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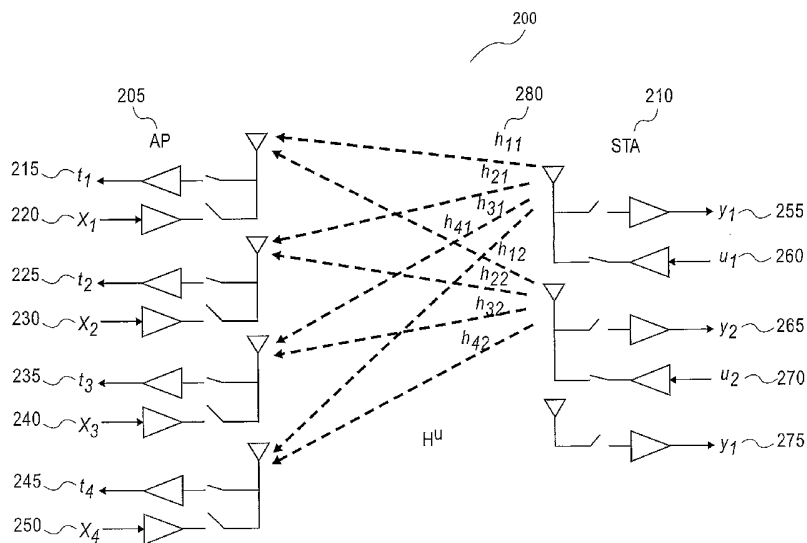
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(54) Title: SYSTEM AND METHOD CAPABLE OF IMPLICIT FEEDBACK FOR THE DEVICES WITH AN UNEQUAL NUMBER OF TRANSMITTER AND RECEIVER CHAINS IN A WIRELESS LOCAL AREA NETWORK



(57) Abstract: An embodiment of the present invention provides a wireless station (STA) capable of implicit feedback in a wireless local area network, comprising at least one power amplifier, a plurality of antennas capable of being connected with said at least one power amplifier, and a switch capable of switching the connection between said plurality of antennas and said at least one power amplifier thereby enabling said wireless station to sound a complete channel matrix for an access point (AP) in communication with said wireless station (STA).

**SYSTEM AND METHOD CAPABLE OF IMPLICIT FEEDBACK FOR THE
DEVICES WITH AN UNEQUAL NUMBER OF TRANSMITTER AND RECEIVER
CHAINS IN A WIRELESS LOCAL AREA NETWORK**

5 BACKGROUND

[0001] Wireless communications has become prevalent throughout society creating the need for faster and more reliable wireless communication techniques. Although not limited in this respect, one such
10 technique, 802.11n is designed to increase WLAN speeds to at least 100M bps for data and actual throughput rates. Unlike current ratified standards—802.11a, 802.11b and 802.11g—802.11n focuses on throughput at the MAC (media access control) interface, rather than as a signaling bit rate in the physical layer. This means the throughput rates will more likely match the
15 highest-possible data rates. This standard may operate in the 5GHz range along with 802.11a, although the present invention is not limited to these frequency ranges.

[0002] One technique used in 802.11n includes calibration and implicit feedback for closed loop multiple input multiple output (MIMO), which
20 depends on the radio calibration to establish the channel reciprocity. However, there are shortcomings to current attempts at implicit feedback.

[0003] Thus, a strong need exists for an apparatus, system and method capable of improved wireless communication techniques that

overcome the aforementioned shortcomings.

BRIEF DESCRIPTION OF THE DRAWINGS

5 **[0004]** The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of operation, together with objects, features, and advantages thereof, may best be understood by reference to the following detailed description when read
10 with the accompanying drawings in which:

[0005] FIG. 1 illustrates a protocol for data exchange in an embodiment of the present invention;

15 **[0006]** FIG. 2 depicts how the wireless station (STA) sounds the channel and the access points (AP) obtains the 4x2 uplink channel matrix in an embodiment of the present invention;

FIG. 3 depicts the channel as seen by the STA in a 3x4 channel
20 matrix in the downlink;

FIG. 4 depicts the short and long preamble format in the MIMO packet header wherein the system has 3 transmit and receive chains.

FIG. 5 illustrates a 1 + 1x2 switch scheme;

FIG. 6 illustrates a 2x3 switch scheme to connect any two of the
5 3 antennas to the 2 PAs;

FIG. 7 depicts the preambles for the "2x3" switch of FIG. 6; and

FIG. 8 depicts the preambles for the "1 + 1x2" switch scheme of
10 FIG. 5.

[0009] It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements are
15 exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals have been repeated among the figures to indicate corresponding or analogous elements.

DETAILED DESCRIPTION

20

[0010] In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the

present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components and circuits have not been described in detail so as not to obscure the present invention.

[0011] Some portions of the detailed description that follows are

5 presented in terms of algorithms and symbolic representations of operations on data bits or binary digital signals within a computer memory. These algorithmic descriptions and representations may be the techniques used by those skilled in the data processing arts to convey the substance of their work to others skilled in the art.

10 **[0012]** An algorithm is here, and generally, considered to be a self-consistent sequence of acts or operations leading to a desired result. These include physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and
15 otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers or the like. It should be understood, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to
20 these quantities.

[0013] Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "processing," "computing," "calculating,"

"determining," or the like, refer to the action and/or processes of a computer or computing system, or similar electronic computing device, that manipulate and/or transform data represented as physical, such as electronic, quantities within the computing system's registers and/or memories into other data similarly represented as physical quantities within the computing system's memories, registers or other such information storage, transmission or display devices.

[0014] Embodiments of the present invention may include apparatuses for performing the operations herein. An apparatus may be specially constructed for the desired purposes, or it may comprise a general purpose computing device selectively activated or reconfigured by a program stored in the device. Such a program may be stored on a storage medium, such as, but not limited to, any type of disk including floppy disks, optical disks, compact disc read only memories (CD-ROMs), magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), electrically programmable read-only memories (EPROMs), electrically erasable and programmable read only memories (EEPROMs), magnetic or optical cards, or any other type of media suitable for storing electronic instructions, and capable of being coupled to a system bus for a computing device.

