PDSCH muting on CRS Locations for Intercell CSI Estimation

Vikram Chandrasekhar, Eko Onggosanusi, Tony Ekpenyong, Runhua Chen
Texas Instruments
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1. Introduction

Future releases of LTE (Rel-10 and beyond) will make use of coordinated transmissions across multiple cells within each cell-site or across multiple cell site (the so-called Coordinated Multipoint Reception, abbreviated as CoMP). CoMP will enhance coverage to UEs (UEs benefiting from CoMP shall be labeled as *advanced UEs*), hitherto experiencing poor coverage because they are served using just a single cell.

However, CoMP operation requires accurate channel state information (CSI) knowledge at the advanced UE. By CSI, we refer to the multi-dimensional channel matrix between each coordinating cell (referred as CoMP cell in the ensuing paragraphs) and the advanced UE. This document describes exemplary schemes for performing inter-cell CSI estimation using the existing *cell-specific reference symbols (CRS)* in Rel-8 LTE.

2. PDSCH muting on Inter-cell CRS

Assume that the advanced UE has a single primary serving cell and N cells which coordinate their transmissions. The coordinating cell set serving the advanced UE of interest are labeled as $\{CoMP\ Cell_0, CoMP\ Cell_1, ..., CoMP\ Cell_N\}$. In Rel-8 LTE, the number of coordinating cells N = 0.

The number of coordinating cells N cannot exceed 4 (this is a limitation enforced "the cell ID modulo 6" pattern for CRS). Without loss of generality, this document assumes that the number of CoMP cells is chosen to equal $N = 2$.

Notation 1: Without loss of generality, CoMP Cell 0 refers the principal serving cell of the advanced UE.

Assumption 1: Advanced UE configured for CoMP operation has knowledge of the cell IDs of all N CoMP cells within the CoMP set.

We now propose PDSCH RE muting schemes for performing inter-cell CSI estimation at an advanced UE configured for CoMP reception.

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Claim 1: The eNodeB (CoMP Cell i, that is, the principal serving cell) shall transmit *PDSCH with zero energy (mute it's PDSCH*[1]*)* on certain inter-cell CRS resource elements. Within the first PRB (PRB 0), let the RE positions (frequency domain) be indexed between 0 and 11. Then, the muted PDSCH RE positions per antenna port are computed using the cell IDs of all CoMP cells other than the cell ID i.

The OFDM symbols in which muting occurs are further defined in Claims 7a through 7h. Mathematically, the muted PDSCH RE positions per transmission antenna port are given as:

Muted PDSCH REs at port y = {6 * k + [3*m_y + Cell ID (CoMP Cell$_j$) modulo 6]} modulo 12.

Here, k = 0 or 1, y = 0 or 1 or 2 or 3, m_y = 0 or 1.
Finally, j = 1,2,.. N, and j does not equal i.

The parameter k takes the values of either 0 or 1 for any transmission antenna port. The values that m_y takes for antenna port y depend on which OFDM symbol is configured for PDSCH muting and are further defined in Claims 7a through 7h.

Claim 2: PDSCH muting on inter-cell CRS – in any PDSCH muting enabled subframe – occurs across the entire bandwidth on OFDM symbols in which PDSCH muting occurs. Within a muting enabled subframe, the *relative location of muted PDSCH REs (within a given RB) shall stay the same* from one RB to the next. See Claim 1 on how to derive the relative location of muted PDSCH REs for each port.

However – as shall be discussed further in Claim 3—the CoMP cells may choose to vary the relative location of their muted PDSCH REs within a PRB across different muting enabled subframes.

Assumption 2: The duty cycle of subframes with PDSCH muting on inter-cell CRS equals "d" ms/frame– that is, the serving eNodeB (Cell 0) performs PDSCH muting every "d" milli-seconds per frame.

We call subframes on which PDSCH muting occurs as *PDSCH muting-enabled subframes*. For example, as shown in Figure 1, if d = 10 ms/frame, then PDSCH muting on inter-cell CRS occurs once per frame.

