(12) STANDARD PATENT (11) Application No. **AU 2012246830 B2**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Apparatus and method for transmitting acknowledgement information in a TDD communication system

(51) International Patent Classification(s)
H04J 11/00 (2006.01) ***H04L 1/18*** (2006.01)

(21) Application No: **2012246830** (22) Date of Filing: **2012.04.19**

(87) WIPO No: **WO12/144832**

(30) Priority Data

(31) Number	(32) Date	(33) Country
61/476,975	**2011.04.19**	**US**

(43) Publication Date: **2012.10.26**
(44) Accepted Journal Date: **2016.06.30**

(71) Applicant(s)
Samsung Electronics Co., Ltd.

(72) Inventor(s)
Papasakellariou, Aris;Cho, Joon-Young

(74) Agent / Attorney
Griffith Hack, GPO Box 1285, Melbourne, VIC, 3001

(56) Related Art
3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding (Release 10), 3GPP TS 36.212 V10.1.0, March 2011, pages 1-76
WO 2010/132006 A1 (TELEFONAKTIEBOLAGET L M ERICSSON (PUBL)) 18 November 2010

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 October 2012 (26.10.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/144832 A3

(51) International Patent Classification:
H04L 1/18 (2006.01) *H04J 11/00* (2006.01)

(21) International Application Number: PCT/KR2012/003020

(22) International Filing Date: 19 April 2012 (19.04.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/476,975 19 April 2011 (19.04.2011) US

(71) Applicant *(for all designated States except US)*: **SAMSUNG ELECTRONICS CO., LTD.** [KR/KR]; 129, Samsung-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do 443-742 (KR).

(72) Inventors: **PAPASAKELLARIOU, Aris**; 2128 Harold Street, Unit B, Houston, Texas 77098 (US). **CHO, Joon-Young**; #224-101, Hwanggolmaeul 2-danji APT., Yeongtong-dong, Yeongtong-gu, Suwon-si, Gyeonggi-do 443-744 (KR).

(74) Agent: **LEE, Keon-Joo**; Mihwa Bldg., 110-2, Myongryun-dong 4-ga, Chongro-gu, Seoul 110-524 (KR).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) Date of publication of the international search report: 10 January 2013

(54) Title: APPARATUS AND METHOD FOR TRANSMITTING ACKNOWLEDGEMENT INFORMATION IN A TDD COMMUNICATION SYSTEM

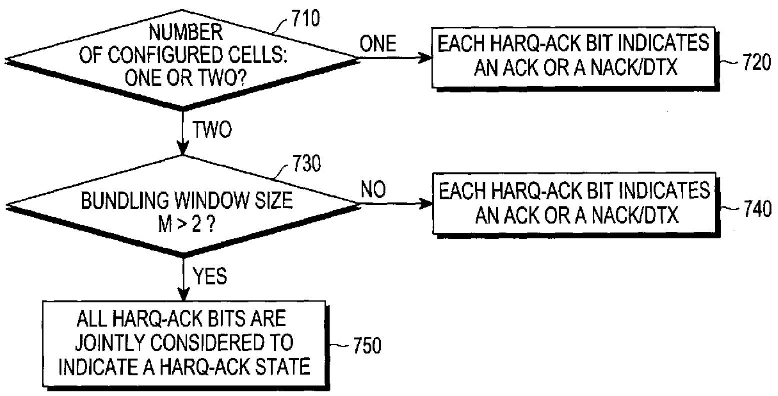

FIG.7

(57) Abstract: ABSTRACT Methods and apparatus are described for a User Equipment (UE) configured with multiple cells in the downlink of a time division duplex communication system to transmit HARQ-ACK information in a Physical Uplink Shared Channel (PUSCH), to map HARQ-ACK bits transmitted in a PUSCH to information regarding correct or incorrect detections of data transport blocks in different cells and different transmission time intervals, and to provide a same understanding with an intended reception point of the information represented by HARQ-ACK bits the UE transmits in a PUSCH.

WO 2012/144832 A3

APPARATUS AND METHOD FOR TRANSMITTING ACKNOWLEDGEMENT INFORMATION IN A TDD COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to wireless communication systems, and more particularly, to the transmission of acknowledgement information in an uplink of a communication system.

2. Description of the Art

A communication system includes a DownLink (DL) that conveys transmission signals from a Base Station (BS or NodeB) to User Equipments (UEs) and an UpLink (UL) that conveys transmission signals from UEs to the NodeB.

More specifically, a UL conveys transmissions of data signals carrying information content, transmissions of control signals providing control information associated with transmissions of data signals in a DL, and transmissions of Reference Signals (RSs), which are commonly referred to as pilot signals. A DL also conveys transmissions of data signals, control signals, and RSs. UL signals may be transmitted over clusters of contiguous REs using a Discrete Fourier Transform Spread Orthogonal Frequency Division Multiplexing (DFT-S-OFDM) method. DL signals may be transmitted using an OFDM method.

UL data signals are conveyed through a Physical Uplink Shared CHannel (PUSCH) and DL data signals are conveyed through a Physical Downlink Shared CHannel (PDSCH).

In the absence of a PUSCH transmission, a UE conveys UL Control Information (UCI) through a Physical Uplink Control CHannel (PUCCH). However, when a UE has a PUSCH transmission, it may convey UCI with data through the PUSCH.

DL control signals may be broadcast or sent in a UE-specific nature. Accordingly, UE-specific control channels can be used, among other purposes, to provide UEs with Scheduling Assignments (SAs) for PDSCH reception (DL SAs) or PUSCH transmission (UL SAs). The SAs are transmitted from the NodeB to respective UEs using DL Control Information (DCI) formats through respective Physical DL Control CHannels (PDCCHs).

The NodeB may configure a UE through higher layer signaling, such as Radio Resource Control (RRC) signaling, a PDSCH, and a PUSCH Transmission Mode (TM). The PDSCH TM or PUSCH TM is respectively associated with a DL SA or a UL SA, and defines whether the respective PDSCH or PUSCH conveys one data Transport Block (TB) or two data TBs.

PDSCH or PUSCH transmissions are either scheduled to a UE by a NodeB through higher layer signaling or through physical layer signaling (e.g., a PDCCH) using a respective DL SA or UL SA, or correspond to non-adaptive retransmissions for a given Hybrid Automatic Repeat reQuest (HARQ) process. Scheduling by higher layer signaling is referred to as Semi-Persistent Scheduling (SPS), and scheduling by a PDCCH is referred to as dynamic. A PDCCH may also be used to release an SPS PDSCH. If a UE fails to detect a PDCCH, this event is referred to as Discontinuous Transmission (DTX).

The UCI includes ACKnowledgment (ACK) information associated with a HARQ process (HARQ-ACK). The HARQ-ACK information may include multiple bits indicating the correct or incorrect detection of multiple data TBs. Typically, a correct detection of a data TB is indicated by a positive acknowledgment (i.e., an ACK) while an incorrect detection is indicated by a Negative ACK (NACK). If a UE misses (e.g., fails to detect) a PDCCH, it may explicitly or implicitly (absence of a signal transmission) indicate DTX (tri-state HARQ-ACK information) or both a DTX and an incorrect reception of a TB can be represented by a NACK (in a combined NACK/DTX state).

In Time Division Duplex (TDD) systems, DL and UL transmissions occur in different Transmission Time Intervals (TTIs), which are referred to as subframes. For example, in a frame including 10 subframes, some the subframes may be used for DL transmissions and some may be used for UL transmissions.

If a PDSCH conveys one data TB, respective HARQ-ACK information typically consists of one bit that is encoded as a binary '1', if the TB is correctly received (i.e., an ACK value), and as a binary '0', if the TB is incorrectly received (i.e., a NACK value). If a PDSCH conveys two data TBs, in accordance with a Single-User Multiple Input Multiple Output (SU-MIMO) transmission method, respective HARQ-ACK information typically consists of two bits $[o_0^{ACK}\ o_1^{ACK}]$ with o_0^{ACK} for a first TB and o_1^{ACK} for a second TB.

FIG. 1 illustrates a conventional TTI for a PUSCH or a PUCCH.

Referring to FIG. 1, a TTI consists of one subframe including two slots for PUSCH 110A or PUCCH 110B transmission. Each slot 120A and 120B includes $N_{\mathrm{symb}}^{\mathrm{UL}}$ symbols 130A used for signaling data or HARQ-ACK information in a PUSCH, or $N_{\mathrm{symb}}^{\mathrm{UL}}$ symbols 130B used for HARQ-ACK information in a PUCCH, and Reference Signals (RS) 140A or 140B, which are used for channel estimation and coherent demodulation of received data or HARQ-ACK information. The transmission BandWidth (BW) consists of frequency resource units that are referred to as Physical Resource Blocks (PRBs). Each PRB consists of $N_{\mathrm{sc}}^{\mathrm{RB}}$ sub-carriers, or Resource Elements (REs). For PUSCH transmission, a UE is allocated M_{PUSCH} PRBs for a total of $M_{\mathrm{sc}}^{\mathrm{PUSCH}} = M_{\mathrm{PUSCH}} \cdot N_{\mathrm{sc}}^{\mathrm{RB}}$ REs 150A. For PUCCH transmission, a UE is allocated 1 PRB 150B, which may be in two different BW locations in each of the two subframe slots.

FIG. 2 illustrates a conventional HARQ-ACK transmission structure in a PUCCH subframe slot.

Referring to FIG. 2, HARQ-ACK bits b 210 modulate 220 a Constant Amplitude Zero Auto-Correlation (CAZAC) sequence 230, for example, using Binary Phase Shift Keying (BPSK) with $b = b_0$ or Quaternary Phase Shift Keying (QPSK) with $b = (b_0, b_1)$. The modulated CAZAC sequence is then transmitted after performing an Inverse Fast Frequency Transform (IFFT) 240. The RS is transmitted through a non-modulated CAZAC sequence after performing an IFFT 250.

FIG. 3 is a block diagram illustrating of a conventional transmitter for a PUCCH.

Referring to FIG. 3, a CAZAC sequence 310 can be used without modulation for an RS or with modulation for HARQ-ACK information. The transmitter in the FIG.3 includes a selector 320, a sub-carrier mapper 330, an IFFT unit 340, a Cyclic Shifter 350, a Cyclic Prefix (CP) inserter 360, and a filter 370 for time windowing.. For sub-carrier mapping in the sub-carrier mapper 330, The selector 320 selects a first PRB and a second PRB for transmission of the CAZAC sequence in a first slot and a second slot, respectively. Subsequently, the IFFT unit 340 performs IFFT, and the Cyclic Shifter 350 applies a Cyclic Shift (CS) to the output of the IFFT unit 340. A CP and filtering are applied by the CP inserter 360 and the filter 370. Thereafter, the signal 380 is transmitted. Additional transmitter circuitry such as a Digital-to-Analog Converter (DAC), analog filters, amplifiers, transmitter antennas, etc., are not shown for brevity.

FIG. 4 is a block diagram illustrating a conventional receiver diagram for a PUCCH.

Referring to FIG. 4, The receiver in the FIG.3 includes a filter 420 for time windowing, a CP remover 430, a CS restorer 440, a Fast Fourier Transform (FFT) unit 450, a sub-carrier de-mapper 460, a selector 465, and a multiplier 470. An antenna (not shown) receives an analog signal and after further processing units (such as filters, amplifiers, frequency down-converters, and Analog-to-Digital Converters (ADCs) that are not shown for brevity), a digital received signal 410 passes through the filter 420 and the CP remover 430. Subsequently, a CS is restored by the CS restorer 440, the FFT 450 unit applies FFT, for sub-carrier demapping in the sub-carrier demapper 460, a selector 465 selects REs in a first PRB and a second PRB in a first slot and in a second slot, respectively, and a multiplier correlates 470 the REs with a replica of a CAZAC sequence 480. The output 490 may then be passed to a channel estimation unit, such as a time-frequency interpolator, when a subframe symbol conveys a RS, or to a detection unit, when a subframe symbol conveys a HARQ-ACK signal.

Different CSs of a same CAZAC sequence provide orthogonal CAZAC sequences and can be allocated to different UEs to achieve orthogonal multiplexing of HARQ-ACK signal transmissions in the same PRB. If T_s is a symbol duration, the number of such CSs is approximately $\lfloor T_s/D \rfloor$, where D is a channel propagation delay spread and $\lfloor\ \rfloor$ is a floor function that rounds a number to its immediately lower integer.

