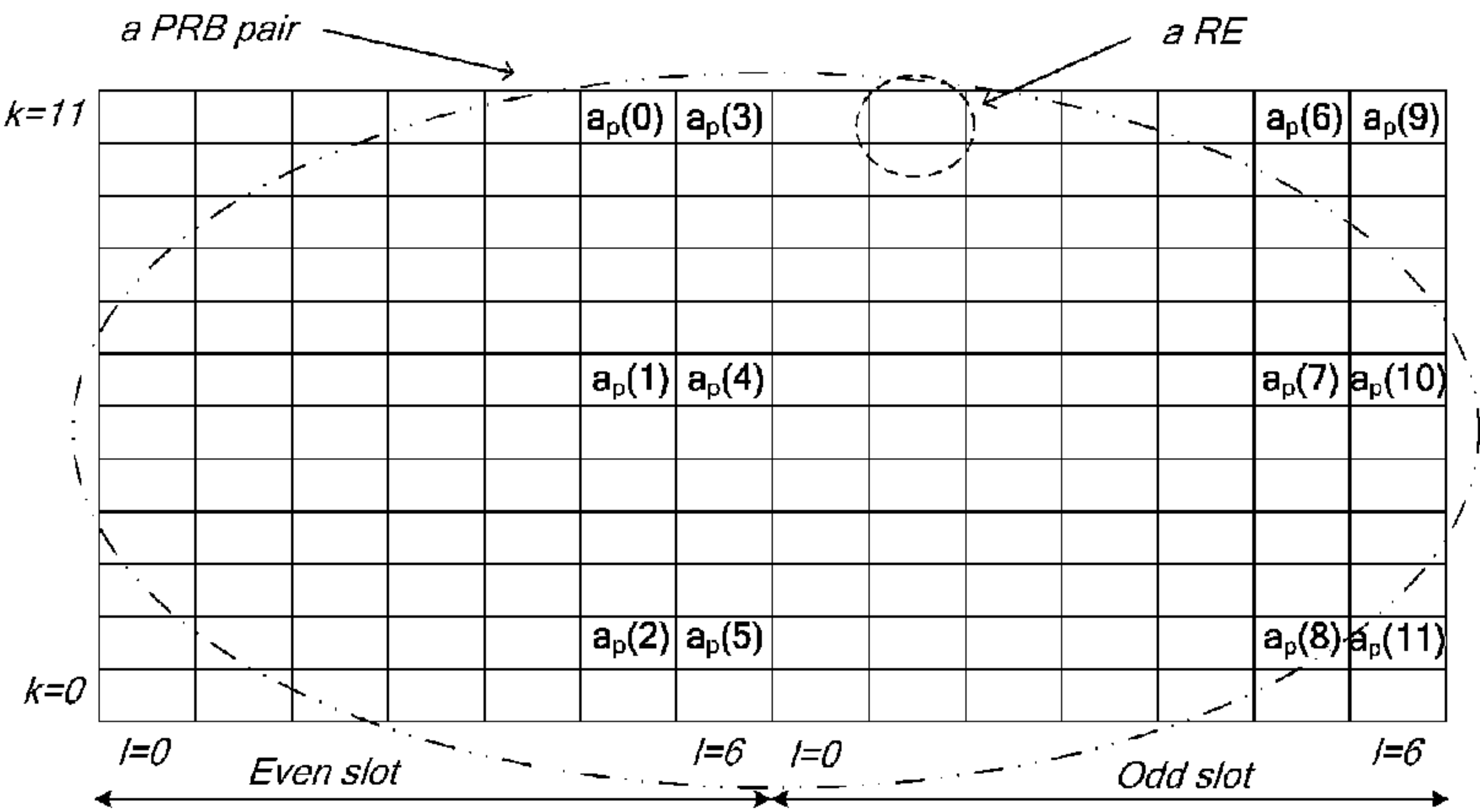




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(54) Titre : PROCÉDE POUR LA GENERATION ET LA TRANSMISSION DE SIGNAUX DE REFERENCE DE DEMODULATION
(54) Title: METHOD FOR GENERATING AND TRANSMITTING DEMODULATION REFERENCE SIGNALS



(57) **Abrégé/Abstract:**
The present invention relates to a method in a transmit node for generating and transmitting demodulation reference signals, and to a corresponding method in a receiver node. The method in the transmit node comprises the steps of: generating at least one first receiver specific demodulation reference signal (PDSCH-DMRS) associated with a receiver specific data channel signal (PDSCH); generating at least one second receiver specific demodulation reference signal (e-PDCCH-DMRS) associated with a receiver specific control channel signal (e-PDCCH); transmitting said receiver specific control channel signal (e-PDCCH) concurrently with said associated second receiver specific demodulation reference signal (e-PDCCH-DMRS); and transmitting said receiver specific data channel signal (PDSCH) concurrently with said associated first receiver specific demodulation reference signal (PDSCH-DMRS). Furthermore, the invention also relates to a transmit device, a receiver device, a computer program, and a computer program product thereof.

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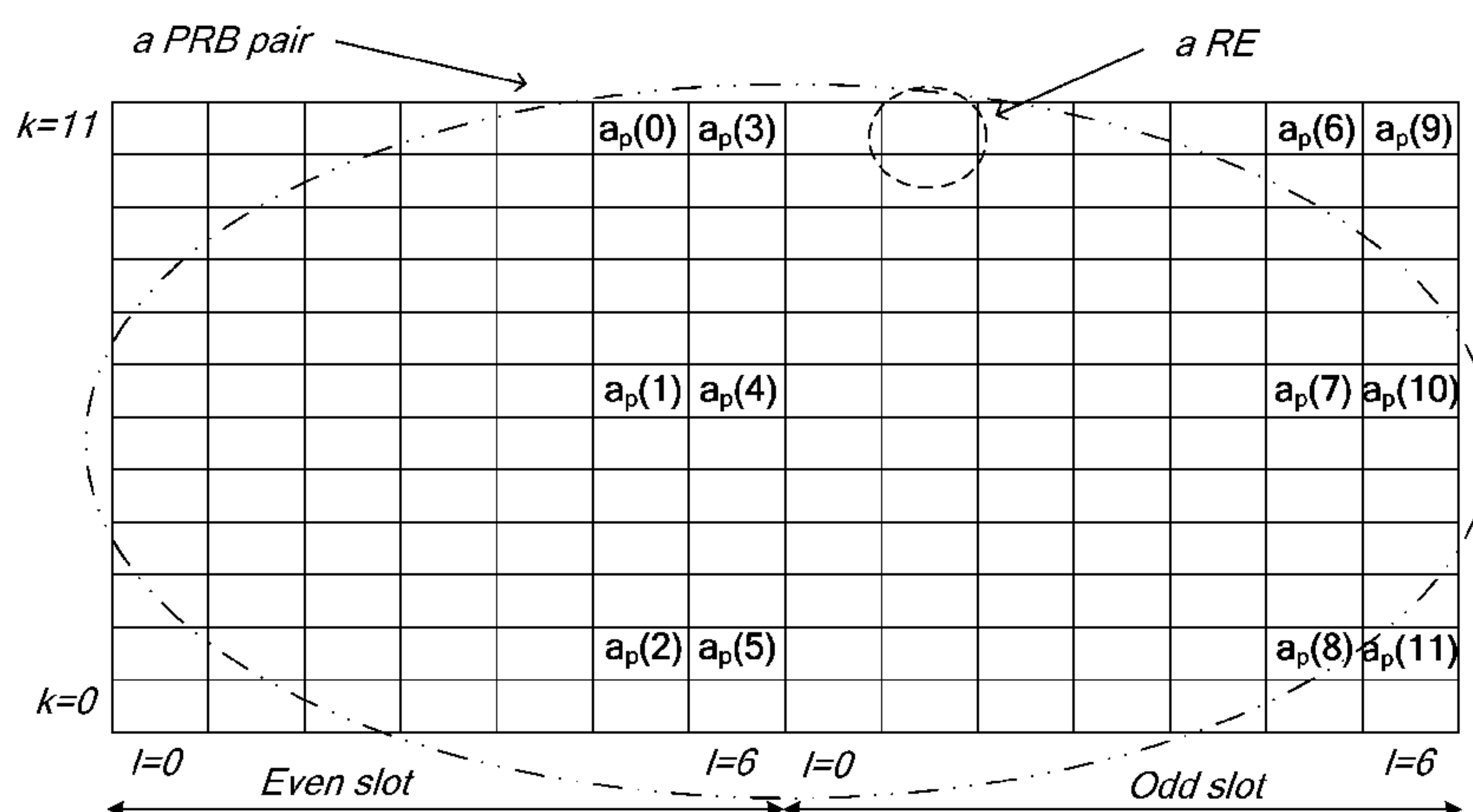


Fig. 2A

(57) **Abstract:** The present invention relates to a method in a transmit node for generating and transmitting demodulation reference signals, and to a corresponding method in a receiver node. The method in the transmit node comprises the steps of: generating at least one first receiver specific demodulation reference signal (PDSCH-DMRS) associated with a receiver specific data channel signal (PDSCH); generating at least one second receiver specific demodulation reference signal (e-PDCCH-DMRS) associated with a receiver specific control channel signal (e-PDCCH); transmitting said receiver specific control channel signal (e-PDCCH) concurrently with said associated second receiver specific demodulation reference signal (e-PDCCH-DMRS); and transmitting said receiver specific data channel signal (PDSCH) concurrently with said associated first receiver specific demodulation reference signal (PDSCH-DMRS). Furthermore, the invention also relates to a transmit device, a receiver device, a computer program, and a computer program product thereof.

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METHOD FOR GENERATING AND TRANSMITTING DEMODULATION REFERENCE SIGNALS

Technical Field

5 The present invention relates to a method for generating and transmitting demodulation reference signals, and to a corresponding method in a receiver node. Furthermore, the invention also relates to a transmit device, a receiver device, a computer program, and a computer program product thereof.

10 Background of the Invention

In a cellular communication system, the downlink (DL) denotes the transmission of the synchronization signals and information from a base station (e.g. eNB) to a mobile user (e.g. a UE). On the uplink (UL) the transmission direction is the opposite.

15 The DL of LTE cellular communication system is based on Orthogonal Frequency Division Multiplex (OFDM) transmission, using both time and frequency resource units for information transmission. The OFDM signal consists of a set of complex sinusoids, called subcarriers, whose frequencies are consecutive integer multiples of the basic (the lowest non-zero) subcarrier frequency, where each complex sinusoid is weighted by a modulation symbol
20 conveying certain number of information bits. In the time domain an OFDM symbol period consists of an active part and a cyclic prefix part. The duration of active part is the inverse of the basic subcarrier frequency. A cyclic prefix (CP) is a signal appended at the beginning of each OFDM symbol, and it consists of a last portion of active OFDM symbol waveform.

25 The smallest time-frequency resource unit for DL LTE information transmission is called *resource element* (RE), occupying a single complex sinusoid frequency in an OFDM symbol. For the purpose of scheduling transmissions to different UEs, the REs are grouped into larger units called *physical resource blocks* (PRB). A PRB occupies a half (called “slot”) of a subframe, i.e. $N_{\text{ymb}}^{\text{DL}} = 7$ (with normal cyclic prefix length) consecutive OFDM symbol
30 intervals in time domain, and $N_{\text{sc}}^{\text{RB}} = 12$ consecutive subcarrier frequencies in frequency domain (occupying in total 180 KHz).

The two PRBs in a subframe occupying the same subcarriers form a *PRB pair*. Each PRB is labeled by a unique PRB number, which is an index denoting the position of the subband that the PRB occupies within a given bandwidth. The PRBs are numbered from 0 to $N_{RB}^{DL} - 1$ within a given bandwidth. Thus, the maximum LTE bandwidth (20 MHz) contains the maximum number (110) of PRBs, which is in LTE standard denoted by $N_{RB}^{max,DL} = 110$. The relation between the *PRB number* n_{PRB} in the frequency domain and resource elements (k, l) in a slot is given by $n_{PRB} = \left\lfloor \frac{k}{N_{sc}^{RB}} \right\rfloor$.