[1] The eNodeB shall perform rate-matching around the muted PDSCH RE locations, which will be already known to the advanced UE that is benefiting from CoMP operation. Therefore, there is no performance degradation as seen at the advanced UE arising from the PDSCH RE muting procedure.

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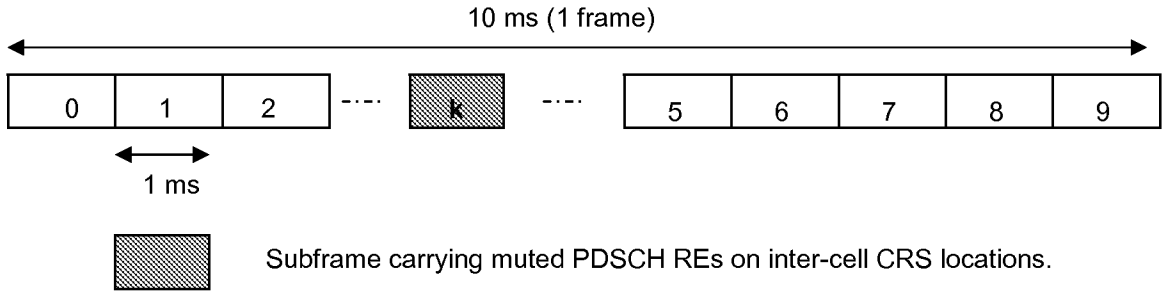
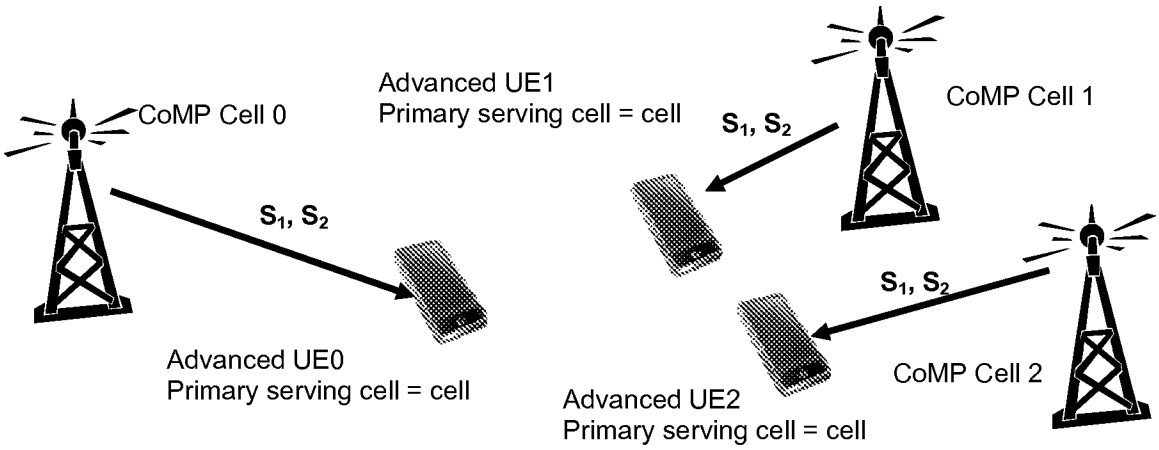


Figure 1 : PDSCH muting enabled subframes for enabling inter-cell CSI estimation. In this figure, the duty cycle (time domain periodicity) of PDSCH muting enabled subframes equals 10 ms (or 1 frame).



Signal $\mathbf{S_1}$ (Four bits): To communicate subframe offset when PDSCH muting occurs.
Signal $\mathbf{S_2}$ (Two bits): To communicate duty cycle (time domain periodicity).

Figure 2 : Transmitted signals from serving eNodeB communicating inter-cell PDSCH muting subframe offset and time domain periodicity. In this figure, we assume that there are three CoMP cells (each of which is a primary serving cell to an advanced UE). The CoMP cells perform CoMP operation and improve coverage to the three advanced UEs.

Claim 3a: The eNodeB shall transmit two signals to the advanced UE_– the first signal S_1—which requires four bits—communicates the subframe offset –taking values between 0 through 9 – on which PDSCH muting for intercell CSI estimation occurs. The second signal S_2—requiring two bits – communicates the time domain periodicity of PDSCH muting enabled subframes. Both signals are communicated using semi-static signaling on the PDSCH of the advanced UE and cell-specific to all cells within a CoMP set.