In addition to orthogonal multiplexing of HARQ-ACK signals and an RS in a same PRB using different CS of a CAZAC sequence, orthogonal multiplexing may also be in the time domain using Orthogonal Covering Codes (OCC). For example, in FIG. 2, a HARQ-ACK signal can be modulated by a length-4 OCC, such as a Walsh-Hadamard (WH) OCC, while an RS can be modulated by a length-3 OCC, such as a DFT OCC (not shown). When using an OCC, the multiplexing capacity per PRB increases by a factor of 3 (determined by the OCC with the smaller length). The sets of WH OCCs $\{W_0, W_1, W_2, W_3\}$, and DFT OCCs $\{D_0, D_1, D_2\}$, are respectively

$$\begin{bmatrix} W_0 \\ W_1 \\ W_2 \\ W_3 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \text{ and } \begin{bmatrix} D_0 \\ D_1 \\ D_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & e^{-j2\pi/3} & e^{-j4\pi/3} \\ 1 & e^{-j4\pi/3} & e^{-j2\pi/3} \end{bmatrix}.$$

Table 1 presents a mapping for a PUCCH resource n_{PUCCH} used for a HARQ-ACK signal and an RS transmission to an OCC n_{oc} and a CS α, assuming 6 CS per symbol and a length-3 OCC (with 3 CS used for each OCC). If all resources within a PUCCH PRB are used, resources in an immediately next PRB can be used.

Table 1: PUCCH Resource Mapping to OCC and CS.

	OCC n_{oc} for a HARQ-ACK and for an RS		
CS α	W_0, D_0	W_1, D_1	W_3, D_2
0	$n_{\text{PUCCH}} = 0$		$n_{\text{PUCCH}} = 6$
1		$n_{\text{PUCCH}} = 3$	
2	$n_{\text{PUCCH}} = 1$		$n_{\text{PUCCH}} = 7$
3		$n_{\text{PUCCH}} = 4$	
4	$n_{\text{PUCCH}} = 2$		$n_{\text{PUCCH}} = 8$
5		$n_{\text{PUCCH}} = 5$	

A PDCCH is transmitted in elementary units that are referred to as Control Channel Elements (CCEs). Each CCE may consist of 36 REs. UEs are informed of a total number of CCEs, N_{CCE}, through a transmission of a Physical Control Format Indicator CHannel (PCFICH) by a serving NodeB. The PCFICH indicates a number of OFDM symbols used for PDCCH transmissions in a respective DL subframe. A one-to-one mapping can exist between PUCCH resources (PRB, CS, OCC) for HARQ-ACK signal transmission and PDCCH CCEs. For example, if a single PUCCH resource is used for HARQ-ACK signal transmission, it may be derived from the CCE with the lowest index in a PDCCH conveying a respective DL SA.

In TDD systems, DL and UL transmissions occur in different subframes and $M \geq 1$ DL subframes may be associated with a single UL subframe. The association is in the sense that HARQ-ACK information generated in response to reception of data TBs in $M \geq 1$ DL subframes is transmitted in a single UL subframe. This set of $M \geq 1$ DL subframes is commonly referred to as a bundling window. Denoting a DL subframe index by $m = 0,1,\cdots,M-1$, a number of CCEs for a PCFICH value of p ($N_0 = 0$) by N_p, and a first PDCCH CCE of a DL SA in subframe m by $n_{\text{CCE}}(m)$, a PUCCH resource indexing for HARQ-ACK signal transmission can be as described below.

A UE first selects a value $p \in \{0,1,2,3\}$ providing $N_p \leq n_{\text{CCE}}(m) < N_{p+1}$ and then considers $n_{\text{PUCCH,m}} = (M-m-1) \times N_p + m \times N_{p+1} + n_{\text{CCE}}(m) + N_{\text{PUCCH}}$ as a PUCCH resource available for HARQ-ACK signal transmission in response to a DL

SA in DL subframe m, where $N_p = \max\{0, \lfloor [N_{RB}^{DL} \times (N_{sc}^{RB} \times p - 4)] / 36 \rfloor\}$, N_{PUCCH} is an offset informed to a UE by higher layer signaling, N_{sc}^{RB} is a number of sub-carriers and N_{RB}^{DL} is a number of PRBs in the DL operating BW.

HARQ-ACK information in a PUCCH may be conveyed with several methods including HARQ-ACK time-domain bundling and HARQ-ACK multiplexing using channel selection (referring to a selection of a PUCCH resource from a set of available PUCCH resources). In both cases, HARQ-ACK spatial-domain bundling applies where a UE generates an ACK, only if it receives all data TBs in a PDSCH correctly, and generates a NACK otherwise.

With HARQ-ACK time-domain bundling, a UE generates an ACK, only if it receives all TBs in a bundling window correctly, and generates a NACK otherwise. Therefore, HARQ-ACK time-domain bundling results in unnecessary retransmissions as a NACK is sent even when the UE correctly receives some of the TBs in a bundling window.

With HARQ-ACK multiplexing using channel selection, a UE conveys HARQ-ACK information for each DL subframe in a bundling window by selecting a PUCCH resource from a set of possible resources and by modulating the HARQ-ACK signal using QPSK modulation.

Table 2 describes HARQ-ACK multiplexing using channel selection for $M = 3$ in a TDD system with a single DL cell and a single UL cell. Specifically, a UE modulates a HARQ-ACK signal using the QPSK constellation point and selects one of PUCCH resources $n_{PUCCH}(0)$, $n_{PUCCH}(1)$, or $n_{PUCCH}(2)$, which are respectively determined by a first CCE of a respective PDCCH conveying a DL SA in a respective first, second, or third DL subframe (if any).

Explicit DTX indication is possible by including a Downlink Assignment Index (DAI) Information Element (IE), which indicates an accumulative number of PDSCH transmission(s) to a UE (the DAI IE is a counter within a bundling window), in DCI formats conveying DL SAs.

Table 2: HARQ-ACK Multiplexing with Channel Selection for $M=3$ DL Subframes

Entry Number	HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	n_{PUCCH}	Constellation
1	ACK, ACK, ACK	$n_{PUCCH,2}$	1, 1
2	ACK, ACK, NACK/DTX	$n_{PUCCH,1}$	1, 1
3	ACK, NACK/DTX, ACK	$n_{PUCCH,0}$	1, 1
4	ACK, NACK/DTX, NACK/DTX	$n_{PUCCH,0}$	0, 1
5	NACK/DTX, ACK, ACK	$n_{PUCCH,2}$	1, 0
6	NACK/DTX, ACK, NACK/DTX	$n_{PUCCH,1}$	0, 0
7	NACK/DTX, NACK/DTX, ACK	$n_{PUCCH,2}$	0, 0
8	DTX, DTX, NACK	$n_{PUCCH,2}$	0, 1
9	DTX, NACK, NACK/DTX	$n_{PUCCH,1}$	1, 0
10	NACK, NACK/DTX, NACK/DTX	$n_{PUCCH,0}$	1, 0
11	DTX, DTX, DTX	N/A	N/A

When HARQ-ACK information is transmitted in a PUSCH, it is encoded depending on a number of HARQ-ACK bits being conveyed. Assuming HARQ-ACK spatial-domain bundling, each HARQ-ACK bit conveys an outcome of each PDSCH reception and is encoded as a binary '1', if the respective TB(s) are correctly received (i.e., an ACK), and is encoded as a binary '0', if the respective TB(s) are incorrectly received (i.e., a NACK). Therefore, an individual HARQ-ACK bit is conveyed for each PDSCH reception. When HARQ-ACK information consists of $O=1$ bit o_0^{ACK} , it is encoded using repetition coding. When HARQ-ACK information consists of $O=2$ bits $[o_0^{ACK}\ o_1^{ACK}]$, it is encoded using a (3, 2) simplex code, as described in Table 3 for Q_m data modulation bits, where $o_2^{ACK}=(o_0^{ACK}+o_1^{ACK})\mathrm{mod}\,2$.

Table 3: Encoding for 1 and 2 HARQ-ACK Information Bits.

Q_m	Encoded HARQ-ACK – 1 bit	Encoded HARQ-ACK – 2 bits
2	$[o_0^{ACK}\ y]$	$[o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}]$
4	$[o_0^{ACK}\ y\ x\ x]$	$[o_0^{ACK}\ o_1^{ACK}\ x\ x\ o_2^{ACK}\ o_0^{ACK}\ x\ x\ o_1^{ACK}\ o_2^{ACK}\ x\ x]$
6	$[o_0^{ACK}\ y\ x\ x\ x\ x]$	$[o_0^{ACK}\ o_1^{ACK}\ x\ x\ x\ x\ o_2^{ACK}\ o_0^{ACK}\ x\ x\ x\ x\ o_1^{ACK}\ o_2^{ACK}\ x\ x\ x\ x]$

When HARQ-ACK information corresponds to a possible reception of more than 2 PDSCHs (assuming HARQ-ACK spatial-domain bundling) and consists of respective $3 \leq O^{ACK} \leq 11$ bits, the coding may be by a (32, O^{ACK}) Reed-Mueller (RM) block code. Denoting the HARQ-ACK information bits by $o_0^{ACK}\ o_1^{ACK},\ldots,o_{O^{ACK}-1}^{ACK}$ and the encoded HARQ-ACK bits by $\tilde{q}_0^{ACK}\ \tilde{q}_1^{ACK},\ldots,\tilde{q}_{31}^{ACK}$, $\tilde{q}_i^{ACK} = \sum_{n=0}^{O-1}\left(o_n^{ACK} \cdot M_{i,n}\right) \bmod 2$, where $M_{i,n}$ are basis sequences of an RM code and i = 0, 1, ..., 31. The output bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK},\ldots, q_{Q_{ACK}-1}^{ACK}$ is obtained by a circular repetition of the bit sequence $\tilde{q}_0^{ACK}\ \tilde{q}_1^{ACK},\ldots,\tilde{q}_{31}^{ACK}$, such that the bit sequence length is equal to Q_{ACK}, which is the total number of coded HARQ-ACK symbols in a PUSCH.

FIG. 5 is a block diagram illustrating a conventional transmitter for data and HARQ-ACK in a PUSCH.

Referring to FIG. 5, the transmitter includes a data encoder 515, an RM encoder 520, a puncturer/inserter 530, a DFT unit 540, a sub-carrier mapper 550, a selector 555, an IFFT unit 560, a CP inserter 570, and a filter 580 for time windowing. Data information bits 505 and HARQ-ACK information bits 510 are respectively provided to the data encoder 515 and the RM encoder 520. For two HARQ-ACK information bits, a simplex encoder is used instead of the RM encoder 520. Encoded data bits are subsequently punctured and replaced by encoded HARQ-ACK bits by the puncturer/inserter 530. The result is then input to a DFT unit 540. A selector 555 selects REs corresponding to the PUSCH transmission BW for subcarrier mapping in the sub-carrier mapper 550, which are then input to the IFFT unit 560. A CP is inserted by the CP inserter 570, and the CP inserted signal then passes through the filter 580 before being transmitted 590. Again, additional transmitter circuitry is not illustrated for conciseness. Also, the modulation process for the transmitted bits is omitted for brevity.

FIG. 6 is a conventional block diagram illustrating a receiver block for data and HARQ-ACK in a PUSCH.

Referring to FIG. 6, the receiver includes a filter 620 for time windowing, a CP remover630, an FFT unit 640, a sub-carrier de-mapper 650, a selector 655, an Inverse DFT (IDFT) unit 660, a de-multiplexer 670, a data decoder 680, and an RM decoder 685. After an antenna (not shown) receives a Radio-Frequency (RF) analog signal and further processing units (not shown) convert the analog signal to a digital signal 610, the digital signal 610 passes through the filter 620 and the CP removal unit 630. The output of the CP removal unit 630 is provided to the FFT unit 640, and a selector 655 controls the sub-carrier de-mapper 650 to select the REs used by the transmitter. The obtained values are provided to the IDFT unit 660 and the de-multiplexer 670, which outputs coded data bits. that the coded data bits are then provided to the data decoder 680 and the coded HARQ-ACK bits are then provided to the RM decoder 685 to respectively output data information bits 690 and HARQ-ACK information bits 695. For two HARQ-ACK information bits, a simplex decoder is used instead of the RM decoder 685. Similar to the transmitter illustrated in FIG. 5, receiver functionalities such as channel estimation, demodulation, and decoding are not illustrated in FIG. 6 for brevity.

In order to increase the supportable data rates to a UE, a NodeB can configure multiple cells to a UE in both a DL and a UL to effectively provide higher operating BWs. For example, to support communication over 40 MHz, two 20 MHz cells can be configured to a UE. A UE is always configured a DL cell and a UL cell to maintain communication and each such cell is referred to as Primary cell (Pcell). Additional cells a UE may be configured are referred to as Secondary cells (Scells).

A transmission of HARQ-ACK information can be in a PUCCH of the UL Pcell. For HARQ-ACK multiplexing using channel selection, a separate PUCCH resource is assigned in a UL Pcell for HARQ-ACK signal transmission in response to a PDSCH reception in each subframe of a bundling window and each DL cell.