[0015] The processes and displays presented herein are not inherently related to any particular computing device or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct a more

specialized apparatus to perform the desired method. The desired structure for a variety of these systems will appear from the description below. In addition, embodiments of the present invention are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein. In addition, it should be understood that operations, capabilities, and features described herein may be implemented with any combination of hardware (discrete or integrated circuits) and software.

[0016] Use of the terms "coupled" and "connected", along with their derivatives, may be used. It should be understood that these terms are not intended as synonyms for each other. Rather, in particular embodiments, "connected" may be used to indicate that two or more elements are in direct physical or electrical contact with each other. "Coupled" may be used to indicate that two or more elements are in either direct or indirect (with other intervening elements between them) physical or electrical contact with each other, and/or that the two or more elements co-operate or interact with each other (e.g. as in a cause and effect relationship).

[0017] It should be understood that embodiments of the present invention may be used in a variety of applications. Although the present invention is not limited in this respect, the devices disclosed herein may be used in many apparatuses such as in the transmitters and receivers of a radio system. Radio systems intended to be included within the scope of the present invention include,

by way of example only, cellular radiotelephone communication systems, satellite communication systems, two-way radio communication systems, one-way pagers, two-way pagers, personal communication systems (PCS), personal digital assistants (PDA's), wireless local area networks (WLAN), personal area networks
5 (PAN, and the like).

[0018] Multiple-input multiple-output (MIMO) antenna technology is a promising candidate for IEEE 802.11n high throughput and 802.16d standard. It is understood that these standards are just a couple of many wireless communication techniques that are intended to fall within the scope
10 of the present invention and any standards illustrated herein are intended to merely exemplify techniques which may obtain benefits by utilizing the present invention.

[0019] The 802.11n standards group has been working on a closed loop MIMO technique which may have significant advantages over the
15 mandatory open loop MIMO systems. An "implicit" feedback, which depends on radio calibration to establish the channel reciprocity, may be used in the 802.11n wireless communication standard and requires calibration. This method has an advantage of potential lower cost on the wireless station (STA) side.

20 In an embodiment of the present invention are described 2 switch schemes and the associated short and long preamble structures used for (automatic gain control) AGC setting and channel training for a 2x3 MIMO system. However, it is understood that although a 2X3 system is exemplified

herein, the principles and methodologies of the present invention can be utilized in many different systems and may be extended to other MIMO system with unequal number of transmitter and receiver chains all of which are intended to be within the scope of the present invention. Since 2x3 is a
5 very popular scheme to extend the range of MIMO spatial multiplexing, these schemes may be put in place to support implicit feedback closed-loop MIMO to further extend the range of the 2x3 system.

In an embodiment of the present invention at least 2x2 MIMO may be provided as a baseline. Further, in an embodiment of the present invention
10 and not limited in this respect, is provided a 2x3 system as well. This notation indicates 2 transmitting chains and 3 receiving chains on the device – again, it is understood that the 2X3 scheme is but one of many schemes and is provided herein for illustrative purposes only. It may be noted that the 2X3 may have a better eigen value distribution compared to that of a 2x2
15 channel matrix, which makes the multiplexing mode usable over a much longer distance.

In an embodiment of the present invention, and as mentioned above not limited in this respect, there are currently two issues with such 2x3 systems and the present invention articulates schemes to mitigate them.
20 Channel reciprocity is one such issue. The close-loop MIMO may send back the Channel State Information (CSI) to the transmitter. Based on the CSI, the transmitter may form spatial beams, which offers a 4 - 10 dB advantage depending on number of transmitting and receiving antennas. “Implicit”

feedback takes advantage of the channel reciprocity when the radios are properly calibrated - which is to say that the downlink channel may be the transpose of the uplink channel. Therefore, the CSI does not need to be sent back "explicitly"; it can be estimated from the reverse traffic.

5 FIG. 1, shown generally as 100, illustrates a protocol for data exchange in an embodiment of the present invention. In an embodiment of the present invention it is assumed the AP 105 needs to send a data packet to the STA 110. The AP 105 initiates the Request To Send (RTS) 115 packet when the media is idle. The STA 110 sends back the Clear To Send (CTS) with channel
10 sounding packet 120 to let the AP 105 obtain the uplink channel. From the reciprocity, the AP 105 also gets the downlink channel and subsequently sends the DATA with beam forming 125. The STA 110 sends back ACK at 130.

 However, in the case of a 2x3 system, the reciprocity does not hold.
15 To illustrate this, assume that an AP has 4 transmit and receive chains and a STA has 2 transmit and 3 receive chains as shown in Fig. 2, which depicts generally at 200 that the STA 210 sounds the channel 280 and the AP 205 obtains the 4x2 uplink channel matrix. 215 – 250 illustrate the AP side with the 4 transmit and receive chains and 255 – 275 illustrate the STA 2 and 3
20 receive chains.

 As shown in FIG. 3 at 300 is the downlink. The channel 380 as seen by the STA 310 is the 3x4 channel matrix. An embodiment of the present invention provides adding an RF switch to switch a Power Amplifier to the

third STA antenna 375 in order to sound the complete channel matrix for the AP 305. 315 - 350 illustrate the AP side with the 4 transmit and receive chains and 355 - 375 illustrate the STA 3 and 4 receive chains.

An embodiment of the present invention provides (automatic gain control) AGC Level Setting and Channel State Measurement. Most of the modern receivers may be able to handle an input signal power between -90dBm to -20 dBm. The typical 8 bit (analog-to-digital converter) ADC does not have enough dynamic range to resolve the full scale. The front end AGC is essential to set the gain level such that the averaged base band signal is in the appropriate ADC range for maximum accuracy. The short preamble may thus be used for the receiver to choose the appropriate AGC setting. The long preambles may be used for channel state measurement.

