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**UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office**

September 28, 2023

**THIS IS TO CERTIFY THAT ANNEXED IS A TRUE COPY FROM THE
RECORDS OF THIS OFFICE OF THE FILE WRAPPER AND CONTENTS
OF:**

APPLICATION NUMBER: 12/999,029

FILING DATE: December 14, 2010

PATENT NUMBER: 8,565,331

ISSUE DATE: October 22, 2013

**By Authority of the
Under Secretary of Commerce for Intellectual Property
and Director of the United States Patent and Trademark Office**


**Rodney Glover
Certifying Officer**



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 P215801.WO-US.01
INTERNATIONAL APPLICATION NO. PCT/US2010/046106		U.S. APPLICATION NO. (If known, see 37 CFR 1.5) Not Yet Allocated
INTERNATIONAL FILING DATE August 20, 2010		PRIORITY DATE CLAIMED August 20, 2010
TITLE OF INVENTION INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS COMMUNICATIONS		
APPLICANT(S) FOR DO/EO/US Ali Yazdan Panah and Robert W. Heath, Jr.		
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. 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.3 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).		

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 FEE S OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Page 1 of 3

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.

U.S. APPLICATION NO. (if known, see 37 CFR 1.5) Not Yet Allocated		INTERNATIONAL APPLICATION NO. PCT/US2010/046106		ATTORNEY'S DOCKET NUMBER P215801.WO-US.01	
20. Other items or information: General Authorization					
The following fees have been submitted				CALCULATIONS	PTO USE ONLY
21. ☒ Basic national fee (37 CFR 1.492(a))..... \$330				\$ 330	
22. ☒ Examination fee (37 CFR 1.492(c))					
If the written opinion prepared by ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4)..... \$0				\$ 220	
All other situations..... \$220					
23. ☒ Search fee (37 CFR 1.492(b))					
If the written opinion of the ISA/US or the International preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4)..... \$0					
Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority..... \$100				\$ 540	
International Search Report prepared by an ISA other than the US and provided to the Office or previously communicated to the US by the IB..... \$430					
All other situations..... \$540					
TOTAL OF 21, 22 and 23 =				1090	
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing in compliance with 37 CFR 1.821(c) or (e) in an electronic medium or computer program listing in an electronic medium) (37 CFR 1.492(j)). The fee is \$270 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 \$270	\$
Surcharge of \$130.00 for furnishing any of the search fee, examination fee, or the oath or declaration after the date of commencement of the national stage (37 CFR 1.492(h)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	\$	
Total claims	20 - 20 =	0	x \$ 52	\$ 0	
Independent claims	4 - 3 =	1	x \$220	\$ 220	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+ \$390	\$ 0
TOTAL OF ABOVE CALCULATIONS =				\$ 220	
☐ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by 1/2.					
SUBTOTAL =				\$ 1310	
Processing fee of \$130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(l)).				+	\$ 0
TOTAL NATIONAL FEE =				\$ 1310	
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 =				\$ 1310	
				Amount to be refunded:	\$
				Amount to be charged	\$

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.

- a. ☐ A check in the amount of \$ _____ to cover the above fees is enclosed.
- b. ☒ Please charge my Deposit Account No. 50-1266 in the amount of \$ 1310 to cover the above fees.
- c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 50-1266.
- d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038. The PTO-2038 should only be mailed or faxed to the USPTO. However, when paying the basic national fee, the PTO-2038 may NOT be faxed to the USPTO.

ADVISORY: If filing by EFS-Web, do NOT attach the PTO-2038 form as a PDF along with your EFS-Web submission. Please be advised that this is not recommended and by doing so your credit card information may be displayed via PAIR. To protect your information, it is recommended paying fees online by using the electronic payment method.

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:



SIGNATURE

JENNIFER M. LANE

NAME

51,916

REGISTRATION NUMBER

APPLICATION DATA SHEET

Inventor Information

Inventor One Given Name : Ali Yazdan
Family Name : Panah
Postal Address Line One : 928 E. 40th Street
Postal Address Line Two : #106
City : Austin
State or Province : Texas
County : Travis
Postal or Zip Code : 78751
City of Residence : Austin
State or Prov. Of Residence : Texas
Country of Residence : United States of America
Citizenship Country : Iran

Inventor Two Given Name : Robert W.
Family Name : Heath
Name Suffix : Jr.
Postal Address Line One : 2143 Barton Hills Drive
City : Austin
State or Province : Texas
County : Travis
Postal or Zip Code : 78704
City of Residence : Austin
State or Prov. Of Residence : Texas
Country of Residence : United States of America
Citizenship Country : United States of America

Correspondence Information

Customer No. : Address associated with Customer No. 27,076

Application Information

Title : INSERTING AND DECODING REPLICATED DATA
SYMBOLS IN WIRELESS COMMUNICATIONS
Total Drawing Sheets : 7
Formal Drawings : YES
Application Type : Utility
Attorney Docket Number : P215801.WO-US.01

Representative Information

Representative Customer No. : 27,076

Prior Foreign Application

This application is a 371 National Stage filing of:

Foreign Application One : PCT/US2010/046106
Filing Date : August 20, 2010
Country : PCT
Priority Claimed : YES

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants : Ali Yazdan Panah and Robert W. Heath, Jr.

Filed : Concurrently Herewith

Attorney Docket No.: P215801.WO-US.01

Title : INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS
COMMUNICATIONS

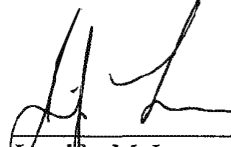
GENERAL AUTHORIZATION

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

Sir:

With respect to the above-identified application, the Commissioner is authorized to charge any fees under 37 C.F.R. §§ 1.16 and 1.17 which may be required and to treat any concurrent or future reply requiring a petition for an extension of time under 37 C.F.R. § 1.136(a)(3) for its timely submission as incorporating a petition therefor for the appropriate length of time and to charge any fees which may be required during the course of prosecution, or credit any overpayment, to Deposit Account No. 50-1266.

Date December 14, 2010



Jennifer M. Lane
Registration No. 51,916

JML:alb

DORSEY & WHITNEY LLP
701 Fifth Avenue, Suite 6100
Seattle, Washington 98104-7043
(206) 903-8800 (telephone)
(206) 299-9288 (fax)

P215801WO01

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PCT REQUESTOriginal (for **SUBMISSION**)

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-SAFE [EASY/EFS-Web mode] Version 3.51.045.221 MT/FOP 20100401/0.20.5.18
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	P215801WO01
I	Title of Invention	INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS COMMUNICATIONS
II	Applicant	
II-1	This person is	Applicant only
II-2	Applicant for	All designated States except US
II-4	Name	THE BOARD OF REGENTS OF THE UNIVERSITY OF TEXAS SYSTEM
II-5	Address	201 W. 7th Street Austin, Texas 78701 United States of America
II-6	State of nationality	US
II-7	State of residence	US
III-1	Applicant and/or inventor	
III-1-1	This person is	Applicant and inventor
III-1-2	Applicant for	US only
III-1-4	Name (LAST, First)	ALI, Yazdan Panah
III-1-5	Address	502 Elmwood Place #101 Austin, Texas 78705 United States of America
III-1-6	State of nationality	IR
III-1-7	State of residence	US

PCT REQUEST

Original (for SUBMISSION)

III-2	Applicant and/or inventor	
III-2-1	This person is	Applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	HEATH, JR., Robert W.
III-2-5	Address	2143 Barton Hills Drive Austin, Texas 78704 United States of America
III-2-6	State of nationality	US
III-2-7	State of residence	US
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
IV-1-1	Name	DORSEY AND WHITNEY LLP
IV-1-2	Address	IP Docket - SE 701 Fifth Avenue, Suite 6100 Seattle, Washington 98104-7043 United States of America
IV-1-3	Telephone No.	206-903-8800
IV-1-4	Facsimile No.	206-299-9288
IV-1-5	e-mail	ipdocket-se@dorsey.com
IV-1-5(a))	E-mail authorization The receiving Office, the International Searching Authority, the International Bureau and the International Preliminary Examining Authority are authorized to use this e-mail address, if the Office or Authority so wishes, to send notifications issued in respect of this international application:	as advance copies followed by notifications
IV-2	Additional agent(s)	additional agent(s) with same address as first named agent
IV-2-1	Name(s)	BULCHIS, Edward W. (26847); MEIKLEJOHN, Paul T. (26569); PARK, Brian C. (45519); ENG, Kimton N. (43605); STEWART, Douglas (51060); BROWN, James Fearon (60837); MEYER, Ryan (61435); LANE, Jennifer M. (51916)
V	DESIGNATIONS	
V-1	The filing of this request constitutes under Rule 4.9(a), the designation of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.	
VI-1	Priority Claim	NONE
VII-1	International Searching Authority Chosen	Australian Patent Office (ISA/AU)

PCT REQUESTOriginal (for **SUBMISSION**)

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)	4	✓
IX-2	Description	21	-
IX-3	Claims	4	-
IX-4	Abstract	1	✓
IX-5	Drawings	7	-
IX-7	TOTAL	37	
	Accompanying Items	Paper document(s) attached	Electronic file(s) attached
IX-8	Fee calculation sheet	✓	-
IX-20	Figure of the drawings which should accompany the abstract	1	
IX-21	Language of filing of the international application	English	
X-1	Signature of applicant, agent or common representative	/Jennifer M. Lane 51916/	
X-1-1	Name (LAST, First)	LANE, Jennifer M.	
X-1-2	Name of signatory		
X-1-3	Capacity		

P215801WO01

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PCT REQUEST

Original (for **SUBMISSION**)

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/AU
10-6	Transmittal of search copy delayed until search fee is paid	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	Date of receipt of the record copy by the International Bureau	
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**INSERTING AND DECODING REPLICATED DATA SYMBOLS
IN WIRELESS COMMUNICATIONS**

BACKGROUND

- [001] Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.
- [002] Multiple-input multiple-output (MIMO) communication systems employ multiple transmit antennas and multiple receive antennas to communicate data symbols over a communications channel. MIMO communication systems may allow a plurality of mobile stations to be serviced utilizing a same frequency band. In this manner, MIMO communication systems may advantageously increase an amount of data the communication systems is able to send to users.
- [003] MIMO systems may find use in a variety of applications including, but not limited to, wireless networks, cellular systems including 3G and 4G systems, such as 3GPP LTE-Advanced, local and wide area networks, and wireless broadband systems (such as WiMAX).
- [004] Generally, a transmitter in a MIMO system may have a plurality of antennas. Receiving devices may each have a single antenna for receipt of data over the communications channel, or may have multiple antennas.
- [005] The communications channel, however, may introduce a variety of non-idealities to a transmitted signal, such as may be caused by multipath interference, reflections, motion of one or more mobile stations, or other properties of a communications channel. The signals received by a receiver over the communications channel may be related to the transmitted signals by a channel matrix $\mathbf{H}$. The channel matrix generally refers to a matrix of data which may represent the operation of the communications channel on the transmitted data symbols, including representations of such effects as reflections.
- [006] Orthogonal frequency division multiplexing (OFDM) modulation techniques may be used to modulate data for transmission over a communications channel. OFDM generally involves modulating different portions of the data to be transmitted using different sub-carrier frequencies.
- [007] Block coding techniques may be used in communication systems to encode data and transmit multiple data streams over a communications channel, which may improve the reliability of data transfer. Block coding techniques include space-time block coding, which

may transmit multiple data streams across multiple antennas. Alamouti space time block coding is one particular type of space-time block coding known in the art. Space-time block coding techniques may require that the communications channel be constant during consecutive data transmission times, which may not always be advantageous. Another type of block coding technique is space-frequency block coding. Alamouti space-frequency block coding is one particular type of space-frequency block coding known in the art. Space-frequency block coding techniques may require that different frequencies experience similar communications channel properties, which may be more advantageous in some cases.

- [008] Block coding techniques may commonly be used in conjunction with OFDM. Decoding of block encoded OFDM transmissions may require knowledge of properties of the communications channel over which the transmission is received. Accordingly, systems utilizing block encoded OFDM transmissions generally measure one or more properties of the communications channel, such as the channel matrix. One way to measure properties of the communications channel is to insert pilot symbols into the transmitted data streams. The pilot symbols may be known to the receiver and the known pilot symbols may be compared with the received signals to generate an estimate of one or more properties of the communications channel. The need to insert pilot symbols into the transmitted data streams may adversely effect a data rate attainable in the communications system.

BRIEF DESCRIPTION OF THE DRAWINGS

- [009] The foregoing and other features of the present disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several examples in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings, in which:

- [010] In the drawings:

Figure 1 is a schematic illustration of an example system that is configured for communication over a communications channel in accordance with at least some examples of the present disclosure;

Figure 2 is a schematic illustration of components of the communications device 110 arranged in accordance with examples of the present disclosure;

Figure 3 is a schematic illustration of signals transmitted over a communications channel in accordance with examples of the present disclosure;

Figure 4 is a schematic illustration of components of the communications device 115 arranged in accordance with examples of the present disclosure;

Figure 5 is a schematic illustration of signals transmitted over the communications channel in accordance with some examples of the present disclosure;

Figure 6 is an example method for transmitting signals over a communications channel arranged in accordance with an example of the present disclosure;

Figure 7 is an example method for receiving signals over a communications channel arranged in accordance with an example of the present disclosure; and

Figure 8 is a block diagram illustrating an example computing device 800 that is arranged for generating an updated channel estimate in accordance with examples of the present disclosure.

SUMMARY

[011] The present disclosure describes a method of transmitting data over a communications channel. Some example methods may include modulating data, inserting data from one stream into another stream, and/or transmitting the data streams over a communications channel. The modulation may be performed in accordance with an orthogonal frequency division multiplexing technique, and may generate at least a first and second data stream for transmission using respective transmit antennas. The inserting may insert at least a portion of data from the first data stream into the second data stream.

[012] The present disclosure describes methods of decoding a signal transmitted over a communications channel. Example methods may include, receiving a pilot symbol over the communications channel, estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol, receiving replicated data from multiple data streams transmitted over the communications channel, decoding the replicated data using the estimated channel matrix, and/or generating an updated estimate of the channel matrix based, at least in part, on the replicated data.

[013] The present disclosure describes communications devices. Example communications devices may include a modulator, a replicator, an encoder, and/or a transmitter. The modulator may be configured to modulate data in accordance with an orthogonal frequency division multiplexing technique for transmission over a communications channel using at

least a first and a second transmit antenna. The modulator may be further configured to generate at least a first data stream for transmission with the first antenna and a second data stream for transmission with the second antenna. The replicator may be coupled to the modulator and configured to receive the first and second data streams. The replicator may also be configured to insert at least one data symbol from the first data stream into the second data stream. The encoder may be coupled to the replicator and may be configured to receive the first and second data streams including the inserted at least one symbol. The encoder may be configured to encode the first and second data streams in accordance with a block coding technique. The transmitter may be coupled to the encoder and may be configured to receive the encoded first and second data streams. The transmitter may be configured to transmit the first data stream over the communications channel using the first antenna and further configured to transmit the second data stream including the inserted at least one symbol over the communications channel using the second antenna.

[014] Example communications devices may include a receiver, a decoder, and/or a channel estimator. The receiver may be configured to receive signals over a communications channel, wherein the signals are based at least in part on first and second data streams transmitted over a communications channel, wherein the second data stream includes at least one data symbol replicated from the first data stream. The decoder may be coupled to the receiver and the channel estimator. The decoder may be configured to receive the received signals and decode the at least one data symbol replicated from the first data stream. The channel estimator may be coupled to the decoder and the receiver, and may be configured to receive the received signals and the decoded at least one data symbol. The channel estimator may be configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol. The decoder may also be configured to decode subsequent received signals based, at least in part, on the estimate of the channel matrix.

[015] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

DETAILED DESCRIPTION

- [016] The following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative examples described in the detailed description, drawings, and claims are not meant to be limiting. Other examples may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are implicitly contemplated herein.
- [017] This disclosure is drawn, inter alia, to methods, systems, devices, and/or apparatus generally related to use of replicated data as a pilot symbol in a communications system. Examples of transmission methods include inserting at least a portion of data from a first data stream into a second data stream to be transmitted over a communications channel. On receipt of the two data streams, examples of receiving methods include receiving the replicated data, decoding the replicated data using an estimated channel matrix, and generating an updated estimate of the channel matrix based, at least in part, on the replicated data.
- [018] Figure 1 is a schematic illustration of an example system that is configured for communication over a communications channel in accordance with at least some examples of the present disclosure. A system 100 may be a multiuser multiple-input multiple-output system configured for communication over a communications channel 105. System 100 may include a communications devices 110, 115, 116, and/or 117. The communications devices may be operated by users (not shown).
- [019] The communications device 110 may be implemented as a base station and may be configured to communicate with multiple mobile stations 115, 116, and 117. The communications device 110 may include antennas 112 and 114, which may be utilized to communicate over the communications channel 105 using multiple antennas for spatial diversity to communicate with multiple users over each frequency.
- [020] The communications device 110 may include antennas 112 and 114, an encoder 158, a transmitter 160, a replicator 162, and/or a modulator 164. Antennas 112 and 114 may be coupled to the transmitter 160. The encoder 158 may be coupled to transmitter 160. The

modulator 164 may be coupled to encoder 158. The replicator 162 may be coupled to modulator 164 and encoder 158.

