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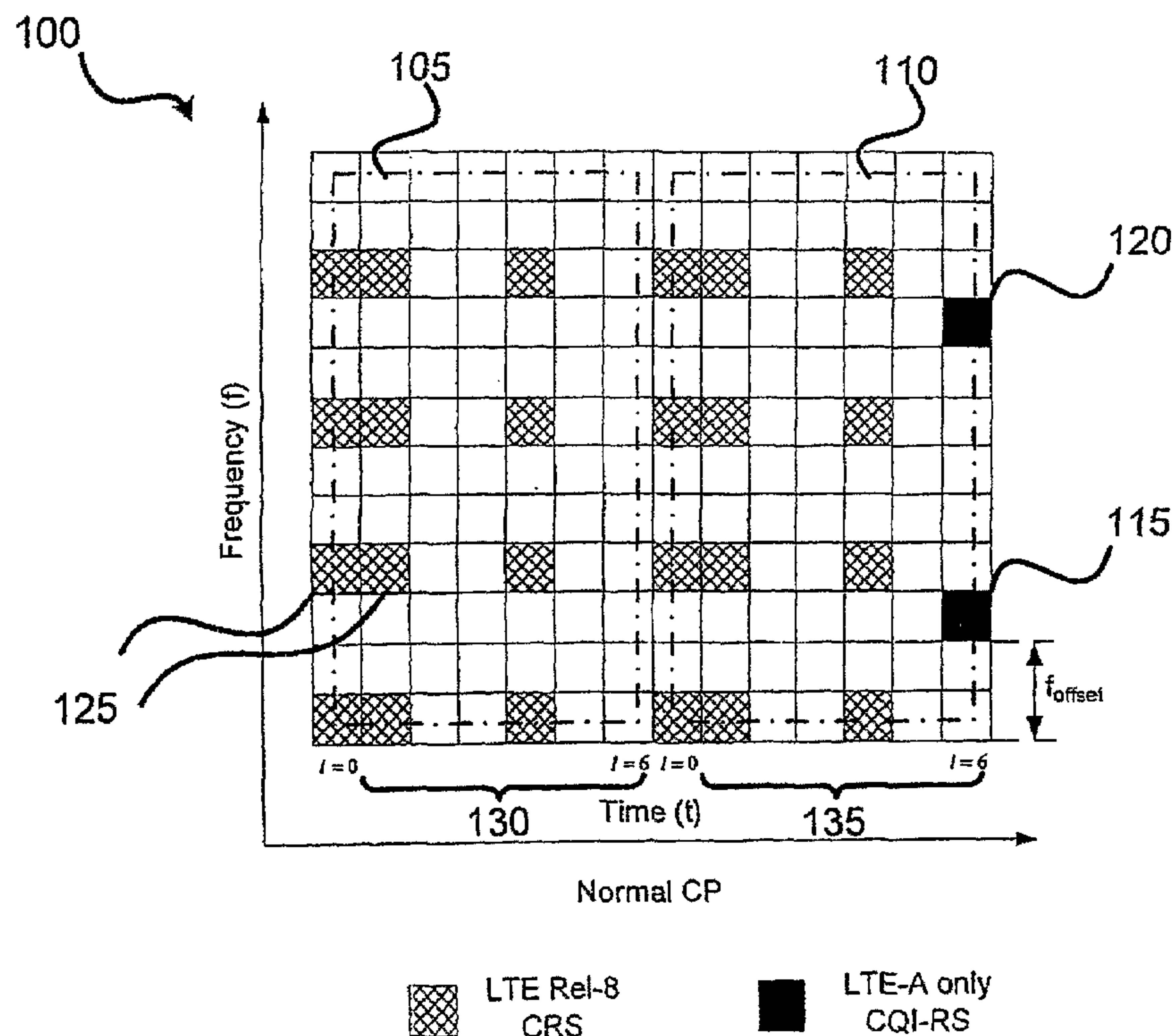
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(54) Title: IMPROVED CHANNEL QUALITY INDICATOR METHOD

Fig.1A



(57) **Abrégé/Abstract:**

It would be to provide a method which will work with future versions of LTE-A, be backwards compatible and alleviate interference to signals for basic system operation. The method includes generating one or more Reference Signals associated with the one or more Channel Quality Indicators, and includes mapping the one or more Channel Quality Indicator-Reference Signals to the last symbol of the second slot of the one or more subframes.

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- [Continued on next page]*

Figure 1 is a time-frequency resource grid diagram. The vertical axis is labeled "Frequency (f)" and the horizontal axis is labeled "Time (t)". The grid is divided into subcarriers and symbols. A legend at the bottom indicates that cross-hatched cells represent "LTE Rel-8 CRS" and solid black cells represent "LTE-A only CQI-RS". The diagram shows a pattern of CRS and CQI-RS across the grid, with a frequency offset f_{offset} indicated for the CQI-RS. The grid is divided into two main sections, 130 and 135, which are further divided into subcarriers labeled $l=0$ and $l=6$. The grid is also divided into two main sections, 105 and 110, which are further divided into subcarriers labeled $l=0$ and $l=6$. The grid is also divided into two main sections, 125 and 120, which are further divided into subcarriers labeled $l=0$ and $l=6$.

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DESCRIPTION

IMPROVED CHANNEL QUALITY INDICATOR METHOD

Technical Field

5 The present invention relates to wireless communications systems, and more particularly to a method for determining and transmitting Channel Quality Indicator Reference Signals (CQI-RS) from one or more subframes such that an associated User Equipment (UE) can use the CQI-RS to measure CQI.