The following illustrates the process in the following 3x3 system. Fig 4, generally at 400, illustrates the short 415 and long 420, 425, 430 preamble format in the MIMO packet header as frequency 405 vs. time 410. The system has 3 transmit and receive chains. The different grayscales or color denote different antennas (i.e., first, second and third antennas in one embodiment). Only 6 tones are shown in the drawing to reduce the clutter, however, in typical use, such as the 802.11a/g standard there may be 52 tones - although the present invention is not limited to specific numbers of tones.

When the STA 125 of FIG. 1 sends the CTS packet 120, the AP 105 needs to measure the uplink channel matrix accurately. The measurement is

done in the short and long preamble portion of the packet shown in FIG. 4. In an exemplary embodiment and not limited in this respect, an AP may be a 4x4 system.

In the short preamble, all antennas and tones may be on so the AGC of the AP may settle to the most appropriate gain level to maximize accuracy. The next 3 long preambles train the 4x3 channel matrix for every tone. The tone interleaving at each time slot is used to make sure the average power stay close to the average. The thicker lines indicate a factor of 3 higher power in each tone in order to make the total output power the same.

If the STA is a 2x3 system, the scheme indicated in Fig. 4 will not work due to the lack of a third transmitter. In another embodiment of the present invention is provided an interleaving scheme to mitigate this problem. For a 2x3 system, the present invention may use an extra switch to connect the third antenna to a Power Amplifier (PA) so the channel reciprocity may be used in implicit feedback. Also provided is a short preamble and long preamble format to facilitate the channel state measurement by the device communicating with this system.

As shown in FIG. 5, generally at 500, is a first switch topology of one embodiment of the present invention where one PA 555 serves the first antenna 570 and another PA 560 serves the other 2 antennas 575 and 580 alternatively through a 1x2 switch (SPDT). The receive chain on the STA 510 side is omitted to simplify the picture. Illustrated at 515 – 550 are the transmit and receive antennas and PAs of AP 505 with channel shown at

565.

Turning now to FIG. 6, illustrated generally at 600, is a second switch scheme which uses a 2x3 switch 612 to connect any two of the three antennas 670, 675 and 680 to the 2 PAs 655 and 660. The channel is
5 generally illustrated at 665 and at 515 – 650 are the transmit and receive antennas and PAs of AP 605.

Looking now at FIG. 7, generally at 700 as frequency 705 vs. time 710, the short 715 preambles and long 720, 725 and 730 preambles are designed according to the "2X3" switch scheme. First, the system keeps
10 track of the power received by each antenna in previous packets from the AP and then ranks them accordingly. From the reciprocity, the antenna that receives the most power also appears stronger to the AP. Therefore, the strongest and the weakest antennas are used to send the short preamble in order to set the AGC in the AP to the appropriate level.

15 Turning now to FIG. 8, the gray scales represent the stronger of antenna 2 and 3. Further, the pair of antennas, 1 and the stronger of 2 and 3 are selected for long preamble 820 and 825. And the other antenna is selected for long preamble 830, such that all tones and antennas are exercised once and only once. The thicker lines indicate a factor of 2 higher
20 power in each tone so that the total emitted power are constant – although the present invention is not limited in this respect.

The switch scheme A outlined in FIG. 4 is less flexible than that of FIG. 5 as it has one PA serving antenna 1 only. The other PA serves either

antenna 2 or 3. The short preamble 815 may be sent using antenna 1 and the stronger of antenna 2 and antenna 3. The long preambles 820, 825 and 830 may be sent with the tone interleaving scheme as if it is a two antenna system. The third long preamble may be sent with the PA switched to the
5 third antenna.

[0032] While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes, and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such
10 modifications and changes as fall within the true spirit of the invention.

Claims:**What is claimed is:**

1. A wireless station (STA) capable of implicit feedback in a
5 wireless local area network, comprising:
at least one power amplifier;
a plurality of antennas capable of being connected with said at
least one power amplifier; and
a switch capable of switching the connection between said
10 plurality of antennas and said at least one power amplifier thereby enabling
said wireless station to sound a complete channel matrix for an access point
(AP) in communication with said wireless station (STA).
2. The wireless station of claim 1, wherein said plurality of
15 antennas is three antennas and said at least one power amplifier is two power
amplifiers.
3. The wireless station of claim 2, wherein a first of said two
power amplifiers is non-switchably connected to a first antenna of said three
20 antennas and a second of said two power amplifiers is switchably connected
to a second and third of said three antennas.

4. The wireless station of claim 1, wherein all of said power amplifiers are switchably connected to all of said antennas.

5. The wireless station of claim 2, wherein both said power
5 amplifiers are switchably connected to all three said antennas.

6. The wireless station of claim 1, wherein said AP keeps track of the power received by each of said plurality of antennas and ranks them accordingly.

10

7. The wireless station of claim 6, wherein based on said ranking, the strongest and the weakest antennas are used to send a short preamble in order to set the automatic gain control (AGC) in said AP to an appropriate level.

15

8. A method of providing implicit feedback by a wireless station (STA) in a wireless local area network, comprising:

associating at least one power amplifier with a plurality of antennas via a switch capable of switching the connection between said
20 plurality of antennas and said at least one power amplifier thereby enabling said wireless station to sound a complete channel matrix for an access point (AP) in communication with said wireless station (STA).

9. The method of claim 8, further comprising associating three antennas and with two power amplifiers.

10. The method of claim 9, further comprising connecting non-
5 switchably a first of said two power amplifiers to a first antenna of said three antennas and switchably connecting a second of said two power amplifiers to a second and third of said three antennas.

11. The method of claim 8, further comprising connecting switchably all of said power amplifiers to all of said antennas.

10

12. The method of claim 9, further comprising connecting switchably both of said power amplifiers to all three said antennas.

13. The method of claim 1, further comprising keeping track by said
15 AP of the power received by each of said plurality of antennas and ranking them accordingly.

14. The method of claim 13, further comprising sending a short preamble in order to set the automatic gain control (AGC) in said AP to an
20 appropriate level based on said ranking.