[021] The modulator 164 may be configured to receive data for transmission over the communications channel 105. The modulator 164 may be configured to modulate the data in accordance with one or more modulation techniques, such as orthogonal frequency division multiplexing (OFDM). Any suitable modulator may be used, and modulator 164 may be implemented in hardware, software, or combinations thereof. The modulator 164 may accordingly generate multiple data streams for communication over the communications channel, one for transmission using each of the respective antennas 112 and 114 in some examples. Pilot symbols may be inserted into the data streams by the modulator 164 or may be inserted before or after the modulator 164 in some examples.

[022] The replicator 162 may be configured to receive one or more data streams generated by the modulator. The replicator 162 may be configured to replicate at least a portion of data from one data stream and insert the replicated data into another data stream, as will be described further below. Any suitable hardware, software, or combinations thereof may be used to implement the replicator 162, including a mixer.

[023] The encoder 158 may be configured to receive one or more data streams generated by the modulator 164 and which may have been modified by the replicator 162. The encoder 158 may be configured to encode the data streams in accordance with a block encoding technique, such as space-time or space-frequency block coding, including in some examples Alamouti space-time or Alamouti space-frequency block coding.

[024] The transmitter 160 may be configured to transmit the encoded data over the communications channel 105 via the cooperative operation of the transmitter 160 and one or more of antennas 112 and/or 114.

[025] Although not shown in Figure 1, the communications device 110 may also include components configured to receive, decode, and demodulate signals received over the communications channel. That is, the communications device 110 may both send and receive signals over the communications channel in some examples.

[026] The communications device 115 may include antenna 119, a receiver 172, a decoder 174, a channel estimator 178, and/or a demodulator 170. Antenna 119 may be coupled to the receiver 172 and the channel estimator 178. The channel estimator 178 may also be coupled to the decoder 174. The demodulator 170 may be coupled to the decoder 174.

- [027] The receiver 172 is configured to cooperate with antenna 119 to receive signals over the communications channel 105 and provide the received signals to decoder 174. Although not shown in Figure 1, in some examples, multiple antennas may be provided at the communications device 115. In examples using Alamouti encoding and decoding, however, a single receive antenna may generally be used to receive signals over the communications channel 105. Any suitable receiver may be used and the receiver 172 may be implemented in hardware, software, or combinations thereof. As will be described further below, the received signals may include data
- [028] The decoder 174 may be configured to decode signals received from the receiver 172 to provide data. Any of a variety of decoding techniques may be used in accordance with a technique used to encode the signals received by the receiver 172. Examples of decoding techniques include block decoding techniques including space-time and space-frequency block decoding, and Alamouti space-time and space-frequency decoding in some examples. Any suitable decoder may be used and the decoder 174 may be implemented in hardware, software, or combinations thereof.
- [029] The demodulator 170 may be configured to demodulate decoded data from the decoder 174. The demodulator 170 may generally implement any demodulation technique, including demodulation in accordance with orthogonal frequency division multiplexing (OFDM) techniques. Any suitable demodulator may be used, and the demodulator 170 may be implemented in hardware, software, or combinations thereof.
- [030] The channel estimator 178 may be configured to estimate all or a portion of a channel matrix H associated with the communications channel 105. As will be described further below, the channel estimator 178 may utilize pilot symbols to estimate the channel matrix. The channel estimator 178 may also be configured to use decoded replicated data as a pilot symbol to estimate the channel matrix and/or update an estimate of the channel matrix. By utilizing replicated data to generate or update an estimate of the channel matrix, the communications device 115 may in some examples require fewer pilot symbols to be inserted into signals communicated over the communications channel 105. Reducing a number of pilot symbols inserted into the transmitted signals may advantageously improve the data rate of the communications system 100 in some examples.
- [031] Although not shown in Figure 1, the communications device 115 may also include components such as a transmitter, encoder, and/or modulator, for transmitting signals over

the communications channel 105. That is, in some examples, the communications device 115 may both transmit and receive signals over the communications channel.

[032] Communications devices 116 and 117 may be similarly configured to communications device 115. The communications device 116 may include antenna 121. The communications device 117 may include antenna 123.

[033] The communications channel 105 may generally include any suitable medium for transmitting electromagnetic signals. The communications channel 105 may be characterized by the channel matrix H describing the operation of the communications channel 105 on transmitted symbols. The channel matrix H may provide a representation of effects such as reflections in the communications channel. The channel matrix H may vary over time, and may be calculated periodically in some examples. While a single communications channel 105 is illustrated in Figure 1, any number of communications channels may be used.

[034] Any number of communications devices may be included in the communications system 100, including the communications devices 115, 116, and 117. Although not shown, the communications devices 116 and 117 may include analogous components to those shown in mobile station 115. The communications devices 115, 116, and 117 may be implemented as mobile stations in some examples.

[035] Figure 2 is a schematic illustration of components of the communications device 110 arranged in accordance with examples of the present disclosure. The modulator 164 may include a mapping and pilot insertion block 202, which may be coupled to a serial to parallel converter 204, which may be coupled to an inverse Fourier transform (IFFT) block 206, which may be coupled to a parallel to serial converter 208. The replicator 162 may be coupled to the parallel to serial converter 208. The encoder 158 may be coupled to the replicator 162.

[036] During operation, data for transmission over a communications channel may be provided to the mapping and pilot insertion block 202, which may be configured to map the data to symbols and insert pilot symbols into the data stream. In some examples, the pilot symbols may be inserted at a later point in the signal processing stream. The serial to parallel converter 204, IFFT 206, and parallel to serial converter 208 may be configured to modulate the data stream in accordance with an OFDM technique to generate multiple data streams for transmission over the communications channel. The replicator 162 may replicate a portion of the modulated data such that some data symbols from one stream are inserted into another stream. The space-time encoder 158 may then encode the data streams, including inserted

symbols, for transmission over the communications channel. The configuration of Figure 2 may provide for space-time encoding of the data streams.

[037] Figure 3 is a schematic illustration of signals transmitted over a communications channel in accordance with examples of the present disclosure. The signals 302, 303, 304, and 305 of Figure 3 may be transmitted by the transmitter 160 of Figure 1 in some examples, and received by the receiver 172. The example of Figure 3 illustrates signals encoded using a space-time block coding technique. In particular, signals 302 and 303 may be transmitted during a first time period while signals 304 and 305 are transmitted during a second time period. Signals 302 and 304 may be transmitted from one location, such as by the antenna 112 of Figure 1. Signals 303 and 305 may be transmitted from another location, such as by the antenna 114 of Figure 1. The relationships between the signals 302, 303, 304, and 305 may generally be specified by the space-time coding technique used. Each of the illustrated signals may encode multiple data symbols, shown as boxes in Figure 3. For example, the signal 302 may encode the symbols 310-317. Pilot symbols may also be encoded by the signals. In the example of Figure 3, the symbols 310 and 314 may represent pilot symbols. The pilot symbols 310 and 314 may accordingly also be present at similar frequencies in the signal 303. Further, replicated data symbols from the signal 302 may be included in the signal 303. In this example of Figure 3, the data symbols 312 and 316 may have been replicated to symbol locations at corresponding frequencies at the second spatial location, as shown. Additional data symbols 318-321 may be included in the signals 303.

[038] The example of Figure 3 illustrates replicated data symbols inserted at a midpoint between two pilot symbols in a data stream. In other examples, replicated data symbols may be inserted at a location other than a midpoint between two pilot symbols, and the replicated data symbol may be inserted at a location closer to one pilot symbol than another. In some examples, some pilot symbols may have no replicated data symbols inserted between them. In general, any number or arrangement of replicated data symbols may be inserted into a data stream. As will be described further below, the replicated data symbols may be utilized in a manner similar to pilot symbols to estimate the communications channel. Since the replicated data symbols also encode data, the use of replicated data symbols as pilot symbols may increase the data rate of the over communications system in some examples.

[039] Figure 4 is a schematic illustration of components of the communications device 115 arranged in accordance with examples of the present disclosure. The demodulator 170 may include a serial to parallel converter 402, a fast Fourier transform unit (FFT) 404, a parallel to

serial converter 406, and a mapping block 408. The serial to parallel converter 402 may be coupled to the FFT 404. The FFT 404 may be coupled to the channel estimator and a space-time decoder 174. The space-time decoder 174 may be coupled to the parallel to serial converter 406. The parallel to serial converter 406 may be coupled to the mapping block 408.

[040] In operation, signals received by the receiver 172, such as the signals 302-305 of Figure 3, may be provided to the serial to parallel converter 402 and converted into parallel streams. The FFT 404 may perform a Fourier transform of the streams, and provide the Fourier transformed signals to the channel estimator 178 and the space-time decoder 174. In accordance with the methods described below, the channel estimator 178 may estimate all or a portion of the channel matrix based on received pilot symbols and/or replicated data symbols. The space-time decoder 174 may decode the data streams in accordance with the estimated channel matrix. Moreover, the space-time decoder 174 may provide signals indicative of the replicated data symbols to the channel estimator 178. The replicated data symbols may be used by the channel estimator 178 to estimate all or a part of the channel matrix, or to update an estimate of the channel matrix. Decoded signals may be provided from the space-time decoder 174 to the parallel-to-serial converter 406 and converted into a serial data stream of decoded symbols. The symbols may be provided to the mapping block 408 and may be converted into a stream of output data. In this manner, data may be encoded, transmitted, received, and decoded in the communications system in some examples.

[041] In some examples, the positioning of the encoder and decoder relative to the FFT and IFFT blocks of the modulator may vary. In particular, the configuration shown in Figure 4 may correspond to examples using space-time coding and decoding techniques. In some examples, space-frequency coding and decoding may be used. In examples where space-frequency coding is used, the encoder 158 may be coupled between the serial to parallel converter 204 and the IFFT 206.

[042] Figure 5 is a schematic illustration of signals transmitted over the communications channel in accordance with some examples of the present disclosure. The example shown in Figure 5 may pertain to examples employing space-frequency coding techniques. Input data symbols 505 including symbols labeled S1-S11 may be provided to the modulator 164 of Figure 1. Following modulation, pilot insertion, data replication, and coding in accordance with a space-frequency coding technique, one signal stream 510 may be generated for transmission from a first location, such as the antenna 112 of Figure 1, and a second signal stream 515 may be generated for transmission from a second location, such as the antenna

114 of Figure 1. The relationship between the symbols in the streams 510 and 515 is generally specified by the space-frequency coding technique.

[043] Pilot symbols 520-525 are shown in the data stream 510, with corresponding data symbols in the data stream 515. Data symbols 530-539 are included in the data stream 510, with corresponding data symbols in the data stream 515. The pilot symbols 520-525 have been inserted amongst the data symbols 530-539. Data symbols 530 and 531 have been replicated from one frequency to another frequency in the data streams 510 and 515. The replicated data symbols have been inserted at a location between the pilot symbols 523 and 524. As generally described above, any number or positioning of replicated data symbols may generally be used. In the example shown in Figure 5, data symbols have been replicated in pairs. Replicating a pair of data symbols may be advantageous in some examples for consistency with the coding technique employed to code the data stream.

[044] Figure 6 is an example method for transmitting signals over a communications channel arranged in accordance with an example of the present disclosure. The method may include one or more of blocks 605, 610, 615, 620, and/or 625. The various blocks described herein may be performed sequentially, in parallel, or in a different order than those described herein. It should also be appreciated that in some implementations one or more of the illustrated blocks may be eliminated, combined or separated into additional blocks. The method 600 may include block 605, "Modulate data in accordance with an orthogonal frequency division multiplexing technique to generate multiple data streams." Block 605 may be followed by block 610 "Insert pilot symbols into the data streams." Block 610 may be followed by block 615 "Replicate data from one data stream and insert the replicated data into another data stream." Block 615 may be followed by block 620 "Encode the data streams in accordance with a block encoding technique." Block 620 may be followed by block 625 "Transmit the data streams over a communications channel."

[045] Data may be modulated in accordance with an OFDM technique in block 605. The modulation may be performed, for example, by any suitable structure in a communications device, such as a DSP or other processing unit. In some examples, one data stream may be generated for each antenna to be used in transmitting the data over the communications channel.

[046] In block 610, pilot symbols may be inserted into the data streams. The insertion may be performed, for, example, by any suitable structure in a communications device, including a mixer or multiplexor. Generally, the pilot symbols correspond to symbols known by the

transmitting and receiving devices of a communications system. By decoding signals encoding a known pilot symbol, a receiving device may generate an estimate of the channel matrix of the communications channel. Pilot symbols may be stored in any memory structure in communication with the communications device, or may be communicated to the communications device. Any number of pilot symbols may generally be inserted into the data streams with substantially any spacing. The more pilot symbols are inserted into the data streams, the more the overall data transmission rate of the communications system may decrease. However, in examples having more pilot symbols inserted into the data streams, the estimates of the channel matrix by a receiving communications device may be more accurate. Accordingly, there may be a tradeoff between data rate and accuracy of the channel estimation. As will be described further below, use of replicated data symbols as pilot symbols may advantageously increase the channel estimation accuracy while not impacting the overall data rate as severely as using more pilot symbols.

[047] In block 615, data may be replicated from one data stream and inserted into another data stream. The replication may be performed by any suitable structure in a communications device, including a mixer or multiplexor for example. In some examples, a same structure may be used to insert the replicated data as was used to insert the pilot symbols. The replicated data may include one or more symbols from a data stream. In some examples, pairs of symbols may be replicated. The data may be inserted such that it is transmitted at a same frequency band in each of the data streams. Any number of replicated data instances may be included in a transmission. As will be described further below, the replicated data may be utilized to improve estimates of a channel matrix associated with a communications channel. Accordingly, as more replicated data is inserted, the accuracy of the channel matrix estimate may increase. However, as more replicated data is inserted, the overall data rate of the communications system may be reduced, although the reduction may not be as severe as if more known pilot symbols were inserted. The replicated data may be inserted between two pilot symbols, and may be inserted at a midpoint between the two pilot symbols. However, the replicated data may be inserted at substantially any location in some examples.

[048] In block 620, the data streams may be encoded in accordance with a block encoding technique. The encoding may be performed by any suitable structure in a communications device, for example by a DSP or other processing unit. As described above, any block encoding technique may be used, including space-time coding or space-frequency coding.

[049] In block 625, the data streams may be transmitted over a communications channel. The transmission may be performed by a transmitter acting in cooperation with one or more antennas in some examples. In some examples, each antenna may be used to transmit one of the data streams.

[050] Figure 7 is an example method for receiving signals over a communications channel arranged in accordance with an example of the present disclosure. The method 700 may include one or more of blocks 705, 710, 715, 720, 725, and/or 730. The various blocks described herein may be performed sequentially, in parallel, or in a different order than those described herein. It should also be appreciated that in some implementations one or more of the illustrated blocks may be eliminated, combined or separated into additional blocks. The method 700 may include block 705 "Receiving a known pilot symbol over a communications channel." Block 705 may be followed by block 710 "Estimating the communications channel based, at least in part, on the known pilot symbol." Block 710 may be followed by block 715 "Receiving replicated data from multiple data streams over the communications channel." Block 715 may be followed by block 720 "Decoding the replicated data using the estimate of the communications channel." Block 720 may be followed by block 725 "Updating the estimate of the communications channel based, at least in part, on the replicated data." Block 725 may be followed by block 730 "Decoding subsequently received data using the updated channel estimate."

[051] In block 705, a known pilot symbol may be received over a communications channel. The symbol may be received by any suitable receiver of a communications device. Signals may generally be received that encode the known pilot symbol. The received signals may also provide an indication that the encoded symbol is a pilot symbol.

[052] In block 710, the communications channel may be estimated based, at least in part, on the received pilot symbol. The estimation may be performed by any suitable structure of a communications device, such as a DSP or other processing unit. Generally, all or a portion of a channel matrix may be estimated by comparing a decoded received pilot symbol with the known pilot symbol. Known pilot symbols may be stored at the communications device or otherwise communicated to the communications device for comparison with decoded pilot symbols received over the communications channel. The estimated channel, including data estimating all or a portion of a channel matrix, may be stored in some examples.

[053] In block 715, replicated data from multiple data streams may be received over the communications channel. Any suitable receiver may be used to receive the replicated data.