For two configured cells and a bundling window size of $M > 1$ DL subframes, denoting PUCCH resources associated with reception of PDSCH(s) on the DL Pcell by $n_{\mathrm{PUCCH},0}$ and $n_{\mathrm{PUCCH},1}$ and PUCCH resources associated with reception of PDSCH(s) on the Scell and by HARQ-ACK(j), $0 \le j \le M-1$, by $n_{\mathrm{PUCCH},2}$ and $n_{\mathrm{PUCCH},3}$, the ACK/NACK/DTX response for a PDSCH with corresponding DAI value in a PDCCH equal to '$j+1$', a UE performs channel selection according to Table 4 for $M=3$ and Table 5 for $M=4$ and transmits a HARQ-ACK signal using QPSK modulation $\{b(0),b(1)\}$ on PUCCH resource n_{PUCCH}. For the last state in Table 4 and the last two states in Table 5, there is no transmission in a PUCCH, as a UE cannot determine a valid PUCCH resource. The value 'any' can be either 'ACK' or 'NACK/DTX'.

Table 4: HARQ-ACK Multiplexing with Channel Selection for $M=3$ DL Subframes and 2 Configured Cells.

Primary Cell	Secondary Cell	Resource	Constellation
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	n_{PUCCH}	$b(0),b(1)$
ACK, ACK, ACK	ACK, ACK, ACK	$n_{\mathrm{PUCCH},1}$	1, 1
ACK, ACK, NACK/DTX	ACK, ACK, ACK	$n_{\mathrm{PUCCH},1}$	0, 0
ACK, NACK/DTX, any	ACK, ACK, ACK	$n_{\mathrm{PUCCH},3}$	1, 1
NACK/DTX, any, any	ACK, ACK, ACK	$n_{\mathrm{PUCCH},3}$	0, 1
ACK, ACK, ACK	ACK, ACK, NACK/DTX	$n_{\mathrm{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX	$n_{\mathrm{PUCCH},3}$	1, 0
ACK, NACK/DTX, any	ACK, ACK, NACK/DTX	$n_{\mathrm{PUCCH},0}$	0, 1
NACK/DTX, any, any	ACK, ACK, NACK/DTX	$n_{\mathrm{PUCCH},3}$	0, 0
ACK, ACK, ACK	ACK, NACK/DTX, any	$n_{\mathrm{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX	ACK, NACK/DTX, any	$n_{\mathrm{PUCCH},2}$	0, 1
ACK, NACK/DTX, any	ACK, NACK/DTX, any	$n_{\mathrm{PUCCH},2}$	1, 0

NACK/DTX, any, any	ACK, NACK/DTX, any	$n_{PUCCH,2}$	0, 0
ACK, ACK, ACK	NACK/DTX, any, any	$n_{PUCCH,1}$	1, 0
ACK, ACK, NACK/DTX	NACK/DTX, any, any	$n_{PUCCH,1}$	0, 1
ACK, NACK/DTX, any	NACK/DTX, any, any	$n_{PUCCH,0}$	1, 1
NACK, any, any	NACK/DTX, any, any	$n_{PUCCH,0}$	0, 0
DTX, any, any	NACK/DTX, any, any	No Transmission	

Table 5: HARQ-ACK Multiplexing with Channel Selection for $M = 4$ DL Subframes and 2 Configured Cells.

Primary Cell	Secondary Cell	Resource	Constellation
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	n_{PUCCH}	$b(0), b(1)$
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, NACK/DTX	$n_{PUCCH,1}$	1, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, NACK/DTX	$n_{PUCCH,1}$	0, 0
ACK, DTX, DTX, DTX	ACK, ACK, ACK, NACK/DTX	$n_{PUCCH,3}$	1, 1
ACK, ACK, ACK, ACK	ACK, ACK, ACK, NACK/DTX	$n_{PUCCH,3}$	1, 1
NACK/DTX, any, any, any	ACK, ACK, ACK, NACK/DTX	$n_{PUCCH,3}$	0, 1
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	ACK, ACK, ACK, NACK/DTX	$n_{PUCCH,3}$	0, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX, any	$n_{PUCCH,0}$	1, 0
ACK, ACK, NACK/DTX, any	ACK, ACK, NACK/DTX, any	$n_{PUCCH,3}$	1, 0
ACK, DTX, DTX, DTX	ACK, ACK, NACK/DTX, any	$n_{PUCCH,0}$	0, 1
ACK, ACK, ACK, ACK	ACK, ACK, NACK/DTX,	$n_{PUCCH,0}$	0, 1

	any		
NACK/DTX, any, any, any	ACK, ACK, NACK/DTX, any	$n_{PUCCH,3}$	0, 0
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	ACK, ACK, NACK/DTX, any	$n_{PUCCH,3}$	0, 0
ACK, ACK, ACK, NACK/DTX	ACK, DTX, DTX, DTX	$n_{PUCCH,2}$	1, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, ACK	$n_{PUCCH,2}$	1, 1
ACK, ACK, NACK/DTX, any	ACK, DTX, DTX, DTX	$n_{PUCCH,2}$	0, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, ACK	$n_{PUCCH,2}$	0, 1
ACK, DTX, DTX, DTX	ACK, DTX, DTX, DTX	$n_{PUCCH,2}$	1, 0
ACK, DTX, DTX, DTX	ACK, ACK, ACK, ACK	$n_{PUCCH,2}$	1, 0
ACK, ACK, ACK, ACK	ACK, DTX, DTX, DTX	$n_{PUCCH,2}$	1, 0
ACK, ACK, ACK, ACK	ACK, ACK, ACK, ACK	$n_{PUCCH,2}$	1, 0
NACK/DTX, any, any, any	ACK, DTX, DTX, DTX	$n_{PUCCH,2}$	0, 0
NACK/DTX, any, any, any	ACK, ACK, ACK, ACK	$n_{PUCCH,2}$	0, 0
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	ACK, DTX, DTX, DTX	$n_{PUCCH,2}$	0, 0
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	ACK, ACK, ACK, ACK	$n_{PUCCH,2}$	0, 0
ACK, ACK, ACK, NACK/DTX	NACK/DTX, any, any, any	$n_{PUCCH,1}$	1, 0
ACK, ACK, ACK, NACK/DTX	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{PUCCH,1}$	1, 0
ACK, ACK, NACK/DTX, any	NACK/DTX, any, any, any	$n_{PUCCH,1}$	0, 1
ACK, ACK, NACK/DTX,	{ACK, NACK/DTX, any,	$n_{PUCCH,1}$	0, 1

any	any}, except for {ACK, DTX, DTX, DTX}		
ACK, DTX, DTX, DTX	NACK/DTX, any, any, any	$n_{PUCCH,0}$	1, 1
ACK, DTX, DTX, DTX	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{PUCCH,0}$	1, 1
ACK, ACK, ACK, ACK	NACK/DTX, any, any, any	$n_{PUCCH,0}$	1, 1
ACK, ACK, ACK, ACK	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{PUCCH,0}$	1, 1
NACK, any, any, any	NACK/DTX, any, any, any	$n_{PUCCH,0}$	0, 0
NACK, any, any, any	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{PUCCH,0}$	0, 0
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	NACK/DTX, any, any, any	$n_{PUCCH,0}$	0, 0
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{PUCCH,0}$	0, 0
DTX, any, any, any	NACK/DTX, any, any, any	No Transmission	
DTX, any, any, any	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	No Transmission	

For a single-cell operation, HARQ-ACK multiplexing with channel selection conveys a number of HARQ-ACK states in a PUCCH, as described in the example of Table 3 for $M = 3$, while HARQ-ACK transmission in a PUSCH conveys an individual information bit for each DL subframe in a bundling window (or for a number of DL subframes specified by a DAI IE in a UL SA scheduling a PUSCH transmission, if any). Therefore, a maximum of M HARQ-ACK information bits are conveyed. However, if a same approach for HARQ-ACK transmission in a PUSCH were to be followed for multi-cell (DL CA : Down Link Carrier Aggregation) operation, the maximum number of HARQ-ACK information bits would linearly

2012246830 18 May 2016

scale with the number of configured cells to a UE. However, increasing the number of HARQ-ACK information bits in a PUSCH for UEs configured HARQ-ACK multiplexing with channel selection in a PUCCH may result in a failure to provide the required HARQ-ACK reception reliability and will often lead to different operations depending on the channel, PUCCH, or PUSCH, used to transmit the HARQ-ACK information.

SUMMARY OF THE INVENTION

In accordance with an aspect of the present invention, there is provided a method for transmitting acknowledgement information in response to data Transport Blocks (TBs) received in one or more downlink data channels over Transmission Time Intervals (TTIs) by an User Equipment (UE) in a Time Division Duplex (TDD) communication system, the method comprising the steps of:

generating acknowledgement information comprising four acknowledgment information bits jointly representing a state of reception results for a plurality of data TBs, if a condition applies; and

transmitting the generated acknowledgement information,

wherein the condition includes the UE being configured for reception of the downlink data channels from two cells and a number of the TTIs being three or four.

In accordance with another aspect of the present invention, there is provided an User Equipment (UE) for transmitting acknowledgement information in response to data Transport Blocks (TBs) received in one or more downlink data channels over Transmission Time Intervals (TTIs) in a Time Division Duplex (TDD) communication system, the apparatus comprising:

a controller being configured to generate acknowledgement information comprising four acknowledgment information bits, jointly representing a state of reception results for a plurality of data TBs, if a condition applies; and

a transmitter being configured to transmit the generated acknowledgement information,

wherein the condition includes the UE being configured for reception of the downlink data channels from two cells and a number of the TTIs being three or four.

2012246830 11 Nov 2013

PAGES 16 TO 18 LEFT BLANK INTENTIONALLY

2012246830 11 Nov 2013

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features, and advantages of the present invention will be more apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagram illustrating a conventional TTI for a PUSCH or for a PUCCH;

FIG. 2 is a diagram illustrating a conventional HARQ-ACK transmission structure in a PUCCH subframe slot;

FIG. 3 is a block diagram illustrating a conventional transmitter for a PUCCH;

FIG. 4 is a block diagram illustrating a conventional receiver for a PUCCH;

FIG. 5 is a block diagram illustrating a conventional transmitter for data and HARQ-ACK in a PUSCH;

FIG. 6 is a block diagram illustrating a conventional receiver for data and HARQ-ACK in a PUSCH;

FIG. 7 is a flowchart illustrating a method of identifying HARQ-ACK bit representation depending on a number of configured cells and on a value of a bundling window, according to an embodiment of the present invention;

FIG. 8 is a flowchart illustrating an encoding and decoding process of HARQ-ACK information for a UE configured with two cells, depending on a value of a bundling window, according to an embodiment of the present invention;

FIG. 9 is a flowchart illustrating an encoding and decoding process of HARQ-ACK states, depending on whether a transmission is in a PUCCH or in a PUSCH, for $M=3$ or $M=4$ subframes, according to an embodiment of the present invention;

FIG. 10 is a block diagram illustrating a transmitter for transmitting data and HARQ-ACK information in a PUSCH, according to an embodiment of the present invention; and

FIG. 11 is a block diagram illustrating a receiver for receiving data and HARQ-ACK information in a PUSCH, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Various embodiments of the present invention will now be described more fully hereinafter with reference to the accompanying drawings. This present invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the scope of the present invention to those skilled in the art.

Additionally, although embodiments of the present invention will be described below with reference to DFT-spread OFDM transmission, the present invention is also applicable to Frequency Division Multiplexing (FDM) transmissions, such as Single-Carrier Frequency Division Multiple Access (SC-FDMA) and OFDM.

In the following descriptions for HARQ-ACK transmission in a PUSCH, the value of M (i.e., a number of PDSCHs for which a UE provides HARQ-ACK information or a size of bundling window or a number of TTIs) can either be fixed, as defined by a bundling window size for a particular configuration of a TDD system, or be variable, as defined by a value of a DAI IE in a UL SA conveyed by a PDCCH scheduling a PUSCH transmission, if such a UL SA exists. Further, although for simplicity is the descriptions assume that HARQ-ACK information is generated in response to a PDSCH reception, the HARQ-ACK information may also be generated in response to a PDCCH that does not schedule a PDSCH reception, but instead indicates a release of a Semi-Persistently Scheduled (SPS) PDSCH.

In accordance with an embodiment of the present invention, a UE is configured with two DL cells (the Pcell and a Scell) in a TDD system and mapping of HARQ-ACK states is performed as shown in Tables 4 and 5 (for $M=3$ and $M=4$, respectively) to input bits of an RM code used for encoding HARQ-ACK information in a PUSCH. This mapping is performed under the constraint that the number of HARQ-ACK information bits input to an RM code is limited to four, as HARQ-ACK multiplexing with channel selection in a PUCCH is assumed to be supported for only up to four HARQ-ACK information bits conveying different HARQ-ACK states. That is, two bits are conveyed through the selection of a PUCCH resource among four available resources, and another two bits are conveyed through a QPSK modulated signal by the respective constellation points.