The physical downlink control channel (PDCCH) is defined as a signal containing information needed to receive and demodulate user-specific information transmitted from the eNB to a UE through another signal, called physical downlink shared channel (PDSCH). The PDCCH is transmitted in the control channel region occupying a few OFDM symbols at the beginning of each UE-specific *basic* transmission time interval of 1 ms, called downlink subframe, which is the minimum time resource that can be allocated to a single UE. The number of OFDM symbols in each control channel region ranges from 1 to 3 as indicated by physical control format indicator channel (PCFICH) in each DL subframe.

Downlink control information (DCI) conveyed by PDCCH includes information necessary to demodulate related PDSCH or physical uplink shared channel (PUSCH), such as time-frequency resource allocation, used modulation and coding scheme (MCS), etc. Error detection on DCI transmissions is provided through the Cyclic Redundancy Check (CRC). The CRC bits, calculated from the DCI information bits, are attached to the DCI.

To demodulate the PDCCH signal the UE needs the estimate of the propagation channel. The channel estimate is obtained from reference signals (RS) transmitted through specially allocated REs. The RSs are also used to define so-called antenna ports (APs). An AP is the baseband input into the corresponding separate antenna system. An antenna system consists of an RF chain connected to one or multiple antenna elements that should together produce a desired electro-magnetic radiation pattern. If there is more than one transmit antenna port, and more than one receive antenna port, the transmission is usually classified as Multiple Input Multiple Output (MIMO) transmission. The corresponding propagation paths between

each transmit antenna port and each receive antenna port jointly define a *MIMO propagation channel*. On the LTE DL the different RSs are transmitted on different antenna ports, and thus can serve at the UE to identify separate propagation paths in MIMO propagation channel. In this way each RS defines a unique AP.

5

Up to eight DMRS antenna ports {7, 8, 9, 10, 11, 12, 13, 14} are defined to support up to eight spatial layers PDSCH transmission in LTE Rel-10. PDSCH is directly mapped onto the antenna ports defined by DMRS as illustrated in Fig. 2, showing the case of rank 2 transmission via AP 7 and AP 8. In Fig. 1 the mapping between APs and physical antennas
10 depends on the implementation, and thus is not specified in the standard.

There are three types of DL reference signals in LTE:

- a) common reference signals (CRS) are broadcasted by a base station to all UEs;
- b) UE-specific channel state information reference signals (CSI-RS); and
- 15 c) UE-specific demodulation reference signals (DMRS).

The first two kinds of RSs are used in the UE for calculating the channel quality indicator (CQI), the parameter which is feedback to the base station to help in determining which UE should be scheduled for the subsequent transmission. The third kind of RS, the DMRS, is used to demodulate the data transmitted on PDSCH in the same PRB as that DMRS. Note
20 however that in some transmission modes of PDSCH the DMRSs are not transmitted, so only the CRS is used for the demodulation of PDSCH in these transmission modes. Besides, the CRSs are the only reference signals used for the demodulation of the PDCCH signals.

All of the RSs are characterized by a unique combination of the particular *time-frequency pattern* of their REs and the *modulation sequence* whose elements modulate these REs. There
25 are two possible time-frequency patterns of DMRSs within a PRB pair, as shown in Fig. 2A and 2B.

According to Fig. 2A and 2B, a DMRS modulation sequence $\{a_p(k)\}, k = 0, 1, \dots, 11$, can be
30 represented by a 3x4 *DMRS modulation matrix* A_p , as:

$$A_p = \begin{bmatrix} a_p(0) & a_p(3) & a_p(6) & a_p(9) \\ a_p(1) & a_p(4) & a_p(7) & a_p(10) \\ a_p(2) & a_p(5) & a_p(8) & a_p(11) \end{bmatrix} \quad (1).$$

The DMRS *modulation sequence* $\{a_p(k)\}$ in each of the scheduled PRB pairs is obtained by multiplying symbol-by-symbol its *antenna port (AP) sequence* $\{w_p(k)\}$ with a *PRB scrambling sequence* $\{q(n_{PRB}, k)\}$, i.e.

$$a_p(k) = w_p(k)q(n_{PRB}, k), \quad k = 0, 1, \dots, 11 \quad (2).$$

The AP sequences are used to make the DMRSs that share a common time frequency pattern orthogonal, either over a slot, or over a subframe. An AP sequence $\{w_p(k)\}$ can be defined through the concatenation of columns of the matrix W_p ,

$$W_p = \begin{bmatrix} w'_p(0) & w'_p(1) & w'_p(2) & w'_p(3) \\ w'_p(3) & w'_p(2) & w'_p(1) & w'_p(0) \\ w'_p(0) & w'_p(1) & w'_p(2) & w'_p(3) \end{bmatrix} \quad (3),$$

where (as in the matrix (1)) each row contains the modulation symbols of REs at the same subcarrier frequency. The symbols of matrix (3) are given in Table 1 below.

Table 1: AP sequence symbols for DMRS ports 7 to 14

(a) when $(n_{PRB} \bmod 2) = 0$

Antenna port p	$w'_p(0)$	$w'_p(1)$	$w'_p(2)$	$w'_p(3)$
7	1	1	1	1
8	1	-1	1	-1
9	1	1	1	1
10	1	-1	1	-1
11	1	1	-1	-1
12	-1	-1	1	1
13	1	-1	-1	1
14	-1	1	1	-1

(b) when $(n_{PRB} \bmod 2) = 1$

Antenna port p	$w'_p(0)$	$w'_p(1)$	$w'_p(2)$	$w'_p(3)$
7	1	1	1	1
8	-1	1	-1	1
9	1	1	1	1

10	-1	1	-1	1
11	-1	-1	1	1
12	1	1	-1	-1
13	1	-1	-1	1
14	-1	1	1	-1

The structure of the AP sequences $\{w_p(k)\}$ given by (3) implies that, at given subcarrier frequency, the propagation channel is considered constant over a subframe because only in that case the different APs occupying the same time frequency positions can be orthogonally separated by correlation in the receiver. Such correlation implies that the DMRS REs are averaged to suppress the additive noise at the receiver, resulting in a single channel coefficient at given subcarrier frequency within a subframe.

Additionally, even the DMRS averaging over all subcarrier frequencies within a PRB pair is possible, because the LTE standard specifies that the proprietary precoding of antenna ports 7 to 14 at the base station has to be constant over all subcarrier frequencies of *at least* one PRB bandwidth. In this way the UE receiver can only see one propagation channel coefficient within a PRB pair of an observed antenna port, even if some antenna port precoding is done at the base station transmitter, as the precoding coefficient is included in all the estimated propagation channel coefficients.

The PRB scrambling sequence $\{q(n_{PRB}, k)\}$ is generated by taking a 12-symbols long segment of a long complex (quadrature) pseudo-random sequence $\{r(m)\}$, $m = 0, 1, \dots, 12N_{RB}^{max, DL} - 1$ that falls into the observed PRB after mapping $\{r(m)\}$ to all REs allocated to the DMRSs in the whole bandwidth.

Similarly as an AP sequence, a PRB scrambling sequence $\{q(n_{PRB}, k)\}$ can be defined through the concatenation of columns of the matrix $Q(n_{PRB})$,

$$Q(n_{PRB}) = \begin{bmatrix} r(n_{PRB} + 2) & r(n_{PRB} + 2 + 3N_{RB}^{max, DL}) & r(n_{PRB} + 2 + 6N_{RB}^{max, DL}) & r(n_{PRB} + 2 + 9N_{RB}^{max, DL}) \\ r(n_{PRB} + 1) & r(n_{PRB} + 1 + 3N_{RB}^{max, DL}) & r(n_{PRB} + 1 + 6N_{RB}^{max, DL}) & r(n_{PRB} + 1 + 9N_{RB}^{max, DL}) \\ r(n_{PRB}) & r(n_{PRB} + 3N_{RB}^{max, DL}) & r(n_{PRB} + 6N_{RB}^{max, DL}) & r(n_{PRB} + 9N_{RB}^{max, DL}) \end{bmatrix} \quad (4),$$

where (as in the matrix (1)) each row contains the modulation symbols of REs at the same subcarrier frequency. From (4) it follows that a PRB scrambling sequence $\{q(n_{PRB}, k)\}$ can be defined as:

$$q(n_{PRB}, k) = r(n_{PRB} + 2 - k \bmod 3 + \lfloor k/3 \rfloor 3N_{RB}^{max, DL}), \quad k = 0, 1, \dots, 11 \quad (5),$$

5 where $\lfloor x \rfloor$ denotes the largest integer not greater than x .

The PRB scrambling sequence depends on the cell ID and a UE-specific parameter which can have two possible values, which can be independently set by the base station at the beginning of each subframe. This parameter is sent to the UE via PDCCH. All UE-specific DMRS ports
10 (7 to 14) have a common PRB scrambling sequence, which can change from subframe to subframe, having one of totally two possible versions, depending of base station scheduler decisions.

It has been widely recognized that the control channel region for LTE PDCCH might be
15 insufficient in future deployment scenarios where a significant increase of the number of users in the system is expected. Additionally, in order to reduce transmission overhead in the future systems the CRS might be removed, making the demodulation of PDCCH not feasible. The major direction in finding the way to increase the capacity of PDCCH and reduce transmission overhead is to introduce a UE-specific control channel, so-called *e-PDCCH*,
20 which is supposed to be dynamically scheduled by the base station to each individual UE, in a similar way as it is routinely done for the transmission of UE-specific information content on PDSCH.

Similar approach has already been adopted in LTE Rel. 10 for the definition of relay node
25 operation. A relay node (RN) is defined as supplementary reception and transmission facility, whose task is to extend the coverage of base stations, both in the downlink and uplink. On the downlink, a RN receives control information from the base station via so-called relay physical downlink control channel (R-PDCCH). The R-PDCCH conveys information necessary to demodulate related PDSCH at RN, or PUSCH transmission from the RN. The time-frequency
30 resources of R-PDCCH are fundamentally different from those of PDCCH: the R-PDCCH PRBs are scheduled and multiplexed with the PDSCH PRBs, both in time and frequency.

The R-PDCCH can be demodulated using either CRS or DMRS reference signals mentioned before; the type of reference signals is configured at the eNB and then signaled to the higher layers software in the RN via the data transmitted over PDSCH. Since the channel between an eNB and a fixed RN varies very slowly in time domain, the PRBs scheduled for R-PDCCH remain optimum within a very long time period and therefore may be signaled to the higher layers software in the RN, meaning that the resource allocation information is transmitted via the data bits over PDSCH, to be interpreted and implemented by higher layers software in the RN.

10 A similar approach can be adopted for the design of e-PDCCH, so that the e-PDCCH is transmitted through the UE-specific specially scheduled PRBs. However, since the channel between an eNB and a UE varies much faster, both in time and frequency, than that between an eNB and a fixed RN, the PRBs scheduled for e-PDCCH can only work within a short time period, meaning that they should be indicated in a relatively frequent manner to the desired
15 UE. As the e-PDCCH is supposed to ultimately replace the PDCCH, and as the frequent resource allocation signaling to the higher layers of the UE would consume capacity of PDSCH, it will be assumed further on that the information about UE-specific scheduled e-PDCCH resource allocation is *not* signaled to the UE.

20 Thus the key problem in designing a stand-alone, independently scheduled e-PDCCH is how to detect in the UE the time-frequency resources dynamically allocated to each newly scheduled e-PDCCH transmission, where the allocated e-PDCCH resources can be localized or distributed in frequency domain.

25 An immediate solution is to use blind decoding at the UE, where the UE tries to detect its e-PDCCH at all possible frequency positions of the PRB pairs within given time-frequency and antenna ports search space. The blind detection consists of demodulation of assumed e-PDCCH REs, to obtain the control channel information bits appended by CRC (Cyclic Redundancy Check) bits calculated at the transmitter, followed by the comparison of these
30 demodulated CRC bits with the “reconstructed” CRC bits calculated by the UE from the demodulated control channel information bits. If the demodulated and the reconstructed CRC bits are the same, the e-PDCCH is considered to be found and successfully decoded.

Such a solution has a large implementation complexity in terms of required number of operations. For example, assuming up to 100 PRB pairs within the system bandwidth and an e-PDCCH with size of either 1 or 2 or 4 PRB pairs, if the e-PDCCH is transmitted via one antenna port, the number of the maximal possible detection on an antenna port is as huge as:

$$5 \quad \binom{100}{1} + \binom{100}{2} + \binom{100}{4} = 3926275,$$

where $\binom{n}{m} = \frac{n*(n-1)*...*(n-m+1)}{m*(m-1)*...*1}$. Furthermore, if 4 antenna ports are considered as candidate antenna ports, the total number of the maximal possible detection over all candidate antenna ports will be as high as 4 times the above number.