15. An article comprising a storage medium having stored thereon instructions, that, when executed by a computing platform, results in

providing implicit feedback by a wireless station (STA) in a wireless local area network by associating at least one power amplifier with a plurality of antennas via a switch capable of switching the connection between said plurality of antennas and said at least one power amplifier thereby enabling
5 said wireless station to sound a complete channel matrix for an access point (AP) in communication with said wireless station (STA).

16. The article of claim 15, wherein said plurality of antennas is three antennas and said at least one power amplifier is two power amplifiers.
10

17. The article of claim 16, wherein a first of said two power amplifiers is non-switchably connected to a first antenna of said three antennas and a second of said two power amplifiers is switchably connected to a second and third of said three antennas.
15

18. The article of claim 15, wherein all of said power amplifiers are switchably connected to all of said antennas.

19. An implicit feedback system in a wireless local area network,
20 comprising:

a wireless station including at least one power amplifier and
a plurality of antennas capable of being switchably connected with said
at least one power amplifier; and

an access point capable of sounding a complete channel matrix with said wireless station (STA).

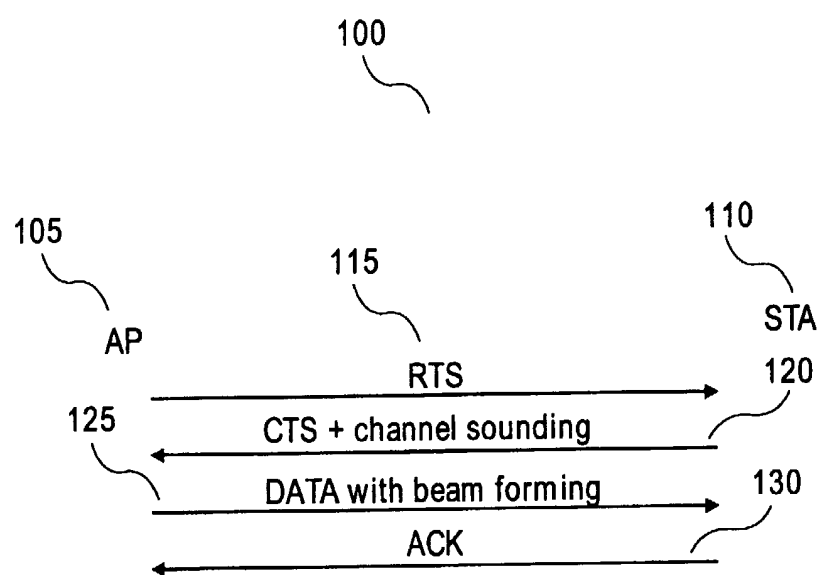
20. The implicit feedback system of claim 19, wherein said plurality
5 of antennas is three antennas and said at least one power amplifier is two power amplifiers.

21. The implicit feedback system of claim 19, wherein a first of said
two power amplifiers is non-switchably connected to a first antenna of said
10 three antennas and a second of said two power amplifiers is switchably connected to a second and third of said three antennas.

22. The implicit feedback system of claim 19, wherein all of said
power amplifiers are switchably connected to all of said antennas.
15

23. The implicit feedback system of claim 19, wherein both said
power amplifiers are switchably connected to all three said antennas.
20