Figure 2 shows the signaling scheme when there are three CoMP cells, which provide CoMP operation to three advanced UEs.

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Claim 3b: As an alternative to Claim 3, the eNodeB shall jointly encode S_1 and S_2 and send a single signal S for transmitting the PDSCH muting starting subframe and time domain periodicity.

Claim 3c: The subframe offset and time domain periodicity signals as claimed in claims 3a and 3b are cell-specific to all cells in a CoMP set. Further, these signals are specific to advanced UEs [2]served by cells within the CoMP set.

Claim 4: In any PDSCH enabled subframe, the eNodeB may perform PDSCH muting on REs within a given PRB, according to a *frequency-hopping pattern*. The frequency hopping pattern determines which value of k is chosen in Claim 1.

For the rest of this document, without loss of generality, k is assumed to take the value 0 and no frequency hopping is performed.

Claim 5: The density of muted PDSCH REs equals *m * N REs/RB/transmit antenna port*, where *m* denotes the number of muted PDSCH REs per antenna port in each RB.

For the remainder of this document, without loss of generality, *m is chosen to equal 1 RE/PRB/port.*

Claim 6: PDSCH muting on the inter-cell CRS for all cells within the CoMP set occurs within identical *OFDM symbols* and within identical muting enabled *subframes*.

3. Choosing OFDM symbols for PDSCH muting

Assuming the PDSCH muting occurs according to claims 1 through 5, we now describe exemplary schemes for determining *which OFDM symbol is configured for PDSCH muting* on inter-cell CRS REs on PDSCH muting enabled subframes.

Notation 2: In any subframe, OFDM symbols are indexed starting from symbol 0 until symbol 13.

Claim 7a: PDSCH muting on Ports 0 & 1 [resp. 2 & 3] shall occur on OFDM symbol 0 [resp. OFDM symbol 1] in any PDSCH muting enabled subframe. The term m_y in Claim 1 is chosen as y modulo 2 for all antenna ports defined by y.

Claim 7b: PDSCH muting on Ports 0 & 1 [resp. 2 & 3] shall occur on OFDM symbol 0 [resp. OFDM symbol 8] in any PDSCH muting enabled subframe. The term m_y in Claim 1 is chosen as y modulo 2 for port y = 0 or 1. For y equaling ports 2 & 3, m_y in Claim 1 is chosen as 1 - y modulo 2.

[2] For non-advanced UEs (that is, Rel-8 LTE UEs) which do not have CoMP reception/inter-cell CSI estimation capability, such signals would be interpreted as RESERVED and hence not decoded/interpreted.

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Claim 7c: PDSCH muting on Ports 0 & 1 [resp. 2 & 3] shall occur on OFDM symbol 3 [resp. OFDM symbol 1] in any PDSCH muting enabled subframe. The term m_y in Claim 1 is chosen as 1 - y modulo 2 for port y = 0 or 1. For y equaling ports 2 & 3, m_y in Claim 1 is chosen as y modulo 2.

Claim 7d: PDSCH muting on Ports 0 & 1 [resp. 2 & 3] shall occur on OFDM symbol 3 [resp. OFDM symbol 8] in any PDSCH muting enabled subframe. The term m_y in Claim 1 is chosen as 1 - y modulo 2 for port y = 0 or 1. For y equaling ports 2 & 3, m_y in Claim 1 is chosen as 1- y modulo 2.

Claim 7e: PDSCH muting on Ports 0 & 1 [resp. 2 & 3] shall occur on OFDM symbol 7 [resp. OFDM symbol 1] in any PDSCH muting enabled subframe. The term m_y in Claim 1 is chosen as y modulo 2 for all antenna ports defined by y.

Claim 7f: PDSCH muting on Ports 0 & 1 [resp. 2 & 3] shall occur on OFDM symbol 7 [resp. OFDM symbol 8] in any PDSCH muting enabled subframe. The term m_y in Claim 1 is chosen as y modulo 2 for port y = 0 or 1. For y equaling ports 2 & 3, m_y in Claim 1 is chosen as 1 - y modulo 2.