10 Thus, it is an open problem how to design the downlink transmission method which would allow for an efficient detection in the UE of the time-frequency resources dynamically allocated and used by the base station for the transmission of UE-specific control information.

15 According to a prior art solution, the frequency location for the e-PDCCH is indicated by a new DCI format transmitted in the PDCCH region. The UEs first performs blind detection in the PDCCH region to find the new DCI format and then determines whether there is e-PDCCH in the data region according to the status of the new DCI format detection. Hence, the detection of e-PDCCH really relies on detecting the new DCI format in the PDCCH region. This design is hierarchical, and is illustrated in Fig. 3. Obviously, this solution relies
20 on explicit signaling of scheduled e-PDCCH time-frequency resources (via PDCCH), so it does not solve the problem under assumptions as mentioned.

25 According to another prior art solutions a semi-static configuration method was proposed to indicate e-PDCCH time-frequency resources by high layer signaling. However, since the semi-static configuration via high layer signaling usually have much longer transmission time delay, it is difficult to adapt to the time-varying fast fading channel.

Summary of the Invention

30 Therefore an object of the present invention is to provide a solution which mitigates or solves the drawbacks and problems of prior art solutions.

According to a first aspect of the invention, the above mentioned objects are achieved by a method in a transmit node adapted for communication in a wireless communication system, said wireless communication system being adapted for using time-frequency resource elements (RE) for transmission of information; said method comprising the steps of:

- 5 - generating at least one first receiver specific demodulation reference signal (PDSCH-DMRS) associated with a receiver specific data channel signal (PDSCH);
- generating at least one second receiver specific demodulation reference signal (e-PDCCH-DMRS) associated with a receiver specific control channel signal (e-PDCCH);
- transmitting said receiver specific control channel signal (e-PDCCH) concurrently with said
- 10 associated second receiver specific demodulation reference signal (e-PDCCH-DMRS); and
- transmitting said receiver specific data channel signal (PDSCH) concurrently with said associated first receiver specific demodulation reference signal (PDSCH-DMRS).

According to a second aspect of the invention, the above mentioned objects are achieved by a

15 method in a receiver node adapted for communication in a wireless communication system, said wireless communication system being adapted for using time-frequency resource elements for transmission of information; said method comprising the steps of:

- receiving at least one receiver specific control channel signal (e-PDCCH) generated according to the method above and an associated second receiver specific demodulation
- 20 reference signal (e-PDCCH-DMRS);
- receiving at least one receiver specific data channel signal (PDSCH) generated according to the method above and an associated first receiver specific demodulation reference signal (PDSCH-DMRS);
- demodulating said receiver specific control channel signal (e-PDCCH) by using said
- 25 associated second receiver specific demodulation reference signal (e-PDCCH-DMRS); and
- using information derived from said step of demodulating said receiver specific control channel signal (e-PDCCH) for demodulating said receiver specific data channel signal (PDSCH).

30 Different embodiments of the methods in a transmit node and a receiver node, respectively, are defined in the appended dependent claims.

The above mentioned methods may also be executed in a computer and comprised in suitable computer programs and computer program products.

According to a third aspect of the invention, the above mentioned objects are achieved with a transmit device adapted for communication in a wireless communication system, said wireless communication system being adapted for using time-frequency resource elements (RE) for transmission of information; said transmit device being arranged to:

- generate at least one first receiver specific demodulation reference signal (PDSCH-DMRS) associated with a receiver specific data channel signal (PDSCH);
- 10 - generate at least one second receiver specific demodulation reference signal (e-PDCCH-DMRS) associated with a receiver specific control channel signal (e-PDCCH);
- transmit said receiver specific control channel signal (e-PDCCH) concurrently with said associated second receiver specific demodulation reference signal (e-PDCCH-DMRS); and
- transmit said receiver specific data channel signal (PDSCH) concurrently with said
- 15 associated first receiver specific demodulation reference signal (PDSCH-DMRS).

According to a fourth aspect of the invention, the above mentioned objects are achieved with a receiver device adapted for communication in a wireless communication system, said wireless communication system being adapted for using time-frequency resource elements for transmission of information; said receiver device being arranged to:

- receive at least one receiver specific control channel signal (e-PDCCH) generated by the transmit device above and an associated second receiver specific demodulation reference signal (e-PDCCH-DMRS);
- receive at least one receiver specific data channel signal (PDSCH) generated by the transmit
- 20 device above and an associated first receiver specific demodulation reference signal (PDSCH-DMRS);
- demodulate said receiver specific control channel signal (e-PDCCH) by using said associated second receiver specific demodulation reference signal (e-PDCCH-DMRS); and
- use information derived from said step of demodulating said receiver specific control
- 25 channel signal (e-PDCCH) for demodulating said receiver specific data channel signal (PDSCH).
- 30

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The present invention provides a solution which solves the problem of DMRS ambiguity by introducing separate, i.e. different DMRSs. This is especially the case for systems employing dynamic allocation of control and data signals to different PRBs. Thereby, mobile users in the system can perform fast detection of the associated e-PDCCH signals.

- 5 According to another aspect, there is provided a method in a transmit node for a wireless communication system, said wireless communication system using time-frequency resource elements (REs) for transmission of information; said method comprising the steps of: generating a first receiver specific demodulation reference signal (DMRS) associated with a receiver specific data channel signal; generating a second receiver specific DMRS associated
- 10 with a receiver specific control channel signal; transmitting said receiver specific control channel signal concurrently with said associated second receiver specific DMRS; and transmitting said receiver specific data channel signal concurrently with said associated first receiver specific DMRS, wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource
- 15 block (PRB) for generation of the first receiver specific DMRS, the first PRB being used for transmission of the data channel signal at a transmitting antenna port p , L is a positive integer.

- A further aspect provides a method in a receiver node for a wireless communication system, said wireless communication system using time-frequency resource elements for transmission of information; said method comprising the steps of: receiving a receiver specific control
- 20 channel signal and an associated second receiver specific demodulation reference signal (DMRS) generated and transmitted a transmit mode method as described above; receiving a receiver specific data channel signal and an associated first receiver specific DMRS generated and transmitted a transmit mode method as described above; demodulating said receiver specific control channel signal by using said associated second receiver specific DMRS; and

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using information derived from said step of demodulating said receiver specific control channel signal for demodulating said receiver specific data channel signal.

There is also provided a computer readable medium having computer executable code means stored thereon, which when executed by a computer causes said computer to execute a method
5 as disclosed herein.

In accordance with a still further aspect, there is provided a computer program product comprising a computer readable medium storing a computer executable program, which when executed by a computer causes said computer to execute a method as disclosed herein, wherein the computer readable medium comprises one or more of: ROM (Read-Only
10 Memory), PROM (Programmable ROM), EPROM (Erasable PROM), Flash memory, EEPROM (Electrically EPROM) and hard disk drive.

There is also provided a transmit device for a wireless communication system, said wireless communication system using time-frequency resource elements (REs) for transmission of information; said transmit device comprising: means for generating a first receiver specific
15 demodulation reference signal (DMRS) associated with a receiver specific data channel signal; means for generating a second receiver specific DMRS associated with a receiver specific control channel signal; means for transmitting said receiver specific control channel signal concurrently with said associated second receiver specific DMRS; and means for transmitting said receiver specific data channel signal concurrently with said associated first
20 receiver specific DMRS, wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block (PRB) for generation of the first receiver specific DMRS, the first PRB being used for transmission of the data channel signal at a transmitting antenna port p , L is a positive integer.

In accordance with a still further aspect, there is provided a receiver device for a wireless
25 communication system, said wireless communication system using time-frequency resource elements for transmission of information; said receiver device comprising: means for receiving a receiver specific control channel signal and an associated second receiver specific

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demodulation reference signal (DMRS) generated and transmitted by a transmit device as described above; means for receiving receive a receiver specific data channel signal and an associated first receiver specific DMRS generated and transmitted by a transmit device as described above; means for demodulating said receiver specific control channel signal by
 5 using said associated second receiver specific DMRS; and means for demodulating said receiver specific data channel signal by using information derived from demodulating said receiver specific control channel signal.

According to another aspect, there is provided a method of transmitting a demodulation reference signal (DMRS) in a wireless communication system, time-frequency resource
 10 elements (REs) being used in the wireless communication system for transmission of information, the method comprising: generating at least one first receiver specific DMRS, the at least one first receiver specific DMRS being associated with a data channel; generating at least one second receiver specific DMRS, the at least one second receiver specific DMRS being associated with a control channel, the control channel being associated with the data
 15 channel, the at least one second receiver specific DMRS being different from the at least one first receiver specific DMRS; transmitting the at least one first receiver specific DMRS with the data channel; and transmitting the at least one second receiver specific DMRS with the control channel, wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block
 20 (PRB) for generation of the at least one first receiver specific DMRS, the first PRB being used for transmission of the data channel at a transmitting antenna port p , L is a positive integer.

A further aspect provides a method of utilizing a demodulation reference signal (DMRS) in a wireless communication system, time-frequency resource elements (REs) being used in the wireless communication system for transmission of information, the method comprising:
 25 receiving at least one first receiver specific DMRS associated with a data channel; receiving at least one second receiver specific DMRS associated with a control channel, wherein the control channel is associated with the data channel, and the at least one second receiver specific DMRS is different from the at least one first receiver specific DMRS; and

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demodulating the control channel by using the at least one second receiver specific DMRS, wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block (PRB) for generation of the at least one first receiver specific DMRS, the first PRB being used for transmission of the data channel at a transmitting antenna port p , L is a positive integer.

There is also provided an apparatus, comprising: a computer readable memory storing computer executable instructions related to: generating at least one first receiver specific DMRS, the at least one first receiver specific DMRS being associated with a data channel; generating at least one second receiver specific DMRS, the at least one second receiver specific DMRS being associated with a control channel, the control channel being associated with the data channel, the at least one second receiver specific DMRS being different from the at least one first receiver specific DMRS; transmitting the at least one first receiver specific DMRS with the data channel; and transmitting the at least one second receiver specific DMRS with the control channel; and a processor, coupled to the memory, configured to execute the instructions stored in the memory, wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block (PRB) for generation of the at least one first receiver specific DMRS, the first PRB being used for transmission of the data channel at a transmitting antenna port p , L is a positive integer.

In accordance with a still further aspect, there is provides an apparatus, comprising: a computer readable memory storing computer executable instructions related to: receiving at least one first receiver specific DMRS associated with a data channel; receiving at least one second receiver specific DMRS associated with a control channel, wherein the control channel is associated with the data channel, and the at least one second receiver specific DMRS is different from the at least one first receiver specific DMRS; demodulating the control channel by using the at least one second receiver specific DMRS; and a processor, coupled to the memory, configured to execute the instructions stored in the memory, wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set

of RE positions in a first physical resource block (PRB) for generation of the at least one first receiver specific DMRS, the first PRB being used for transmission of the data channel at a transmitting antenna port p , L is a positive integer.

A further aspect provides a method in a receiver node adapted for communication in a wireless communication system, said wireless communication system being adapted for using time-frequency resource elements for transmission of information; said method comprising the steps of: receiving at least one receiver specific control channel signal and an associated second receiver specific demodulation reference signal (DMRS); receiving at least one receiver specific data channel signal and an associated first receiver specific DMRS; demodulating said receiver specific control channel signal by using said associated second receiver specific DMRS; and using information derived from said step of demodulating said receiver specific control channel signal for demodulating said receiver specific data channel signal; wherein said first receiver specific DMRS is generated by using a first sequence of symbols $\{a_p(k)\}$, $k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements (REs) at fixed positions within PRBs used for transmission of data channel signals at a transmit antenna port p .

There is also provided an apparatus, comprising: a memory storing instructions related to: receiving at least one receiver specific control channel signal and an associated second receiver specific demodulation reference signal (DMRS); receiving at least one receiver specific data channel signal and an associated first receiver specific DMRS; demodulating said receiver specific control channel signal by using said associated second receiver specific DMRS; and using information derived from said step of demodulating said receiver specific control channel signal for demodulating said receiver specific data channel signal; a processor, coupled to the memory, configured to execute the instructions stored in the memory; wherein said first receiver specific DMRS is generated by using a first sequence of symbols $\{a_p(k)\}$, $k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements (REs) at fixed positions within PRBs used for transmission of data channel signals at a transmit antenna port p .

