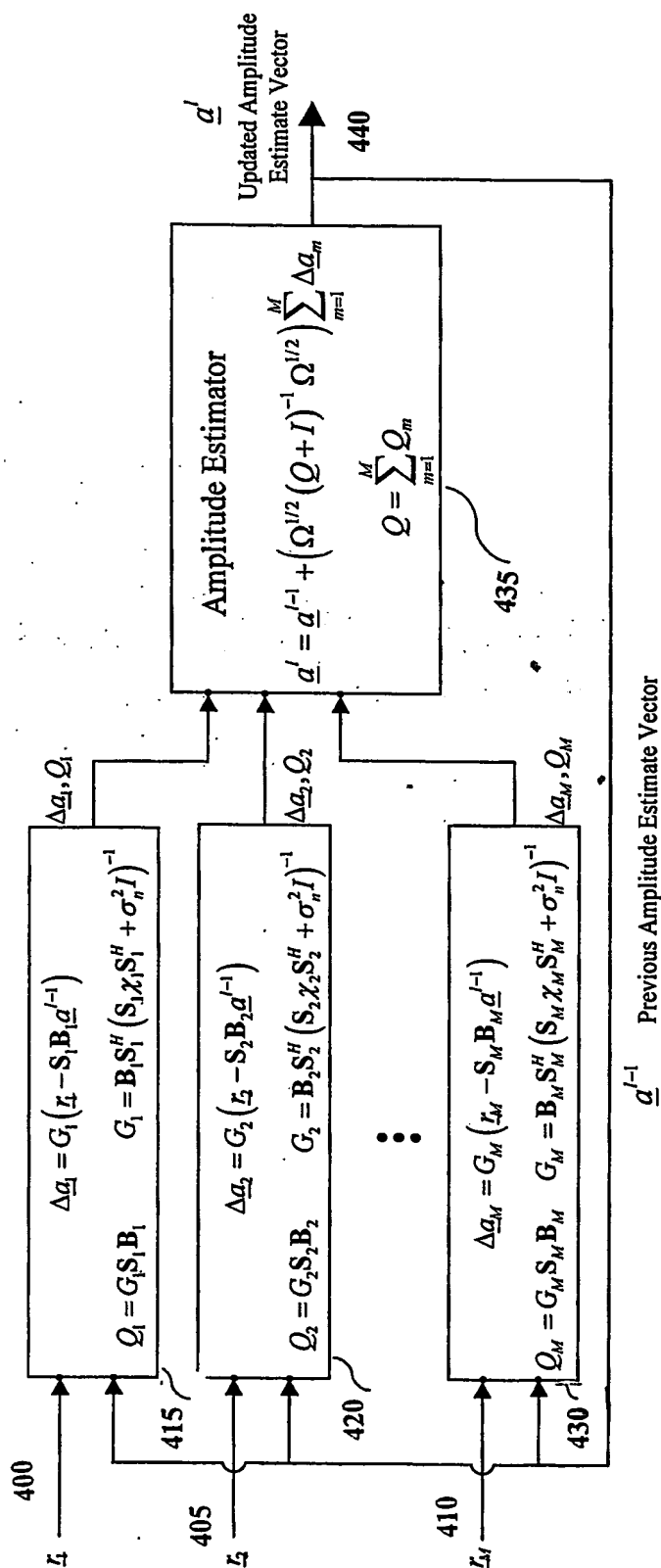


Figure 4

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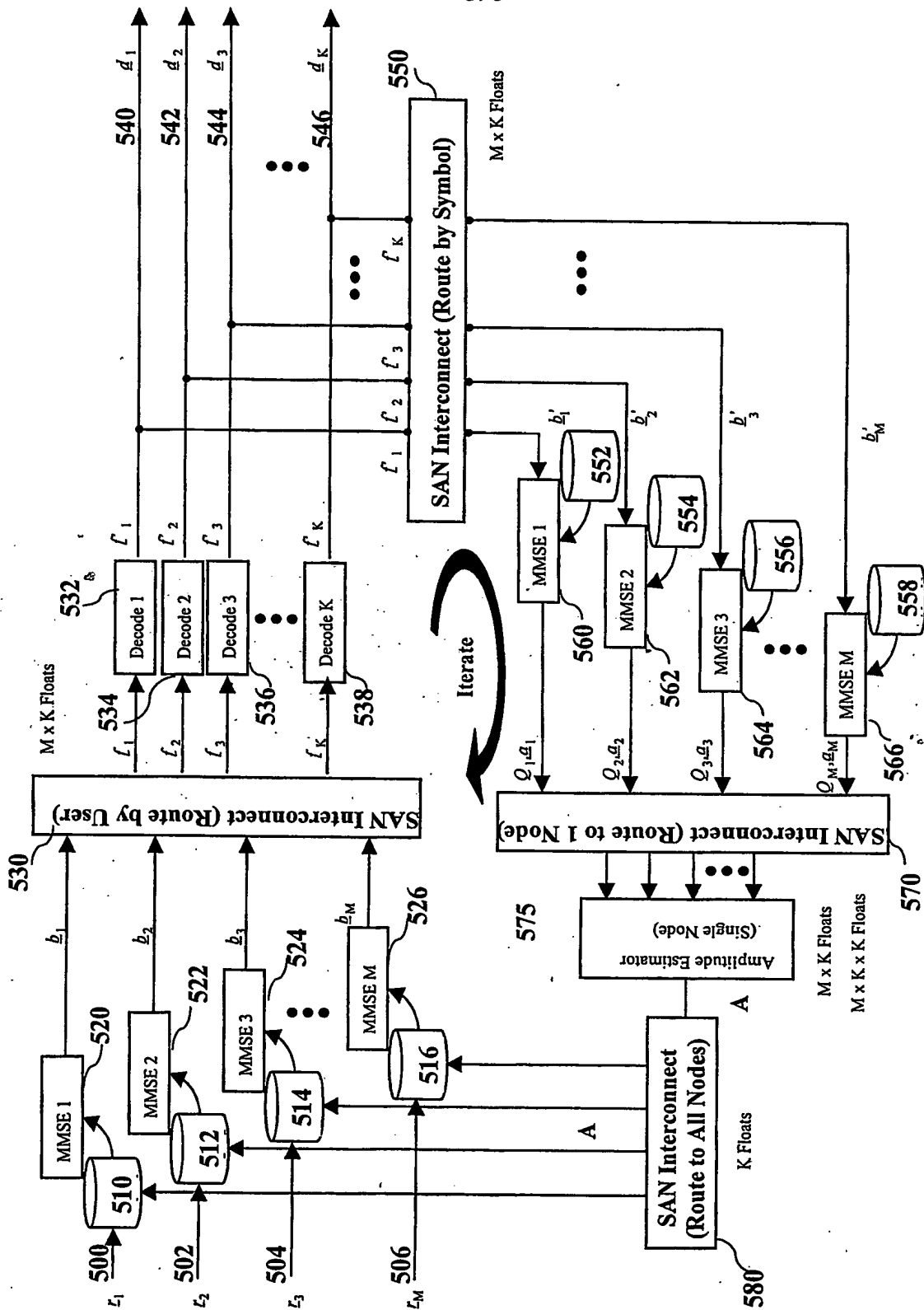