Examples of replicated data have been described above. Generally, signals are received that may encode the replicated data and the signals may also encode an indication that the data includes one or more replicated data symbols. Signals encoding the replicated data may be received by a single antenna in some examples.

[054] In block 720, the replicated data may be decoded using the estimate of the communications channel. Any suitable structure of a communications device may be used to perform the decoding, such as a DSP or other processing unit. In some examples, a joint detection technique is used to decode the replicated data, such as max-ratio combining. By decoding multiple copies of the replicated data, the decoding may be considered to be more accurate than the decoding of single data symbols. Accordingly, the decoded replicated data may be used to generate or update an estimate of the communications channel.

[055] In block 725, the estimate of the communications channel may be updated based, at least in part, on the replicated data. The updating may be performed by any suitable structure in a communications device, such as a DSP or other processing unit. The estimate may be updated by comparing the decoded symbol with the two instances of received signals encoding the symbol. In this manner, the channel estimate may be generated or updated, which may include all or a portion of the channel matrix. The updated channel estimate may be stored in some examples.

[056] In block 730, subsequently received data may be decoded using the updated channel estimate. That is, signals received following the updating of the channel estimate may be decoded using the updated channel estimate. The updated channel estimate may improve decoding performance in some examples.

[057] Accordingly, examples have been described above of estimating a communications channel based on pilot symbols and replicated data symbols. In this manner, the number of pilot symbols may be effectively increased through the use of replicated data symbols. The accuracy of the resultant channel estimates may in some examples approach the accuracy of an example where the effective number of inserted pilot symbols is equal to a sum of the number of pilot symbols plus the number of inserted replicated data symbols. Because the replicated data symbols also transmit data over the communications channel, however, the use of replicated data symbols may not impair the overall data rate of the system as severely as the use of more pilot symbols.

[058] Figure 8 is a block diagram illustrating an example computing device 800 that is arranged for generating an updated channel estimate in accordance with examples of the

present disclosure. In a very basic configuration 801, computing device 800 typically includes one or more processors 810 and system memory 820. A memory bus 830 may be used for communicating between the processor 810 and the system memory 820.

[059] Depending on the desired configuration, processor 810 may be of any type including but not limited to a microprocessor (μ P), a microcontroller (μ C), a digital signal processor (DSP), or any combination thereof. Processor 810 may include one more levels of caching, such as a level one cache 811 and a level two cache 812, a processor core 813, and registers 814. An example processor core 813 may include an arithmetic logic unit (ALU), a floating point unit (FPU), a digital signal processing core (DSP Core), or any combination thereof. An example memory controller 815 may also be used with the processor 810, or in some implementations the memory controller 815 may be an internal part of the processor 810.

[060] Depending on the desired configuration, the system memory 820 may be of any type including but not limited to volatile memory (such as RAM), non-volatile memory (such as ROM, flash memory, etc.) or any combination thereof. System memory 820 may include an operating system 821, one or more applications 822, and program data 824. Application 822 may include a channel estimate routine 823 that is arranged to generate an estimate of a communications channel based on received pilot symbols, replicated data symbols, or combinations thereof. Program Data 824 may include known pilot symbols 825, replicated data symbols 826, channel estimate 827, or combinations thereof, that may be useful for generating channel estimates as generally described above. In some embodiments, application 822 may be arranged to operate with program data 824 on an operating system 821 such that channel estimates are generated and/or updated on the basis of received pilot symbols and replicated data symbols. This described basic configuration is illustrated in Figure 8 by those components within dashed line 801.

[061] Computing device 800 may have additional features or functionality, and additional interfaces to facilitate communications between the basic configuration 801 and any required devices and interfaces. For example, a bus/interface controller 840 may be used to facilitate communications between the basic configuration 801 and one or more data storage devices 850 via a storage interface bus 841. The data storage devices 850 may be removable storage devices 851, non-removable storage devices 852, or a combination thereof. Examples of removable storage and non-removable storage devices include magnetic disk devices such as flexible disk drives and hard-disk drives (HDD), optical disk drives such as compact disk (CD) drives or digital versatile disk (DVD) drives, solid state drives (SSD), and tape drives to

name a few. Example computer storage media may include volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data.

[062] System memory 820, removable storage 851 and non-removable storage 852 are all examples of computer storage media. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which may be used to store the desired information and which may be accessed by computing device 800. Any such computer storage media may be part of device 800.

[063] Computing device 800 may also include an interface bus 842 for facilitating communication from various interface devices (e.g., output interfaces, peripheral interfaces, and communication interfaces) to the basic configuration 801 via the bus/interface controller 840. Example output devices 860 include a graphics processing unit 861 and an audio processing unit 862, which may be configured to communicate to various external devices such as a display or speakers via one or more A/V ports 863. Example peripheral interfaces 870 include a serial interface controller 870 or a parallel interface controller 872, which may be configured to communicate with external devices such as input devices (e.g., keyboard, mouse, pen, voice input device, touch input device, etc.) or other peripheral devices (e.g., printer, scanner, etc.) via one or more I/O ports 873. An example communication device 880 includes a network controller 881, which may be arranged to facilitate communications with one or more other computing devices 890 over a network communication link via one or more communication ports 882.

[064] The network communication link may be one example of a communication media. Communication media may typically be embodied by computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as a carrier wave or other transport mechanism, and may include any information delivery media. A "modulated data signal" may be a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media may include wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, radio frequency (RF),

microwave, infrared (IR) and other wireless media. The term computer readable media as used herein may include both storage media and communication media.

[065] Computing device 800 may be implemented as a portion of a small-form factor portable (or mobile) electronic device such as a cell phone, a personal data assistant (PDA), a personal media player device, a wireless web-watch device, a personal headset device, an application specific device, or a hybrid device that include any of the above functions. Computing device 800 may also be implemented as a personal computer including both laptop computer and non-laptop computer configurations.

[066] The present disclosure is not to be limited in terms of the particular examples described in this application, which are intended as illustrations of various aspects. Many modifications and examples can may be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and examples are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular examples only, and is not intended to be limiting.

[067] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[068] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.).

[069] It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases

“at least one” and “one or more” to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to examples containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an” (e.g., “a” and/or “an” should be interpreted to mean “at least one” or “one or more”); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of “two recitations,” without other modifiers, means at least two recitations, or two or more recitations).

[070] Furthermore, in those instances where a convention analogous to “at least one of A, B, and C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, and C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to “at least one of A, B, or C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, or C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase “A or B” will be understood to include the possibilities of “A” or “B” or “A and B.”

[071] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[072] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at

least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," "greater than," "less than," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 items refers to groups having 1, 2, or 3 items. Similarly, a group having 1-5 items refers to groups having 1, 2, 3, 4, or 5 items, and so forth.

[073] While the foregoing detailed description has set forth various examples of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples, such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one example, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), or other integrated formats. However, those skilled in the art will recognize that some aspects of the examples disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. For example, if a user determines that speed and accuracy are paramount, the user may opt for a mainly hardware and/or firmware vehicle; if flexibility is paramount, the user may opt for a mainly software implementation; or, yet again alternatively, the user may opt for some combination of hardware, software, and/or firmware.

[074] In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as a program product in a variety of forms, and that an illustrative example of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the

following: a recordable type medium such as a floppy disk, a hard disk drive, a Compact Disc (CD), a Digital Versatile Disk (DVD), a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

[075] Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein can be integrated into a data processing system via a reasonable amount of experimentation. Those having skill in the art will recognize that a typical data processing system generally includes one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity; control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[076] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely examples, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably coupleable", to each other to achieve the desired functionality. Specific examples of operably coupleable include but are not limited to physically mateable and/or physically interacting

components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[077] While various aspects and examples have been disclosed herein, other aspects and examples will be apparent to those skilled in the art. The various aspects and examples disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS

What is claimed is:

1. A method of transmitting data over a communications channel, the method comprising:

modulating data for transmission over the communications channel in accordance with an orthogonal frequency division multiplexing technique to generate at least a first and second data stream for transmission using respective transmit antennas;

inserting at least a portion of data from the first data stream into the second data stream; and

transmitting the first and second data streams over the communications channel.

2. The method of claim 1, further comprising:

inserting pilot symbols into the first and second data streams.

3. The method of claim 2 wherein said inserting at least a portion of data from the first data stream into the second data stream comprises inserting the portion of data from the first data stream into the second data stream at a location between two pilot symbols in the second data stream.

4. The method of claim 3 wherein said inserting at least a portion of data from the first data stream into the second data stream comprises inserting a respective portion of data from the first data stream into the second data stream between each two pilot symbols in the second data stream.

5. The method of claim 1 further comprising encoding the first and the second data streams in accordance with a block coding technique.

6. The method of claim 5 wherein the block coding technique comprises a space-time block coding technique.

7. The method of claim 5 wherein the block coding technique comprises a space-frequency block coding technique.

8. A method of decoding a signal transmitted over a communications channel, the method comprising:

receiving a pilot symbol over the communications channel;

estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol;

receiving replicated data from multiple data streams transmitted over the communications channel;

decoding the replicated data using the estimated channel matrix; and

generating an updated estimate of the channel matrix based, at least in part, on the replicated data.

9. The method of claim 8, further comprising decoding subsequently received signals over the communications channel using the updated estimate of the channel matrix.

10. The method of claim 8 wherein said decoding the replicated data comprises using a joint detection technique.

11. The method of claim 8, wherein said decoding the replicated data comprises using a space-time block decoding technique.

12. The method of claim 8, wherein said decoding the replicated data comprises using a space-frequency block decoding technique.

13. The method of claim 8, wherein the replicated data includes same data symbols in multiple data streams.

14. A communication device comprising:

a modulator configured to modulate data in accordance with an orthogonal frequency division multiplexing technique for transmission over a communications channel using at least a first and a second transmit antenna, wherein the modulator is further configured to generate at least a first data stream for transmission with the first antenna and a second data stream for transmission with the second antenna;

a replicator coupled to the modulator and configured to receive the first and second data streams, wherein the replicator is configured to insert at least one data symbol from the first data stream into the second data stream;

an encoder coupled to the replicator and configured to receive the first and second data streams including the inserted at least one symbol, wherein the encoder is configured to encode the first and second data streams in accordance with a block coding technique; and

a transmitter coupled to the encoder and configured to receive the encoded first and second data streams, wherein the transmitter is configured to transmit the first data stream over the communications channel using the first antenna and further configured to transmit the second data stream including the inserted at least one symbol over the communications channel using the second antenna.

15. The communication device of claim 14 wherein the block coding technique comprises a space-time encoding technique.

16. The communication device of claim 14 wherein the block coding technique comprises a space-frequency encoding technique.

17. The communication device of claim 14 wherein the first and second data streams further include at least two pilot symbols, and wherein the replicator is configured to insert the at least one data symbol between the at least two pilot symbols.

18. A communication device comprising:

a receiver configured to receive signals over a communications channel, wherein the signals are based at least in part on first and second data streams transmitted over a communications channel, wherein the second data stream includes at least one data symbol replicated from the first data stream;

a decoder coupled to the receiver and the channel estimator, wherein the decoder is configured to receive the received signals and decode the at least one data symbol replicated from the first data stream;

a channel estimator coupled to the decoder and the receiver, wherein the channel estimator is configured to receive the received signals and the decoded at least one data

symbol, wherein the channel estimator is configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol; and wherein the decoder is further configured to decode subsequent received signals based, at least in part, on the estimate of the channel matrix.

19. The communication device of claim 18 wherein the decoder is configured to decode the at least one data symbol using a joint detection technique.

20. The communication device of claim 18 wherein the first and second data streams each further include at least one pilot symbol, and wherein the channel estimator is configured to receive the at least one pilot symbol and generate an initial estimate of the channel matrix based, at least in part on the at least one pilot symbol.

ABSTRACT

Examples are generally described that include transmission methods including inserting at least a portion of data from a first data stream into a second data stream to be transmitted over a communications channel. On receipt of the two data streams, examples of receiving methods include receiving the replicated data, decoding the replicated data using an estimated channel matrix, and generating an updated estimate of the channel matrix based, at least in part, on the replicated data.

1/7

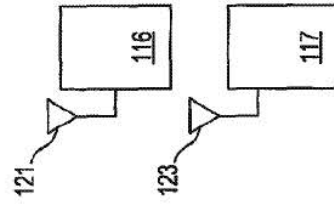
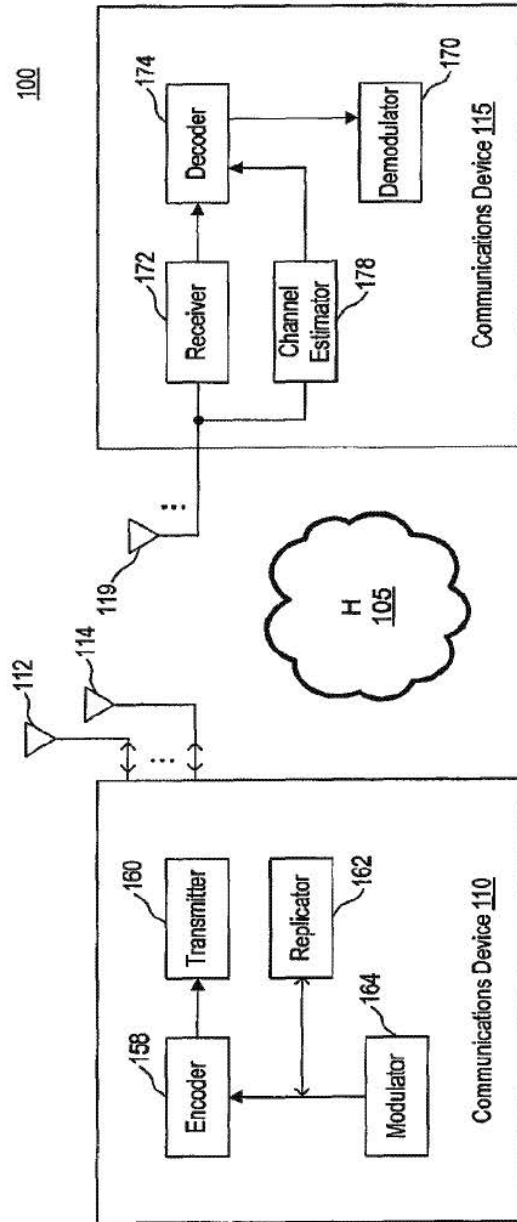