In accordance with a still further aspect, there is provided an apparatus, comprising: a processor, configured to generate at least one first receiver specific demodulation reference signal (DMRS) associated with a receiver specific data channel signal, and generate at least one second receiver specific DMRS associated with a receiver specific control channel signal;
 5 and a transmitter, configured to transmit said receiver specific control channel signal concurrently with said associated second receiver specific DMRS, and transmit said receiver specific data channel signal concurrently with said associated first receiver specific DMRS, wherein said first receiver specific DMRS is generated by using a first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements (REs) at fixed
 10 positions within PRBs used for transmission of data channel signals at a transmit antenna port p .

Further applications and advantages of the invention will be apparent from the following detailed description.

Brief Description of the Drawings

- 15 The appended drawings are intended to clarify and explain different embodiments of the present invention in which:
- Fig. 1 illustrates mapping of different antenna ports;
 - Fig. 2A and 2B shows two possible time-frequency patterns of DMRSs within a PRB pair; and
 - 20 - Fig. 3 illustrates the indication of dynamic resource allocation of e-PDCCH from the control information conveyed in PDCCH.

Detailed Description of the Invention

To achieve the aforementioned and other objects, the present invention relates to a method in a transmit node and to a corresponding method in a receiver node. The method in a transmit
 25 node according to the invention comprises the steps of: generating at least one first receiver specific demodulation reference signal (PDSCH-DMRS) associated with a receiver specific

data channel signal (PDSCH); generating at least one second receiver specific demodulation reference signal (e-PDCCH-DMRS) associated with a receiver specific control channel signal (e-PDCCH); transmitting said receiver specific control channel signal (e-PDCCH) concurrently with the associated second receiver specific demodulation reference signal (e-PDCCH-DMRS); and transmitting the receiver specific data channel signal (PDSCH) concurrently with the associated first receiver specific demodulation reference signal (PDSCH-DMRS). Concurrently in this context should be interpreted as meaning “at the same time”.

The method in a receiver node according to the invention comprises the steps of: receiving at least one receiver specific control channel signal (e-PDCCH) generated according to the

method above and an associated second receiver specific demodulation reference signal (e-PDCCH-DMRS); receiving at least one receiver specific data channel signal (PDSCH) generated according to the method above and an associated first receiver specific demodulation reference signal (PDSCH-DMRS); demodulating the receiver specific control channel signal (e-PDCCH) by using the associated second receiver specific demodulation reference signal (e-PDCCH-DMRS); and using information derived from the step of demodulating the receiver specific control channel signal (e-PDCCH) for demodulating the receiver specific data channel signal (PDSCH).

According to an embodiment of the invention the method in the transmit node further comprises the step of: dynamically allocating the receiver specific data channel signal (PDSCH) and the receiver specific control channel signal (e-PDCCH) to different PRBs.

According to yet another embodiment of the invention the method in the transmit node involves: generating the first receiver specific demodulation reference signal (PDSCH-DMRS) by using a first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements at fixed positions within physical resource blocks used for transmission of data channel signals (PDSCHs) at a transmit antenna port p ; and generating the second receiver specific demodulation reference signal (e-PDCCH-DMRS) by using a second sequence of symbols $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements at fixed positions within physical resource blocks used for transmission of e-PDCCHs at a transmit antenna port p . The second sequence of symbols $\{b_{u,p}(k)\}$ is a u -th sequence from a set of U sequences that can be allocated to one or more receiver nodes (such as UEs) in said wireless communication system.

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As the DMRSs are transmitted in the same PRBs as the corresponding e-PDCCH or PDSCH signals, searching for a receiver-specific DMRS modulation sequence at the receiver, in all PRBs within a given time-frequency search space, and in all possible antenna ports that can be used for the transmission of DMRSs, can result in identifying the PRBs allocated for the transmission of either e-PDCCH or PDSCH signal. The major problem in that case would be that the receiver could not determine whether the detected PRBs are allocated to the e-

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PDCCH or to the PDSCH signal, as in the current LTE system any UE-specific DMRS modulation sequence is the same for both of these signals.

In order to resolve the DMRS ambiguity the present invention introduces separate, i.e. different DMRSs for e-PDCCH and for PDSCH, respectively, such that both are UE-specific, both are using the same time-frequency REs, but are using different DMRS modulation sequences. The e-PDCCH-specific DMRS modulation sequence would allow the UE to unambiguously identify detected the PRB allocated to the e-PDCCH.

To reduce the complexity of searching the e-PDCCH DMRS, as well as to maintain compatibility with legacy UEs, i.e. previous versions of the LTE standard, it is beneficial that the existing LTE DMRS modulation sequences $\{a_p(k)\}$, described by equation (1), are allocated to the PDSCH, while the e-PDCCH-DMRS modulation sequence is a new modulation sequence $\{b_{u,p}(k)\}$. This means that $a_p(k) = w_p(k)q(n_{PRB}, k)$, $k = 0, 1, \dots, 11$ where $q(n_{PRB}, k)$ is a PRB scrambling sequence according to 3GPP LTE standard.

Preferably, the e-PDCCH-DMRS modulation sequence $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$ is obtained by multiplying symbol-by-symbol the PDSCH-DMRS modulation sequence $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ with a UE-specific e-PDDCH *signature sequence* $\{s_u(k)\}, k = 0, 1, \dots, L - 1$, i.e.

$$b_{u,p}(k) = a_p(k)s_u(k), \quad k = 0, 1, \dots, L - 1 \quad (6),$$

where index u labels a u -th sequence from a set of U signature sequences that can possibly be allocated to one or more receiver nodes in the system. The index u may be implicitly or explicitly signaled to one or more receivers according to a further embodiment of the invention.

The number of symbols in a signature sequence L is 12, i.e. equal to the number of DMRS-REs in a PRB pair according to the latest version of the LTE standard (Rel. 10). It is, however, straightforward to use the above construction of e-PDCCH-DMRS modulation sequences with some other number L of DMRS-REs in a PRB pair.

An e-PDCCH signature sequence can be also represented by a matrix S_u , e.g. as:

$$S_u = \begin{bmatrix} s_u(0) & s_u(3) & s_u(6) & s_u(9) \\ s_u(1) & s_u(4) & s_u(7) & s_u(10) \\ s_u(2) & s_u(5) & s_u(8) & s_u(11) \end{bmatrix} \quad (7).$$

In some deployment scenarios, the base station might decide to allocate the different frequency positions to PRBs scheduled jointly within a subframe. Even in that case a single
 5 UE-specific e-PDCCH signature sequence of L symbols can be associated to each such pair of PRBs, so that the symbols are mapped to e-PDCCH DMRS REs as described by the e-PDCCH signature matrix (7).

According to an embodiment that allows for very simple generation of e-PDCCH-DMRS
 10 modulation sequences, and for a simple searching procedure in the UE receiver, the e-PDCCH signature sequence can be a binary sequence with alphabet consisting of two values, +1 and -1.

According to another embodiment the transmit node (e.g. base station or relay node) transmits
 15 simultaneously multiple e-PDCCH and PDSCH signals, corresponding to multiple UEs, over a common set of antenna ports, i.e. the cases when $U > 1$.

If all the UEs share the same scrambling sequence in the corresponding PDSCH-DMRS modulation sequences (what depends on the base station scheduler decision), then using the
 20 same e-PDCCH signature sequence in all UE-specific e-PDCCH transmission makes it impossible for each of the involved UEs to tell whether the corresponding e-PDDCH signal is its own, or it belongs to some other UE. This UE-ambiguity can be optimally resolved by multiple, UE-specific orthogonal e-PDCCH signature sequences as described in the following disclosure.

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For example, the set of 11 orthogonal binary e-PDCCH signature sequences of length 12 is given by the columns 2 to 12 of 12x12 Hadamard matrix H, where

$$H = \begin{bmatrix} +1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 \\ +1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 \\ +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 \\ +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 \\ +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 \\ +1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 \\ +1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 \\ +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 \\ +1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 \\ +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 \end{bmatrix} \quad (8).$$

The first column of (8), i.e. the vector of all +1s, can be interpreted as a transparent “PDSCH signature sequence”, which means that each of the e-PDCCH-DMRS modulation sequences generated using the signature sequences (8) is orthogonal to the corresponding PDSCH-DMRS modulation sequence. It is easy to see that the columns of H would remain orthogonal if the rows of H are permuted.

However, in some deployment scenarios it might be beneficial that the e-PDCCH signature sequences are also orthogonal over a number of symbols smaller than L. For example, the UEs that move at high speed, or have the different frequency positions allocated to PRBs scheduled jointly within a subframe, might benefit from performing the e-PDCCH detection independently in each slot. In that case the interference from other UE-specific e-PDCCH signature sequences would be minimized if all e-PDCCH signatures are orthogonal both over L symbols and over L/2 symbols.

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Such e-PDCCH signatures can be obtained, for example, from the $L \times L$ orthogonal matrices that can be structured as:

$$G = \begin{bmatrix} A & A \\ A & -A \end{bmatrix} \quad (9),$$

where A is an $L/2 \times L/2$ orthogonal matrix. For example, we can define an orthogonal matrix A_0 as the 6×6 DFT matrix, i.e.

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$$A_0 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & W_6^1 & W_6^2 & W_6^3 & W_6^4 & W_6^5 \\ +1 & W_6^2 & W_6^4 & +1 & W_6^2 & W_6^4 \\ +1 & W_6^3 & +1 & W_6^3 & +1 & W_6^3 \\ +1 & W_6^4 & W_6^2 & +1 & W_6^4 & W_6^2 \\ +1 & W_6^5 & W_6^4 & W_6^3 & W_6^2 & W_6^1 \end{bmatrix} \quad (10),$$

where $W_6^1 = e^{i2\pi/6}$, $i = \sqrt{-1}$. If we insert A_0 in (9) we obtain the 12×12 matrix G_0 , given as

$$G_0 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & W_6^1 & W_6^2 & W_6^3 & W_6^4 & W_6^5 & +1 & W_6^1 & W_6^2 & W_6^3 & W_6^4 & W_6^5 \\ +1 & W_6^2 & W_6^4 & +1 & W_6^2 & W_6^4 & +1 & W_6^2 & W_6^4 & +1 & W_6^2 & W_6^4 \\ +1 & W_6^3 & +1 & W_6^3 & +1 & W_6^3 & +1 & W_6^3 & +1 & W_6^3 & +1 & W_6^3 \\ +1 & W_6^4 & W_6^2 & +1 & W_6^4 & W_6^2 & +1 & W_6^4 & W_6^2 & +1 & W_6^4 & W_6^2 \\ +1 & W_6^5 & W_6^4 & W_6^3 & W_6^2 & W_6^1 & +1 & W_6^5 & W_6^4 & W_6^3 & W_6^2 & W_6^1 \\ +1 & +1 & +1 & +1 & +1 & +1 & -1 & -1 & -1 & -1 & -1 & -1 \\ +1 & W_6^1 & W_6^2 & W_6^3 & W_6^4 & W_6^5 & -1 & -W_6^1 & -W_6^2 & -W_6^3 & -W_6^4 & -W_6^5 \\ +1 & W_6^2 & W_6^4 & +1 & W_6^2 & W_6^4 & -1 & -W_6^2 & -W_6^4 & -1 & -W_6^2 & -W_6^4 \\ +1 & W_6^3 & +1 & W_6^3 & +1 & W_6^3 & -1 & -W_6^3 & -1 & -W_6^3 & -1 & -W_6^3 \\ +1 & W_6^4 & W_6^2 & +1 & W_6^4 & W_6^2 & -1 & -W_6^4 & -W_6^2 & -1 & -W_6^4 & -W_6^2 \\ +1 & W_6^5 & W_6^4 & W_6^3 & W_6^2 & W_6^1 & -1 & -W_6^5 & -W_6^4 & -W_6^3 & -W_6^2 & -W_6^1 \end{bmatrix} \quad (11).$$

The corresponding orthogonal e-PDCCH signature sequences of length 12, being also
5 orthogonal over the intervals of 6 symbols, as well as orthogonal to the “PDSCH signature sequence” over the intervals of 6 symbols, are given either by the columns 2 to 6, or by the columns 8 to 12 of matrix G_0 .