Unlike conventional HARQ-ACK transmission in a PUSCH, where each HARQ-ACK information bit represents the outcome of respective data TB reception(s) in a PDSCH, in accordance with an embodiment of the present invention, the mapping of HARQ-ACK information to four input bits of an RM encoder for the above operating scenario includes HARQ-ACK states (a HARQ-ACK state is a set of correct or incorrect detection outcomes for data TBs) conveying combinations for values of HARQ-ACK bits as shown in Tables 4 and 5. Therefore, all four HARQ-ACK information bits are jointly considered and an individual HARQ-ACK bit does not have a respective individual interpretation (as it does not indicate an individual correct or incorrect detection outcome for data TBs). This alternative representation is used because the four input bits to an RM code do not suffice to represent all possible combinations for the individual outcomes of data TB reception(s) in each PDSCH in two cells for $M = 3$ or $M = 4$ (i.e., 6 or 8 bits, respectively, would be needed).

Conversely, for $M = 2$, four input bits to an RM encoder can provide individual HARQ-ACK information about the outcome of data TB reception(s) in a PDSCH for each respective subframe of a bundling window and for each of the two cells (Pcell and Scell). For example, two of the four bits can be used to represent HARQ-ACK information for the Pcell and the other two can be used to represent HARQ-ACK information for the Scell with the first of the two bits corresponding to the first of the $M = 2$ subframes and the second of the two bits corresponding to the second of the $M = 2$ subframes. For $M = 1$, two input bits to an RM encoder can provide individual HARQ-ACK information about the outcome a PDSCH reception in the Pcell and the Scell, respectively.

FIG. 7 is a flowchart illustrating a method of identifying HARQ-ACK bit representation depending on a number of configured cells and on a value of a bundling window, according to an embodiment of the present invention.

Referring to FIG. 7, for a PUSCH transmitter and a PUSCH receiver, the meaning of HARQ-ACK information bits in a PUSCH depends on whether a UE is configured one or two cells in step 710. If a UE is configured one cell, in step 720, the PUSCH transmitter or receiver determines that each HARQ-ACK information bit represents an outcome (e.g., ACK for binary '1' or NACK/DTX for binary '0') for a reception of TB(s) in a corresponding PDSCH, regardless of the value of M. This assumes that HARQ-ACK spatial-domain bundling applies if a PDSCH conveys multiple TBs, that a DTX state and a NACK state are jointly represented, and the explicit DTX feedback is not supported in a PUSCH; however, the reverse may also apply.

If a UE is configured two cells, the representation of HARQ-ACK information bits depends on the value of M in step 730. If M is smaller than or equal to 2, in step 740, the PUSCH transmitter or receiver determines that each HARQ-ACK information bit again represents an outcome (ACK for binary '1' or NACK/DTX for binary '0') for a reception of TB(s) in a corresponding PDSCH. However, if M is larger than 2, in step 750, the PUSCH transmitter or receiver determines that each HARQ-ACK information bit does not provide any information on its own and all HARQ-ACK information bits are jointly considered to indicate a HARQ-ACK state (set of outcomes for correct or incorrect detection of data TB(s) in respective PDSCH(s)) corresponding to both cells and all PDSCHs for which HARQ-ACK information is provided by a UE.

In accordance with another embodiment of the present invention, HARQ-ACK states, as represented in Tables 4 and 5, are transmitted in a PUCCH using channel selection, by the four input bits $\left\{o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_3^{ACK}\right\}$ to an RM encoder for transmission in a PUSCH. This representation is obtained by one-to-one mapping of a PUCCH resource and a constellation point of a QPSK modulation of a HARQ-ACK signal in a PUCCH to four input bits $\left\{o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_3^{ACK}\right\}$ of an RM code in a PUSCH, e.g., as shown in Table 6 for $M = 3$ and in Table 7 for $M = 4$.

For example, the first four PUCCH resources $\left\{n_{\text{PUCCH},0}, n_{\text{PUCCH},1}, n_{\text{PUCCH},2}, n_{\text{PUCCH},3}\right\}$ may be represented by RM input bits $\left\{o_0^{ACK}\ o_1^{ACK}\right\}$ and the four QPSK constellation points $\{(0,0), (0,1), (1,0), (1,1)\}$ in a PUCCH may be represented by RM input bits $\left\{o_2^{ACK}\ o_3^{ACK}\right\}$. In general, any representation of any two RM input bits for four PUCCH resources and of the other two RM input bits for the QPSK constellation points in a PUCCH may be used.

<u>Table 6</u>: Mapping of HARQ-ACK States to Input Bits of the RM Code for $M = 3$.

Primary Cell	Secondary Cell	Resource	Constellation	RM Code Input Bits
HARQ-ACK(0), HARQ-	HARQ-ACK(0), HARQ-	n_{PUCCH}	$b(0), b(1)$	$\left\{o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_3^{ACK}\right\}$

ACK(1), HARQ-ACK(2)	ACK(1), HARQ-ACK(2)			
ACK, ACK, ACK	ACK, ACK, ACK	$n_{PUCCH,1}$	1, 1	0, 1, 1, 1
ACK, ACK, NACK/DTX	ACK, ACK, ACK	$n_{PUCCH,1}$	0, 0	0, 1, 0, 0
ACK, NACK/DTX, any	ACK, ACK, ACK	$n_{PUCCH,3}$	1, 1	1, 1, 1, 1
NACK/DTX, any, any	ACK, ACK, ACK	$n_{PUCCH,3}$	0, 1	1, 1, 0, 1
ACK, ACK, ACK	ACK, ACK, NACK/DTX	$n_{PUCCH,0}$	1, 0	0, 0, 1, 0
ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX	$n_{PUCCH,3}$	1, 0	1, 1, 1, 0
ACK, NACK/DTX, any	ACK, ACK, NACK/DTX	$n_{PUCCH,0}$	0, 1	0, 0, 0, 1
NACK/DTX, any, any	ACK, ACK, NACK/DTX	$n_{PUCCH,3}$	0, 0	1, 1, 0, 0
ACK, ACK, ACK	ACK, NACK/DTX, any	$n_{PUCCH,2}$	1, 1	1, 0, 1, 1
ACK, ACK, NACK/DTX	ACK, NACK/DTX, any	$n_{PUCCH,2}$	0, 1	1, 0, 0, 1
ACK, NACK/DTX, any	ACK, NACK/DTX, any	$n_{PUCCH,2}$	1, 0	1, 0, 1, 0
NACK/DTX, any, any	ACK, NACK/DTX, any	$n_{PUCCH,2}$	0, 0	1, 0, 0, 0
ACK, ACK,	NACK/DTX,	$n_{PUCCH,1}$	1, 0	0, 1, 1, 0

ACK	any, any			
ACK, ACK, NACK/DTX	NACK/DTX, any, any	$n_{\text{PUCCH},1}$	0, 1	0, 1, 0, 1
ACK, NACK/DTX, any	NACK/DTX, any, any	$n_{\text{PUCCH},0}$	1, 1	0, 0, 1, 1
NACK, any, any	NACK/DTX, any, any	$n_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
DTX, any, any	NACK/DTX, any, any	No Transmission		0, 0, 0, 0

Table 7: Mapping of HARQ-ACK States to Input Bits of the RM Code for $M = 4$.

Primary Cell	Secondary Cell	Resource	Constellation	RM Code Input Bits
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	n_{PUCCH}	$b(0), b(1)$	$\{o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_3^{ACK}\}$
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},1}$	1, 1	0, 1, 1, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},1}$	0, 0	0, 1, 0, 0
ACK, DTX, DTX, DTX	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},3}$	1, 1	1, 1, 1, 1
ACK, ACK, ACK, ACK	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},3}$	1, 1	1, 1, 1, 1
NACK/DTX,	ACK, ACK,	$n_{\text{PUCCH},3}$	0, 1	1, 1, 0, 1

any, any, any	ACK, NACK/DTX			
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	ACK, ACK, ACK, NACK/DTX	$n_{PUCCH,3}$	0, 1	1, 1, 0, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX, any	$n_{PUCCH,0}$	1, 0	0, 0, 1, 0
ACK, ACK, NACK/DTX, any	ACK, ACK, NACK/DTX, any	$n_{PUCCH,3}$	1, 0	1, 1, 1, 0
ACK, DTX, DTX, DTX	ACK, ACK, NACK/DTX, any	$n_{PUCCH,0}$	0, 1	0, 0, 0, 1
ACK, ACK, ACK, ACK	ACK, ACK, NACK/DTX, any	$n_{PUCCH,0}$	0, 1	0, 0, 0, 1
NACK/DTX, any, any, any	ACK, ACK, NACK/DTX, any	$n_{PUCCH,3}$	0, 0	1, 1, 0, 0
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	ACK, ACK, NACK/DTX, any	$n_{PUCCH,3}$	0, 0	1, 1, 0, 0
ACK, ACK, ACK, NACK/DTX	ACK, DTX, DTX, DTX	$n_{PUCCH,2}$	1, 1	1, 0, 1, 1
ACK, ACK, ACK,	ACK, ACK, ACK, ACK	$n_{PUCCH,2}$	1, 1	1, 0, 1, 1

NACK/DTX				
ACK, ACK, NACK/DTX, any	ACK, DTX, DTX, DTX	$n_{\mathrm{PUCCH},2}$	0, 1	1, 0, 0, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, ACK	$n_{\mathrm{PUCCH},2}$	0, 1	1, 0, 0, 1
ACK, DTX, DTX, DTX	ACK, DTX, DTX, DTX	$n_{\mathrm{PUCCH},2}$	1, 0	1, 0, 1, 0
ACK, DTX, DTX, DTX	ACK, ACK, ACK, ACK	$n_{\mathrm{PUCCH},2}$	1, 0	1, 0, 1, 0
ACK, ACK, ACK, ACK	ACK, DTX, DTX, DTX	$n_{\mathrm{PUCCH},2}$	1, 0	1, 0, 1, 0
ACK, ACK, ACK, ACK	ACK, ACK, ACK, ACK	$n_{\mathrm{PUCCH},2}$	1, 0	1, 0, 1, 0
NACK/DTX, any, any, any	ACK, DTX, DTX, DTX	$n_{\mathrm{PUCCH},2}$	0, 0	1, 0, 0, 0
NACK/DTX, any, any, any	ACK, ACK, ACK, ACK	$n_{\mathrm{PUCCH},2}$	0, 0	1, 0, 0, 0
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	ACK, DTX, DTX, DTX	$n_{\mathrm{PUCCH},2}$	0, 0	1, 0, 0, 0
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	ACK, ACK, ACK, ACK	$n_{\mathrm{PUCCH},2}$	0, 0	1, 0, 0, 0
ACK, ACK, ACK, NACK/DTX	NACK/DTX, any, any, any	$n_{\mathrm{PUCCH},1}$	1, 0	0, 1, 1, 0

ACK, ACK, ACK, NACK/DTX	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{PUCCH,1}$	1, 0	0, 1, 1, 0
ACK, ACK, NACK/DTX, any	NACK/DTX, any, any, any	$n_{PUCCH,1}$	0, 1	0, 1, 0, 1
ACK, ACK, NACK/DTX, any	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{PUCCH,1}$	0, 1	0, 1, 0, 1
ACK, DTX, DTX, DTX	NACK/DTX, any, any, any	$n_{PUCCH,0}$	1, 1	0, 0, 1, 1
ACK, DTX, DTX, DTX	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{PUCCH,0}$	1, 1	0, 0, 1, 1
ACK, ACK, ACK, ACK	NACK/DTX, any, any, any	$n_{PUCCH,0}$	1, 1	0, 0, 1, 1
ACK, ACK, ACK, ACK	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{PUCCH,0}$	1, 1	0, 0, 1, 1
NACK, any, any, any	NACK/DTX, any, any, any	$n_{PUCCH,0}$	0, 0	0, 0, 0, 0
NACK, any,	{ACK,	$n_{PUCCH,0}$	0, 0	0, 0, 0, 0

any, any	NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}			
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	NACK/DTX, any, any, any	$n_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	$n_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
DTX, any, any, any	NACK/DTX, any, any, any	No Transmission		0, 0, 0, 0
DTX, any, any, any	{ACK, NACK/DTX, any, any}, except for {ACK, DTX, DTX, DTX}	No Transmission		0, 0, 0, 0

Conversely, the representation of HARQ-ACK states to four input bits $\{o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_3^{ACK}\}$ of an RM encoder for $M=2$ is obtained as shown in Table 8 below. Each individual HARQ-ACK bit now provides individual information with a binary '1' representing an 'ACK' and a binary '0' representing a 'NACK/DTX' for a corresponding PDSCH reception. There is no link between the four input bits $\{o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_3^{ACK}\}$ of an RM code for HARQ-ACK transmission in a PUSCH and the PUCCH resources or the constellation point of a QPSK modulated signal for HARQ-ACK in a PUCCH. Similar observations apply for the representation of

HARQ-ACK states to the two input bits $\{o_0^{ACK}\ o_1^{ACK}\}$ of a simplex (3, 2) code for $M=1$, which is obtained as shown in Table 9.