Figure 1

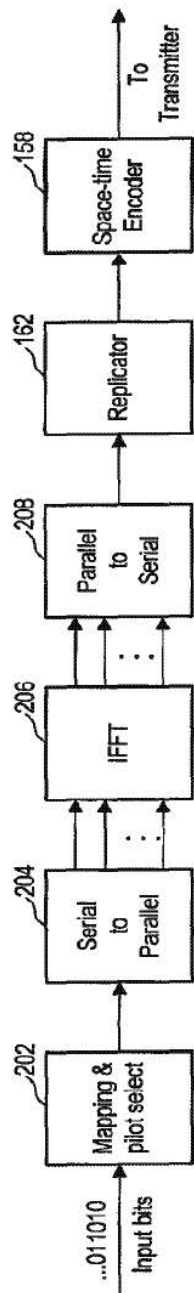


Figure 2

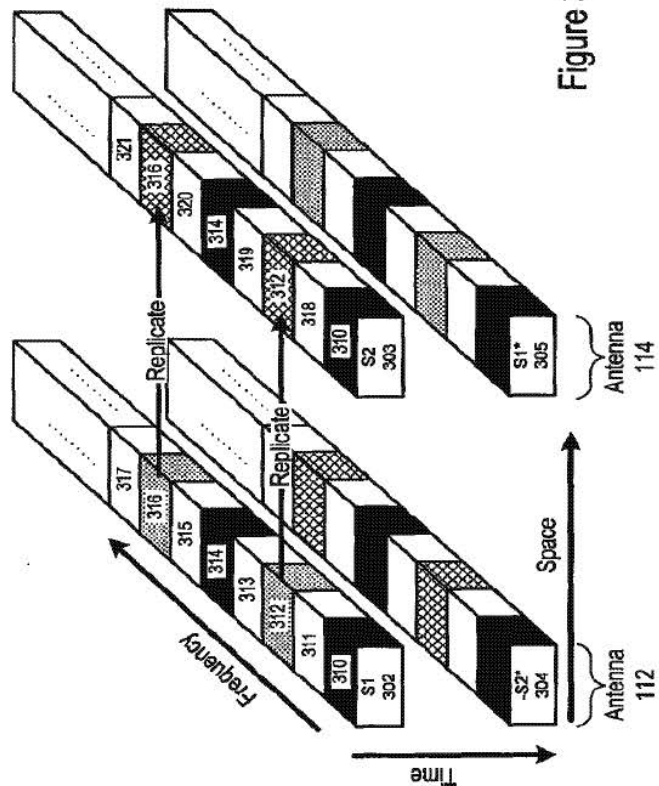


Figure 3

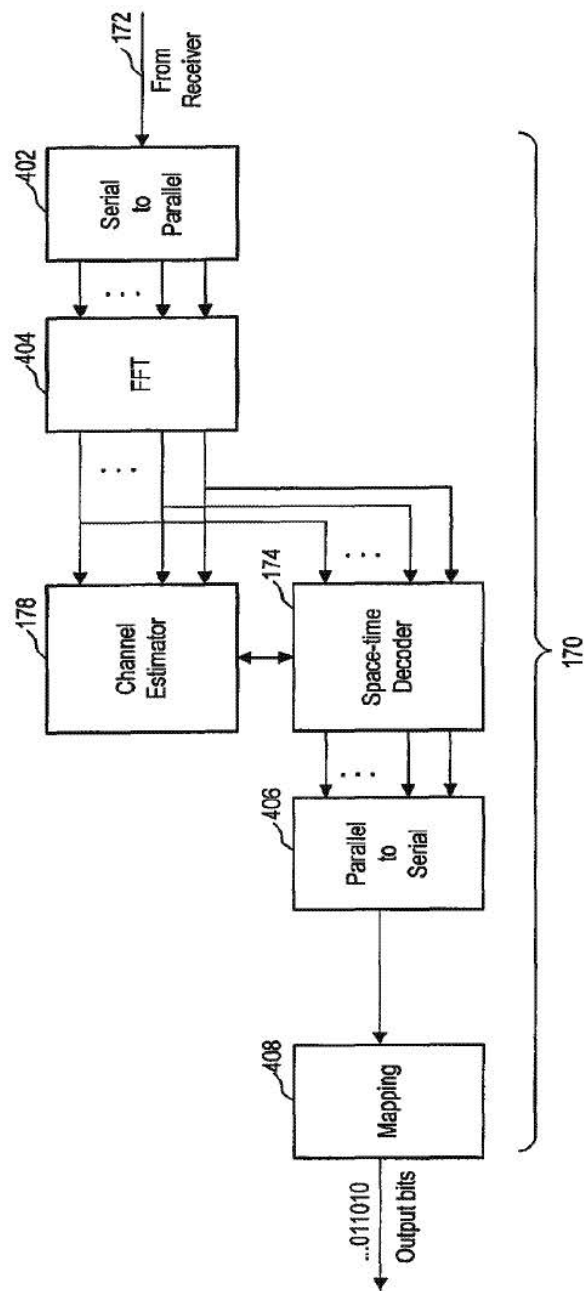


Figure 4

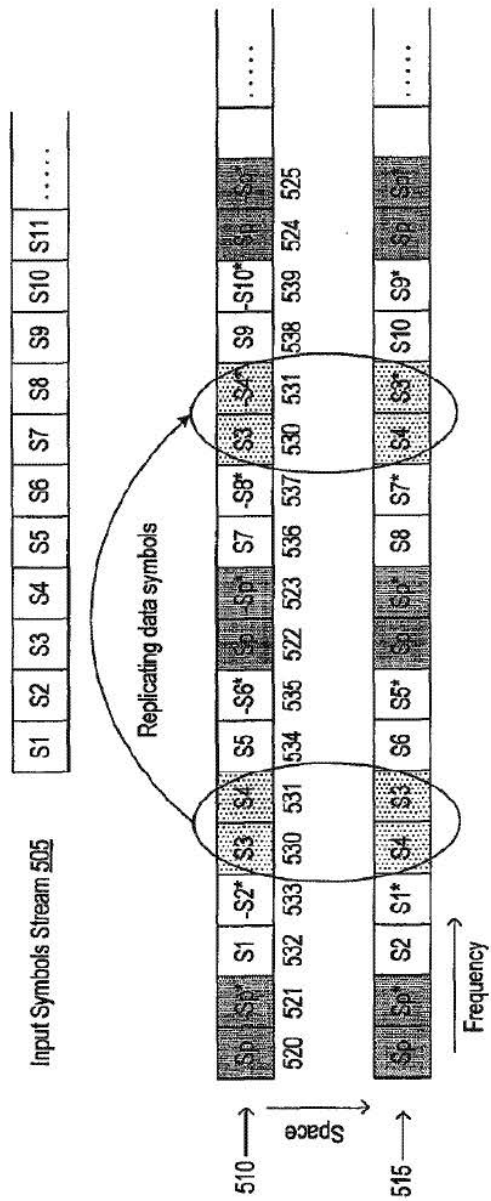


Figure 5

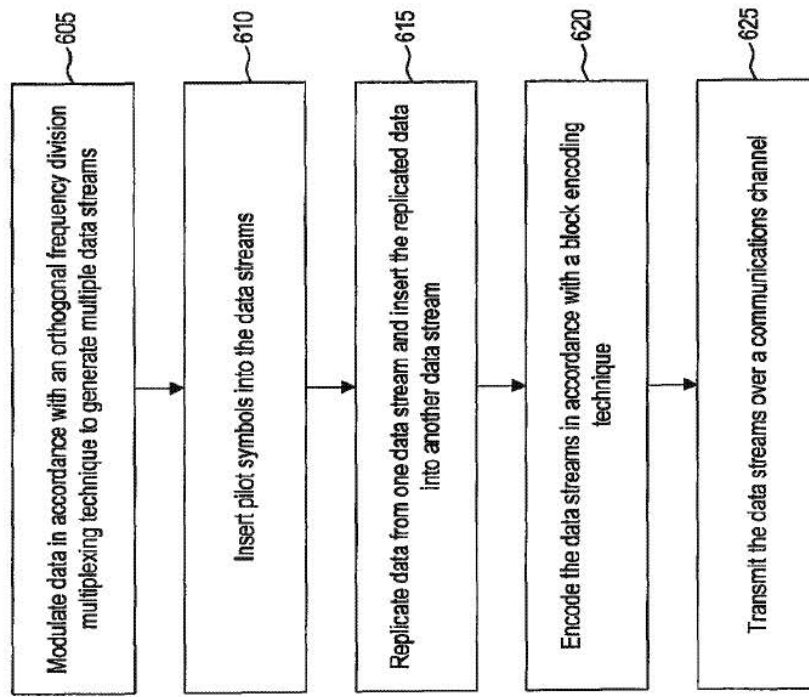


Figure 6

6/7

700

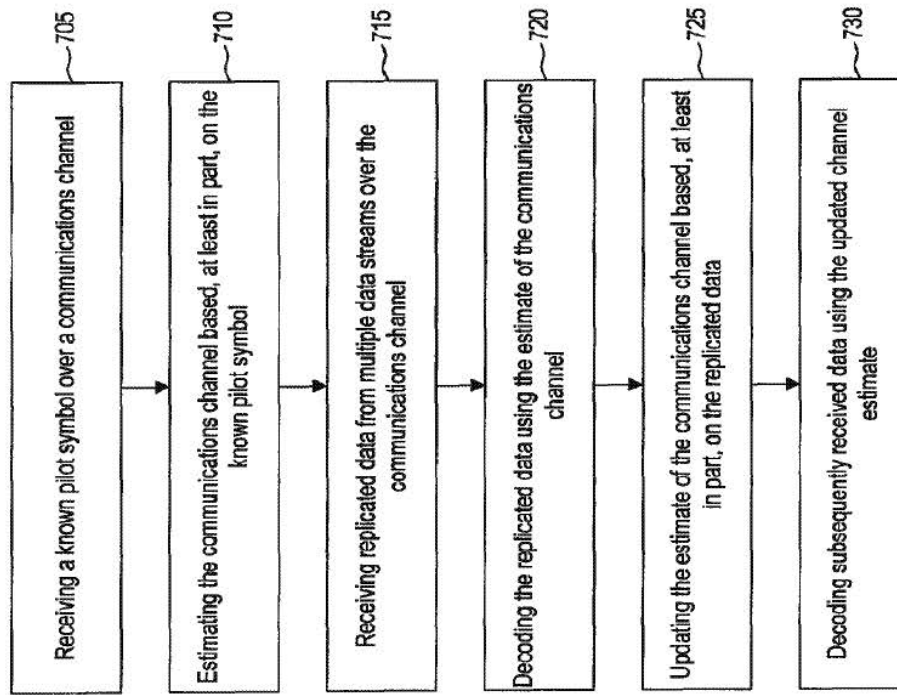


Figure 7

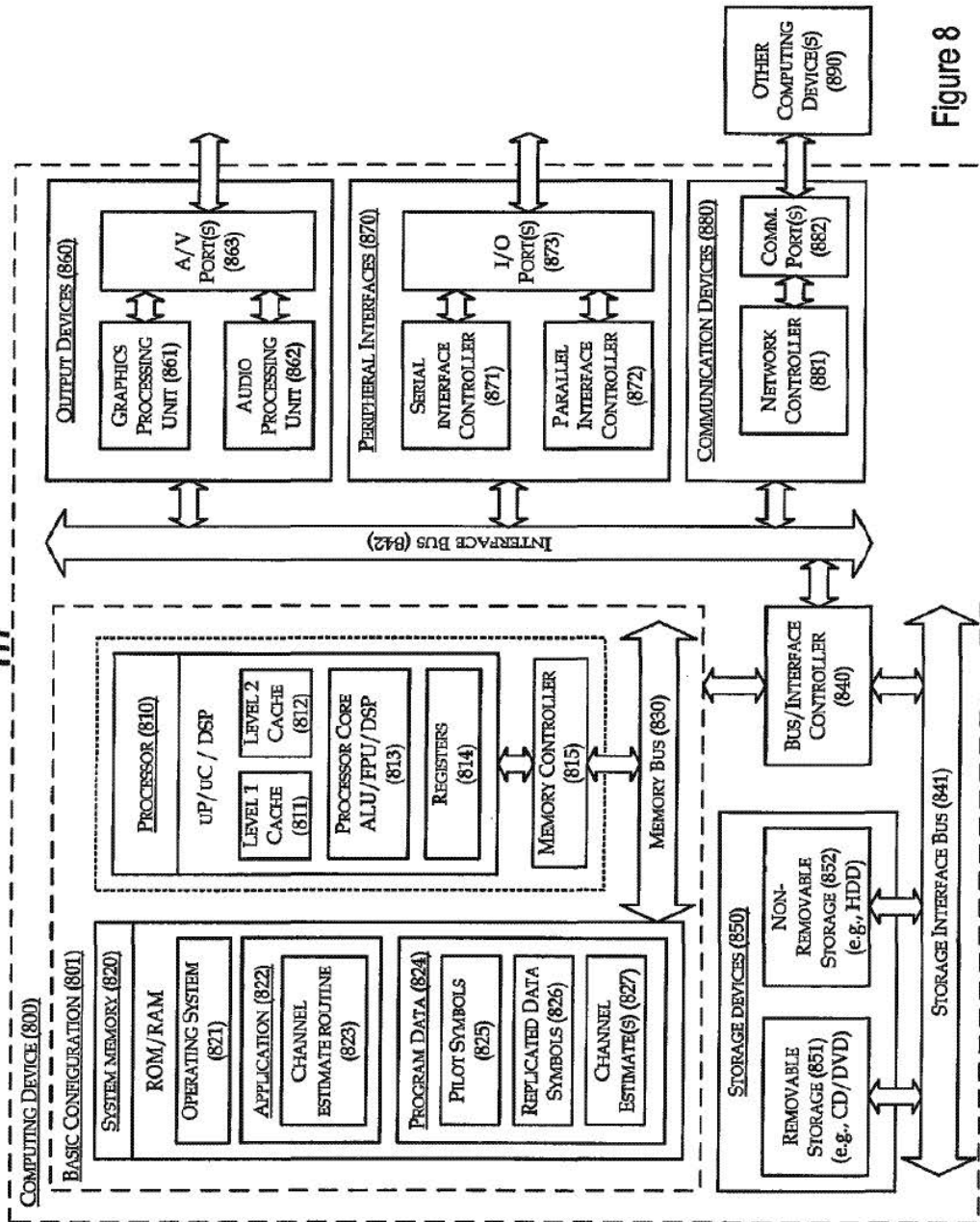


Figure 8

DECLARATION

I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe the inventor(s) named below to be the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS COMMUNICATIONS

the specification and application of which:

☐ is attached hereto;

☐ was filed on August 20, 2010 as United States Application No. _____ or PCT International Application No. PCT/US2010/046106 and was amended on _____ (if applicable);

or

☐ will be filed as a PCT International Application after the execution date of this Declaration; the PCT International Application No. and filing date will be provided by an appointed Attorney or Agent in an Application Data Sheet when the U.S. national stage is commenced under Title 35 U.S.C. §371 or a related U.S. application is filed under Title 35 U.S.C. §§120 and 365(c).

I hereby state that I have reviewed and understand the contents of the above-identified application, including the claim(s), as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 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 national or PCT international filing date of the continuation-in-part application.

PRIORITY CLAIMS

I hereby claim foreign priority benefits under Title 35 U.S.C. § 119(a)-(d) or (f) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT international application(s) which designated at least one country other than the United States of America listed below and have also identified, by checking the box, any foreign application(s) for patent or inventor's certificate or any PCT international application(s) having a filing date before that of the application(s) on which priority is claimed.

- ☒ no such applications have been filed.
☐ such applications have been filed as follows:

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER § 119 or § 365	
			☒ YES	☐ NO
			☒ YES	☐ NO
			☒ YES	☐ NO
			☒ YES	☐ NO

I hereby claim the benefit under Title 35 U.S.C. § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35 U.S.C. § 112, I acknowledge the duty to disclose material information as defined in Title 37 C.F.R. § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

- ☒ no such applications have been filed.
☐ such applications have been filed as follows:

U.S. APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

UNITED STATES PATENT

Attorney Docket No. P215801.US.01

I hereby claim the benefit under Title 35 U.S.C. § 119(e) of any United States provisional application(s) listed below:

☒ no such applications have been filed.
☐ such applications have been filed as follows:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (day, month, year)

DECLARATION

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 Title 18 U.S.C. § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURE(S)

Given Name:	Ali Yazdan Panah		
Inventor's Signature:		Date	09/12/10
Residence:	Austin, Texas, U.S.A.	Citizenship:	Iran
Mailing Address:	928 E. 40 th Street, #105 Austin, Texas 78751		

Given Name:	Robert W. Heath, Jr.		
Inventor's Signature:		Date	
Residence:	Austin, Texas	Citizenship:	U.S.A.
Mailing Address:	2143 Barton Hills Drive Austin, Texas 78704		

Attorney Docket No. P215801.US.01

no such applications have been filed.
such applications have been filed as follows:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (day, month, year)

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 Title 18 U.S.C. § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Given Name:	<u>Ali Yazdan Panah</u>	
Inventor's Signature:	<u></u>	Date <u></u>
Residence:	<u>Austin, Texas, U.S.A.</u>	Citizenship: <u>Iran</u>
Mailing Address:	<u>928 E. 40th Street, #106</u> <u>Austin, Texas 78751</u>	

Given Name:	<u>Robert W. Heath, Jr.</u>	
Inventor's Signature:	<u></u>	Date <u>9/3/2010</u>
Residence:	<u>Austin, Texas</u>	Citizenship: <u>U.S.A.</u>
Mailing Address:	<u>2143 Barton Hills Drive</u> <u>Austin, Texas 78704</u>	

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants : Ali Yazdan Panah and Robert W. Heath, Jr.
Filed : Concurrently Herewith Attorney Docket No.: P215801.WO-US.01
Title : INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS
COMMUNICATIONS

INFORMATION DISCLOSURE STATEMENT

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

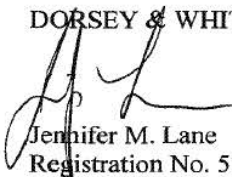
Sir:

In accordance with 37 C.F.R. §§ 1.56 and 1.97 through 1.98, applicants wish to make known to the Patent and Trademark Office the references set forth on the attached form PTO-1449. A copy of the cited non-patent literature reference, as required under 37 C.F.R. § 1.98(a)(2), is enclosed. Copies of the cited U.S. patents and U.S. patent application publication will not be submitted herewith in accordance with the waiver by the Office of the requirement under 37 C.F.R. § 1.98(a)(2)(i) for U.S. national patent applications filed after June 30, 2003.

Please acknowledge receipt of this Information Disclosure Statement and kindly make the cited references of record in the above-identified application.