Another interesting special case of (9) can be obtained by using any of quadriphase 6×6
10 orthogonal matrices $A = A_i$, $i = 1, \dots, 4$, for example as:

$$A_1 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & -i & +1 & +i & -1 \\ +1 & +i & -1 & +i & -i & -i \\ +1 & +1 & -i & -1 & -1 & +i \\ +1 & -i & +i & -1 & +1 & -1 \\ +1 & -1 & +i & -i & -1 & +1 \end{bmatrix} \quad (12),$$

$$A_2 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & +i & +1 & -i & -1 \\ +1 & -i & -1 & -i & +i & +i \\ +1 & +1 & +i & -1 & -1 & -i \\ +1 & +i & -i & -1 & +1 & -1 \\ +1 & -1 & -i & +i & -1 & +1 \end{bmatrix} \quad (13),$$

$$A_3 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & -i & -i & +i & +i \\ +1 & +i & -1 & +1 & -i & -1 \\ +1 & +i & +1 & -1 & -1 & -i \\ +1 & -i & +i & -1 & +1 & -1 \\ +1 & -i & -1 & +i & -1 & +1 \end{bmatrix} \quad (14),$$

$$A_4 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & +i & +i & -i & -i \\ +1 & -i & -1 & +1 & +i & -1 \\ +1 & -i & +1 & -1 & -1 & +i \\ +1 & +i & -i & -1 & +1 & -1 \\ +1 & +i & -1 & -i & -1 & +1 \end{bmatrix} \quad (15).$$

For example, if we insert A_1 in (9) the corresponding orthogonal e-PDCCH signature sequences of length 12, being also orthogonal over the intervals of 6 symbols, as well as orthogonal to the “PDSCH signature sequence” over the intervals of 6 symbols, are given by the columns 2 to 6 and 8 to 12 of the 12×12 matrix G_1 , given as:

$$G_1 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & -i & +1 & +i & -1 & +1 & -1 & -i & +1 & +i & -1 \\ +1 & +i & -1 & +i & -i & -i & +1 & +i & -1 & +i & -i & -i \\ +1 & +1 & -i & -1 & -1 & +i & +1 & +1 & -i & -1 & -1 & +i \\ +1 & -i & +i & -1 & +1 & -1 & +1 & -i & +i & -1 & +1 & -1 \\ +1 & -1 & +i & -i & -1 & +1 & +1 & -1 & +i & -i & -1 & +1 \\ +1 & +1 & +1 & +1 & +1 & +1 & -1 & -1 & -1 & -1 & -1 & -1 \\ +1 & -1 & -i & +1 & +i & -1 & -1 & +1 & +i & -1 & -i & +1 \\ +1 & +i & -1 & +i & -i & -i & -1 & -i & +1 & -i & +i & +i \\ +1 & +1 & -i & -1 & -1 & +i & -1 & -1 & +i & +1 & +1 & -i \\ +1 & -i & +i & -1 & +1 & -1 & -1 & +i & -i & +1 & -1 & +1 \\ +1 & -1 & +i & -i & -1 & +1 & -1 & +1 & -i & +i & +1 & -1 \end{bmatrix} \quad (16).$$

The orthogonal e-PDCCH signature sequences can be labeled by an index $u = 0, 1, \dots, L - 2$ (from the set of U signature sequences), so a UE-specific e-PDCCH signature sequence is obtained by allocating a certain value of u to a specific UE. The allocation of e-PDCCH signature sequences to specific UEs can be done, for example, by specifying in the standard the index u as a function of some UE identification number in the network, known as Radio Network Temporary Identifier (RNTI) in the LTE standard, which is signaled to each UE by the base station once the connection is established. The other option is to send the index u to the UE by higher layer signaling (through PDSCH) to be used in a subsequent scheduling interval. Therefore, both implicit and explicit signaling of the index u or equivalent may be performed by the system.

Regarding the method in the receiver node, mentioned method according to an embodiment of the invention further comprises: searching for the second receiver specific demodulation reference signal (e-PDCCH-DMRS) in all PRBs within a given time-frequency search space

so as to identify PRBs allocated for receiver specific control channel signals (e-PDCCHs). Preferably, the search is performed in all antenna ports that are used for transmission of the second receiver specific demodulation reference signal (e-PDCCH-DMRS) if multiple antenna ports are used in the transmissions.

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According to yet another embodiment the searching step further involves:

- i) indentifying a set of candidate e-PDCCH PRB pairs by searching the given time-frequency search space for a UE-specific and e-PDCCH-specific DMRS modulation sequence; and
 - ii) demodulating and performing CRC check for candidates belonging to the set, and if a CRC
- 10 check is positive for a candidate - assume that the candidate is correct.

Moreover, the searching may further involve:

- iii) performing blind detection on the remaining e-PDCCH PRB pairs in the given time-frequency search space if step ii) above does not result in a positive CRC check.

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Hence, in other words: if there is more than one e-PDCCH signature sequence, the e-PDCCH searching algorithm should be adapted to encompass the corresponding additional detection statistics. Besides, the searching algorithm can be done in several iterations. In the first iteration the UE can identify the set of candidate, i.e. potential e-PDCCH PRB pairs, by

20 searching for its own e-PDCCH-DMRS modulation sequence over the whole given time-frequency search space; in the second iteration the UE performs one-by-one demodulation of each candidate e-PDCCH PRB pair and performs the CRC check: if the CRC check of selected candidate e-PDCCH PRB pair is positive, the e-PDCCH is considered successfully detected and decoded. If not, the UE move on to another candidate e-PDCCH PRB pair in the

25 set. If none of the candidate e-PDCCH PRB pairs produces a successful CRC check, the UE should perform e-PDCCH blind detection on the remaining PRB pairs in the time-frequency search space.

If only one UE is scheduled at the time, the same e-PDCCH signature can be shared between

30 multiple UEs. In that case a basic implementation of an e-PDCCH searching procedure in the receiver node may comprise of the following steps:

- 1) Decomposing all received OFDM symbols within a subframe into subcarriers with corresponding modulation symbols,

- 2) Selecting in the decomposed received signal the PRB pair in the frequency domain which has not been searched;
- 3) Assuming certain DMRS port;
- 4) Re-modulating REs that are allocated to the assumed DMRS port with the complex-conjugate of the corresponding PDSCH-DMRS modulation sequence; such re-modulated RE-s represent the first propagation channel estimate;
- 5) Re-modulating the first propagation channel estimate with the complex-conjugate of the e-PDCCH signature sequence, to obtain the second propagation channel estimate;
- 6) Summing all the samples of the first propagation channel estimate, and then find the (squared) absolute value of the sum, to obtain the first detection statistic;
- 7) Summing all the samples of the second propagation channel estimate, and then find the (squared) absolute value of the sum, to obtain the second detection statistic;
- 8) Finding the maximum detection statistic;
- 9) Comparing the maximum detection statistic with an estimated noise-level threshold, to determine whether the observed PRB pair contains a DMRS transmission;
- 10) Choosing, if the observed PRB contains a DMRS transmission, the PRB affiliation (PDSCH or e-PDCCH) that corresponds to the maximum detection statistic, otherwise repeat the procedure starting from step 2;
- 11) Repeating, if the observed PRB pair was a PDSCH PRB pair, the procedure starting from the step 2.

The above searching procedure can be easily adapted to the case when the different UE-specific e-PDCCH signatures are assigned to different frequency positions of PRB pairs of a given UE. However, the searching procedure will be simpler if a single, common UE-specific e-PDCCH signature is assigned to any frequency position of PRB pairs of a given UE.

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The above searching procedure is based on the aforementioned fact that the LTE standard specifies that the proprietary precoding of antenna ports 7 to 14 at the base station has to be constant over all subcarrier frequencies of at least one PRB bandwidth. Consequently, if the channel estimate samples within a PRB pair are summed together, a common precoding coefficient can be drawn out of sum, so it does not influence the outcome of the comparison of detection statistics. From the same reason the e-PDCCH detection performances will be optimum if the propagation channel is constant over a PRB pair.

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Moreover, in the above searching procedure, the step of re-modulating the REs with the complex-conjugate of the corresponding PDSCH-DMRS modulation sequence, involves the UE-specific scrambling sequence, as describe earlier. The UE-specific parameter of the scrambling sequences in the existing LTE transmission modes is sent to the UE via PDCCH, which is demodulated by CRS. However, it has been assumed that there is no PDCCH and no CRS, which means that either the UE has to make search for e-PDCCH using both versions of the scrambling sequence, or the UE-specific scrambling sequences parameter has to be sent to the UE by higher layer signaling (through PDSCH) to be used in a subsequent scheduling interval.

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Furthermore, as understood by the person skilled in the art, any method according to the present invention may also be implemented in a computer program, having code means, which when run in a computer causes the computer to execute the steps of the method. The computer program is included in a computer readable medium of a computer program product. The computer readable medium may consist of essentially any memory, such as a ROM (Read-Only Memory), a PROM (Programmable Read-Only Memory), an EPROM (Erasable PROM), a Flash memory, an EEPROM (Electrically Erasable PROM), or a hard disk drive.

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The invention further relates to a transmit device and a receiver device corresponding to the above methods. It should be noted that the transmit device and receiver device can be modified, mutatis mutandis, according to the different embodiments of aforementioned methods. The devices comprise the suitable means for providing the functions described above. These means may e.g. be: processing means, transmitting means, receiving means, memory means, buffer means, antenna means, etc.

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The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretations consistent with the description as a whole.

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CLAIMS:

1. A method in a transmit node for a wireless communication system, said wireless communication system using time-frequency resource elements (REs) for transmission of information; said method comprising the steps of:

- 5 - generating a first receiver specific demodulation reference signal (DMRS) associated with a receiver specific data channel signal;
- generating a second receiver specific DMRS associated with a receiver specific control channel signal;
- 10 - transmitting said receiver specific control channel signal concurrently with said associated second receiver specific DMRS; and
- transmitting said receiver specific data channel signal concurrently with said associated first receiver specific DMRS,

wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block (PRB) for

15 generation of the first receiver specific DMRS, the first PRB being used for transmission of the data channel signal at a transmitting antenna port p , L is a positive integer.

2. The method according to claim 1, further comprising the step of:

- dynamically allocating said receiver specific data channel signal and said receiver specific control channel signal to different physical resource blocks.

20 3. The method according to claim 1, wherein a second sequence of symbols $\{b_{u,p}(k)\}$, $k = 0, 1, \dots, L - 1$ is used for modulating time-frequency REs at a second set of RE positions in a second PRB for generation of the second receiver specific DMRS, the second PRB being used for transmission of the control channel signal at the transmitting antenna port

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p , said second sequence of symbols $\{b_{u,p}(k)\}$ being a u -th sequence from a set of U sequences that can be allocated to one or more receiver nodes in said wireless communication system.

4. The method according to claim 3, wherein said first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ is different from said second sequence of symbols $\{b_{u,p}(k)\}, k =$
5 $0, 1, \dots, L - 1$.
5. The method according to claim 4, wherein said first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ is defined as: $a_p(k) = w_p(k)q(n_{PRB}, k)$, $k = 0, 1, \dots, 11$, where $q(n_{PRB}, k)$ is a physical resource block (PRB) scrambling sequence according to 3GPP LTE standard.
- 10 6. The method according to claim 4 or 5, wherein said second sequence of symbols $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$ is obtained by multiplying, symbol-by-symbol, said first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ with a receiver specific signature sequence $\{s_u(k)\}, k = 0, 1, \dots, L - 1$ so that $b_{u,p}(k) = a_p(k)s_u(k)$, $k = 0, 1, \dots, L - 1$, said receiver specific signature sequence $\{s_u(k)\}$ being a u -th sequence from a set of U signature sequences
15 that can be allocated to one or more receiver nodes in said wireless communication system.
7. The method according to claim 6, wherein said receiver specific signature sequence $\{s_u(k)\}$ comprises elements having values +1 or -1.
8. The method according to claim 6, wherein $U = 1$.
9. The method according to claim 6, wherein $U > 1$.
- 20 10. The method according to claim 9, wherein said receiver specific signature sequences $\{s_u(k)\}$ are orthogonal to each other.
11. The method according to claim 10, wherein said receiver specific signature sequence $\{s_u(k)\}$ is a column of a Hadamard matrix H whose rows can be arbitrarily permuted, where:

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$$H = \begin{bmatrix} +1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 \\ +1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 \\ +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 \\ +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 \\ +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 \\ +1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 \\ +1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 \\ +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 \\ +1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 \\ +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 \end{bmatrix}.$$

12. The method according to claim 10, wherein said receiver specific signature sequence $\{s_u(k)\}$ is a column of matrix $G = \begin{bmatrix} A & A \\ A & -A \end{bmatrix}$, having dimension $L \times L$ and whose rows can be arbitrarily permuted, and where A is an $L/2 \times L/2$ orthogonal matrix.