Claim 7g: PDSCH muting on Ports 0 & 1 [resp. 2 & 3] shall occur on OFDM symbol 11 [resp. OFDM symbol 1] in any PDSCH muting enabled subframe. The term m_y in Claim 1 is chosen as 1 - y modulo 2 for port y = 0 or 1. For y equaling ports 2 & 3, m_y in Claim 1 is chosen as y modulo 2.

Claim 7h: PDSCH muting on Ports 0 & 1 [resp. 2 & 3] shall occur on OFDM symbol 11 [resp. OFDM symbol 8] in any PDSCH muting enabled subframe. The term m_y in Claim 1 is chosen as 1 - y modulo 2 for all antenna ports defined by y.

Claim 8: In any muting enabled subframe, PDSCH muting on inter-cell CRS locations may be *time-hopped* according to a pre-determined time-hopping sequence – that is already known to the advanced UE – which is a subset chosen according to one or more of Claims 7a through 7h.

4. Exemplary PDSCH muting patterns

In this section, we present sample PDSCH muting patterns according to Scheme 1a. Without loss of generality, we assume that the serving cell (CoMP cell 0) has a cell ID equalling 0 modulo 6 (example 432). We further assume that the other two CoMP cells have cell IDs equalling 4 modulo 6 (for example, cell ID = 430) and 5 modulo 6 (for example, Cell ID = 431) respectively.

Figure 3 through Figure 6 illustrate PDSCH muting patterns on inter-cell CRS for an eNodeB with cell ID equaling 0 modulo 6 and equipped four antenna transmission ports. Muted PDSCH REs on inter-cell RE locations are shown by light blue and dark green colors. In all figures, it is assumed that the PDSCH muting on inter-cell CRS locations

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occurs with a frequency domain periodicity of N REs/PRB/port, where N, the number of CoMP cells (excluding the serving eNodeB) is assumed to equal 2.

Figure 7 and Figure 8 show the corresponding muting patterns for such an eNodeB in case it is equipped with two antenna transmission ports.

Notation 3: R_i represents resource element corresponding to intra-cell CRS on antenna transmission port i.

Notation 4: R_{ij} represents resource element corresponding to inter-cell CRS on antenna transmission port i, transmitted from CoMP cell j, where i and j cannot exceed the total number of transmission antennas in the serving cell and the total number of CoMP cells (N) respectively.

Assumption 2: Without loss of generality, our assumption is that all CoMP cells (including serving cell 0) have the same number of transmission antenna ports.

Muting patterns for Claims 7b through 7h are obtainable straightforwardly. Further, muting patterns for cell IDs equaling 1 and 2 modulo 6 are obtainable straightforwardly from the above discussion.