Table 8: Mapping of HARQ-ACK States to Input Bits of the RM Code for $M=2$.

Primary Cell	Secondary Cell	RM Code Input Bits
HARQ-ACK(0), HARQ-ACK(1)	HARQ-ACK(0), HARQ-ACK(1)	$\{o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_3^{ACK}\}$
ACK, ACK	ACK, ACK	1, 1, 1, 1
ACK, NACK/DTX	ACK, ACK	1, 0, 1, 1
NACK/DTX, ACK	ACK, ACK	0, 1, 1, 1
NACK/DTX, NACK/DTX	ACK, ACK	0, 0, 1, 1
ACK, ACK	ACK, NACK/DTX	1, 1, 1, 0
ACK, NACK/DTX	ACK, NACK/DTX	1, 0, 1, 0
NACK/DTX, ACK	ACK, NACK/DTX	0, 1, 1, 0
NACK/DTX, NACK/DTX	ACK, NACK/DTX	0, 0, 1, 0
ACK, ACK	NACK/DTX, ACK	1, 1, 0, 1
ACK, NACK/DTX	NACK/DTX, ACK	1, 0, 0, 1
NACK/DTX, ACK	NACK/DTX, ACK	0, 1, 0, 1
NACK/DTX, NACK/DTX	NACK/DTX, ACK	0, 0, 0, 1
ACK, ACK	NACK/DTX, NACK/DTX	1, 1, 0, 0
ACK, NACK/DTX	NACK/DTX, NACK/DTX	1, 0, 0, 0
NACK/DTX, ACK	NACK/DTX, NACK/DTX	0, 1, 0, 0
NACK/DTX, NACK/DTX	NACK/DTX, NACK/DTX	0, 0, 0, 0

Table 9: Mapping of HARQ-ACK States to Input Bits of the Simplex Code for $M=1$.

Primary Cell	Secondary Cell	Simplex Code Input Bits
HARQ-ACK(0)	HARQ-ACK(0)	$\{o_0^{ACK}\ o_1^{ACK}\}$
ACK	ACK	1, 1
NACK/DTX	ACK	0, 1
ACK	NACK/DTX	1, 0
NACK/DTX	NACK/DTX	0, 0

FIG. 8 illustrates encoding and decoding of HARQ-ACK information for a UE configured with two cells depending on a value of a bundling window, according to an embodiment of the present invention.

Referring to FIG. 8, the encoding and decoding for a UE configured with two cells and for a PUSCH transmitter and a PUSCH receiver, respectively, depends on a value of M in step 810. If M is less than two, in step 820, each HARQ-ACK information bit represents an outcome (e.g., ACK or NACK/DTX) of a respective PDSCH reception. However, if M is greater than two, in step 830, each HARQ-ACK information bit does not provide individual information; instead, all four HARQ-ACK information bits are jointly considered to represent a HARQ-ACK state (set of outcomes for correct or incorrect detection of data TB(s) in respective PDSCH(s)) for the Pcell and a HARQ-ACK state for the Scell using a mapping as shown in Table 6 for $M=3$ or a mapping as shown in Table 7 for $M=4$.

In accordance with another embodiment of the present invention, a same understanding is established between a UE and a serving NodeB for the inclusion of HARQ-ACK information in a PUSCH. Consequently, a serving NodeB is not required to detect whether a particular set of PUSCH REs conveys data information or HARQ-ACK information, because such detection may not be reliable. For HARQ-ACK signal transmission in a PUCCH, such detection is relatively simple as a NodeB can decide whether a signal is transmitted or not by merely computing the received energy in candidate PUCCH resources.

If a PUSCH transmission is scheduled by a UL SA through the transmission of a corresponding PDCCH, the respective DCI format is assumed to include a DAI IE informing a UE whether or not a NodeB expects it to transmit HARQ-ACK information in a PUSCH. This DAI IE may also provide additional information, e.g., the maximum number of PDSCH transmitted to a UE either in the Pcell or in the Scell, and the value of M can be set equal to this number. If a PUSCH transmission is SPS and not scheduled by a UL SA, then a UE may include HARQ-ACK information in a PUSCH for all DL subframes in a bundling window. M is then equal to the bundling window size.

In order to include HARQ-ACK information in a PUSCH (when a NodeB expects a UE to transmit HARQ-ACK information in a PUSCH), the HARQ-ACK states as shown in Tables 4 or 5, for which a UE does not transmit a HARQ-ACK signal in a PUCCH, should be mapped to actual HARQ-ACK information bits in a PUSCH, when $M = 3$ and $M = 4$.

For $M = 3$, the last state in Table 4 is overlapped with the second to last state in Table 6 and both are represented by {0, 0, 0, 0} input bits to an RM encoder. Similarly, for $M = 4$, the last two states in Table 5 are overlapped with the {NACK, any, any, any} and the {NACK/DTX, any, any, any} states in Table 7 for the Pcell and the Scell, respectively, and are represented by {0, 0, 0, 0} input bits to an RM encoder.

FIG. 9 illustrates an encoding and decoding process of HARQ-ACK states depending on whether a transmission is in a PUCCH or in a PUSCH for $M = 3$ or $M = 4$ subframes, according to an embodiment of the present invention.

Referring to FIG. 9, the encoding and decoding of the {DTX, any, any} state in the Pcell and of the {NACK/DTX, any, any} state in the Scell for $M = 3$ in step 910, and the encoding and decoding of the {DTX, any, any, any} state in the Pcell and of the {NACK/DTX, any, any, any} or the {ACK, NACK/DTX, any, any} state (except for {ACK, DTX, DTX, DTX} state) in the Scell for $M = 4$ in step 920 depends on whether HARQ-ACK information is to be transmitted in a PUCCH or in a PUSCH in step 930. When HARQ-ACK information is to be transmitted in a PUCCH, there is no HARQ-ACK signal transmission for these HARQ-ACK states in step 940. When HARQ-ACK information is to be transmitted in a PUSCH, {0, 0, 0, 0} bits are used to represent these HARQ-ACK states in step 950.

FIG. 10 illustrates block diagram of a transmitter for data and HARQ-ACK in a PUSCH, according to an embodiment of the present invention. Specifically, in FIG. 10, a representation of HARQ-ACK information bits depends on the number of cells a UE is configured and on whether each HARQ-ACK information bit informs of an outcome for a respective PDSCH reception in a respective cell or whether all HARQ-ACK information bits jointly inform of HARQ-ACK states corresponding to M PDSCH receptions in both cells.

Referring to FIG. 10, if a UE is configured with one cell or if a UE is configured with two cells and it is $M \leq 2$, each HARQ-ACK information bit corresponds to an outcome (ACK or NACK/DTX) of a respective PDSCH reception as described with reference to FIG. 5. However, if a UE is configured with two cells and $M > 2$, a UE transmitter as illustrated in FIG. 10 operates similarly to the transmitter of FIG. 5, except that the outcomes for M PDSCH receptions (combinations of ACK and NACK/DTX) for each of the two cells 1010 form two respective HARQ-ACK states, which are provided to a mapper 1020, as described for example in Table 6 for $M = 3$ and Table 7 for $M = 4$, which then generates the HARQ-ACK information bits 1030, which are provided to an RM encoder.

FIG. 11 illustrates a block diagram of a receiver for data and HARQ-ACK in a PUSCH, according to an embodiment of the present invention. Specifically, in FIG. 11, a representation of HARQ-ACK information bits depends on the number of cells a UE is configured and on whether each HARQ-ACK information bit informs of an outcome for a respective PDSCH reception in a respective cell or whether all HARQ-ACK information bits jointly inform of HARQ-ACK states corresponding to M PDSCH receptions in both cells.

Referring to FIG. 11, if a UE is configured with one cell or if a UE is configured with two cells and it is $M \leq 2$, each HARQ-ACK information bit corresponds to an outcome (ACK or NACK/DTX) of a respective PDSCH reception, as described with reference to FIG. 6. However, if a UE is configured with two cells and $M > 2$, a NodeB receiver as illustrated in FIG. 11 operates similarly to the receiver illustrated in FIG. 6, except that a decoder output for HARQ-ACK information bits 1110 is provided to a mapper 1120, e.g., as described in Table 6 for $M = 3$ or Table 7 for $M = 4$, which then generates two HARQ-ACK states representing outcomes 1130 for M PDSCH receptions (combinations of ACK and NACK/DTX) for each of the two cells.

One or more blocks in a transmitter and a receiver described in embodiments of the present invention can be implemented into a controller and the controller generates or receives acknowledgement bits (i.e. acknowledgement information) according to the present invention.

2012246830 11 Nov 2013

While the present invention has been shown and described with reference to certain embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the appended claims and their equivalents.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

CLAIMS:

1. A method for transmitting acknowledgement information in response to data Transport Blocks (TBs) received in one or more downlink data channels over Transmission Time Intervals (TTIs) by an User Equipment (UE) in a Time Division Duplex (TDD) communication system, the method comprising the steps of:

generating acknowledgement information comprising four acknowledgment information bits jointly representing a state of reception results for a plurality of data TBs, if a condition applies; and

transmitting the generated acknowledgement information,

wherein the condition includes the UE being configured for reception of the downlink data channels from two cells and a number of the TTIs being three or four.

2. The method of claim 1, further comprising:

generating acknowledgement information respectively representing a reception result for each data TB by a corresponding acknowledgement information bit.

3. The method of claim 2, wherein the further condition includes the UE being configured for reception of the downlink data channels from a single cell, or the UE being configured for reception of the downlink data channels from two cells and a number of the TTIs being one or two.

4. The method of claim 3, before transmitting, further comprising:

encoding the generated acknowledgement information; and

multiplexing the encoded acknowledgement information.

5. The method of claim 4, wherein the encoding is Reed-Mueller (RM) encoding.

6. The method of claim 1, wherein one of the state of reception results is represented as {NACK, any, any, any} and {NACK/DTX, any, any, any} for a first cell

2012246830 18 May 2016

and a second cell of the two cell, respectively, by the all acknowledgement information bits {0, 0, 0, 0}, if the condition applies, and

wherein the ‘NACK’ means ‘Negative ACK’, the ‘DTX’ means ‘Discontinuous Transmission’, the ‘any’ means either ‘ACK’ or ‘NACK/DTX’.

7. The method of claim 1, wherein a single outcome is generated by the UE, when the UE receives more than one data TB in the downlink data channel, and

wherein the single outcome indicates correct detection, if all of the data TBs were correctly detected, and indicates incorrect detection, if at least one of the data TBs was incorrectly detected by the UE.

8. The method of claim 1, wherein when the UE does not detect a data TB or a control channel releasing transmission of the downlink data channel in a TTI, the UE generates a single outcome indicating the incorrect detection.

9. The method of claim 1, wherein when the acknowledgement information is transmitted in an uplink control channel, the acknowledgement information is generated by using bits indicating resources of the uplink control channel and bits indicating a constellation point of the uplink control channel.

10. An User Equipment (UE) for transmitting acknowledgement information in response to data Transport Blocks (TBs) received in one or more downlink data channels over Transmission Time Intervals (TTIs) in a Time Division Duplex (TDD) communication system, the apparatus comprising:

a controller being configured to generate acknowledgement information comprising four acknowledgment information bits, jointly representing a state of reception results for a plurality of data TBs, if a condition applies; and

a transmitter being configured to transmit the generated acknowledgement information,

wherein the condition includes the UE being configured for reception of the downlink data channels from two cells and a number of the TTIs being three or four.

2012246830 18 May 2016

11. The UE of claim 10, wherein the controller is further configured to generate acknowledgement information respectively representing a reception result for each data TB by a corresponding acknowledgement information bit.

12. The UE of claim 11, wherein the UE is also configured to receive the downlink data channels from a single cell, or wherein the UE is also configured to receive the downlink data channels from two cells over one or two TTIs.

13. The UE of claim 12, further comprising:

an encoder for encoding the generated acknowledgement information; and

a multiplexer for multiplexing the encoded acknowledgement information.