Respectfully submitted,

DORSEY & WHITNEY LLP



Jennifer M. Lane
Registration No. 51,916

701 Fifth Avenue, Suite 6100
Seattle, WA 98104-7043
Telephone: (206) 903-8800
Facsimile: (206) 299-9288

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

Substitute for form 1449A/PTO					
INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(Use as many sheets as necessary)</i>				<i>Complete if Known</i>	
				Application Number	To be allocated
				Filing Date	Filed concurrently herewith
				First Named Inventor	Ali Yazdan Panah
				Art Unit	To be allocated
				Examiner Name	To be allocated
Sheet	1	of	1	Attorney Docket No: P215801.WO-US.01	

US PATENT DOCUMENTS					
Examiner Initial*	Cite No	Document Number	Publication Date	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2002/0122381 A1	Sep 5, 2002	Wu, S. et al.	
		7397862B2	Jul 8, 2008	Ouyang, X. et al.	
		7778337B2	Aug 17, 2010	Tong, W. et al.	

FOREIGN PATENT DOCUMENTS					
Examiner Initials*	Cite No	Foreign Patent Document	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

OTHER DOCUMENTS -- 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.		
		"International Search Report dated November 9, 2010 for Application No. PCT/US2010/046106"		

EXAMINER

DATE CONSIDERED

Substitute Disclosure Statement Form (PTO-1449)

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

PATENT COOPERATION TREATY

Reviewed by
Docketing

From the INTERNATIONAL SEARCHING AUTHORITY

To:

DORSEY AND WHITNEY LLP
IP Docket - SE, 701 Fifth Ave
Suite 6100, Seattle, Washington 98104-7043, USA

PCT

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT AND
THE WRITTEN OPINION OF THE INTERNATIONAL
SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Date of mailing (day/month/year)	09 NOV 2010
Applicant's or agent's file reference P215801WO01	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US2010/046106	International filing date (day/month/year) 20 August 2010
Applicant THE BOARD OF REGENTS OF THE UNIVERSITY OF TEXAS SYSTEM et al	

- ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.
Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):
When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.
Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes
1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70
For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 - 9.011.
- ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.
- ☐ With regard to any protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.
☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.
- Reminders**
The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. Following the expiration of 30 months from the priority date, these comments will also be made available to the public.
Shortly after the expiration of 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).
Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later); otherwise, the applicant must, within 20 months from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.
In respect of other designated Offices, the time limit of 30 months (or later) will apply even if no demand is filed within 19 months.
For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustalia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer JUZER KHANBELAI AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61 2 6283 2176
--	--



Australian Government

IP Australia

Discovery House, Philip ACT 2606
PO Box 200, Woden ACT 2606
Australia
Phone: 1300 651 010
International Callers: +61-2 6283 2999
Facsimile: +61-2 6283 7999
Email: assn@ipaustalia.gov.au
Website: www.ipaustralia.gov.au

Dear Applicant,

This International Searching Authority will, upon receipt of payment of AU\$50.00 per citation, promptly transmit the requested documents which were cited in the International Search Report established on the International Application.

Please email salesteam@ipaustalia.gov.au if any cited documents are required.

Regards
PCT Administration

PATENT COOPERATION TREATY

From the:
INTERNATIONAL SEARCHING AUTHORITY

To:

DORSEY AND WHITNEY LLP
IP Docket - SE, 701 Fifth Ave
Suite 6100, Seattle, Washington 98104-7043, USA

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing
(day/month/year) 09 NOV 2010

Applicant's or agent's file reference
P215801WO01

FOR FURTHER ACTION
See paragraph 2 below

International application No.

PCT/US2010/046106

International filing date (day/month/year)

20 August 2010

Priority date (day/month/year)

20 August 2010

International Patent Classification (IPC) or both national classification and IPC
Int. Cl.

H04L 27/28 (2006.01) H04J 11/00 (2006.01)
H04B 7/04 (2006.01) H04K 1/10 (2006.01)

Applicant

THE BOARD OF REGENTS OF THE UNIVERSITY OF TEXAS SYSTEM et al

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
☐ Box No. II Priority
☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐ Box No. IV Lack of unity of invention
☒ Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
☐ Box No. VI Certain documents cited
☐ Box No. VII Certain defects in the international application
☐ Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA
AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
E-mail address: pct@ipaustralia.gov.au
Facsimile No. +61 2 6283 7999

Date of completion of this opinion

03 November 2010

Authorized Officer
JUZER KHANBHAI
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No. +61 2 6283 2176

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.

PCT/US2010/046106

Box No. I	Basis of this opinion
1.	With regard to the language, this opinion has been established on the basis of: ☒ The international application in the language in which it was filed ☐ A translation of the international application into, _____, which is the language of a translation furnished for the purposes of international search (under Rules 12.3(a) and 23.1(b)).
2.	☐ This opinion has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3.	With regard to any nucleotide and/or amino acid sequence disclosed in the international application, this opinion has been established on the basis of a sequence listing filed or furnished: a. (means) ☐ on paper ☐ in electronic form b. (time) ☐ in the international application as filed ☐ together with the international application in electronic form ☐ subsequently to this Authority for the purposes of search
4.	☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5.	Additional comments:

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2010/046106

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statements

Novelty (N)	Claims 1-20	YES
	Claims NONE	NO
Inventive step (IS)	Claims 1-20	YES
	Claims NONE	NO
Industrial applicability (IA)	Claims 1-20	YES
	Claims NONE	NO

2. Citations and explanations:

The following documents identified in the International Search Report have been considered for the purposes of this opinion:

D1- US 7778337 B2

D2- US 7397862 B2

D3- US 2002/0122381 A1

NOVELTY (N)

Independent claims 1, 8, 14 and 18 meet the criteria set forth in PCT Article 33(2) for novelty. The prior art published before the priority date does not disclose inserting and/or replicating at least a portion of data from the first data stream into the second data stream and transmitting the first and second data streams over the communication channel.

Appended claims 2-7, 9-13, 15-17 and 19-20 add further features to those defined in claims 1, 8, 14 and 18 and are therefore also novel.

Therefore the subject matter of claims 1 to 20 is new and meets the requirements of Article 33(2) of the PCT with regard to novelty.

INVENTIVE STEP (IS)

Claims 1 to 20 meet the criteria set out in PCT Article 33(3) with regard to the requirement of Inventive Step because the prior art does not obviously suggest to a person skilled in the art the feature of inserting and/or replicating at least a portion of data from the first data stream into the second data stream and transmitting the first and second data streams over the communication channel. The claimed invention is not obvious in the light of any of the cited documents nor is it disclosed in any obvious combination of them. It is also considered that it would not be obvious to a person skilled in the art in the light of common general knowledge either by itself or in combination with any of these documents.

Therefore the subject matter of claims 1 to 20 is not obvious and meets the requirements of Article 33(3) of the PCT with regard to inventive step.

INDUSTRIAL APPLICABILITY (IA)

The invention defined in the claims 1 to 20 is considered to meet the requirements of Industrial Applicability under Article 33(4) of the PCT because it can be made by, or used in, industry.

PATENT COOPERATION TREATY
PCT
INTERNATIONAL SEARCH REPORT
(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference P215801WO01	FOR FURTHER ACTION see Form PCT/ISA/220 as well as, where applicable, item 5 below.	
International application No. PCT/US2010/046106	International filing date (day/month/year) 20 August 2010	(Earliest) Priority Date (day/month/year) 20 August 2010
Applicant THE BOARD OF REGENTS OF THE UNIVERSITY OF TEXAS SYSTEM et al		
This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau. This international search report consists of a total of 3 sheets. ☐ It is also accompanied by a copy of each prior art document cited in this report.		
1. Basis of the report a. With regard to the language, the international search was carried out on the basis of: ☒ The international application in the language in which it was filed. ☐ A translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)). b. ☐ This international search report has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43.6bis(a)). c. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, see Box No. I. 2. ☐ Certain claims were found unsearchable (See Box No. II). 3. ☐ Unity of invention is lacking (See Box No. III). 4. With regard to the title, ☒ the text is approved as submitted by the applicant. ☐ the text has been established by this Authority to read as follows: 5. With regard to the abstract, ☒ the text is approved as submitted by the applicant. ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority. 6. With regard to the drawings, a. the figure of the drawings to be published with the abstract is Figure No. 1 ☒ as suggested by the applicant. ☐ as selected by this Authority, because the applicant failed to suggest a figure. ☐ as selected by this Authority, because this figure better characterizes the invention. b. ☐ none of the figures is to be published with the abstract.		

Form PCT/ISA/210 (first sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2010/046106

A. CLASSIFICATION OF SUBJECT MATTER		
Int. Cl.		
H04L 27/28 (2006.01) H04J 11/00 (2006.01)		
H04B 7/04 (2006.01) H04K 1/10 (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
EPODOC, WPI: mimo, miso, ofdm, multiple antenna, first, second stream, insert, embed, overlap, replicat, pilot and similar terms.		
INSPEC: mimo, miso, ofdm, multiple antenna, first stream, second stream, insert, embed, overlap, replicat, pilot and similar terms.		
GOOGLE, GOOGLE SCHOLAR: mimo, ofdm, first, second, (insert or embed or overlap), stream, pilot		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7778337 B2 (TONG et al.) 17 August 2010 Abstract; Col. 4 line 12-Col. 6 line 21	1-20
A	US 7397862 B2 (OUYANG et al.) 8 July 2008 Abstract; Col. 1 line 64-Col. 2 line 19	1-20
A	US 2002/0122381 A1 (WU et al.) 5 September 2002 Abstract; Paras [0011]-[0015]	1-20
☐ Further documents are listed in the continuation of Box C ☒ See patent family annex		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "Z" document member of the same patent family		
Date of the actual completion of the international search 03 November 2010		Date of mailing of the international search report 09 NOV 2010
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999		Authorized officer JUZER KHANEHAI AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2176

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2010/046106

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report			Patent Family Member				
US	7778337	CN	1605172	CN	101188597	EP	1442549
		US	2003072254	US	7248559	US	2007253324
		US	7545734	US	2007053282	US	2009225891
		US	2010271930	WO	03034644		
US	7397862	US	2007086538				
US	2002/0122381	CA	2351140	CA	2355433	EP	1185001
		EP	1185048	EP	1686703	US	6850481
		US	2002122383	US	6985434	US	2002122382
		US	7009931	US	2002041635	US	7233625
		US	2006104196	US	7336601	US	2007274408
		US	7403570	US	2008002568	US	7688710
		US	2007036069	US	7801019		
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.							
END OF ANNEX							

Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS COMMUNICATIONS		
First Named Inventor/Applicant Name:		Ali Yazdan Panah		
Filer:		Jennifer Marie Lane/Alexandra Beggs		
Attorney Docket Number:		P215801.WO-US.01		
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:				
National Stage Fee	1631	1	330	330
National Stage Search - all other cases	1632	1	540	540
National Stage Exam - all other cases	1633	1	220	220
Pages:				
Claims:				
Independent claims in excess of 3	1614	1	220	220
Miscellaneous-Filing:				
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				1310

Electronic Acknowledgement Receipt	
EFS ID:	9033326
Application Number:	12999029
International Application Number:	PCT/US10/46106
Confirmation Number:	1213
Title of Invention:	INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS COMMUNICATIONS
First Named Inventor/Applicant Name:	Ali Yazdan Panah
Customer Number:	27076
Filer:	Jennifer Marie Lane/Alexandra Beggs
Filer Authorized By:	Jennifer Marie Lane
Attorney Docket Number:	P215801.WO-US.01
Receipt Date:	14-DEC-2010
Filing Date:	
Time Stamp:	16:40:42
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	\$1310
RAM confirmation Number	3731
Deposit Account	501266
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. 1.492 (National application filing, search, and examination fees) Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		215801WOUS01_AppAsFiled_1 2142010.PDF	1994414 99e48b5cbb5cbb56da4069a8a9f86bf837f cacc	yes	48
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Transmittal of New Application		1	3	
	Application Data Sheet		4	4	
	Authorization for Extension of Time all replies		5	5	
	Specification		6	30	
	Claims		31	34	
	Abstract		35	35	
	Drawings-only black and white line drawings		36	42	
	Oath or Declaration filed		43	46	
	Transmittal Letter		47	47	
	Information Disclosure Statement (IDS) Filed (SB/08)		48	48	
Warnings:					
Information:					
2	NPL Documents	215801WO01_ISRWO_1109201 0.PDF	349624 5109d1c5ee5fa2b0c62ebe74858dfa70950 a1d1	no	8
Warnings:					
Information:					
3	Fee Worksheet (PTO-875)	fee-info.pdf	36658 8badf26507ac636af1b47a402dffb20c5292 5d57	no	2
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

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.

POWER OF ATTORNEY OR REVOCATION OF POWER OF ATTORNEY WITH A NEW POWER OF ATTORNEY AND CHANGE OF CORRESPONDENCE ADDRESS	Application Number	12/999,029
	Filing Date	August 20, 2010
	First Named Inventor	Ali Yazdan Panah
	Title	Inserting and Decoding Replicated Data Symbols in Wireless Communications
	Art Unit	Not known
	Examiner Name	Not known
	Attorney Docket Number	P215801.WO-US.01

I hereby revoke all previous powers of attorney given in the above-identified application.

☐ A Power of Attorney is submitted herewith.

OR

☒ I hereby appoint Practitioner(s) associated with the following Customer Number as my/our 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:

27,076

OR

☐ I hereby appoint Practitioner(s) named below as my/our 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:

Practitioner(s) Name	Registration Number

Please recognize or change the correspondence address for the above-identified application to:

☒ The address associated with the above-mentioned Customer Number.

OR

☐ The address associated with Customer Number:

☐ Firm or Individual Name

Address

City

State

Zip

Country

Telephone

Email

I am the:

☐ Applicant/Inventor.

OR

☒ Assignee of record of the entire interest. See 37 CFR 3.71.
Statement under 37 CFR 3.73(b) (Form PTO/SB/96) submitted herewith or filed on _____.

SIGNATURE of Applicant or Assignee of Record

Signature	Date
Name	Telephone
Title and Company	

Barry D. Burgdorf February 21, 2011 (512) 499-4462

Vice Chancellor & General Counsel Board of Regents, The University of Texas System

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☐ *Total of _____ forms are submitted.

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:	9523496
Application Number:	12999029
International Application Number:	
Confirmation Number:	1213
Title of Invention:	INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS COMMUNICATIONS
First Named Inventor/Applicant Name:	Ali Yazdan Panah
Customer Number:	27076
Filer:	Jennifer Marie Lane/Eric Eaton
Filer Authorized By:	Jennifer Marie Lane
Attorney Docket Number:	P215801.WO-US.01
Receipt Date:	24-FEB-2011
Filing Date:	
Time Stamp:	13:50:12
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no
------------------------	----

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		P215801WOUS01_POA.pdf	126074 7bba366412bb31711dfb0e01ce6adb92e039ec9a	yes	2

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Assignee showing of ownership per 37 CFR 3.73(b).	1	1
	Power of Attorney	2	2
Warnings:			
Information:			
Total Files Size (in bytes):		126074	
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.			

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Robert W. Heath, Jr., Ali Yazdan Panah

Application No.: 12/999,029

Filed Date: August 20, 2010

Entitled: INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS COMMUNICATIONS

The Board of Regents of the University of Texas System, a University

(Name of Assignee)

(Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

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/patent identified above by virtue of either:

A. ☒ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel 025499 Frame 0517, or a true copy of the assignment is attached.

OR

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

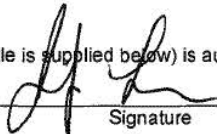
1. From: _____ To: _____
The document was recorded in the United States Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.
2. From: _____ To: _____
The document was recorded in the United States Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.
3. From: _____ To: _____
The document was recorded in the United States Patent and Trademark Office at
Reel _____, Frame _____, 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 Assignment Division in accordance with 37 CFR Part 3, if the assignment is to be recorded 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

February 23, 2011
Date

Jennifer M. Lane
Printed or Typed Name

206-903-8800
Telephone Number

Attorney of Record
Title

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1459
Alexandria, Virginia 22313-1450
www.uspto.gov

U.S. APPLICATION NUMBER NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
12/999,029	Ali Yazdan Panah	P215801.WO-US.01

27076
DORSEY & WHITNEY LLP
INTELLECTUAL PROPERTY DEPARTMENT
Columbia Center
701 Fifth Avenue, Suite 6100
SEATTLE, WA 98104-7043

INTERNATIONAL APPLICATION NO.

PCT/US10/46106

I.A. FILING DATE	PRIORITY DATE
------------------	---------------

CONFIRMATION NO. 1213
371 ACCEPTANCE LETTER



Date Mailed: 04/01/2011

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:

12/14/2010
DATE OF RECEIPT OF 35 U.S.C. 371(c)(1),
(c)(2) and (c)(4) REQUIREMENTS

12/14/2010
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 12/14/2010
- Copy of the International Search Report filed on 12/14/2010
- Copy of IPE Report filed on 12/14/2010
- Information Disclosure Statements filed on 12/14/2010
- Oath or Declaration filed on 12/14/2010
- Request for Immediate Examination filed on 12/14/2010
- U.S. Basic National Fees filed on 12/14/2010
- Priority Documents filed on 12/14/2010

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)

VALERIE D KINARD

Telephone: (703) 756-1432



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1459
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY DOCKET NO	TOT CLAIMS	IND CLAIMS
12/999,029	12/14/2010		1310	P215801.WO-US.01	20	4

CONFIRMATION NO. 1213

27076
DORSEY & WHITNEY LLP
INTELLECTUAL PROPERTY DEPARTMENT
Columbia Center
701 Fifth Avenue, Suite 6100
SEATTLE, WA 98104-7043

FILING RECEIPT



OC000000046857600

Date Mailed: 04/01/2011

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. 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 submit a written request for a Filing Receipt Correction. 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**

Applicant(s)

Ali Yazdan Panah, Austin, TX;
Robert W. Heath JR., Austin, TX;

Power of Attorney: The patent practitioners associated with Customer Number 27076

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/US10/46106 08/20/2010

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.)