4.1. Four Transmission Antenna Ports

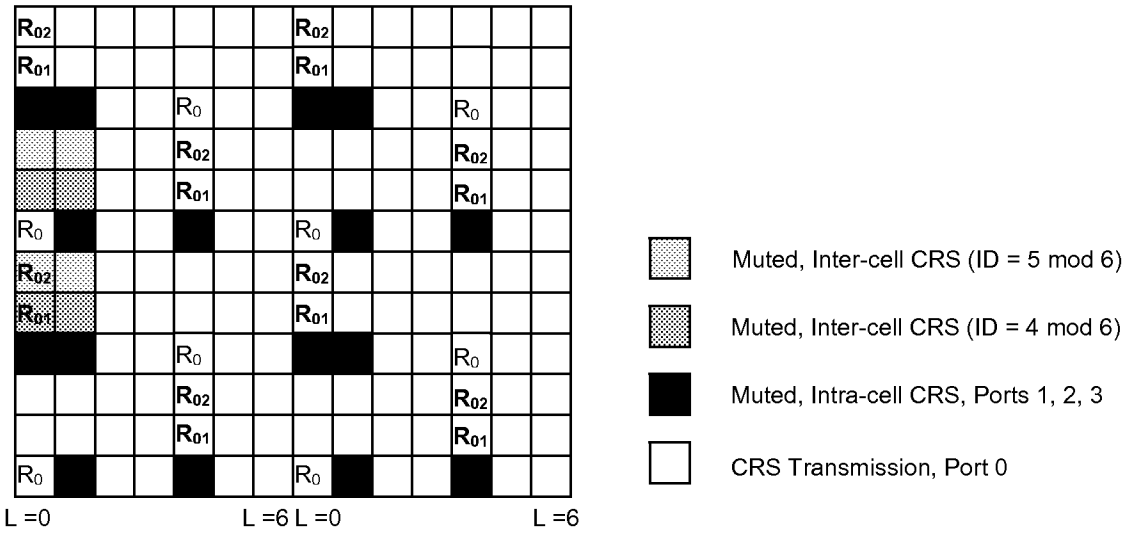

Figure 3: PDSCH muting pattern for transmission antenna port 0 (four antenna ports).

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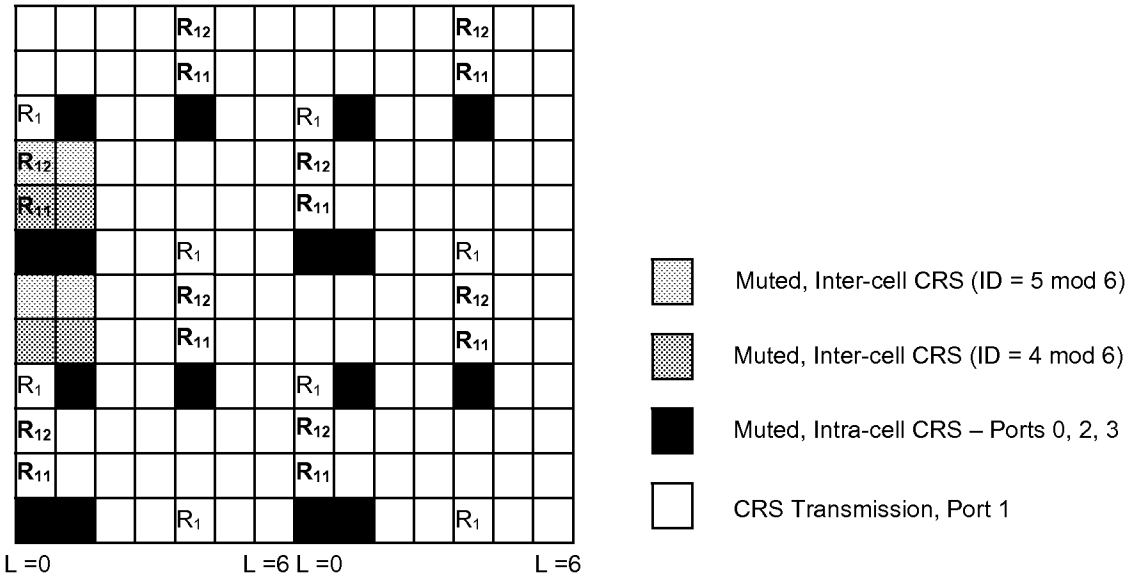

Figure 4 : PDSCH muting pattern for transmission antenna port 1 (four antenna ports).