14. The UE of claim 13, wherein the encoding is Reed-Mueller (RM) encoding.

15. The UE of claim 10, wherein one of the state of reception results is represented as {NACK, any, any, any} and {NACK/DTX, any, any, any} for a first cell and a second cell of the two cell, respectively, by the all acknowledgement information bits {0, 0, 0, 0}, if the condition applies, and

wherein the 'NACK' means 'Negative ACK', the 'DTX' means 'Discontinuous Transmission', the 'any' means either 'ACK' or 'NACK/DTX'.

16. The UE of claim 10, wherein the controller generates a single outcome, when the UE receives more than one data TB in the downlink data channel, and

wherein the controller represents the single outcome to indicate correct detection, if all of the data TBs were correctly detected, and to indicate incorrect detection, if at least one of the data TBs was incorrectly detected.

17. The UE of claim 10, wherein when the controller does not detect a data TB or a control channel releasing transmission of the downlink data channel in a TTI, the controller generates a single outcome indicating incorrect detection as the acknowledgement information.

2012246830 18 May 2016

18. The UE of claim 10, wherein when the acknowledgement information is transmitted in an uplink control channel, the controller generates the acknowledgement information by using bits indicating resources of the uplink control channel and bits indicating a constellation point of the uplink control channel.

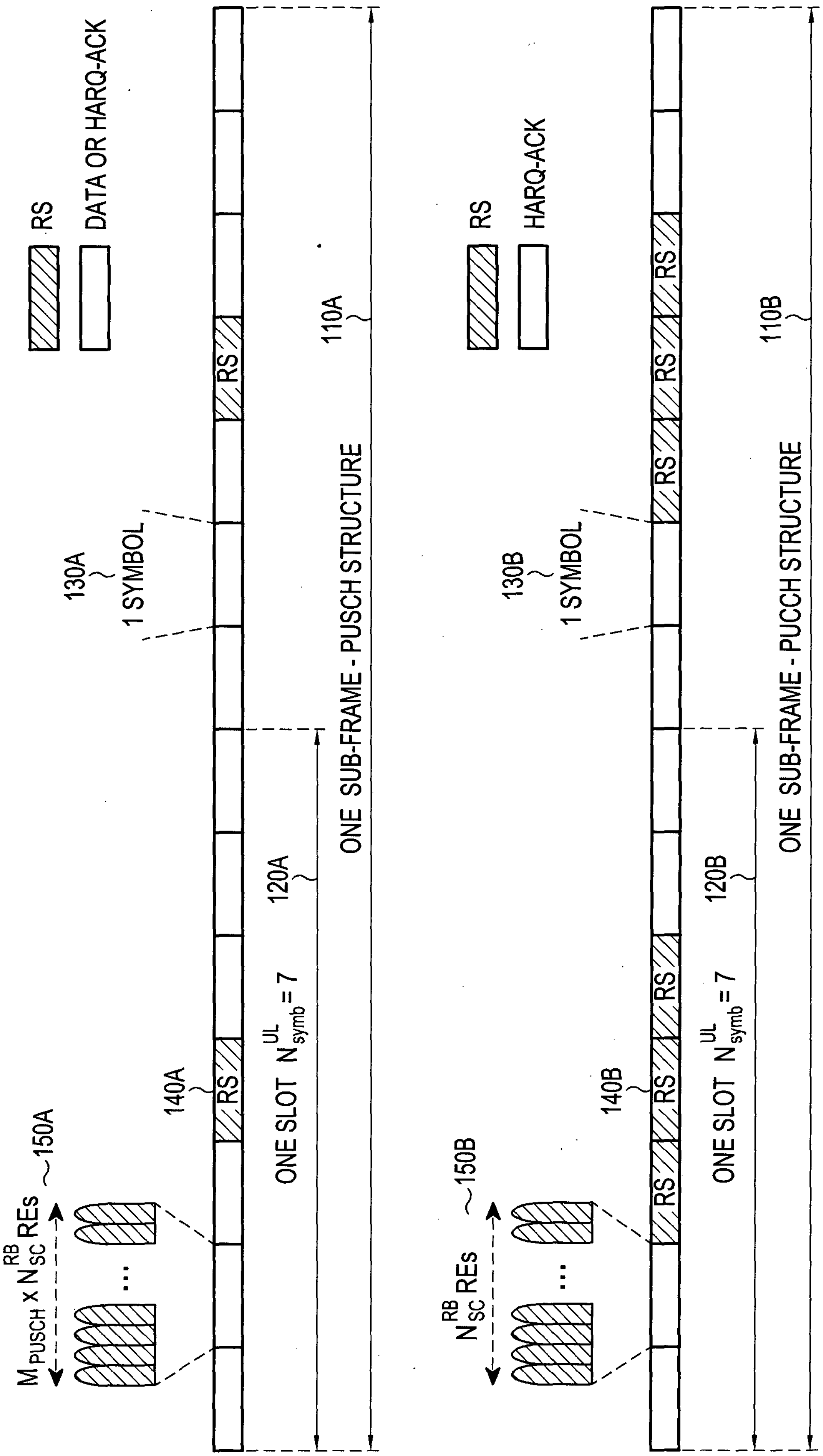
RS
DATA OR HARQ-ACK
$M_{PUSCH} \times N_{SC}^{RB}$ REs
150A
140A
RS
RS
130A
1 SYMBOL
ONE SLOT $N_{symb}^{UL} = 7$
120A
ONE SUB-FRAME - PUSCH STRUCTURE
110A
RS
HARQ-ACK
N_{SC}^{RB} REs
150B
140B
RS
RS
RS
RS
RS
RS
130B
1 SYMBOL
ONE SLOT $N_{symb}^{UL} = 7$
120B
ONE SUB-FRAME - PUCCH STRUCTURE
110B

FIG.1

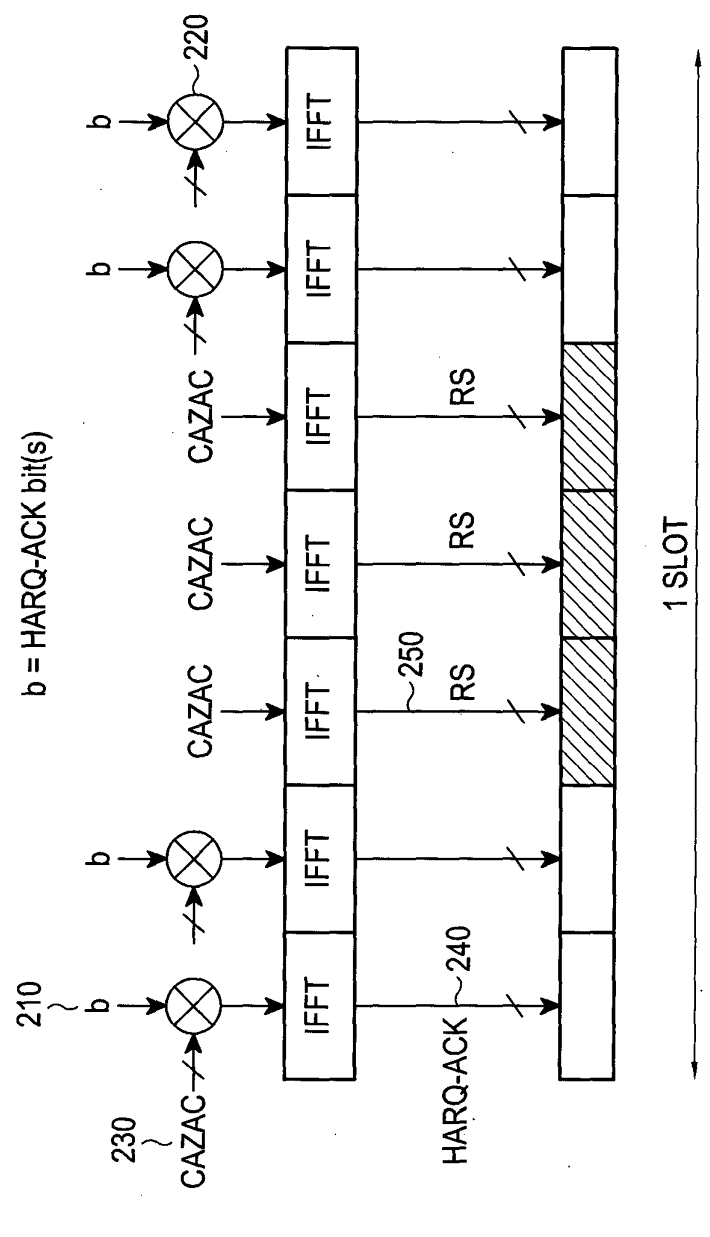
b = HARQ-ACK bit(s)
210
b
220
230
CAZAC
IFFT
HARQ-ACK
240
RS
250
1 SLOT

FIG.2

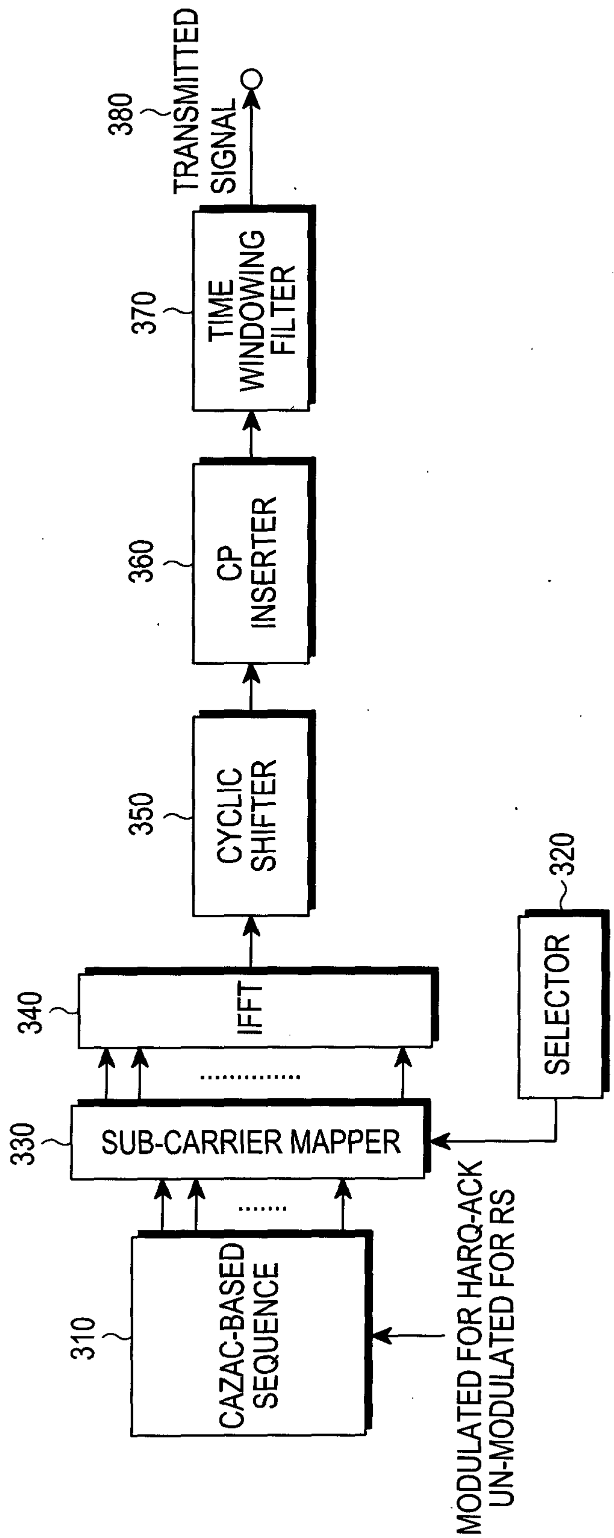
380
TRANSMITTED SIGNAL
370
TIME WINDOWING FILTER
360
CP INSERTER
350
CYCLIC SHIFTER
340
IFFT
330
SUB-CARRIER MAPPER
320
SELECTOR
310
CAZAC-BASED SEQUENCE
MODULATED FOR HARQ-ACK
UN-MODULATED FOR RS