5 13. The method according to claim 12, wherein A is a Discrete Fourier Transform (DFT) matrix.

14. The method according to claim 13,

wherein $A = A_0$:

$$A_0 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & W_6^1 & W_6^2 & W_6^3 & W_6^4 & W_6^5 \\ +1 & W_6^2 & W_6^4 & +1 & W_6^2 & W_6^4 \\ +1 & W_6^3 & +1 & W_6^3 & +1 & W_6^3 \\ +1 & W_6^4 & W_6^2 & +1 & W_6^4 & W_6^2 \\ +1 & W_6^5 & W_6^4 & W_6^3 & W_6^2 & W_6^1 \end{bmatrix},$$

10 where $W_6^1 = e^{i2\pi/6}$, $i = \sqrt{-1}$.

15. The method according to claim 12, wherein A is a quadriphase orthogonal matrix.

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16. The method according to claim 15, wherein $A = A_i, i = 1, \dots, 4$:

$$A_1 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & -i & +1 & +i & -1 \\ +1 & +i & -1 & +i & -i & -i \\ +1 & +1 & -i & -1 & -1 & +i \\ +1 & -i & +i & -1 & +1 & -1 \\ +1 & -1 & +i & -i & -1 & +1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & +i & +1 & -i & -1 \\ +1 & -i & -1 & -i & +i & +i \\ +1 & +1 & +i & -1 & -1 & -i \\ +1 & +i & -i & -1 & +1 & -1 \\ +1 & -1 & -i & +i & -1 & +1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & -i & -i & +i & +i \\ +1 & +i & -1 & +1 & -i & -1 \\ +1 & +i & +1 & -1 & -1 & -i \\ +1 & -i & +i & -1 & +1 & -1 \\ +1 & -i & -1 & +i & -1 & +1 \end{bmatrix}$$

$$A_4 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & +i & +i & -i & -i \\ +1 & -i & -1 & +1 & +i & -1 \\ +1 & -i & +1 & -1 & -1 & +i \\ +1 & +i & -i & -1 & +1 & -1 \\ +1 & +i & -1 & -i & -1 & +1 \end{bmatrix}.$$

17. The method according to claim 9, wherein u is implicitly or explicitly signaled as an index to one or more receiver nodes in said wireless communication system.

5 18. A method in a receiver node for a wireless communication system, said wireless communication system using time-frequency resource elements for transmission of information; said method comprising the steps of:

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- receiving a receiver specific control channel signal and an associated second receiver specific demodulation reference signal (DMRS) generated and transmitted according to any one of claims 1 to 17;

5 - receiving a receiver specific data channel signal and an associated first receiver specific DMRS generated and transmitted according to any one of claims 1 to 17;

- demodulating said receiver specific control channel signal by using said associated second receiver specific DMRS; and

- using information derived from said step of demodulating said receiver specific control channel signal for demodulating said receiver specific data channel signal.

10 19. The method according to claim 18, further comprising the step of:

- searching for said second receiver specific DMRS in all physical resource blocks (PRBs) within a given time-frequency search space so as to identify PRBs allocated for receiver specific control channel signals.

15 20. The method according to claim 19, wherein said wireless communication system employs multiple antenna port transmissions, and said step of searching further involves:

- searching in all antenna ports that are used for transmission of said second receiver specific DMRS.

21. The method according to claims 19 or 20, wherein said step of searching involves:

20 - i) identifying a set of candidate receiver specific control channel signal PRB pairs by searching said given time-frequency search space; and

- ii) demodulating and performing Cyclic Redundancy Check (CRC) check for candidates in said set, and if a CRC check is positive for a candidate assume that said candidate is correct.

22. The method according to claim 21, further comprising the step of:

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- performing blind detection on remaining receiver specific control channel signal PRB pairs in said given time-frequency search space if step ii) does not result in a positive CRC check.

23. The method according to any one of claims 1 to 17, wherein said transmit node is a base station (eNB) or a relay node.

5 24. The method according to any one of claims 18 to 22, wherein said receiver node is a mobile station or user equipment (UE).

25. The method according to any one of claims 1 to 17, wherein said wireless communication system is an Orthogonal Frequency Division Multiplex (OFDM) transmission system, such as Long Term Evolution (LTE) or LTE Advanced.

10 26. A computer readable medium having computer executable code means stored thereon, which when executed by a computer causes said computer to execute said method according to any one of claims 1-25.

27. A computer program product comprising a computer readable medium storing a computer executable program, which when executed by a computer causes said computer to
15 execute said method according to any one of claims 1-25, wherein the computer readable medium comprises one or more of: ROM (Read-Only Memory), PROM (Programmable ROM), EPROM (Erasable PROM), Flash memory, EEPROM (Electrically EPROM) and hard disk drive.

28. A transmit device for a wireless communication system, said wireless
20 communication system using time-frequency resource elements (REs) for transmission of information; said transmit device comprising:

- means for generating a first receiver specific demodulation reference signal (DMRS) associated with a receiver specific data channel signal;

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- means for generating a second receiver specific DMRS associated with a receiver specific control channel signal;

- means for transmitting said receiver specific control channel signal concurrently with said associated second receiver specific DMRS; and

5 - means for transmitting said receiver specific data channel signal concurrently with said associated first receiver specific DMRS,

wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block (PRB) for generation of the first receiver specific DMRS, the first PRB being used for transmission of
10 the data channel signal at a transmitting antenna port p , L is a positive integer.

29. A receiver device for a wireless communication system, said wireless communication system using time-frequency resource elements for transmission of information; said receiver device comprising:

- means for receiving a receiver specific control channel signal and an associated second
15 receiver specific demodulation reference signal (DMRS) generated and transmitted by the transmit device according to claim 28;

- means for receiving a receiver specific data channel signal and an associated first receiver specific DMRS generated and transmitted by the transmit device according to claim 28;

- means for demodulating said receiver specific control channel signal by using said
20 associated second receiver specific DMRS; and

- means for demodulating said receiver specific data channel signal by using information derived from demodulating said receiver specific control channel signal.

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30. A method of transmitting a demodulation reference signal (DMRS) in a wireless communication system, time-frequency resource elements (REs) being used in the wireless communication system for transmission of information, the method comprising:

5 generating at least one first receiver specific DMRS, the at least one first receiver specific DMRS being associated with a data channel;

generating at least one second receiver specific DMRS, the at least one second receiver specific DMRS being associated with a control channel, the control channel being associated with the data channel, the at least one second receiver specific DMRS being different from the at least one first receiver specific DMRS;

10 transmitting the at least one first receiver specific DMRS with the data channel; and

transmitting the at least one second receiver specific DMRS with the control channel,

15 wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block (PRB) for generation of the at least one first receiver specific DMRS, the first PRB being used for transmission of the data channel at a transmitting antenna port p , L is a positive integer.

31. The method of claim 30, wherein the at least one first receiver specific DMRS is modulated in a way different from the way that the at least one second receiver specific
20 DMRS is modulated.

32. The method of claim 30, wherein a first modulation sequence is used for generation of the at least one first receiver specific DMRS, a second modulation sequence is used for generation of the at least one second receiver specific DMRS, and the first modulation sequence is different from the second modulation sequence.

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33. The method of claim 30, wherein the control channel is an enhanced physical downlink control channel (EPDCCH).

34. The method of claim 30, wherein the data channel is a physical downlink shared channel (PDSCH).

5 35. The method of claim 30, wherein a second sequence of symbols $\{b_{u,p}(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a second set of RE positions in a second PRB for generation of the at least one second receiver specific DMRS, the second PRB being used for transmission of the control channel at the transmitting antenna port p , L is a positive integer.

10 36. The method of claim 35, wherein the second sequence of symbols $\{b_{u,p}(k)\}$ is a u -th sequence selected from a set of U sequences, u and U being positive integers, the set of U sequences being capable of being allocated to one or more receiver nodes in the wireless communication system.

15 37. The method of claim 30, wherein the first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is defined as: $a_p(k)=w_p(k)q(n_{PRB}, k)$, $k=0, 1, \dots, L-1$, where $q(n_{PRB}, k)$ is a PRB scrambling sequence.

38. The method of claim 35, wherein the second sequence of symbols $\{b_{u,p}(k)\}$, $k=0, 1, \dots, L-1$ is obtained by multiplying the first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ with a receiver specific signature sequence $\{s_u(k)\}$, $k=0, 1, \dots, L-1$, so that
20 $b_{u,p}(k)=a_p(k)s_u(k)$, $k=0, 1, \dots, L-1$.

39. The method of claim 38, wherein the receiver specific signature sequence $\{s_u(k)\}$ is a u -th sequence selected from a set of U signature sequences, u and U being positive integers, the set of U sequences being capable of being allocated to one or more receiver nodes in the wireless communication system.

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40. The method of claim 38, wherein the receiver specific signature sequence $\{s_u(k)\}$ comprises elements having values being +1 or -1.

41. The method of claim 39, wherein the set of U signature sequences comprises orthogonal signature sequences.

5 42. The method of claim 38, wherein the receiver specific signature sequence $\{s_u(k)\}$ is a column of a Hadamard matrix H , where:

$$H = \begin{bmatrix} +1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 \\ +1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 \\ +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 \\ +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 \\ +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 & +1 \\ +1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 & -1 \\ +1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 & -1 \\ +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 & +1 \\ +1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 & -1 \\ +1 & -1 & +1 & -1 & -1 & -1 & +1 & +1 & +1 & -1 & +1 & +1 \end{bmatrix}.$$

43. The method of claim 38, wherein the receiver specific signature sequence $\{s_u(k)\}$ is a column of matrix $G = \begin{bmatrix} A & A \\ A & -A \end{bmatrix}$, where G has dimension $L \times L$, and A is an

10 $L/2 \times L/2$ orthogonal matrix.

44. The method of claim 43, wherein A is a Discrete Fourier Transform (DFT) matrix.

45. The method of claim 43, wherein $A=A_0$:

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$$A_0 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & W_6^1 & W_6^2 & W_6^3 & W_6^4 & W_6^5 \\ +1 & W_6^2 & W_6^4 & +1 & W_6^2 & W_6^4 \\ +1 & W_6^3 & +1 & W_6^3 & +1 & W_6^3 \\ +1 & W_6^4 & W_6^2 & +1 & W_6^4 & W_6^2 \\ +1 & W_6^5 & W_6^4 & W_6^3 & W_6^2 & W_6^1 \end{bmatrix}$$

where $W_6^1 = e^{i2\pi/6}$, $i = \sqrt{-1}$.

46. The method of claim 43, wherein A is a quadriphase orthogonal matrix.

47. The method of claim 46, wherein $A=A_i, i=1, \dots, 4$:

$$A_1 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & -i & +1 & +i & -1 \\ +1 & +i & -1 & +i & -i & -i \\ +1 & +1 & -i & -1 & -1 & +i \\ +1 & -i & +i & -1 & +1 & -1 \\ +1 & -1 & +i & -i & -1 & +1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & +i & +1 & -i & -1 \\ +1 & -i & -1 & -i & +i & +i \\ +1 & +1 & +i & -1 & -1 & -i \\ +1 & +i & -i & -1 & +1 & -1 \\ +1 & -1 & -i & +i & -1 & +1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & -i & -i & +i & +i \\ +1 & +i & -1 & +1 & -i & -1 \\ +1 & +i & +1 & -1 & -1 & -i \\ +1 & -i & +i & -1 & +1 & -1 \\ +1 & -i & -1 & +i & -1 & +1 \end{bmatrix}$$

$$A_4 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & +i & +i & -i & -i \\ +1 & -i & -1 & +1 & +i & -1 \\ +1 & -i & +1 & -1 & -1 & +i \\ +1 & +i & -i & -1 & +1 & -1 \\ +1 & +i & -1 & -i & -1 & +1 \end{bmatrix}.$$

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48. The method of claim 39, wherein u is signaled as an index to the one or more receiver nodes in the wireless communication system.