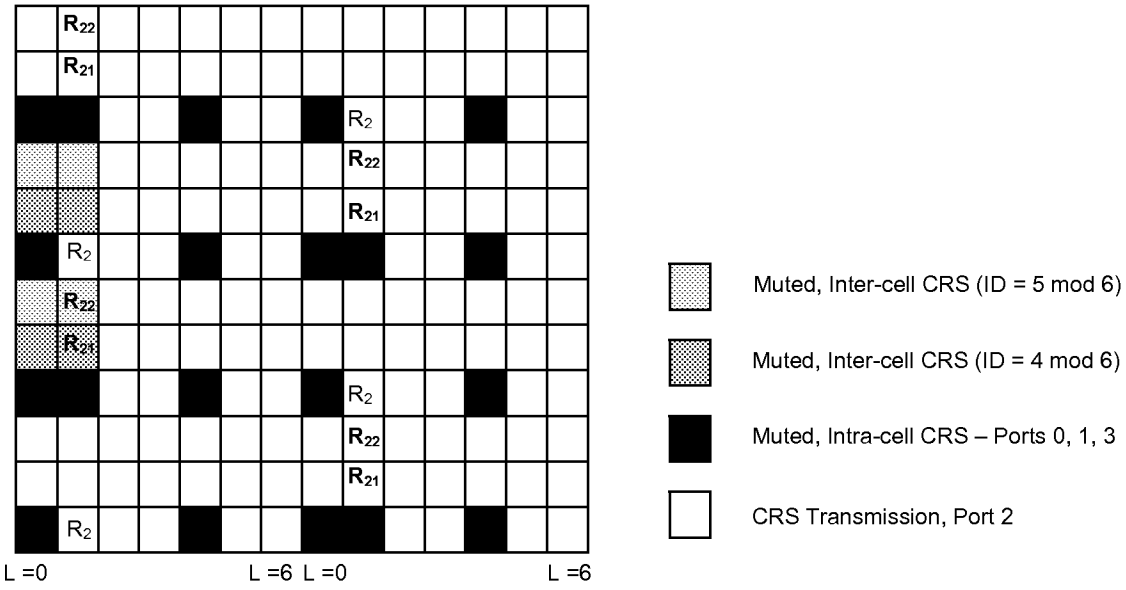

Figure 5 : PDSCH muting pattern for transmission antenna port 2 (four transmit ports).

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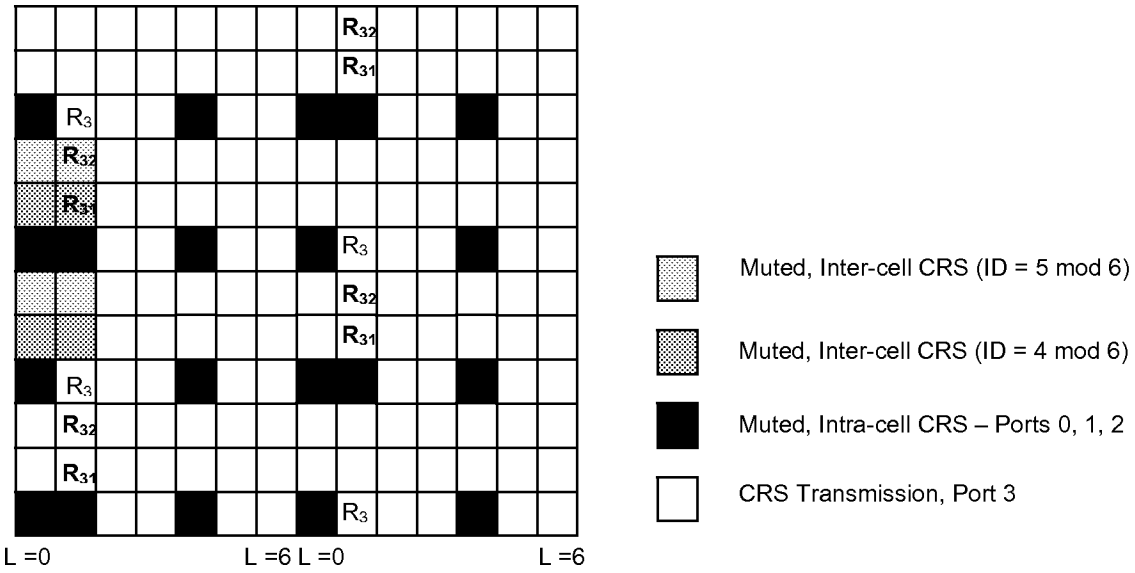

Figure 6: PDSCH muting pattern for transmission antenna port 3 (four transmit ports).