FIG.3

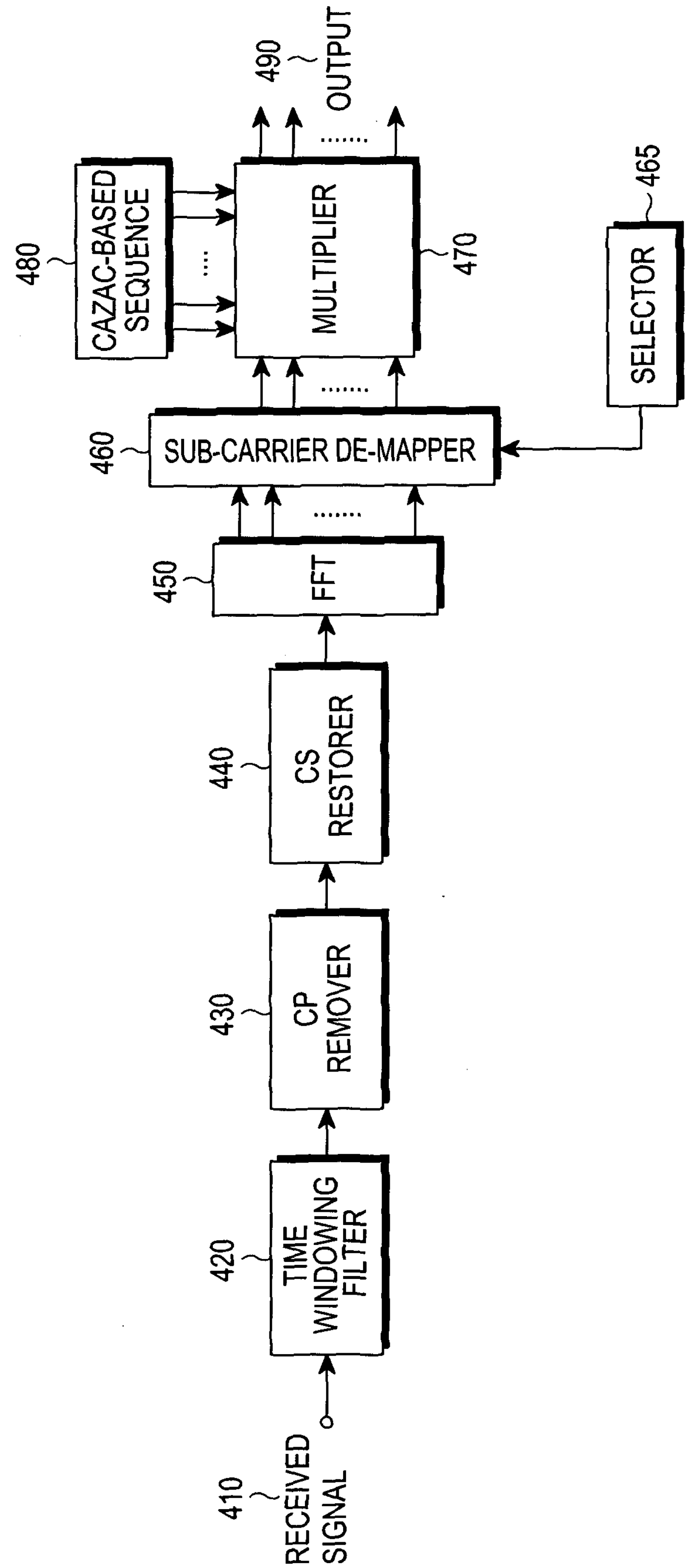
410
RECEIVED SIGNAL
420
TIME WINDOWING FILTER
430
CP REMOVER
440
CS RESTORER
450
FFT
460
SUB-CARRIER DE-MAPPER
465
SELECTOR
470
MULTIPLIER
480
CAZAC-BASED SEQUENCE
490
OUTPUT

FIG.4

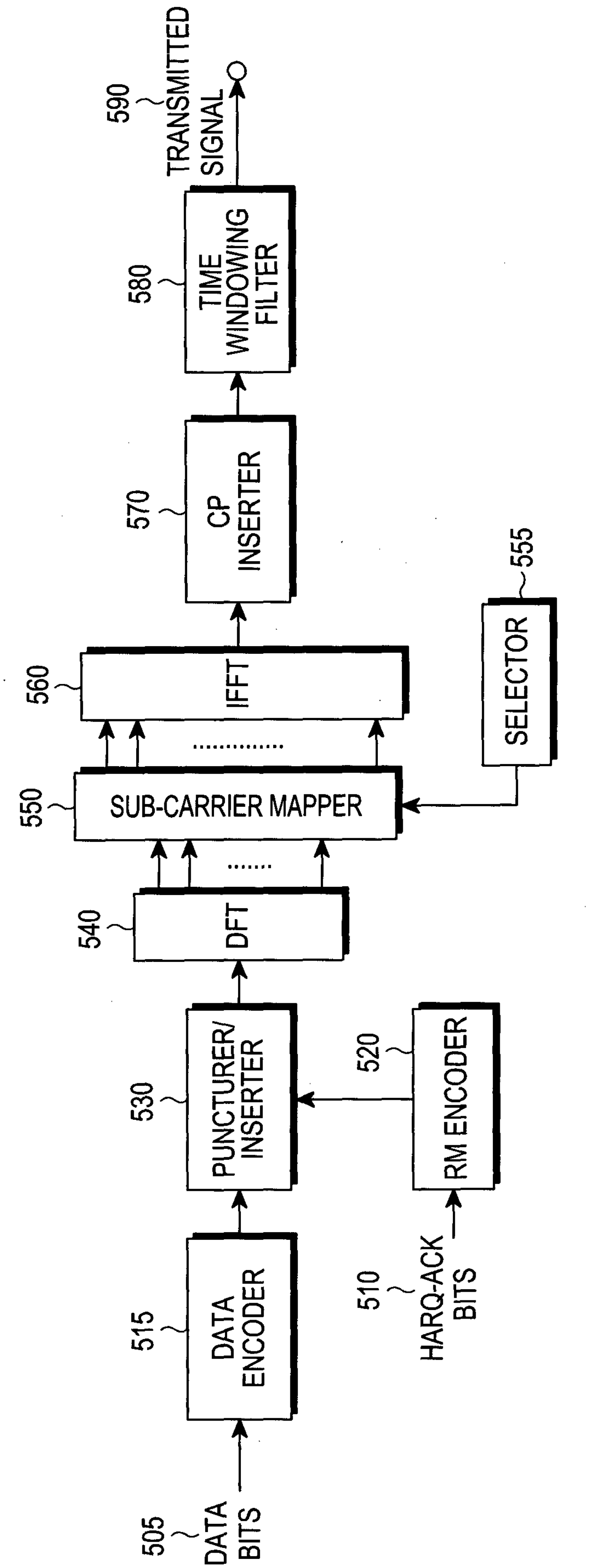
505
DATA BITS
515
DATA ENCODER
510
HARQ-ACK BITS
520
RM ENCODER
530
PUNCTURER/ INSERTER
540
DFT
550
SUB-CARRIER MAPPER
555
SELECTOR
560
IFFT
570
CP INSERTER
580
TIME WINDOWING FILTER
590
TRANSMITTED SIGNAL

FIG.5

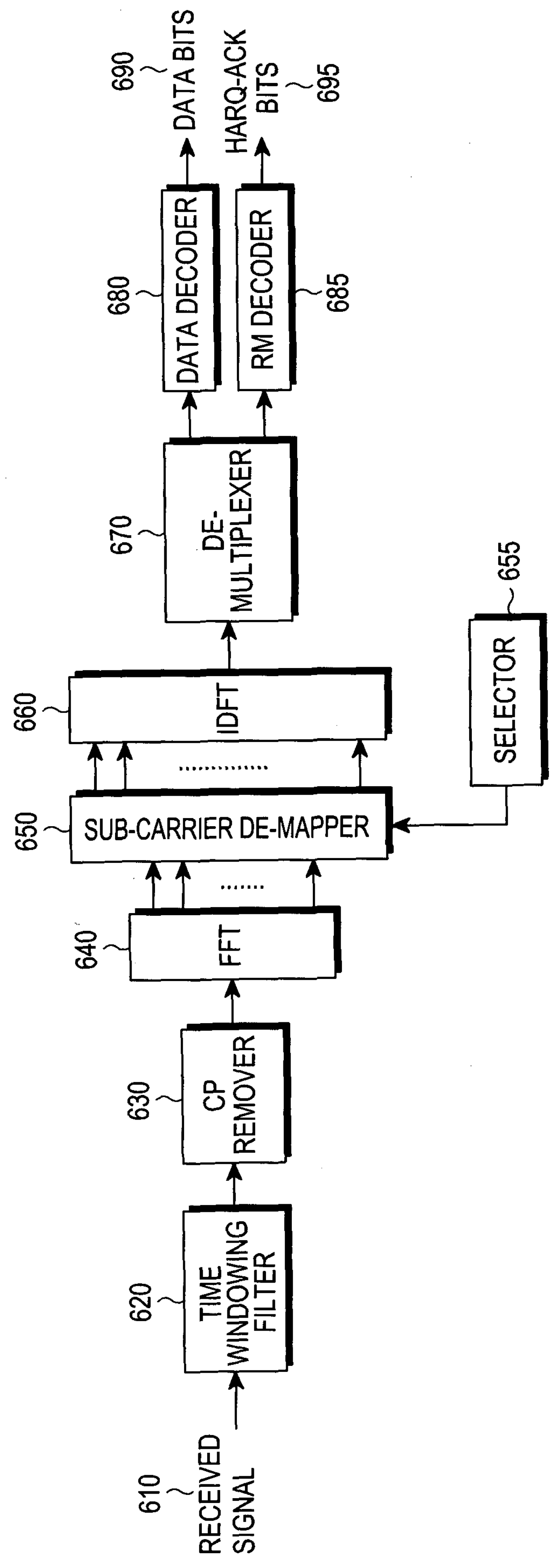
610
RECEIVED SIGNAL
620
TIME WINDOWING FILTER
630
CP REMOVER
640
FFT
650
SUB-CARRIER DE-MAPPER
655
SELECTOR
660
IDFT
670
DE-MULTIPLEXER
680
DATA DECODER
685
RM DECODER
690
DATA BITS
695
HARQ-ACK BITS

FIG.6

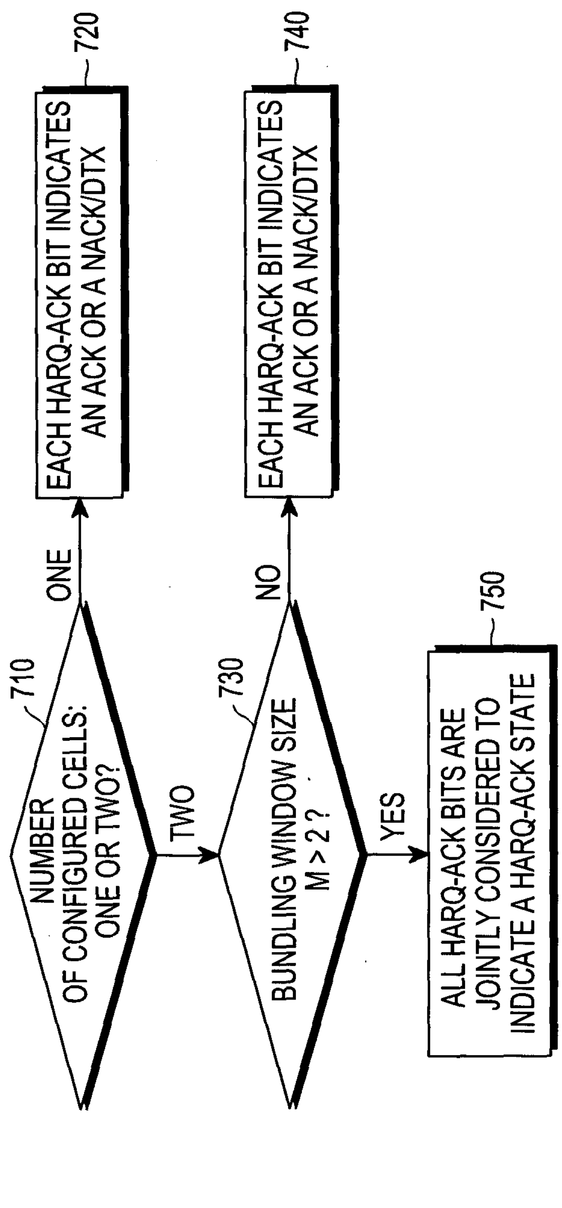
NUMBER OF CONFIGURED CELLS: ONE OR TWO?
710
ONE
EACH HARQ-ACK BIT INDICATES AN ACK OR A NACK/DTX
720
TWO
BUNDLING WINDOW SIZE M > 2 ?
730
NO
EACH HARQ-ACK BIT INDICATES AN ACK OR A NACK/DTX
740
YES
ALL HARQ-ACK BITS ARE JOINTLY CONSIDERED TO INDICATE A HARQ-ACK STATE
750