If Required, Foreign Filing License Granted: 03/30/2011

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/999,029**

Projected Publication Date: 02/23/2012

Non-Publication Request: No

Early Publication Request: No

Title

INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS COMMUNICATIONS

Preliminary Class**PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER**Title 35, United States Code, Section 184****Title 37, Code of Federal Regulations, 5.11 & 5.15****GRANTED**

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier

license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign Assets Control, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875						Application or Docket Number 12/999,029				
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	330			
SEARCH FEE (37 CFR 1.16(k), (j), or (m))	N/A	N/A	N/A			N/A	430			
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	220			
TOTAL CLAIMS (37 CFR 1.16(i))	20	minus 20 =				x 52 =	0.00			
INDEPENDENT CLAIMS (37 CFR 1.16(h))	4	minus 3 =	1			x 220 =	220			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$270 (\$135 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).						0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL		TOTAL	1200			
APPLICATION AS AMENDED - PART II										
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY		
AMENDMENT A		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=		x	=
	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	
AMENDMENT B		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x	=		x	=
	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	
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MULTIPLE DEPENDENT CLAIM FEE CALCULATION SHEET Substitute for Form PTO-1360 (For use with Form PTO/SB/06)							Application Number 12999029		Filing Date				
							Applicant(s) Ali Panah						
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CLAIMS	AS FILED		AFTER FIRST AMENDMENT		AFTER SECOND AMENDMENT			*		*		*	
	Indep	Depend	Indep	Depend	Indep	Depend		Indep	Depend	Indep	Depend	Indep	Depend
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- (72) **Inventors:** and
- (75) **Inventors/Applicants** (for US only): **ALI, Yazdan Panah** [IR/US]; 502 Elmwood Place, #101, Austin, Texas 78705 (US). **HEATH, Robert, W., Jr.** [US/US]; 2143 Barton Hills Drive, Austin, Texas 78704 (US).
- (74) **Agents:** **DORSEY AND WHITNEY LLP** et al.; IP Docket - SE, 701 Fifth Avenue, Suite 6100, Seattle, Washington 98104-7043 (US).

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(54) **Title:** INSERTING AND DECODING REPLICATED DATA SYMBOLS IN WIRELESS COMMUNICATIONS

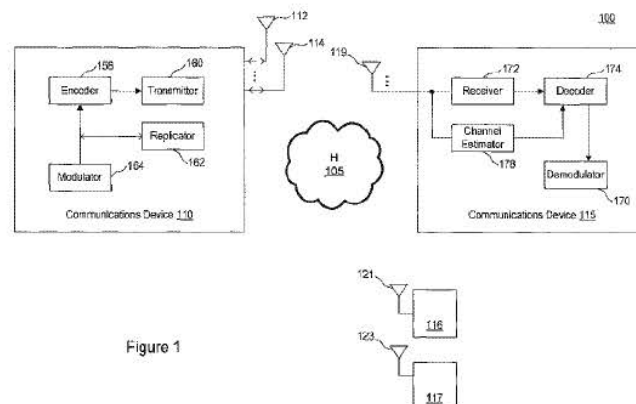


Figure 1

(57) **Abstract:** Examples are generally described that include transmission methods including inserting at least a portion of data from a first data stream into a second data stream to be transmitted over a communications channel. On receipt of the two data streams, examples of receiving methods include receiving the replicated data, decoding the replicated data using an estimated channel matrix, and generating an updated estimate of the channel matrix based, at least in part, on the replicated data.

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**INSERTING AND DECODING REPLICATED DATA SYMBOLS
IN WIRELESS COMMUNICATIONS**

BACKGROUND

- [001] Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.
- [002] Multiple-input multiple-output (MIMO) communication systems employ multiple transmit antennas and multiple receive antennas to communicate data symbols over a communications channel. MIMO communication systems may allow a plurality of mobile stations to be serviced utilizing a same frequency band. In this manner, MIMO communication systems may advantageously increase an amount of data the communication systems is able to send to users.
- [003] MIMO systems may find use in a variety of applications including, but not limited to, wireless networks, cellular systems including 3G and 4G systems, such as 3GPP LTE-Advanced, local and wide area networks, and wireless broadband systems (such as WiMAX).
- [004] Generally, a transmitter in a MIMO system may have a plurality of antennas. Receiving devices may each have a single antenna for receipt of data over the communications channel, or may have multiple antennas.
- [005] The communications channel, however, may introduce a variety of non-idealities to a transmitted signal, such as may be caused by multipath interference, reflections, motion of one or more mobile stations, or other properties of a communications channel. The signals received by a receiver over the communications channel may be related to the transmitted signals by a channel matrix **H**. The channel matrix generally refers to a matrix of data which may represent the operation of the communications channel on the transmitted data symbols, including representations of such effects as reflections.
- [006] Orthogonal frequency division multiplexing (OFDM) modulation techniques may be used to modulate data for transmission over a communications channel. OFDM generally involves modulating different portions of the data to be transmitted using different sub-carrier frequencies.
- [007] Block coding techniques may be used in communication systems to encode data and transmit multiple data streams over a communications channel, which may improve the reliability of data transfer. Block coding techniques include space-time block coding, which

may transmit multiple data streams across multiple antennas. Alamouti space time block coding is one particular type of space-time block coding known in the art. Space-time block coding techniques may require that the communications channel be constant during consecutive data transmission times, which may not always be advantageous. Another type of block coding technique is space-frequency block coding. Alamouti space-frequency block coding is one particular type of space-frequency block coding known in the art. Space-frequency block coding techniques may require that different frequencies experience similar communications channel properties, which may be more advantageous in some cases.

[008] Block coding techniques may commonly be used in conjunction with OFDM. Decoding of block encoded OFDM transmissions may require knowledge of properties of the communications channel over which the transmission is received. Accordingly, systems utilizing block encoded OFDM transmissions generally measure one or more properties of the communications channel, such as the channel matrix. One way to measure properties of the communications channel is to insert pilot symbols into the transmitted data streams. The pilot symbols may be known to the receiver and the known pilot symbols may be compared with the received signals to generate an estimate of one or more properties of the communications channel. The need to insert pilot symbols into the transmitted data streams may adversely effect a data rate attainable in the communications system.

BRIEF DESCRIPTION OF THE DRAWINGS

[009] The foregoing and other features of the present disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several examples in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings, in which:

[010] In the drawings:

Figure 1 is a schematic illustration of an example system that is configured for communication over a communications channel in accordance with at least some examples of the present disclosure;

Figure 2 is a schematic illustration of components of the communications device 110 arranged in accordance with examples of the present disclosure;

Figure 3 is a schematic illustration of signals transmitted over a communications channel in accordance with examples of the present disclosure;

Figure 4 is a schematic illustration of components of the communications device 115 arranged in accordance with examples of the present disclosure;

Figure 5 is a schematic illustration of signals transmitted over the communications channel in accordance with some examples of the present disclosure;

Figure 6 is an example method for transmitting signals over a communications channel arranged in accordance with an example of the present disclosure;

Figure 7 is an example method for receiving signals over a communications channel arranged in accordance with an example of the present disclosure; and

Figure 8 is a block diagram illustrating an example computing device 800 that is arranged for generating an updated channel estimate in accordance with examples of the present disclosure.

SUMMARY

- [011] The present disclosure describes a method of transmitting data over a communications channel. Some example methods may include modulating data, inserting data from one stream into another stream, and/or transmitting the data streams over a communications channel. The modulation may be performed in accordance with an orthogonal frequency division multiplexing technique, and may generate at least a first and second data stream for transmission using respective transmit antennas. The inserting may insert at least a portion of data from the first data stream into the second data stream.
- [012] The present disclosure describes methods of decoding a signal transmitted over a communications channel. Example methods may include, receiving a pilot symbol over the communications channel, estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol, receiving replicated data from multiple data streams transmitted over the communications channel, decoding the replicated data using the estimated channel matrix, and/or generating an updated estimate of the channel matrix based, at least in part, on the replicated data.
- [013] The present disclosure describes communications devices. Example communications devices may include a modulator, a replicator, an encoder, and/or a transmitter. The modulator may be configured to modulate data in accordance with an orthogonal frequency division multiplexing technique for transmission over a communications channel using at

least a first and a second transmit antenna. The modulator may be further configured to generate at least a first data stream for transmission with the first antenna and a second data stream for transmission with the second antenna. The replicator may be coupled to the modulator and configured to receive the first and second data streams. The replicator may also be configured to insert at least one data symbol from the first data stream into the second data stream. The encoder may be coupled to the replicator and may be configured to receive the first and second data streams including the inserted at least one symbol. The encoder may be configured to encode the first and second data streams in accordance with a block coding technique. The transmitter may be coupled to the encoder and may be configured to receive the encoded first and second data streams. The transmitter may be configured to transmit the first data stream over the communications channel using the first antenna and further configured to transmit the second data stream including the inserted at least one symbol over the communications channel using the second antenna.

[014] Example communications devices may include a receiver, a decoder, and/or a channel estimator. The receiver may be configured to receive signals over a communications channel, wherein the signals are based at least in part on first and second data streams transmitted over a communications channel, wherein the second data stream includes at least one data symbol replicated from the first data stream. The decoder may be coupled to the receiver and the channel estimator. The decoder may be configured to receive the received signals and decode the at least one data symbol replicated from the first data stream. The channel estimator may be coupled to the decoder and the receiver, and may be configured to receive the received signals and the decoded at least one data symbol. The channel estimator may be configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol. The decoder may also be configured to decode subsequent received signals based, at least in part, on the estimate of the channel matrix.

[015] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

DETAILED DESCRIPTION

- [016] The following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative examples described in the detailed description, drawings, and claims are not meant to be limiting. Other examples may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are implicitly contemplated herein.
- [017] This disclosure is drawn, inter alia, to methods, systems, devices, and/or apparatus generally related to use of replicated data as a pilot symbol in a communications system. Examples of transmission methods include inserting at least a portion of data from a first data stream into a second data stream to be transmitted over a communications channel. On receipt of the two data streams, examples of receiving methods include receiving the replicated data, decoding the replicated data using an estimated channel matrix, and generating an updated estimate of the channel matrix based, at least in part, on the replicated data.
- [018] Figure 1 is a schematic illustration of an example system that is configured for communication over a communications channel in accordance with at least some examples of the present disclosure. A system 100 may be a multiuser multiple-input multiple-output system configured for communication over a communications channel 105. System 100 may include a communications devices 110, 115, 116, and/or 117. The communications devices may be operated by users (not shown).
- [019] The communications device 110 may be implemented as a base station and may be configured to communicate with multiple mobile stations 115, 116, and 117. The communications device 110 may include antennas 112 and 114, which may be utilized to communicate over the communications channel 105 using multiple antennas for spatial diversity to communicate with multiple users over each frequency.
- [020] The communications device 110 may include antennas 112 and 114, an encoder 158, a transmitter 160, a replicator 162, and/or a modulator 164. Antennas 112 and 114 may be coupled to the transmitter 160. The encoder 158 may be coupled to transmitter 160. The

modulator 164 may be coupled to encoder 158. The replicator 162 may be coupled to modulator 164 and encoder 158.

[021] The modulator 164 may be configured to receive data for transmission over the communications channel 105. The modulator 164 may be configured to modulate the data in accordance with one or more modulation techniques, such as orthogonal frequency division multiplexing (OFDM). Any suitable modulator may be used, and modulator 164 may be implemented in hardware, software, or combinations thereof. The modulator 164 may accordingly generate multiple data streams for communication over the communications channel, one for transmission using each of the respective antennas 112 and 114 in some examples. Pilot symbols may be inserted into the data streams by the modulator 164 or may be inserted before or after the modulator 164 in some examples.

[022] The replicator 162 may be configured to receive one or more data streams generated by the modulator. The replicator 162 may be configured to replicate at least a portion of data from one data stream and insert the replicated data into another data stream, as will be described further below. Any suitable hardware, software, or combinations thereof may be used to implement the replicator 162, including a mixer.

[023] The encoder 158 may be configured to receive one or more data streams generated by the modulator 164 and which may have been modified by the replicator 162. The encoder 158 may be configured to encode the data streams in accordance with a block encoding technique, such as space-time or space-frequency block coding, including in some examples Alamouti space-time or Alamouti space-frequency block coding.

[024] The transmitter 160 may be configured to transmit the encoded data over the communications channel 105 via the cooperative operation of the transmitter 160 and one or more of antennas 112 and/or 114.

[025] Although not shown in Figure 1, the communications device 110 may also include components configured to receive, decode, and demodulate signals received over the communications channel. That is, the communications device 110 may both send and receive signals over the communications channel in some examples.

[026] The communications device 115 may include antenna 119, a receiver 172, a decoder 174, a channel estimator 178, and/or a demodulator 170. Antenna 119 may be coupled to the receiver 172 and the channel estimator 178. The channel estimator 178 may also be coupled to the decoder 174. The demodulator 170 may be coupled to the decoder 174.

- [027] The receiver 172 is configured to cooperate with antenna 119 to receive signals over the communications channel 105 and provide the received signals to decoder 174. Although not shown in Figure 1, in some examples, multiple antennas may be provided at the communications device 115. In examples using Alamouti encoding and decoding, however, a single receive antenna may generally be used to receive signals over the communications channel 105. Any suitable receiver may be used and the receiver 172 may be implemented in hardware, software, or combinations thereof. As will be described further below, the received signals may include data.
- [028] The decoder 174 may be configured to decode signals received from the receiver 172 to provide data. Any of a variety of decoding techniques may be used in accordance with a technique used to encode the signals received by the receiver 172. Examples of decoding techniques include block decoding techniques including space-time and space-frequency block decoding, and Alamouti space-time and space-frequency decoding in some examples. Any suitable decoder may be used and the decoder 174 may be implemented in hardware, software, or combinations thereof.
- [029] The demodulator 170 may be configured to demodulate decoded data from the decoder 174. The demodulator 170 may generally implement any demodulation technique, including demodulation in accordance with orthogonal frequency division multiplexing (OFDM) techniques. Any suitable demodulator may be used, and the demodulator 170 may be implemented in hardware, software, or combinations thereof.
- [030] The channel estimator 178 may be configured to estimate all or a portion of a channel matrix H associated with the communications channel 105. As will be described further below, the channel estimator 178 may utilize pilot symbols to estimate the channel matrix. The channel estimator 178 may also be configured to use decoded replicated data as a pilot symbol to estimate the channel matrix and/or update an estimate of the channel matrix. By utilizing replicated data to generate or update an estimate of the channel matrix, the communications device 115 may in some examples require fewer pilot symbols to be inserted into signals communicated over the communications channel 105. Reducing a number of pilot symbols inserted into the transmitted signals may advantageously improve the data rate of the communications system 100 in some examples.
- [031] Although not shown in Figure 1, the communications device 115 may also include components such as a transmitter, encoder, and/or modulator, for transmitting signals over

the communications channel 105. That is, in some examples, the communications device 115 may both transmit and receive signals over the communications channel.

[032] Communications devices 116 and 117 may be similarly configured to communications device 115. The communications device 116 may include antenna 121. The communications device 117 may include antenna 123.

[033] The communications channel 105 may generally include any suitable medium for transmitting electromagnetic signals. The communications channel 105 may be characterized by the channel matrix H describing the operation of the communications channel 105 on transmitted symbols. The channel matrix H may provide a representation of effects such as reflections in the communications channel. The channel matrix H may vary over time, and may be calculated periodically in some examples. While a single communications channel 105 is illustrated in Figure 1, any number of communications channels may be used.

[034] Any number of communications devices may be included in the communications system 100, including the communications devices 115, 116, and 117. Although not shown, the communications devices 116 and 117 may include analogous components to those shown in mobile station 115. The communications devices 115, 116, and 117 may be implemented as mobile stations in some examples.

[035] Figure 2 is a schematic illustration of components of the communications device 110 arranged in accordance with examples of the present disclosure. The modulator 164 may include a mapping and pilot insertion block 202, which may be coupled to a serial to parallel converter 204, which may be coupled to an inverse Fourier transform (IFFT) block 206, which may be coupled to a parallel to serial converter 208. The replicator 162 may be coupled to the parallel to serial converter 208. The encoder 158 may be coupled to the replicator 162.