49. The method of claim 30, wherein time-frequency REs of more than one PRB are utilized for transmission of the control channel, the time-frequency REs of more than one
5 PRB are localized in frequency domain.

50. The method of claim 30, wherein time-frequency REs of more than one PRB are utilized for transmission of the control channel, the time-frequency REs of more than one PRB are distributed in frequency domain.

51. A method of utilizing a demodulation reference signal (DMRS) in a wireless
10 communication system, time-frequency resource elements (REs) being used in the wireless communication system for transmission of information, the method comprising:

receiving at least one first receiver specific DMRS associated with a data channel;

receiving at least one second receiver specific DMRS associated with a control
15 channel, wherein the control channel is associated with the data channel, and the at least one second receiver specific DMRS is different from the at least one first receiver specific DMRS;
and

demodulating the control channel by using the at least one second receiver specific DMRS,

20 wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block (PRB) for generation of the at least one first receiver specific DMRS, the first PRB being used for transmission of the data channel at a transmitting antenna port p , L is a positive integer.

52. An apparatus, comprising:

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a computer readable memory storing computer executable instructions related to:

generating at least one first receiver specific DMRS, the at least one first receiver specific DMRS being associated with a data channel;

5 generating at least one second receiver specific DMRS, the at least one second receiver specific DMRS being associated with a control channel, the control channel being associated with the data channel, the at least one second receiver specific DMRS being different from the at least one first receiver specific DMRS;

10 transmitting the at least one first receiver specific DMRS with the data channel; and

transmitting the at least one second receiver specific DMRS with the control channel; and

a processor, coupled to the memory, configured to execute the instructions stored in the memory,

15 wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block (PRB) for generation of the at least one first receiver specific DMRS, the first PRB being used for transmission of the data channel at a transmitting antenna port p , L is a positive integer.

53. An apparatus, comprising:

20 a computer readable memory storing computer executable instructions related to:

receiving at least one first receiver specific DMRS associated with a data channel;

receiving at least one second receiver specific DMRS associated with a control channel, wherein the control channel is associated with the data channel, and the at least one second receiver specific DMRS is different from the at least one first receiver specific DMRS;

5 demodulating the control channel by using the at least one second receiver specific DMRS; and

a processor, coupled to the memory, configured to execute the instructions stored in the memory,

wherein a first sequence of symbols $\{a_p(k)\}$, $k=0, 1, \dots, L-1$ is used for modulating time-frequency REs at a first set of RE positions in a first physical resource block (PRB) for generation of the at least one first receiver specific DMRS, the first PRB being used
10 for transmission of the data channel at a transmitting antenna port p , L is a positive integer.

54. A method in a receiver node adapted for communication in a wireless communication system, said wireless communication system being adapted for using time-frequency resource elements for transmission of information; said method comprising the
15 steps of:

receiving at least one receiver specific control channel signal and an associated second receiver specific demodulation reference signal (DMRS);

receiving at least one receiver specific data channel signal and an associated first receiver specific DMRS;

20 demodulating said receiver specific control channel signal by using said associated second receiver specific DMRS; and

using information derived from said step of demodulating said receiver specific control channel signal for demodulating said receiver specific data channel signal;

wherein said first receiver specific DMRS is generated by using a first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements (REs) at fixed positions within PRBs used for transmission of data channel signals at a transmit antenna port p .

5 55. The method according to claim 54, wherein said second receiver specific DMRS is generated by using a second sequence of symbols $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements (REs) at fixed positions within physical resource blocks (PRBs) used for transmission of receiver specific control channel signals at a transmit antenna port p , said second sequence of symbols $\{b_{u,p}(k)\}$ being a u -th sequence from a set of U
10 sequences that can be allocated to one or more receiver nodes in said wireless communication system.

56. The method according to claim 55, wherein said first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ is different from said second sequence of symbols $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$.

15 57. The method according to claim 54, further comprising the step of:

- searching for said second receiver specific demodulation reference signal in all physical resource blocks (PRBs) within a given time-frequency search space so as to identify PRBs allocated for receiver specific control channel signals.

58. The method according to claim 57, wherein said wireless communication system
20 employs multiple antenna port transmissions, and said step of searching further involves:

- searching in all antenna ports that are used for transmission of said second receiver specific DMRS.

59. The method according to claims 57 or 58, wherein said step of searching involves:

identifying a set of candidate receiver specific control channel signal PRB pairs by searching said given time-frequency search space; and

demodulating and performing Cyclic Redundancy Check (CRC) check for candidates in said set, and if a CRC check is positive for a candidate assume that said candidate is correct.

5 60. The method according to claim 59, further comprising the step of:

- performing blind detection on remaining receiver specific control channel signal PRB pairs in said given time-frequency search space if step ii) does not result in a positive CRC check.

61. The method according to claim 54, wherein said receiver node is a mobile station or user equipment (UE).

10 62. An apparatus, comprising:

a memory storing instructions related to:

receiving at least one receiver specific control channel signal and an associated second receiver specific demodulation reference signal (DMRS);

15 receiving at least one receiver specific data channel signal and an associated first receiver specific DMRS;

demodulating said receiver specific control channel signal by using said associated second receiver specific DMRS; and

using information derived from said step of demodulating said receiver specific control channel signal for demodulating said receiver specific data channel signal;

20 a processor, coupled to the memory, configured to execute the instructions stored in the memory;

wherein said first receiver specific DMRS is generated by using a first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements (REs) at fixed positions within PRBs used for transmission of data channel signals at a transmit antenna port p .

5 63. The apparatus according to claim 62, wherein said second receiver specific DMRS is generated by using a second sequence of symbols $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements (REs) at fixed positions within physical resource blocks (PRBs) used for transmission of receiver specific control channel signals at a transmit antenna port p , said second sequence of symbols $\{b_{u,p}(k)\}$ being a u -th sequence
10 from a set of U sequences that can be allocated to one or more receiver nodes.

64. The apparatus according to claim 63, wherein said first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ is different from said second sequence of symbols $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$.

65. The apparatus according to claim 62, wherein the apparatus is a mobile station or
15 user equipment (UE).

66. An apparatus, comprising:

a processor, configured to generate at least one first receiver specific demodulation reference signal (DMRS) associated with a receiver specific data channel signal, and generate at least one second receiver specific DMRS associated with a receiver specific control channel signal;
20 and

a transmitter, configured to transmit said receiver specific control channel signal concurrently with said associated second receiver specific DMRS, and transmit said receiver specific data channel signal concurrently with said associated first receiver specific DMRS;

wherein said first receiver specific DMRS is generated by using a first sequence of symbols
25 $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ for modulating time-frequency resource elements (REs) at fixed

positions within PRBs used for transmission of data channel signals at a transmit antenna port p .

67. The apparatus according to claim 66, wherein said second receiver specific DMRS is generated by using a second sequence of symbols $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$ for
 5 modulating time-frequency resource elements (REs) at fixed positions within physical resource blocks (PRBs) used for transmission of receiver specific control channel signals at a transmit antenna port p , said second sequence of symbols $\{b_{u,p}(k)\}$ being a u -th sequence from a set of U sequences that can be allocated to one or more receiver nodes.

68. The apparatus according to claim 67, wherein said first sequence of symbols
 10 $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ is different from said second sequence of symbols $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$.

69. The apparatus according to claim 66, wherein the processor is further configured to:
 dynamically allocate said receiver specific data channel signal and said receiver specific control channel signal to different physical resource blocks (PRBs).

15 70. The apparatus according to claim 68, wherein said first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ is defined as: $a_p(k) = w_p(k)q(n_{PRB}, k)$, $k = 0, 1, \dots, 11$, where $q(n_{PRB}, k)$ is a physical resource block (PRB) scrambling sequence according to 3GPP LTE standard.

71. The apparatus according to claim 68 or 70, wherein the processor is configured to
 20 obtain said second sequence of symbols $\{b_{u,p}(k)\}, k = 0, 1, \dots, L - 1$ by : multiplying, symbol-by-symbol, said first sequence of symbols $\{a_p(k)\}, k = 0, 1, \dots, L - 1$ with a receiver specific signature sequence $\{s_u(k)\}, k = 0, 1, \dots, L - 1$ so that $b_{u,p}(k) = a_p(k)s_u(k)$, $k = 0, 1, \dots, L - 1$, said receiver specific signature sequence $\{s_u(k)\}$ being a u -th sequence from a set of U signature sequences that can be allocated to one or more receiver nodes.

72. The apparatus according to claim 71, wherein said receiver specific signature sequence $\{s_u(k)\}$ comprises elements having values +1 or -1.

73. The apparatus according to claim 71, wherein said receiver specific signature sequences $\{s_u(k)\}$ are orthogonal to each other.

5 74. The apparatus according to claim 66, wherein the apparatus is a base station (eNB) or a relay node.