FIG.7

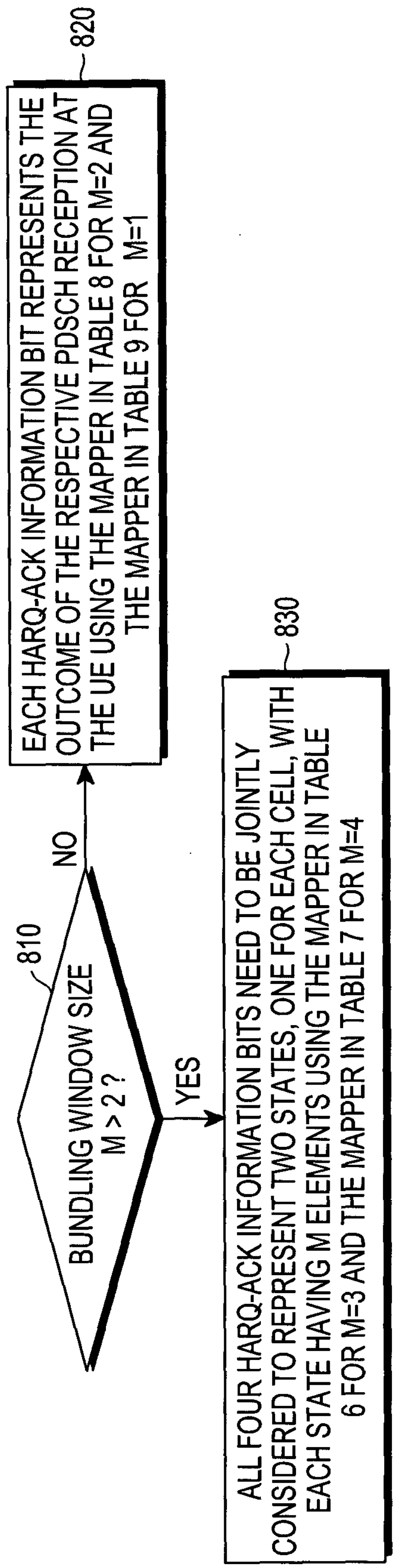
820
EACH HARQ-ACK INFORMATION BIT REPRESENTS THE OUTCOME OF THE RESPECTIVE PDSCH RECEPTION AT THE UE USING THE MAPPER IN TABLE 8 FOR M=2 AND THE MAPPER IN TABLE 9 FOR M=1
NO
810
BUNDLING WINDOW SIZE M > 2 ?
YES
830
ALL FOUR HARQ-ACK INFORMATION BITS NEED TO BE JOINTLY CONSIDERED TO REPRESENT TWO STATES, ONE FOR EACH CELL, WITH EACH STATE HAVING M ELEMENTS USING THE MAPPER IN TABLE 6 FOR M=3 AND THE MAPPER IN TABLE 7 FOR M=4

FIG.8

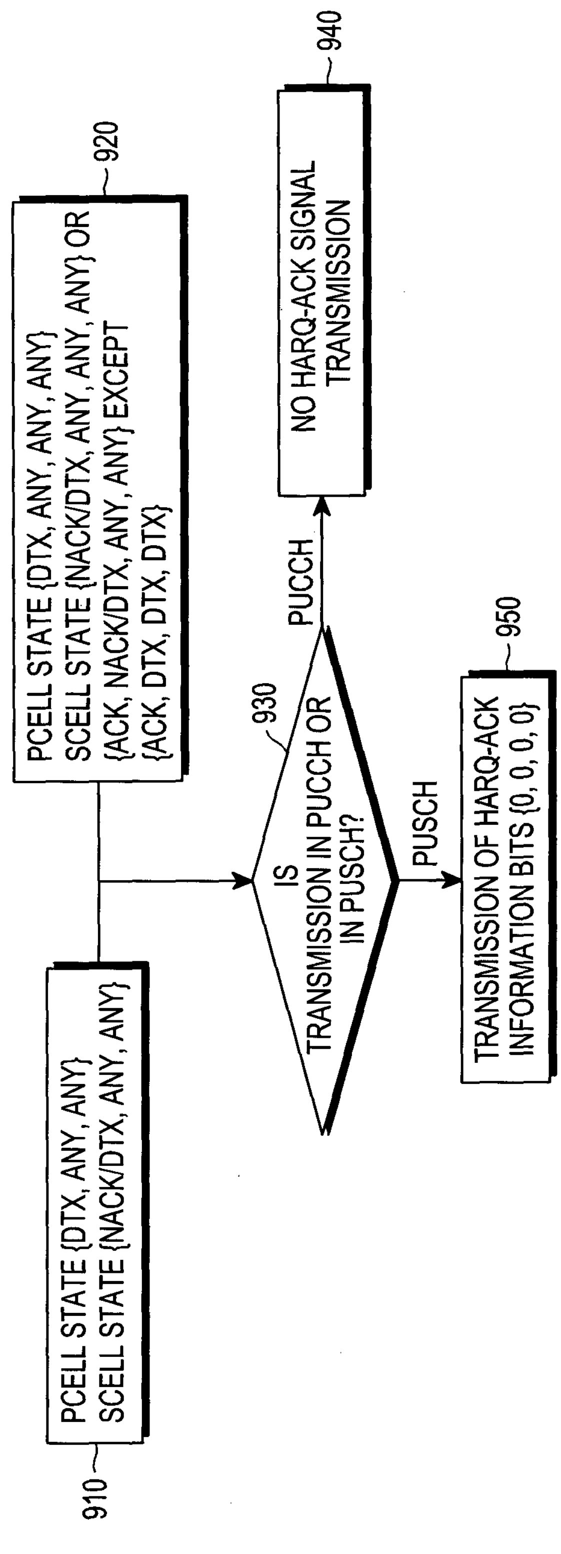
910
PCELL STATE {DTX, ANY, ANY}
SCELL STATE {NACK/DTX, ANY, ANY}
920
PCELL STATE {DTX, ANY, ANY, ANY}
SCELL STATE {NACK/DTX, ANY, ANY, ANY} OR
{ACK, NACK/DTX, ANY, ANY} EXCEPT
{ACK, DTX, DTX, DTX}
930
IS
TRANSMISSION IN PUCCH OR
IN PUSCH?
PUCCH
PUSCH
940
NO HARQ-ACK SIGNAL
TRANSMISSION
950
TRANSMISSION OF HARQ-ACK
INFORMATION BITS {0, 0, 0, 0}

FIG.9

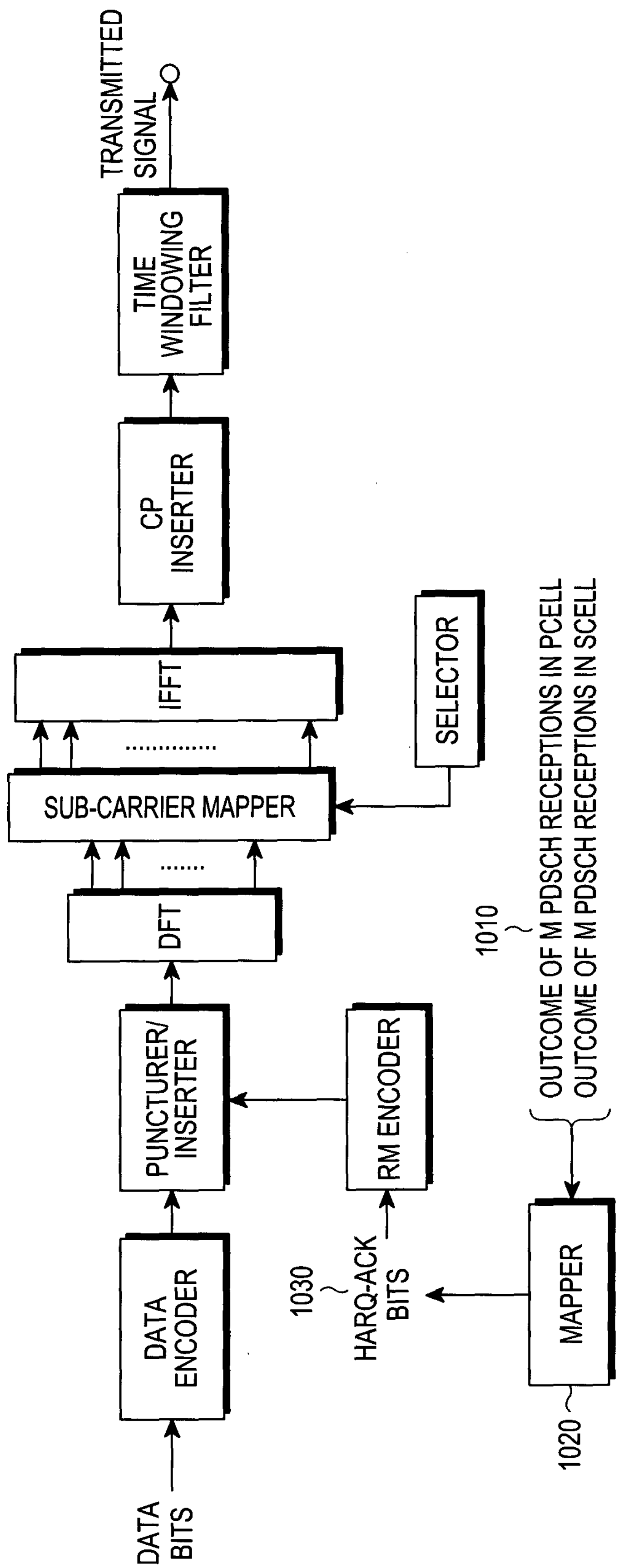
DATA BITS
DATA ENCODER
PUNCTURER/ INSERTER
DFT
SUB-CARRIER MAPPER
IFFT
CP INSERTER
TIME WINDOWING FILTER
TRANSMITTED SIGNAL
RM ENCODER
SELECTOR
1030
HARQ-ACK BITS
MAPPER
1020
1010
OUTCOME OF M PDSCH RECEPTIONS IN PCELL
OUTCOME OF M PDSCH RECEPTIONS IN SCELL

FIG.10

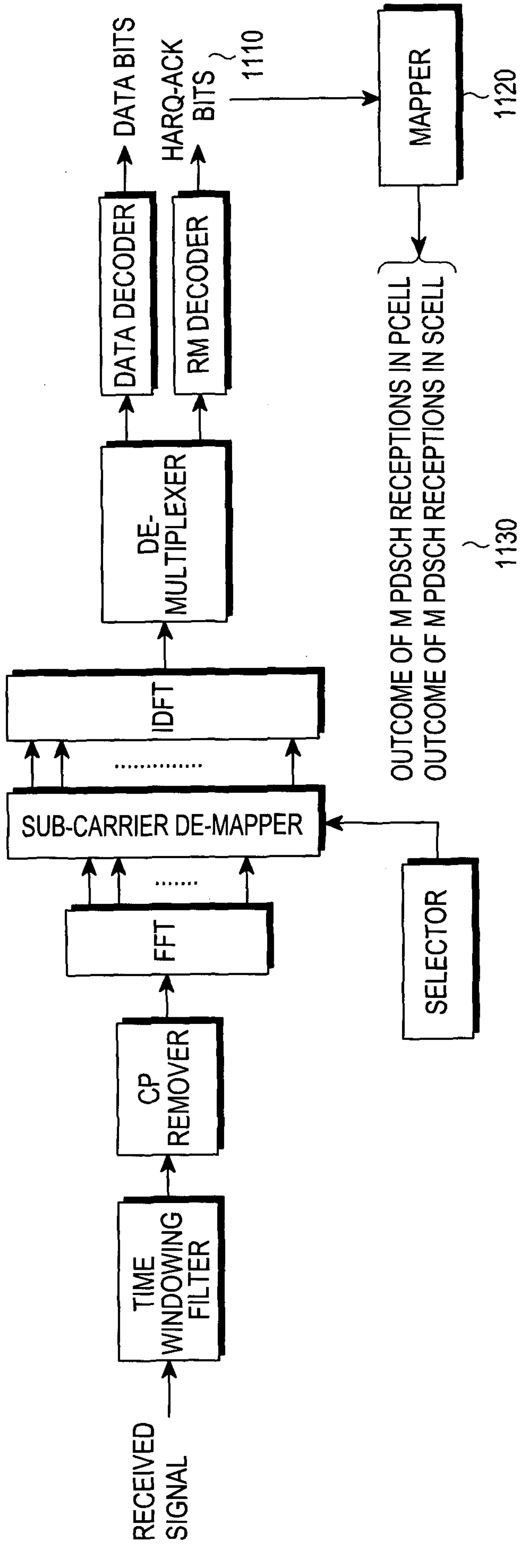
RECEIVED SIGNAL
TIME WINDOWING FILTER
CP REMOVER
FFT
SUB-CARRIER DE-MAPPER
SELECTOR
IDFT
DE-MULTIPLEXER
DATA DECODER
RM DECODER
DATA BITS
HARQ-ACK BITS
1110
MAPPER
1120
OUTCOME OF M PDSCH RECEPTIONS IN PCELL
OUTCOME OF M PDSCH RECEPTIONS IN SCELL
1130

FIG.11