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**FIG. 1**

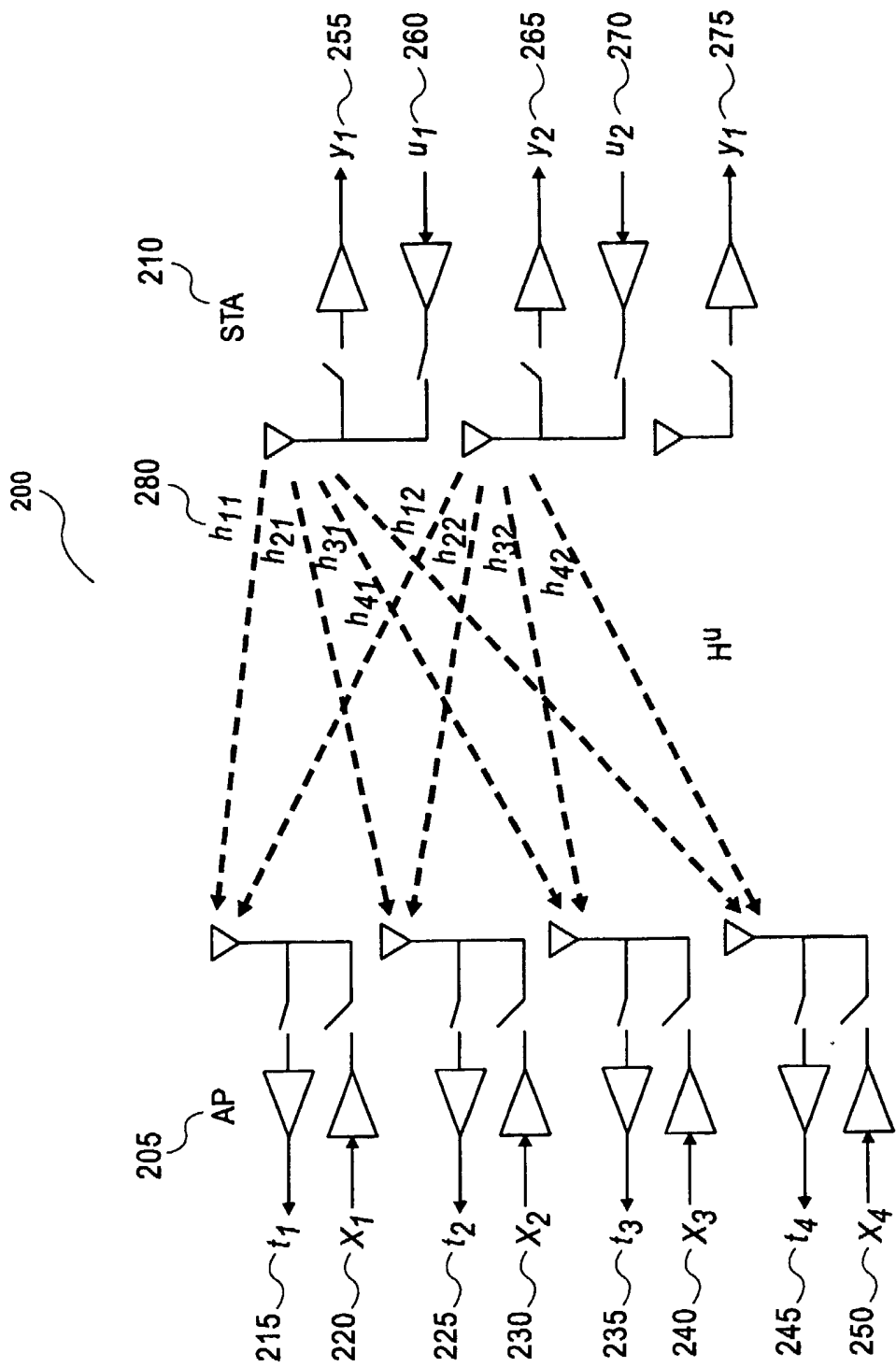