[036] During operation, data for transmission over a communications channel may be provided to the mapping and pilot insertion block 202, which may be configured to map the data to symbols and insert pilot symbols into the data stream. In some examples, the pilot symbols may be inserted at a later point in the signal processing stream. The serial to parallel converter 204, IFFT 206, and parallel to serial converter 208 may be configured to modulate the data stream in accordance with an OFDM technique to generate multiple data streams for transmission over the communications channel. The replicator 162 may replicate a portion of the modulated data such that some data symbols from one stream are inserted into another stream. The space-time encoder 158 may then encode the data streams, including inserted

symbols, for transmission over the communications channel. The configuration of Figure 2 may provide for space-time encoding of the data streams.

[037] Figure 3 is a schematic illustration of signals transmitted over a communications channel in accordance with examples of the present disclosure. The signals 302, 303, 304, and 305 of Figure 3 may be transmitted by the transmitter 160 of Figure 1 in some examples, and received by the receiver 172. The example of Figure 3 illustrates signals encoded using a space-time block coding technique. In particular, signals 302 and 303 may be transmitted during a first time period while signals 304 and 305 are transmitted during a second time period. Signals 302 and 304 may be transmitted from one location, such as by the antenna 112 of Figure 1. Signals 303 and 305 may be transmitted from another location, such as by the antenna 114 of Figure 1. The relationships between the signals 302, 303, 304, and 305 may generally be specified by the space-time coding technique used. Each of the illustrated signals may encode multiple data symbols, shown as boxes in Figure 3. For example, the signal 302 may encode the symbols 310-317. Pilot symbols may also be encoded by the signals. In the example of Figure 3, the symbols 310 and 314 may represent pilot symbols. The pilot symbols 310 and 314 may accordingly also be present at similar frequencies in the signal 303. Further, replicated data symbols from the signal 302 may be included in the signal 303. In this example of Figure 3, the data symbols 312 and 316 may have been replicated to symbol locations at corresponding frequencies at the second spatial location, as shown. Additional data symbols 318-321 may be included in the signals 303.

[038] The example of Figure 3 illustrates replicated data symbols inserted at a midpoint between two pilot symbols in a data stream. In other examples, replicated data symbols may be inserted at a location other than a midpoint between two pilot symbols, and the replicated data symbol may be inserted at a location closer to one pilot symbol than another. In some examples, some pilot symbols may have no replicated data symbols inserted between them. In general, any number or arrangement of replicated data symbols may be inserted into a data stream. As will be described further below, the replicated data symbols may be utilized in a manner similar to pilot symbols to estimate the communications channel. Since the replicated data symbols also encode data, the use of replicated data symbols as pilot symbols may increase the data rate of the over communications system in some examples.

[039] Figure 4 is a schematic illustration of components of the communications device 115 arranged in accordance with examples of the present disclosure. The demodulator 170 may include a serial to parallel converter 402, a fast Fourier transform unit (FFT) 404, a parallel to

serial converter 406, and a mapping block 408. The serial to parallel converter 402 may be coupled to the FFT 404. The FFT 404 may be coupled to the channel estimator and a space-time decoder 174. The space-time decoder 174 may be coupled to the parallel to serial converter 406. The parallel to serial converter 406 may be coupled to the mapping block 408.

[040] In operation, signals received by the receiver 172, such as the signals 302-305 of Figure 3, may be provided to the serial to parallel converter 402 and converted into parallel streams. The FFT 404 may perform a Fourier transform of the streams, and provide the Fourier transformed signals to the channel estimator 178 and the space-time decoder 174. In accordance with the methods described below, the channel estimator 178 may estimate all or a portion of the channel matrix based on received pilot symbols and/or replicated data symbols. The space-time decoder 174 may decode the data streams in accordance with the estimated channel matrix. Moreover, the space-time decoder 174 may provide signals indicative of the replicated data symbols to the channel estimator 178. The replicated data symbols may be used by the channel estimator 178 to estimate all or a part of the channel matrix, or to update an estimate of the channel matrix. Decoded signals may be provided from the space-time decoder 174 to the parallel-to-serial converter 406 and converted into a serial data stream of decoded symbols. The symbols may be provided to the mapping block 408 and may be converted into a stream of output data. In this manner, data may be encoded, transmitted, received, and decoded in the communications system in some examples.

[041] In some examples, the positioning of the encoder and decoder relative to the FFT and IFFT blocks of the modulator may vary. In particular, the configuration shown in Figure 4 may correspond to examples using space-time coding and decoding techniques. In some examples, space-frequency coding and decoding may be used. In examples where space-frequency coding is used, the encoder 158 may be coupled between the serial to parallel converter 204 and the IFFT 206.

[042] Figure 5 is a schematic illustration of signals transmitted over the communications channel in accordance with some examples of the present disclosure. The example shown in Figure 5 may pertain to examples employing space-frequency coding techniques. Input data symbols 505 including symbols labeled S1-S11 may be provided to the modulator 164 of Figure 1. Following modulation, pilot insertion, data replication, and coding in accordance with a space-frequency coding technique, one signal stream 510 may be generated for transmission from a first location, such as the antenna 112 of Figure 1, and a second signal stream 515 may be generated for transmission from a second location, such as the antenna

114 of Figure 1. The relationship between the symbols in the streams 510 and 515 is generally specified by the space-frequency coding technique.

[043] Pilot symbols 520-525 are shown in the data stream 510, with corresponding data symbols in the data stream 515. Data symbols 530-539 are included in the data stream 510, with corresponding data symbols in the data stream 515. The pilot symbols 520-525 have been inserted amongst the data symbols 530-539. Data symbols 530 and 531 have been replicated from one frequency to another frequency in the data streams 510 and 515. The replicated data symbols have been inserted at a location between the pilot symbols 523 and 524. As generally described above, any number or positioning of replicated data symbols may generally be used. In the example shown in Figure 5, data symbols have been replicated in pairs. Replicating a pair of data symbols may be advantageous in some examples for consistency with the coding technique employed to code the data stream.

[044] Figure 6 is an example method for transmitting signals over a communications channel arranged in accordance with an example of the present disclosure. The method may include one or more of blocks 605, 610, 615, 620, and/or 625. The various blocks described herein may be performed sequentially, in parallel, or in a different order than those described herein. It should also be appreciated that in some implementations one or more of the illustrated blocks may be eliminated, combined or separated into additional blocks. The method 600 may include block 605, "Modulate data in accordance with an orthogonal frequency division multiplexing technique to generate multiple data streams." Block 605 may be followed by block 610 "Insert pilot symbols into the data streams." Block 610 may be followed by block 615 "Replicate data from one data stream and insert the replicated data into another data stream." Block 615 may be followed by block 620 "Encode the data streams in accordance with a block encoding technique." Block 620 may be followed by block 625 "Transmit the data streams over a communications channel."

[045] Data may be modulated in accordance with an OFDM technique in block 605. The modulation may be performed, for example, by any suitable structure in a communications device, such as a DSP or other processing unit. In some examples, one data stream may be generated for each antenna to be used in transmitting the data over the communications channel.

[046] In block 610, pilot symbols may be inserted into the data streams. The insertion may be performed, for, example, by any suitable structure in a communications device, including a mixer or multiplexor. Generally, the pilot symbols correspond to symbols known by the

transmitting and receiving devices of a communications system. By decoding signals encoding a known pilot symbol, a receiving device may generate an estimate of the channel matrix of the communications channel. Pilot symbols may be stored in any memory structure in communication with the communications device, or may be communicated to the communications device. Any number of pilot symbols may generally be inserted into the data streams with substantially any spacing. The more pilot symbols are inserted into the data streams, the more the overall data transmission rate of the communications system may decrease. However, in examples having more pilot symbols inserted into the data streams, the estimates of the channel matrix by a receiving communications device may be more accurate. Accordingly, there may be a tradeoff between data rate and accuracy of the channel estimation. As will be described further below, use of replicated data symbols as pilot symbols may advantageously increase the channel estimation accuracy while not impacting the overall data rate as severely as using more pilot symbols.

[047] In block 615, data may be replicated from one data stream and inserted into another data stream. The replication may be performed by any suitable structure in a communications device, including a mixer or multiplexor for example. In some examples, a same structure may be used to insert the replicated data as was used to insert the pilot symbols. The replicated data may include one or more symbols from a data stream. In some examples, pairs of symbols may be replicated. The data may be inserted such that it is transmitted at a same frequency band in each of the data streams. Any number of replicated data instances may be included in a transmission. As will be described further below, the replicated data may be utilized to improve estimates of a channel matrix associated with a communications channel. Accordingly, as more replicated data is inserted, the accuracy of the channel matrix estimate may increase. However, as more replicated data is inserted, the overall data rate of the communications system may be reduced, although the reduction may not be as severe as if more known pilot symbols were inserted. The replicated data may be inserted between two pilot symbols, and may be inserted at a midpoint between the two pilot symbols. However, the replicated data may be inserted at substantially any location in some examples.

[048] In block 620, the data streams may be encoded in accordance with a block encoding technique. The encoding may be performed by any suitable structure in a communications device, for example by a DSP or other processing unit. As described above, any block encoding technique may be used, including space-time coding or space-frequency coding.

[049] In block 625, the data streams may be transmitted over a communications channel. The transmission may be performed by a transmitter acting in cooperation with one or more antennas in some examples. In some examples, each antenna may be used to transmit one of the data streams.

[050] Figure 7 is an example method for receiving signals over a communications channel arranged in accordance with an example of the present disclosure. The method 700 may include one or more of blocks 705, 710, 715, 720, 725, and/or 730. The various blocks described herein may be performed sequentially, in parallel, or in a different order than those described herein. It should also be appreciated that in some implementations one or more of the illustrated blocks may be eliminated, combined or separated into additional blocks. The method 700 may include block 705 "Receiving a known pilot symbol over a communications channel." Block 705 may be followed by block 710 "Estimating the communications channel based, at least in part, on the known pilot symbol." Block 710 may be followed by block 715 "Receiving replicated data from multiple data streams over the communications channel." Block 715 may be followed by block 720 "Decoding the replicated data using the estimate of the communications channel." Block 720 may be followed by block 725 "Updating the estimate of the communications channel based, at least in part, on the replicated data." Block 725 may be followed by block 730 "Decoding subsequently received data using the updated channel estimate."

[051] In block 705, a known pilot symbol may be received over a communications channel. The symbol may be received by any suitable receiver of a communications device. Signals may generally be received that encode the known pilot symbol. The received signals may also provide an indication that the encoded symbol is a pilot symbol.

[052] In block 710, the communications channel may be estimated based, at least in part, on the received pilot symbol. The estimation may be performed by any suitable structure of a communications device, such as a DSP or other processing unit. Generally, all or a portion of a channel matrix may be estimated by comparing a decoded received pilot symbol with the known pilot symbol. Known pilot symbols may be stored at the communications device or otherwise communicated to the communications device for comparison with decoded pilot symbols received over the communications channel. The estimated channel, including data estimating all or a portion of a channel matrix, may be stored in some examples.

[053] In block 715, replicated data from multiple data streams may be received over the communications channel. Any suitable receiver may be used to receive the replicated data.

Examples of replicated data have been described above. Generally, signals are received that may encode the replicated data and the signals may also encode an indication that the data includes one or more replicated data symbols. Signals encoding the replicated data may be received by a single antenna in some examples.

[054] In block 720, the replicated data may be decoded using the estimate of the communications channel. Any suitable structure of a communications device may be used to perform the decoding, such as a DSP or other processing unit. In some examples, a joint detection technique is used to decode the replicated data, such as max-ratio combining. By decoding multiple copies of the replicated data, the decoding may be considered to be more accurate than the decoding of single data symbols. Accordingly, the decoded replicated data may be used to generate or update an estimate of the communications channel.

[055] In block 725, the estimate of the communications channel may be updated based, at least in part, on the replicated data. The updating may be performed by any suitable structure in a communications device, such as a DSP or other processing unit. The estimate may be updated by comparing the decoded symbol with the two instances of received signals encoding the symbol. In this manner, the channel estimate may be generated or updated, which may include all or a portion of the channel matrix. The updated channel estimate may be stored in some examples.

[056] In block 730, subsequently received data may be decoded using the updated channel estimate. That is, signals received following the updating of the channel estimate may be decoded using the updated channel estimate. The updated channel estimate may improve decoding performance in some examples.

[057] Accordingly, examples have been described above of estimating a communications channel based on pilot symbols and replicated data symbols. In this manner, the number of pilot symbols may be effectively increased through the use of replicated data symbols. The accuracy of the resultant channel estimates may in some examples approach the accuracy of an example where the effective number of inserted pilot symbols is equal to a sum of the number of pilot symbols plus the number of inserted replicated data symbols. Because the replicated data symbols also transmit data over the communications channel, however, the use of replicated data symbols may not impair the overall data rate of the system as severely as the use of more pilot symbols.

[058] Figure 8 is a block diagram illustrating an example computing device 800 that is arranged for generating an updated channel estimate in accordance with examples of the

present disclosure. In a very basic configuration 801, computing device 800 typically includes one or more processors 810 and system memory 820. A memory bus 830 may be used for communicating between the processor 810 and the system memory 820.

[059] Depending on the desired configuration, processor 810 may be of any type including but not limited to a microprocessor (μ P), a microcontroller (μ C), a digital signal processor (DSP), or any combination thereof. Processor 810 may include one more levels of caching, such as a level one cache 811 and a level two cache 812, a processor core 813, and registers 814. An example processor core 813 may include an arithmetic logic unit (ALU), a floating point unit (FPU), a digital signal processing core (DSP Core), or any combination thereof. An example memory controller 815 may also be used with the processor 810, or in some implementations the memory controller 815 may be an internal part of the processor 810.

[060] Depending on the desired configuration, the system memory 820 may be of any type including but not limited to volatile memory (such as RAM), non-volatile memory (such as ROM, flash memory, etc.) or any combination thereof. System memory 820 may include an operating system 821, one or more applications 822, and program data 824. Application 822 may include a channel estimate routine 823 that is arranged to generate an estimate of a communications channel based on received pilot symbols, replicated data symbols, or combinations thereof. Program Data 824 may include known pilot symbols 825, replicated data symbols 826, channel estimate 827, or combinations thereof, that may be useful for generating channel estimates as generally described above. In some embodiments, application 822 may be arranged to operate with program data 824 on an operating system 821 such that channel estimates are generated and/or updated on the basis of received pilot symbols and replicated data symbols. This described basic configuration is illustrated in Figure 8 by those components within dashed line 801.

[061] Computing device 800 may have additional features or functionality, and additional interfaces to facilitate communications between the basic configuration 801 and any required devices and interfaces. For example, a bus/interface controller 840 may be used to facilitate communications between the basic configuration 801 and one or more data storage devices 850 via a storage interface bus 841. The data storage devices 850 may be removable storage devices 851, non-removable storage devices 852, or a combination thereof. Examples of removable storage and non-removable storage devices include magnetic disk devices such as flexible disk drives and hard-disk drives (HDD), optical disk drives such as compact disk (CD) drives or digital versatile disk (DVD) drives, solid state drives (SSD), and tape drives to

name a few. Example computer storage media may include volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data.

[062] System memory 820, removable storage 851 and non-removable storage 852 are all examples of computer storage media. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which may be used to store the desired information and which may be accessed by computing device 800. Any such computer storage media may be part of device 800.

[063] Computing device 800 may also include an interface bus 842 for facilitating communication from various interface devices (e.g., output interfaces, peripheral interfaces, and communication interfaces) to the basic configuration 801 via the bus/interface controller 840. Example output devices 860 include a graphics processing unit 861 and an audio processing unit 862, which may be configured to communicate to various external devices such as a display or speakers via one or more A/V ports 863. Example peripheral interfaces 870 include a serial interface controller 870 or a parallel interface controller 872, which may be configured to communicate with external devices such as input devices (e.g., keyboard, mouse, pen, voice input device, touch input device, etc.) or other peripheral devices (e.g., printer, scanner, etc.) via one or more I/O ports 873. An example communication device 880 includes a network controller 881, which may be arranged to facilitate communications with one or more other computing devices 890 over a network communication link via one or more communication ports 882.

[064] The network communication link may be one example of a communication media. Communication media may typically be embodied by computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as a carrier wave or other transport mechanism, and may include any information delivery media. A “modulated data signal” may be a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media may include wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, radio frequency (RF),

microwave, infrared (IR) and other wireless media. The term computer readable media as used herein may include both storage media and communication media.