4.2. Two Transmission Antenna Ports

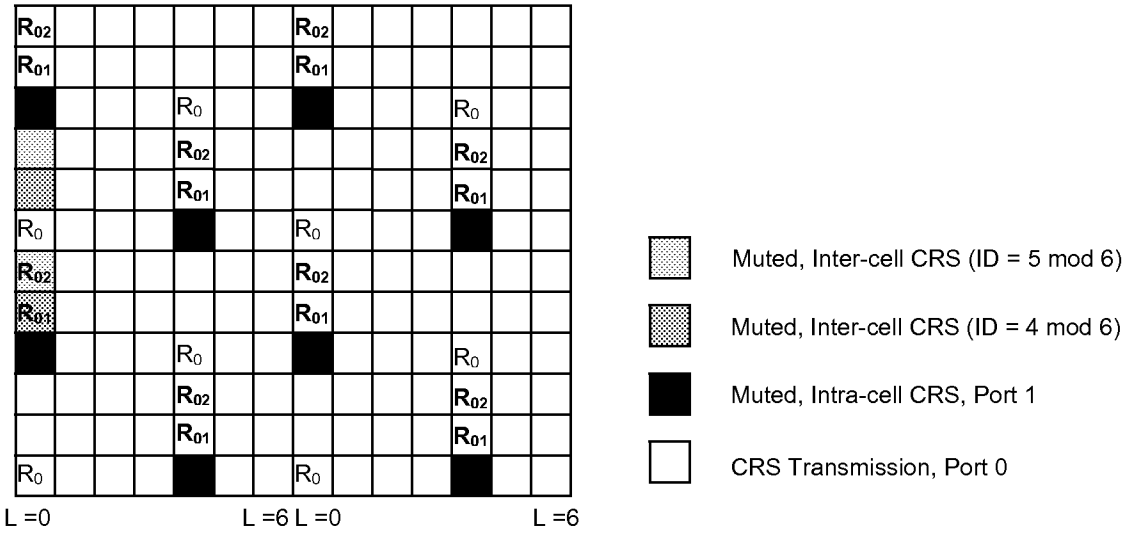

Figure 7 : PDSCH muting pattern for transmission antenna port 0 (two transmit ports).

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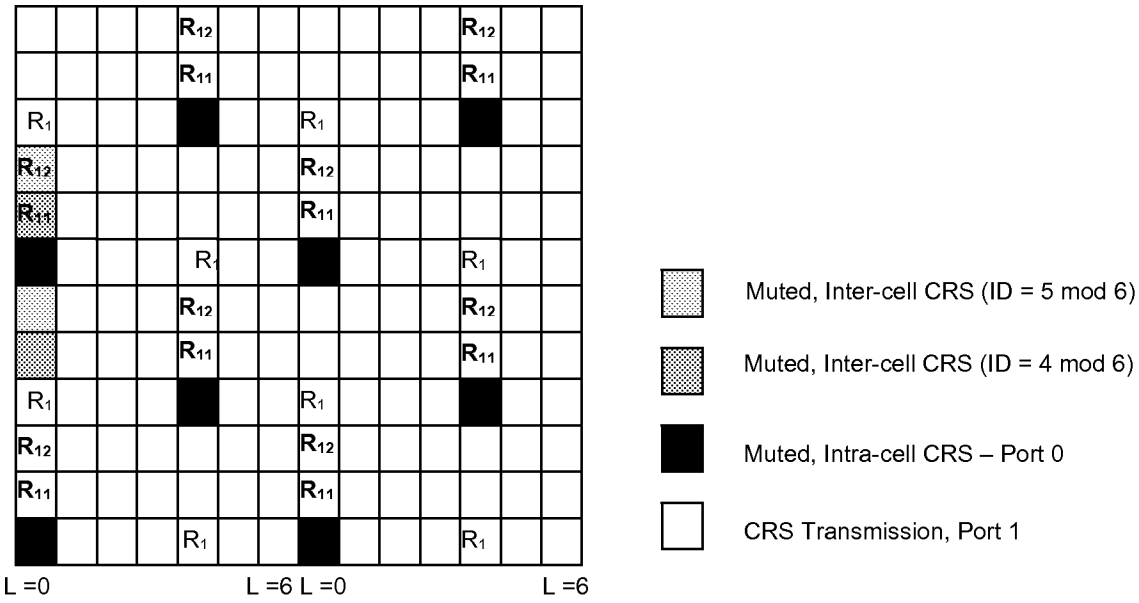

Figure 8 : PDSCH muting pattern for transmission antenna port 1 (two transmit ports).

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