FIG. 2

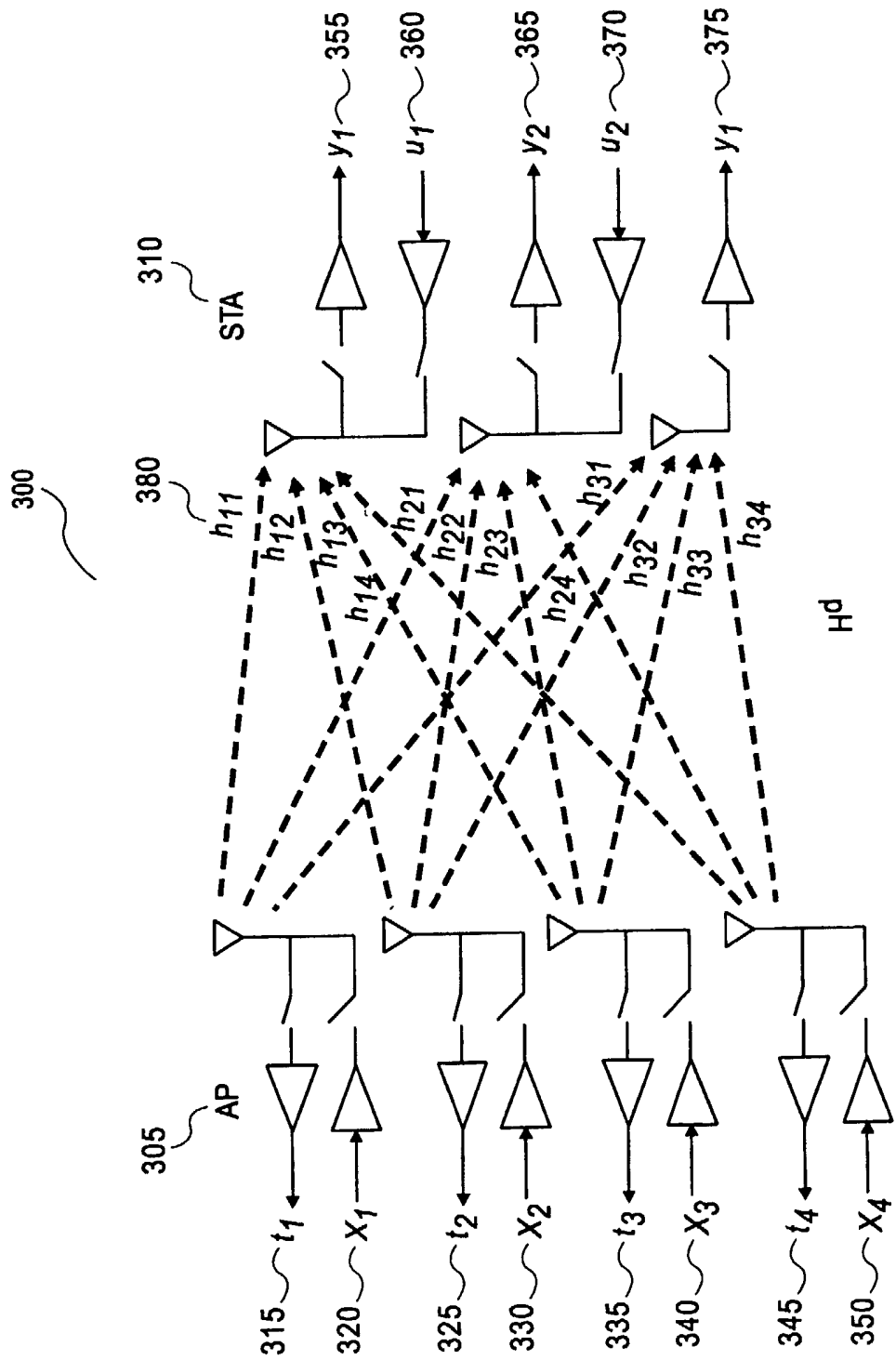
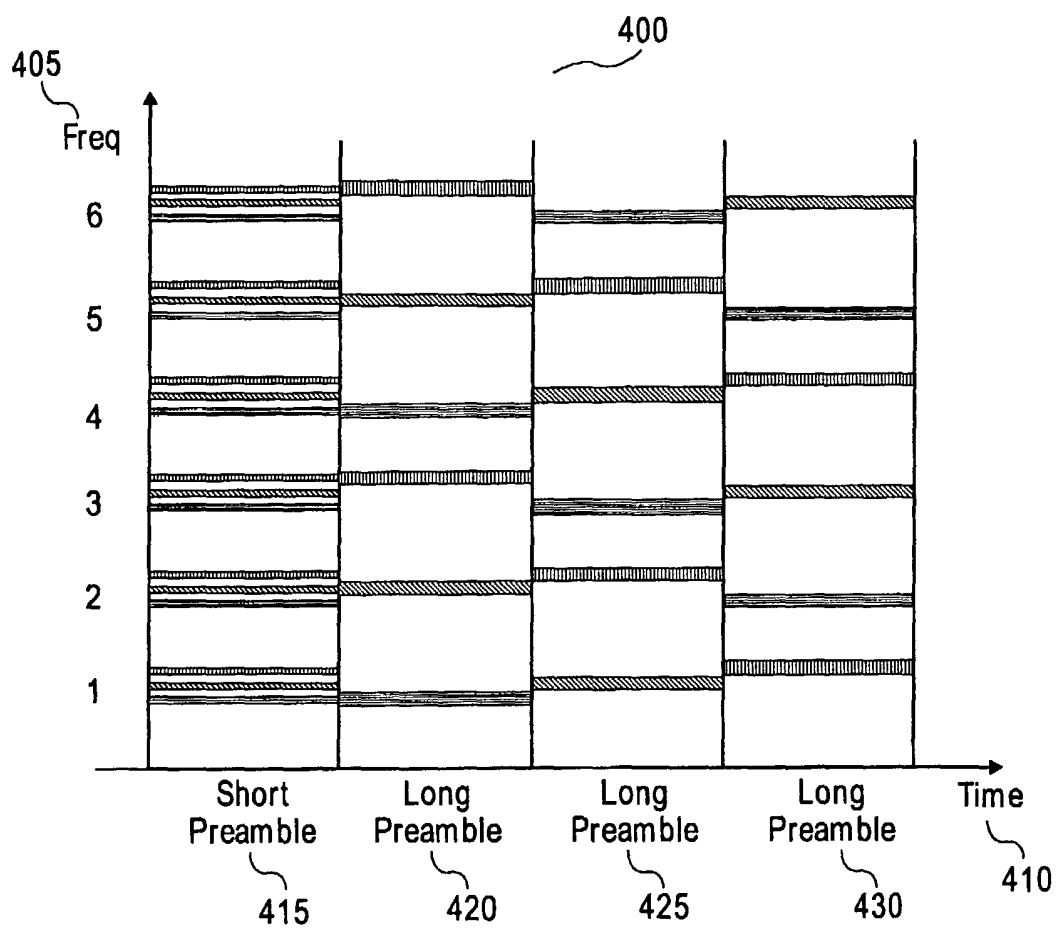