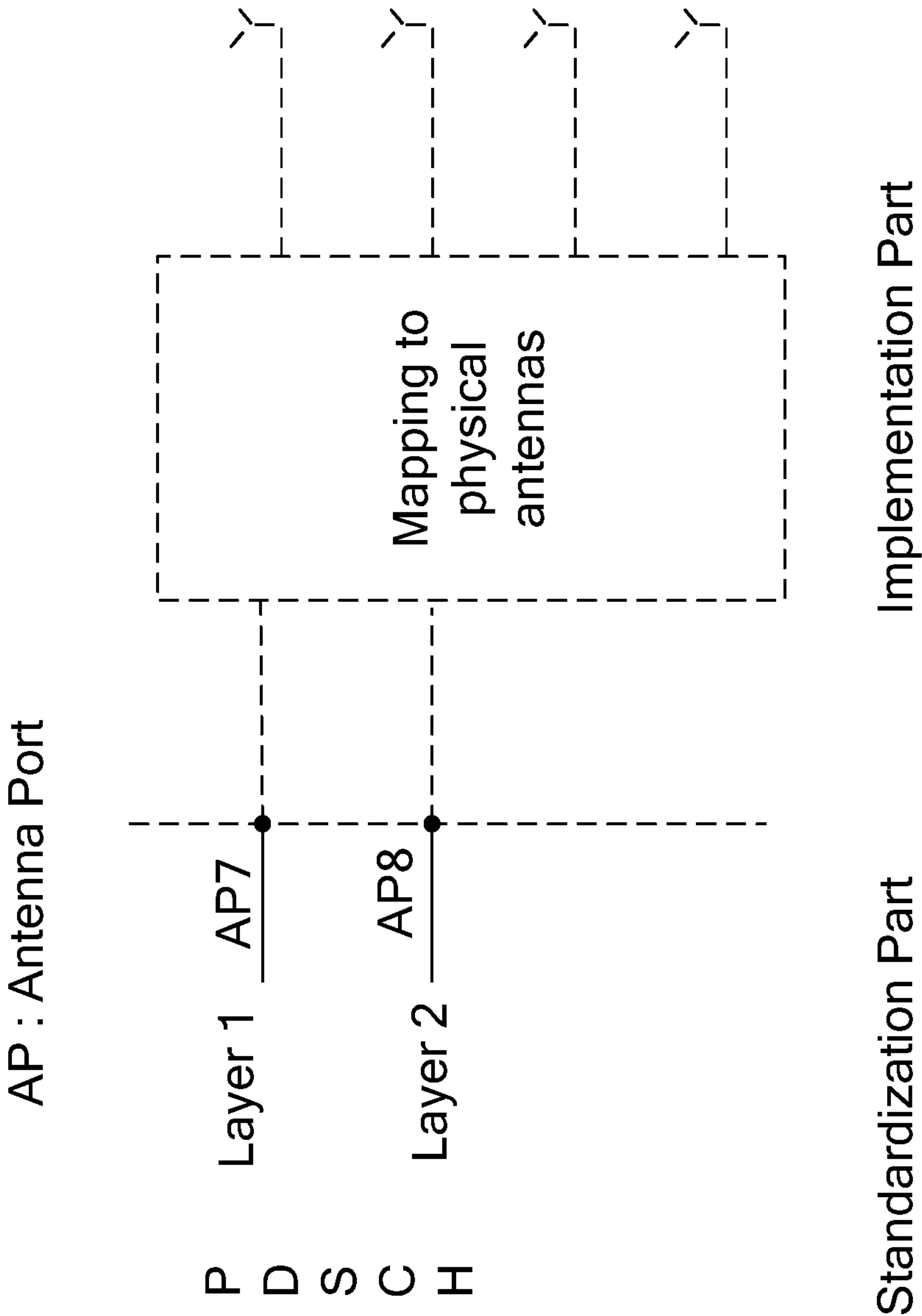


Fig. 1

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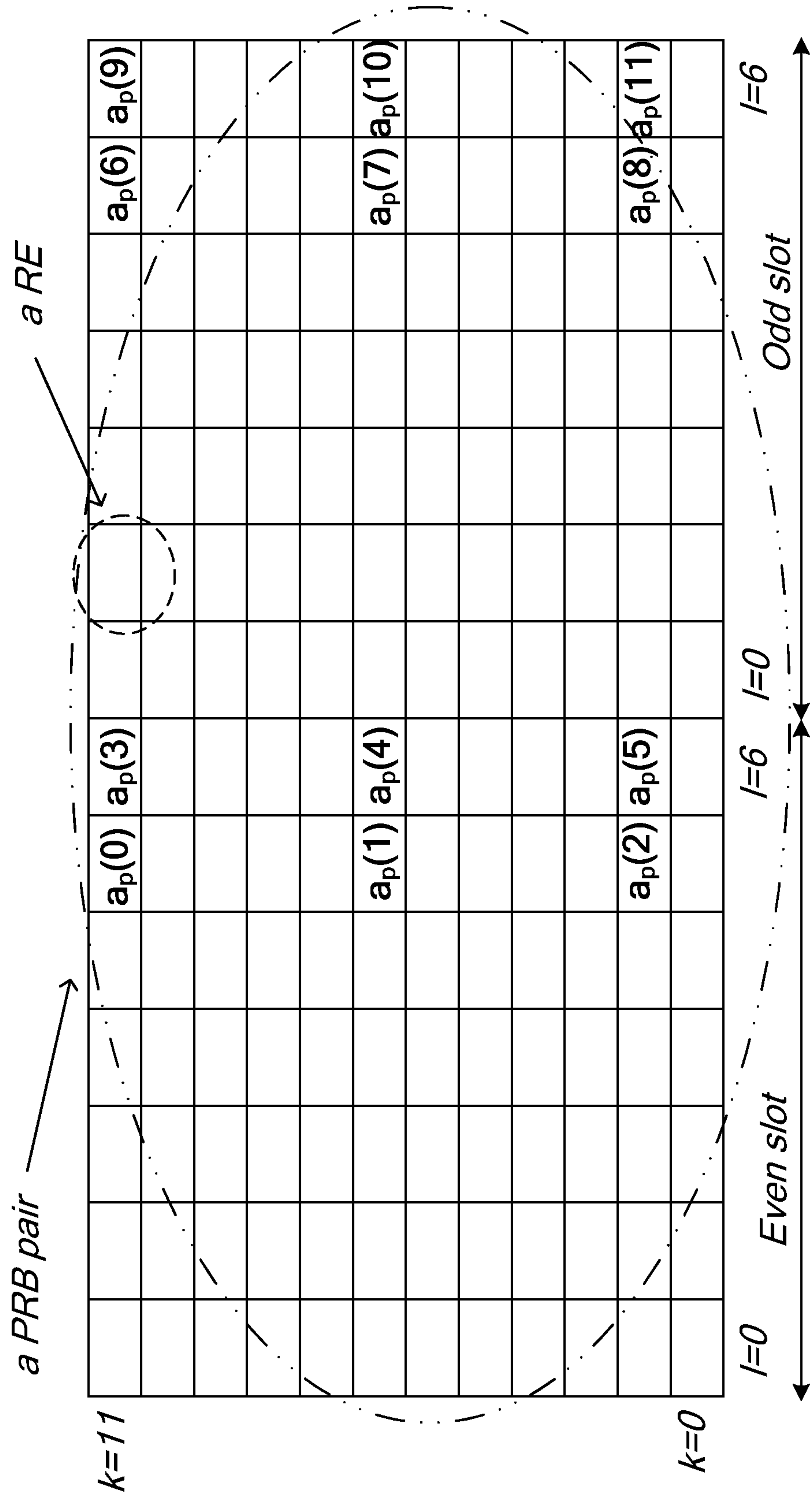


Fig. 2A

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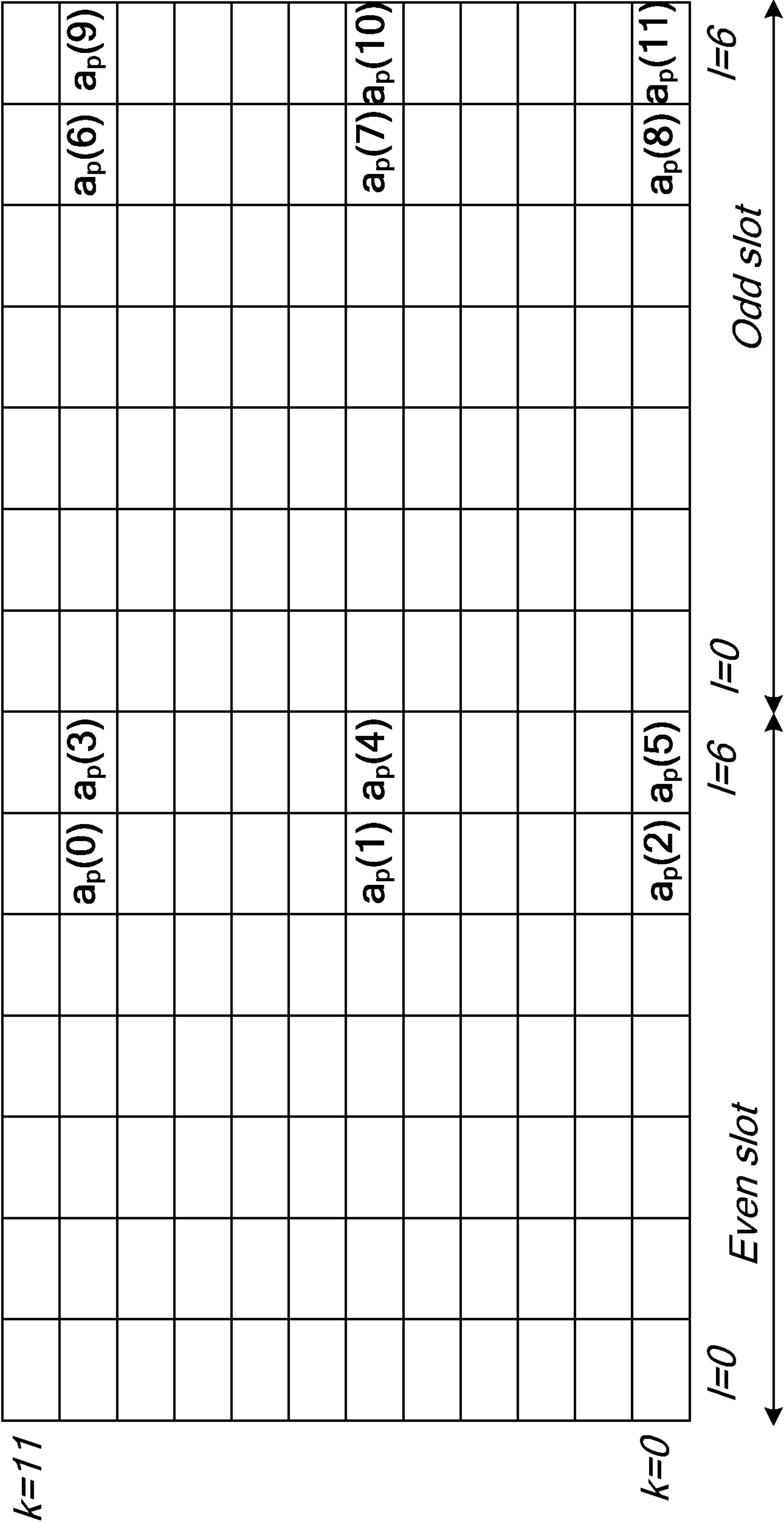


Fig. 2B

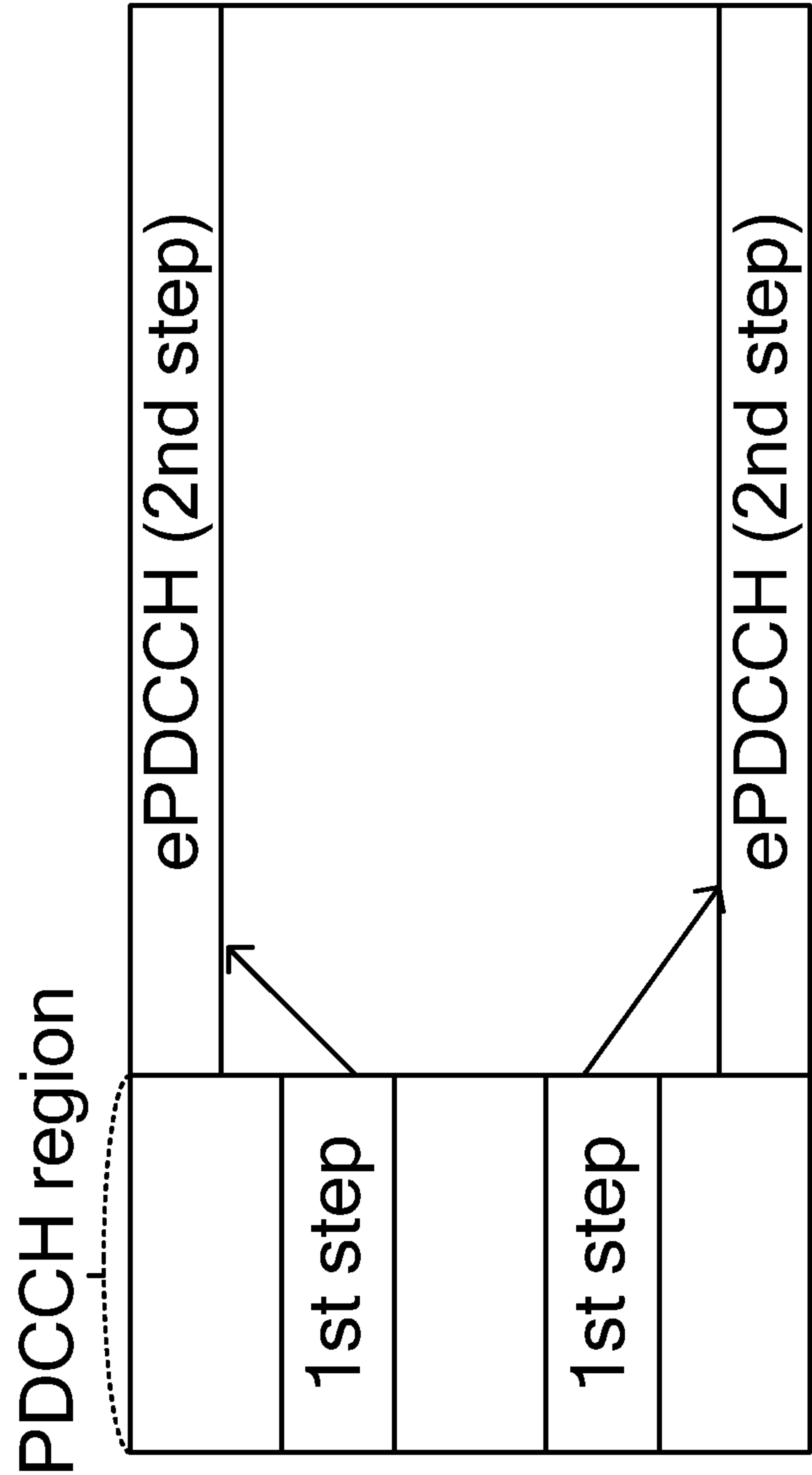


Fig. 3