[065] Computing device 800 may be implemented as a portion of a small-form factor portable (or mobile) electronic device such as a cell phone, a personal data assistant (PDA), a personal media player device, a wireless web-watch device, a personal headset device, an application specific device, or a hybrid device that include any of the above functions. Computing device 800 may also be implemented as a personal computer including both laptop computer and non-laptop computer configurations.

[066] The present disclosure is not to be limited in terms of the particular examples described in this application, which are intended as illustrations of various aspects. Many modifications and examples can may be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and examples are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular examples only, and is not intended to be limiting.

[067] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[068] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as “open” terms (e.g., the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at least,” the term “includes” should be interpreted as “includes but is not limited to,” etc.).

[069] It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases

“at least one” and “one or more” to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to examples containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an” (e.g., “a” and/or “an” should be interpreted to mean “at least one” or “one or more”); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of “two recitations,” without other modifiers, means at least two recitations, or two or more recitations).

[070] Furthermore, in those instances where a convention analogous to “at least one of A, B, and C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, and C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to “at least one of A, B, or C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, or C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase “A or B” will be understood to include the possibilities of “A” or “B” or “A and B.”

[071] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[072] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at

least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as “up to,” “at least,” “greater than,” “less than,” and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 items refers to groups having 1, 2, or 3 items. Similarly, a group having 1-5 items refers to groups having 1, 2, 3, 4, or 5 items, and so forth.

[073] While the foregoing detailed description has set forth various examples of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples, such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one example, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), or other integrated formats. However, those skilled in the art will recognize that some aspects of the examples disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. For example, if a user determines that speed and accuracy are paramount, the user may opt for a mainly hardware and/or firmware vehicle; if flexibility is paramount, the user may opt for a mainly software implementation; or, yet again alternatively, the user may opt for some combination of hardware, software, and/or firmware.

[074] In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as a program product in a variety of forms, and that an illustrative example of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the

following: a recordable type medium such as a floppy disk, a hard disk drive, a Compact Disc (CD), a Digital Versatile Disk (DVD), a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

[075] Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein can be integrated into a data processing system via a reasonable amount of experimentation. Those having skill in the art will recognize that a typical data processing system generally includes one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity; control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[076] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely examples, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable", to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting

components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[077] While various aspects and examples have been disclosed herein, other aspects and examples will be apparent to those skilled in the art. The various aspects and examples disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS

What is claimed is:

1. A method of transmitting data over a communications channel, the method comprising:

modulating data for transmission over the communications channel in accordance with an orthogonal frequency division multiplexing technique to generate at least a first and second data stream for transmission using respective transmit antennas;

inserting at least a portion of data from the first data stream into the second data stream; and

transmitting the first and second data streams over the communications channel.

2. The method of claim 1, further comprising:

inserting pilot symbols into the first and second data streams.

3. The method of claim 2 wherein said inserting at least a portion of data from the first data stream into the second data stream comprises inserting the portion of data from the first data stream into the second data stream at a location between two pilot symbols in the second data stream.

4. The method of claim 3 wherein said inserting at least a portion of data from the first data stream into the second data stream comprises inserting a respective portion of data from the first data stream into the second data stream between each two pilot symbols in the second data stream.

5. The method of claim 1 further comprising encoding the first and the second data streams in accordance with a block coding technique.

6. The method of claim 5 wherein the block coding technique comprises a space-time block coding technique.

7. The method of claim 5 wherein the block coding technique comprises a space-frequency block coding technique.

8. A method of decoding a signal transmitted over a communications channel, the method comprising:

receiving a pilot symbol over the communications channel;

estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol;

receiving replicated data from multiple data streams transmitted over the communications channel;

decoding the replicated data using the estimated channel matrix; and

generating an updated estimate of the channel matrix based, at least in part, on the replicated data.

9. The method of claim 8, further comprising decoding subsequently received signals over the communications channel using the updated estimate of the channel matrix.

10. The method of claim 8 wherein said decoding the replicated data comprises using a joint detection technique.

11. The method of claim 8, wherein said decoding the replicated data comprises using a space-time block decoding technique.

12. The method of claim 8, wherein said decoding the replicated data comprises using a space-frequency block decoding technique.

13. The method of claim 8, wherein the replicated data includes same data symbols in multiple data streams.

14. A communication device comprising:

a modulator configured to modulate data in accordance with an orthogonal frequency division multiplexing technique for transmission over a communications channel using at least a first and a second transmit antenna, wherein the modulator is further configured to generate at least a first data stream for transmission with the first antenna and a second data stream for transmission with the second antenna;

a replicator coupled to the modulator and configured to receive the first and second data streams, wherein the replicator is configured to insert at least one data symbol from the first data stream into the second data stream;

an encoder coupled to the replicator and configured to receive the first and second data streams including the inserted at least one symbol, wherein the encoder is configured to encode the first and second data streams in accordance with a block coding technique; and

a transmitter coupled to the encoder and configured to receive the encoded first and second data streams, wherein the transmitter is configured to transmit the first data stream over the communications channel using the first antenna and further configured to transmit the second data stream including the inserted at least one symbol over the communications channel using the second antenna.

15. The communication device of claim 14 wherein the block coding technique comprises a space-time encoding technique.

16. The communication device of claim 14 wherein the block coding technique comprises a space-frequency encoding technique.

17. The communication device of claim 14 wherein the first and second data streams further include at least two pilot symbols, and wherein the replicator is configured to insert the at least one data symbol between the at least two pilot symbols.

18. A communication device comprising:

a receiver configured to receive signals over a communications channel, wherein the signals are based at least in part on first and second data streams transmitted over a communications channel, wherein the second data stream includes at least one data symbol replicated from the first data stream;

a decoder coupled to the receiver and the channel estimator, wherein the decoder is configured to receive the received signals and decode the at least one data symbol replicated from the first data stream;

a channel estimator coupled to the decoder and the receiver, wherein the channel estimator is configured to receive the received signals and the decoded at least one data

symbol, wherein the channel estimator is configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol; and wherein the decoder is further configured to decode subsequent received signals based, at least in part, on the estimate of the channel matrix.

19. The communication device of claim 18 wherein the decoder is configured to decode the at least one data symbol using a joint detection technique.

20. The communication device of claim 18 wherein the first and second data streams each further include at least one pilot symbol, and wherein the channel estimator is configured to receive the at least one pilot symbol and generate an initial estimate of the channel matrix based, at least in part on the at least one pilot symbol.

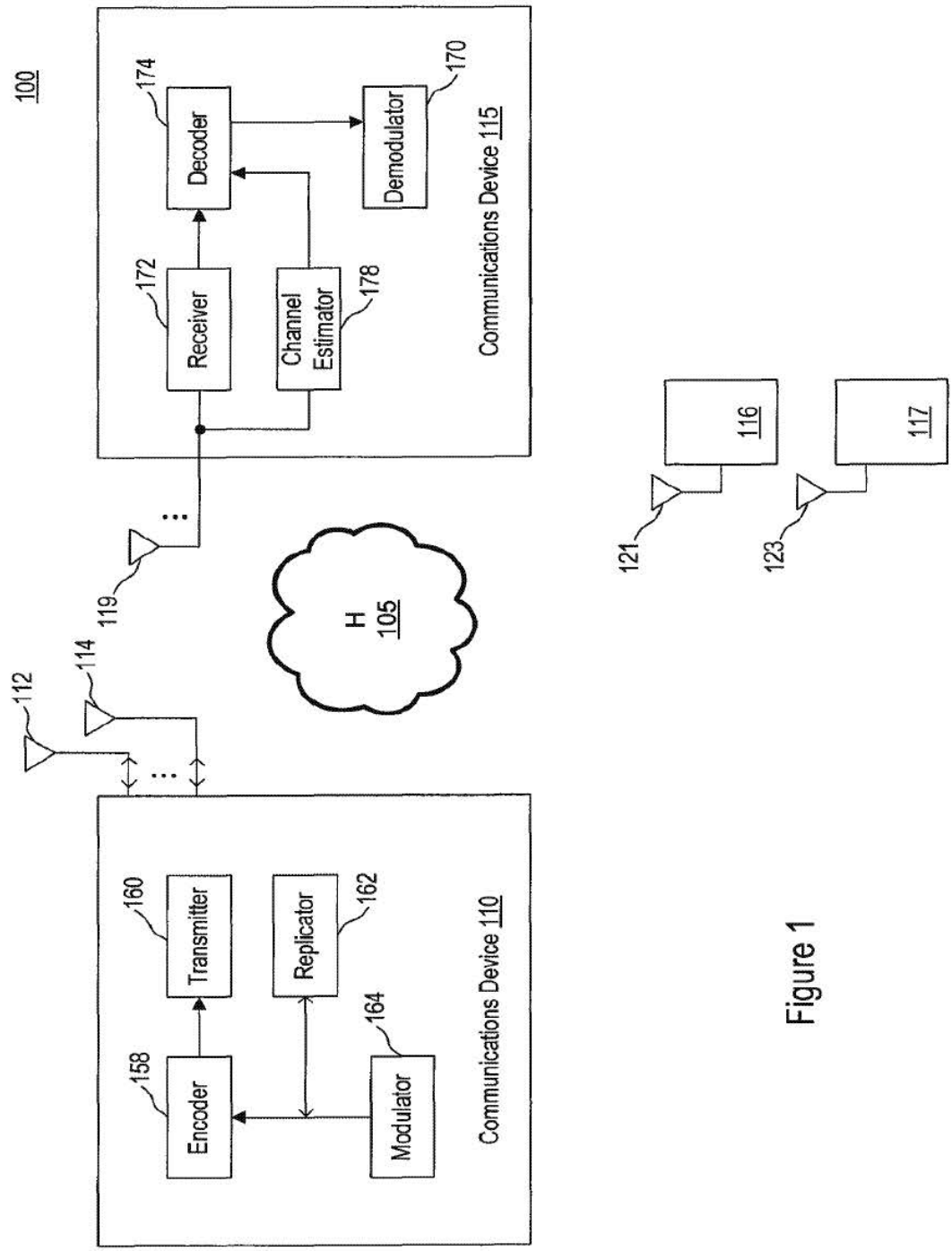


Figure 1

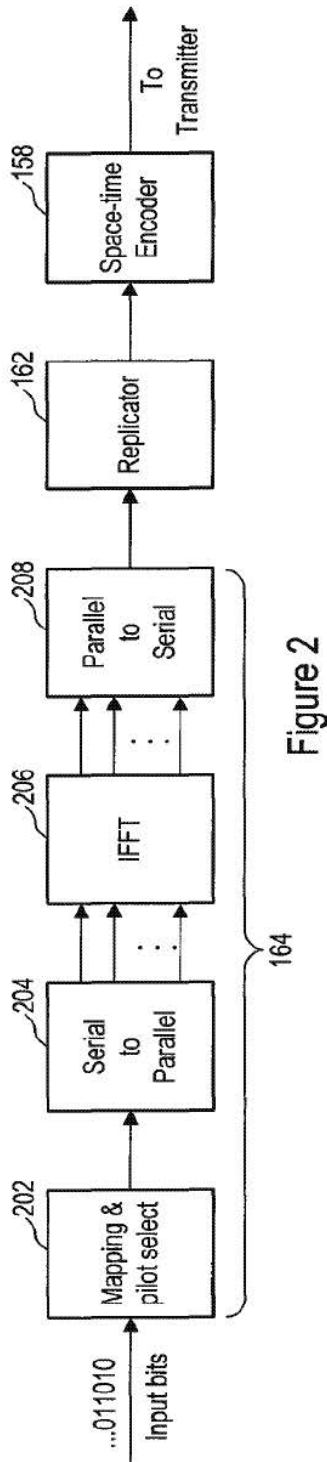


Figure 2

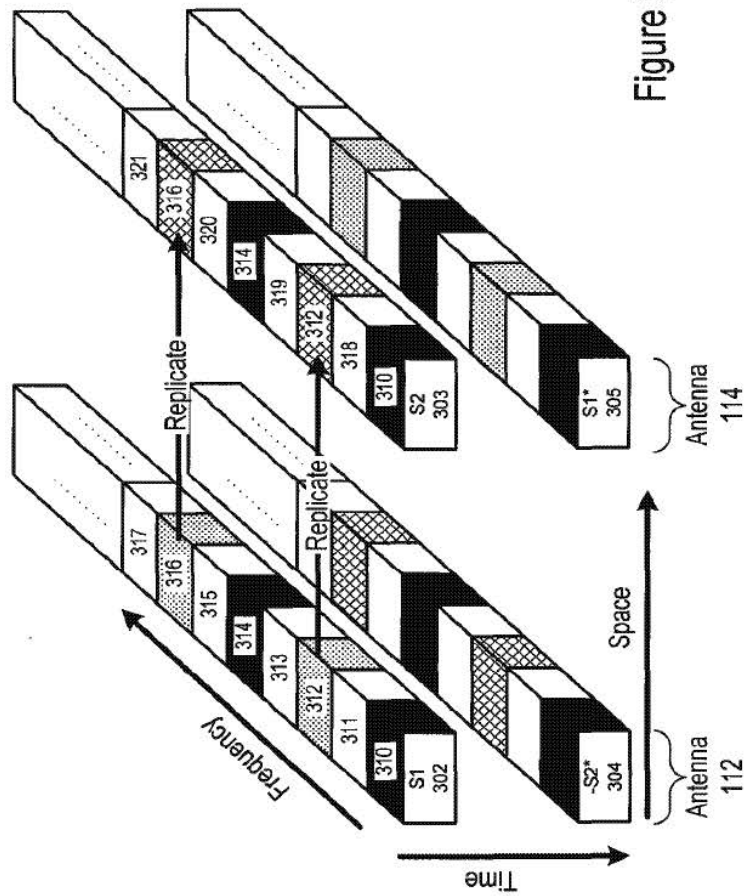


Figure 3

3/7

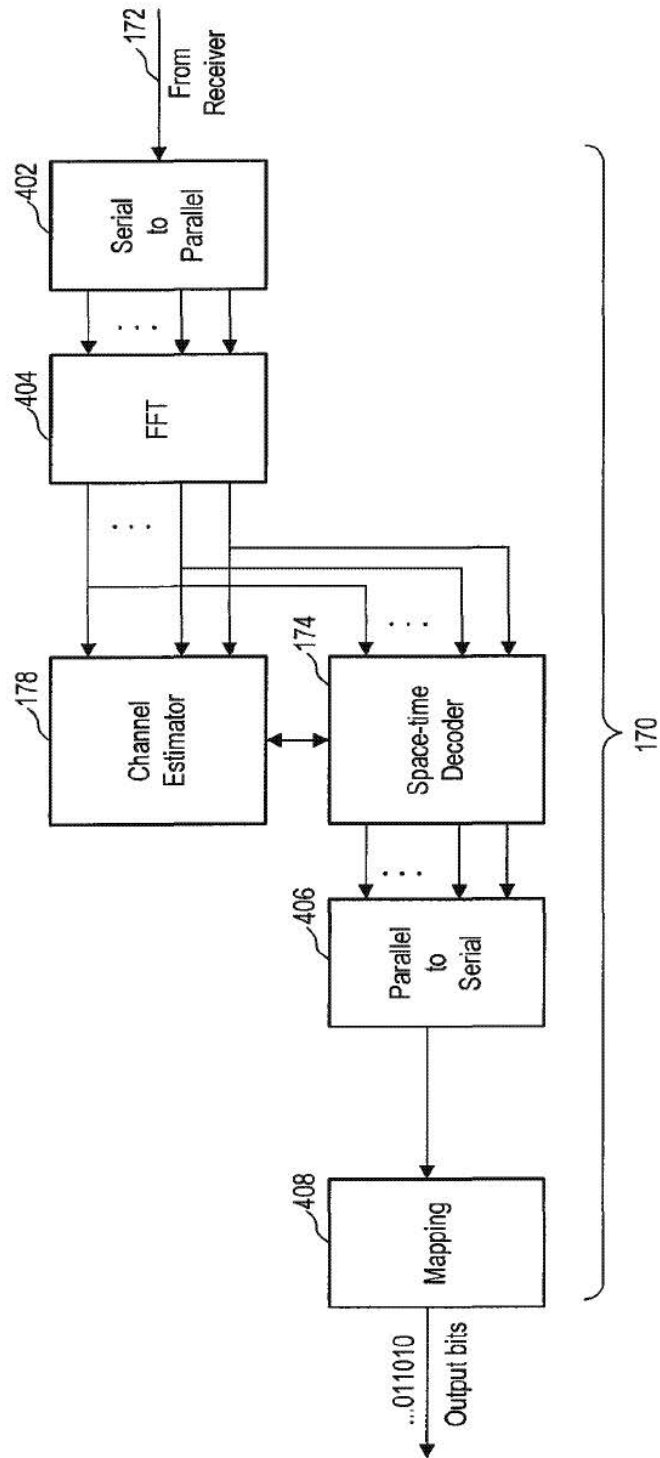


Figure 4