FIG. 3

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**FIG. 4**

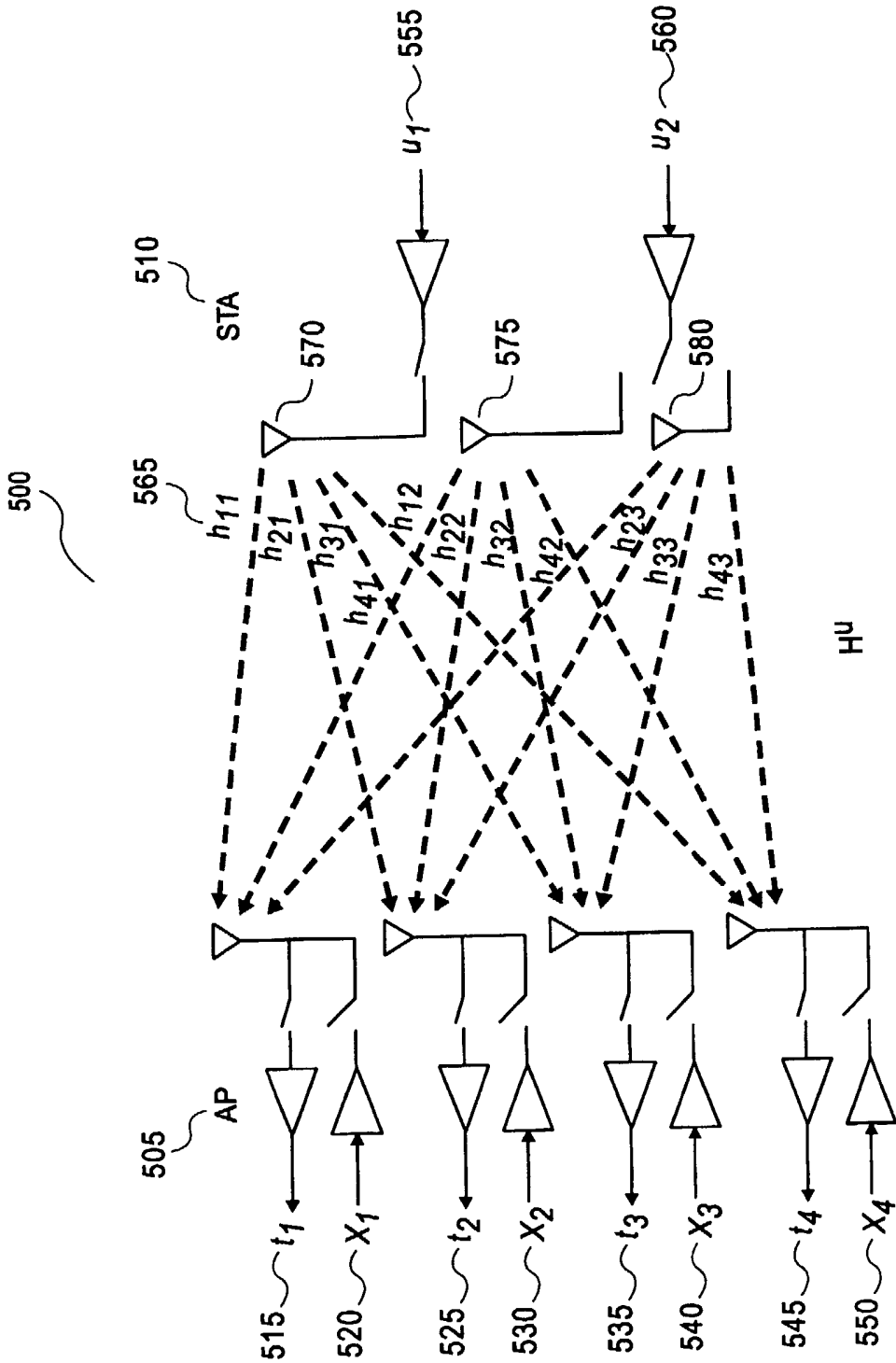


FIG. 5

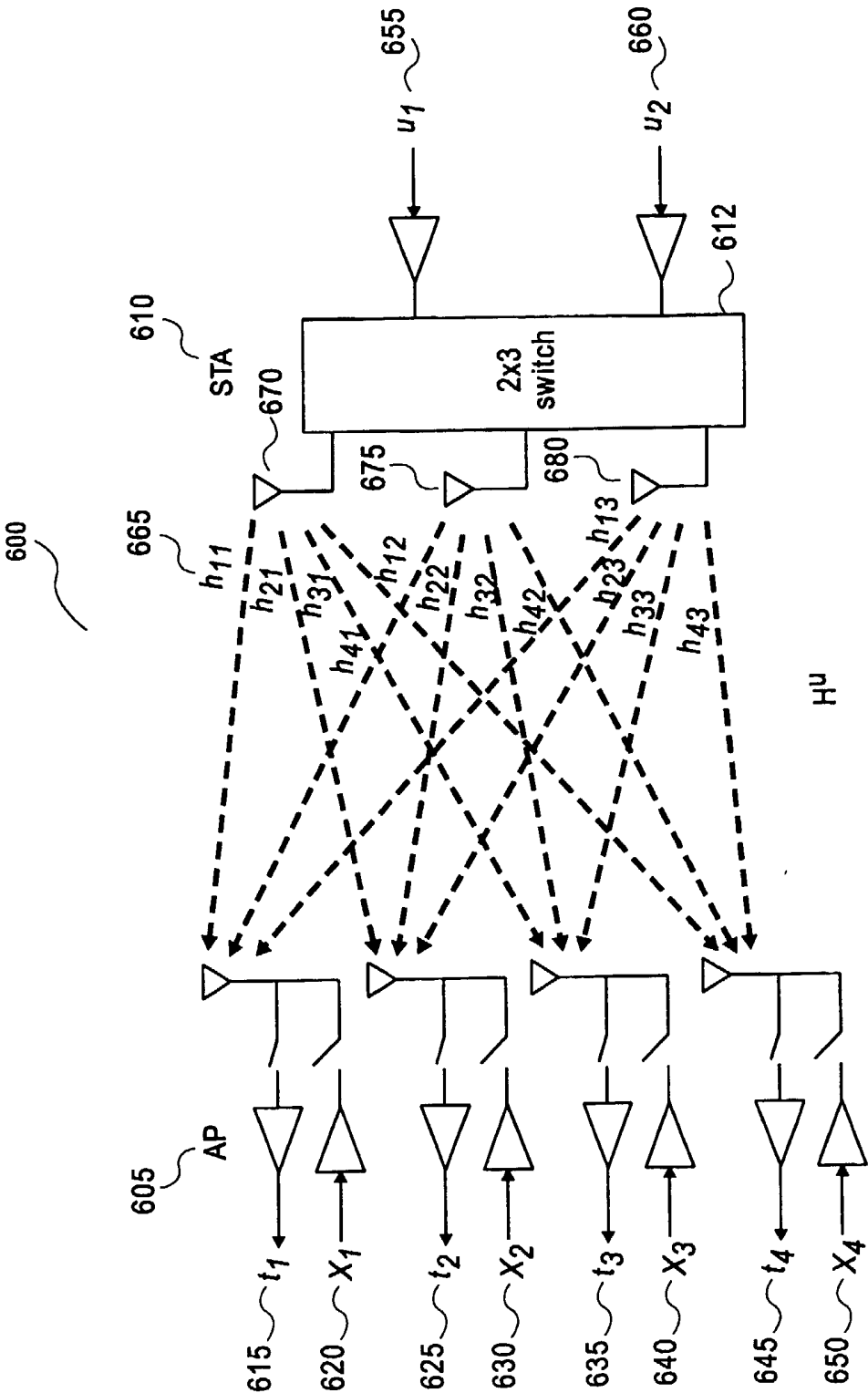


FIG. 6

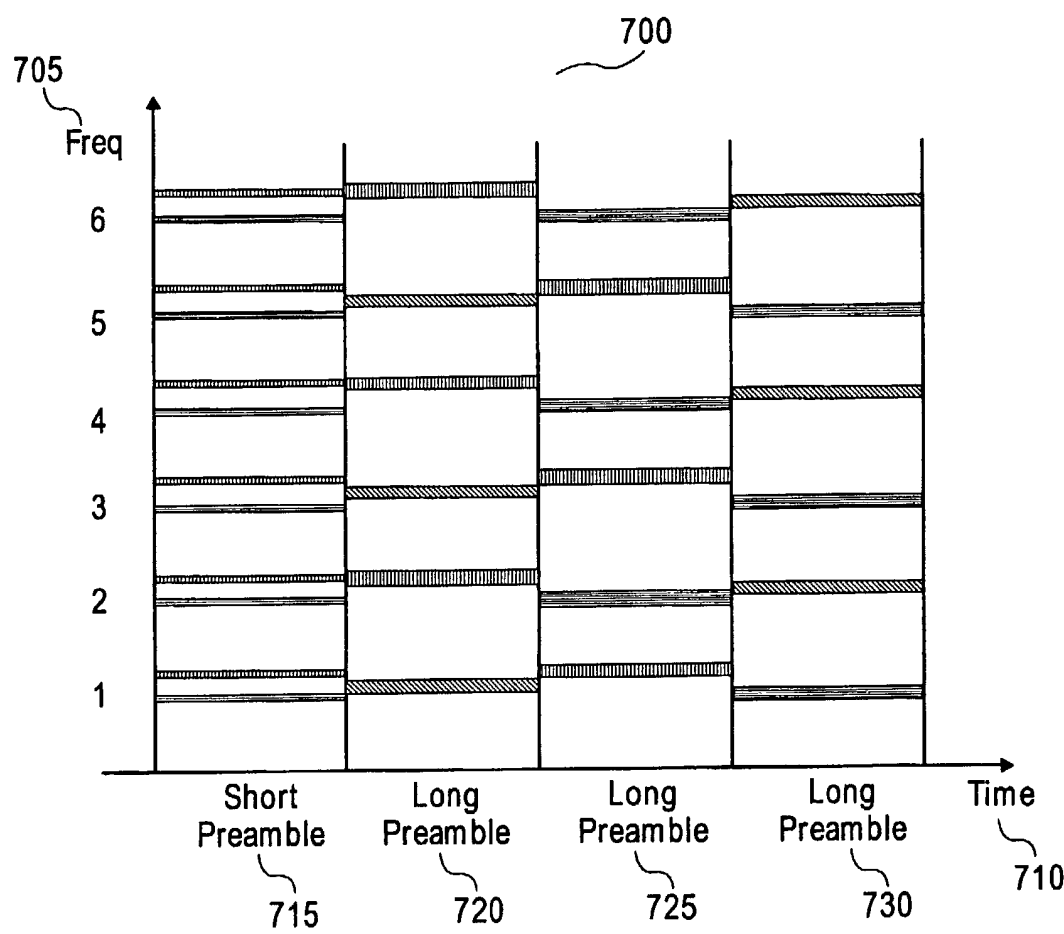
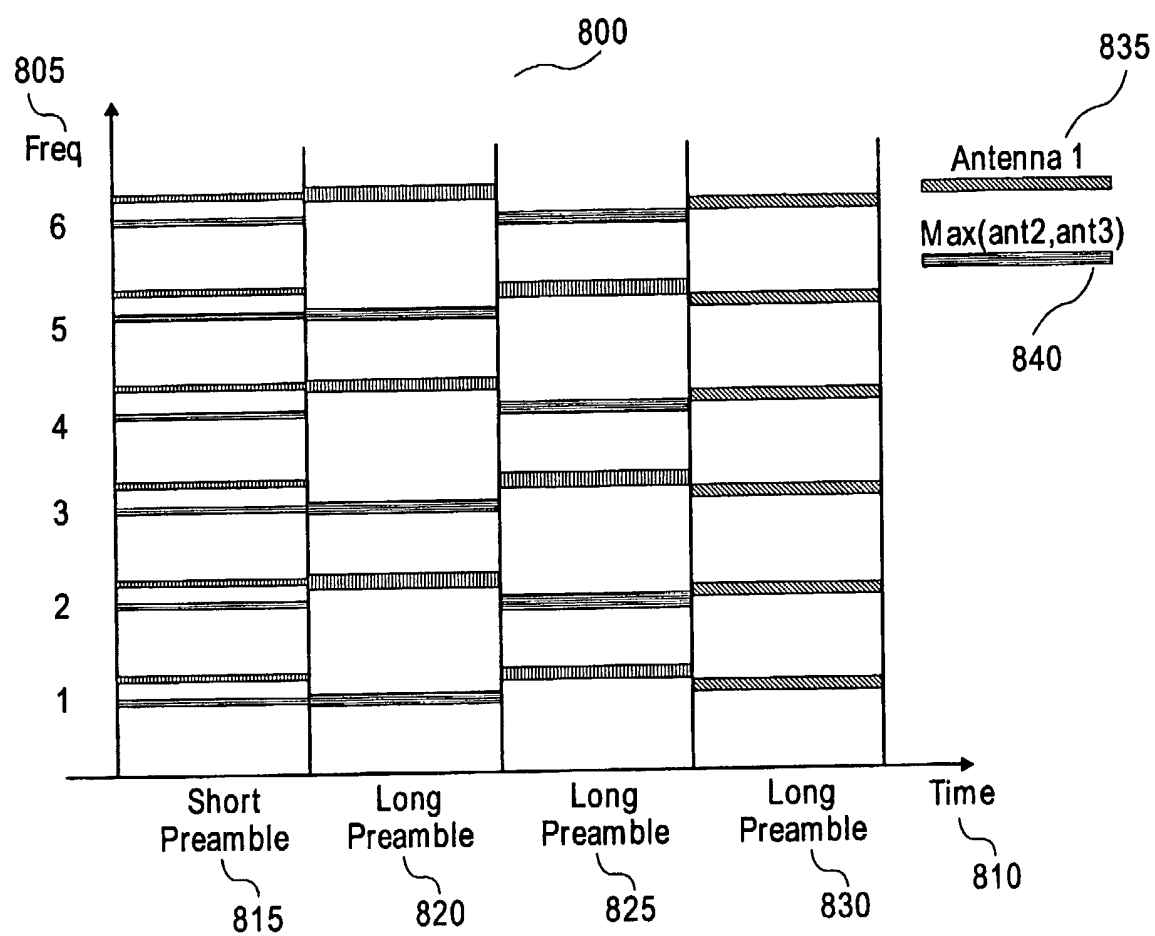


FIG. 7

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**FIG. 8**

INTERNATIONAL SEARCH REPORT

 International application No
 PCT/US2005/044700

 A. CLASSIFICATION OF SUBJECT MATTER
 H04B7/04

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)
 H04B H04L

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 practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	BARRIAC G ET AL: "Space-Time Communication for OFDM with Implicit Channel Feedback" GLOBECOM'03. 2003 - IEEE GLOBAL TELECOMMUNICATIONS CONFERENCE. CONFERENCE PROCEEDINGS. SAN FRANCISCO, DEC. 1 - 5, 2003, IEEE GLOBAL TELECOMMUNICATIONS CONFERENCE, NEW YORK, NY : IEEE, US, vol. VOL. 7 OF 7, 1 December 2003 (2003-12-01), pages 1321-1325, XP010677509 ISBN: 0-7803-7974-8 abstract page 1324, paragraph 4 - page 1325, paragraph 3 ----- -/--	1,8,15, 19

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

28 March 2006

Date of mailing of the international search report

04/04/2006

Name and mailing address of the ISA/

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Authorized officer

Lopez Marquez, T

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2005/044700

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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P,A	EP 1 530 299 A (NOKIA CORPORATION) 11 May 2005 (2005-05-11) abstract page 2, paragraph 2 - page 3, paragraph 11 -----	1,8,15, 19

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Information on patent family members

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