Figure 5

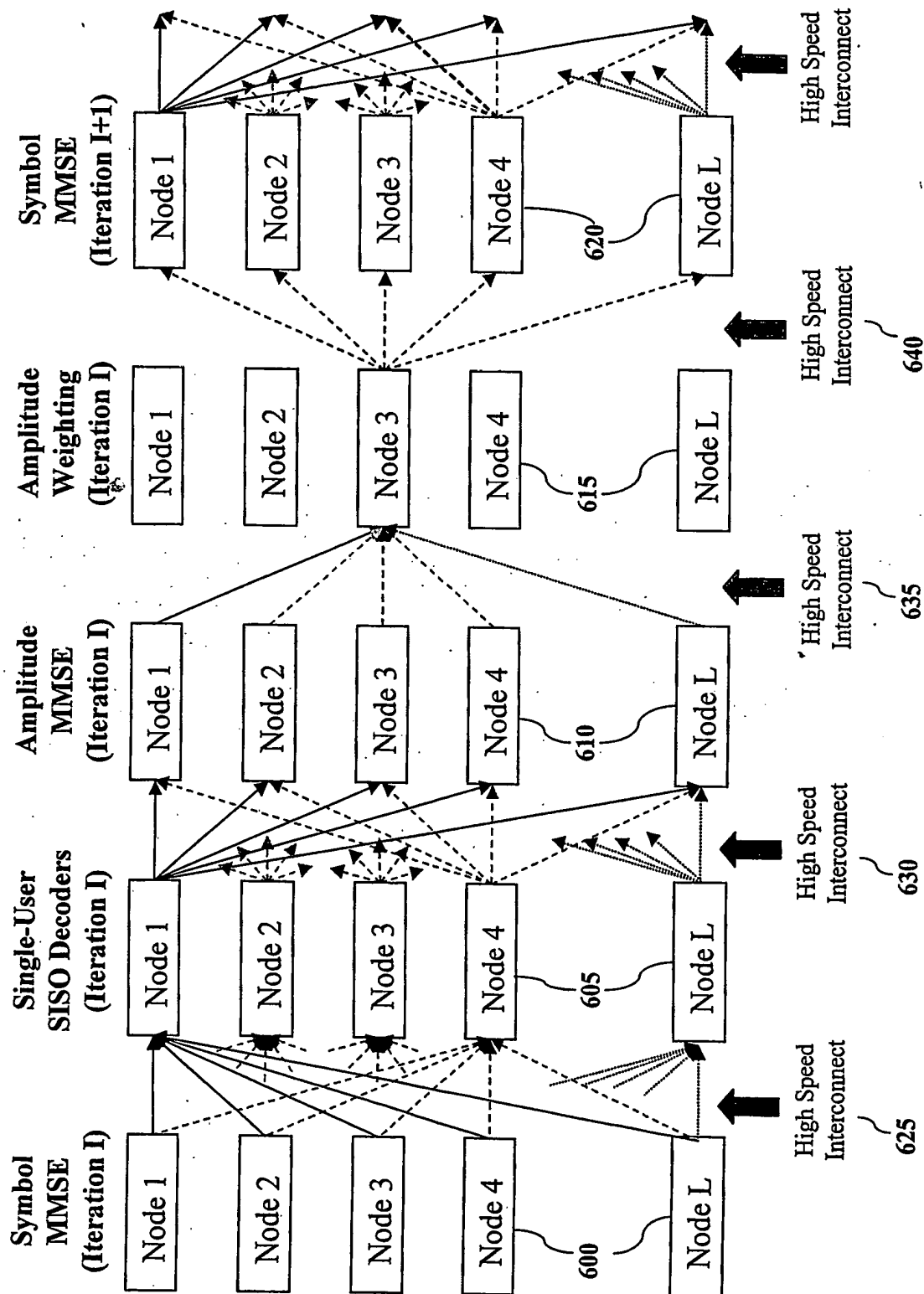


Figure 6