10 Background Art

 In advanced mobile communication systems, such as the Long-Term-Evolution (LTE) system and the Long-Term-Evolution Advanced (LTE-A) system, User Equipment (UE) is utilised to measure and to report a number of parameters in the communication system including Rank Indicator (RI), Channel Quality Indicator (CQI) or Precoding Matrix Indicator (PMI) to the
15 evolved Node B (eNB) thereby enabling support of resource allocation, link adaptation and spatial multiplexing transmission.

 Currently, LTE (Release-8) RI, CQI/PMI measurement is performed based on the cell-specific reference signals (CRS). Each CRS is associated with transmit antenna ports at the eNB (there is a maximum of 4 transmit antenna ports). Therefore, the maximum number of
20 transmission layers that can be supported for spatial multiplexing is limited by the number of antenna ports available (i.e. 4).

 It is envisaged that for LTE-A (Release-10), the number of antenna ports used for spatial multiplexing or the number of transmission layers should be up to 8. Therefore, more Reference Signals are needed to enable the support of higher-order MIMO transmission.

25 Further, a new technology under consideration for LTE-A is Coordinated Multi-Point (CoMP) transmission. The LTE-A UE may therefore also be required to measure and report the RI, CQI/PMI (or similar metric) for the Reference Signal transmitted from the eNBs that participate in CoMP transmission.

 A problem with this increase in complexity is the possibility of interference to signals
30 important for basic system operation together with backward compatibility issues on older UEs.

 It would therefore be desirable to provide a method which will work with future versions of LTE-A, be backwards compatible and alleviate interference to signals for basic system operation.

 It will be appreciated that a reference herein to any matter which is given as prior art is

not to be taken as an admission that that matter was, in Australia or elsewhere, known or that the information it contains was part of the common general knowledge as at the priority date of the claims forming part of this specification.

5 Disclosure of the Invention

A improved channel quality indicator method for determining and transmitting one or more Channel Quality Indicator Reference Signals from one or more subframes such that an associated User Equipment can use the Channel Quality Indicator Reference Signals to measure Channel Quality Indicator, the subframes including first and second slots, each of the first and
10 second slots including a plurality of symbols, and each of the first and second slots forming a resource block, wherein the method comprising:

generating one or more Reference Signals associated with the one or more Channel Quality Indicators;

mapping the one or more Channel Quality Indicator-Reference Signals to the last symbol
15 of the second slot of the one or more subframes.

The following description refers in more detail to the various features and steps of the present invention. To facilitate an understanding of the invention, reference is made in the description to the accompanying drawings where the invention is illustrated in a preferred embodiment. It is to be understood however that the invention is not limited to the preferred
20 embodiment illustrated in the drawings.

Brief Description of the Drawings

Figure 1A is a schematic diagram of a subframe having two normal Cyclic Prefix (CP) resource blocks illustrating the location of the CQI-RS for one layer;

25 Figure 1B is a schematic diagram of a subframe having two extended Cyclic Prefix (CP) resource blocks illustrating the location of the CQI-RS for one layer;

Figure 2 is a schematic diagram of a subframe having two normal Cyclic Prefix (CP) resource blocks illustrating the location of the CQI-RS for multiple layers for multiplexing via (Frequency Division Multiplexing) FDM;

30 Figure 3 is a schematic diagram of a subframe having two normal Cyclic Prefix (CP) resource blocks illustrating the location of the CQI-RS for multiple layers for multiplexing via hybrid FDM and (Code Division Multiplexing) CDM;

Figure 4 is a schematic diagram of a subframe having two normal Cyclic Prefix (CP) resource blocks illustrating the location of the CQI-RS for multiple layers for CoMP cells

multiplexed via hybrid FDM and CDM;

Figure 5 is a schematic diagram of a series of subframes illustrating use of a cell-specific subframe offset;

Figure 6 is a schematic diagram of a series of subframes illustrating use of a cell-specific subframe offset designed for CoMP cells;

Figure 7 is a schematic diagram of bandwidth of subframes illustrating the use of the resource block offset parameter RB_{offset} ; and

Figure 8 is a schematic diagram of bandwidth of subframes illustrating the use of the resource block offset parameter RB_{offset} suitable for CoMP cells.

10

Carrying Out the Invention

Exemplary embodiments of the present invention are next described in detail with reference to the accompanying figures

Referring now to Figure 1A, there is shown a subframe 100 having two normal Cyclic Prefix (CP) resource blocks 105, 110. The subframe 100 is shown with a frequency (f) axis and a time (t) axis. The resource blocks 105, 110 are transmission units which are one slot 130, 135 wide in time (t) and twelve subcarriers wide in frequency (f). Included in each of the slots 130, 135 are seven symbols along the time axis for a normal Cyclic Prefix resource block 105, 110. A number of resource elements which make up the overall resource block 105, 110 are cell-specific reference signals (CRS) 25 and first and second “Long Term Evolution – Advanced Channel Quality Indicator-Reference Signal” (LTE-A CQI-RS) 115, 120.

In operation, the CQI-RS of a layer is transmitted in last OFDM symbol (i.e. OFDM symbol number 6 in the second slot 135), in order to avoid collision with Rel-8 cell-specific reference signals (CRS), Rel-8 Dedicated Reference Signal (DRS), and Physical Broadcast Channel (PBCH) and synchronisation signals. Preferably, there are two CQI-RS REs within a resource block 105, 110 and the CQI-RSs are uniformly distributed over the 12 subcarriers of the resource block. Providing two CQI-RS REs for each layer is advantageous since it has been found to provide a good balance between CQI-RS overhead and CQI measurement performance.

Also shown in Figure 1A, is a first cell-specific subcarrier offset f_{offset} for higher-layer configurations. First f_{offset} determines the Resource Element (RE) location offset of the CQI-RS from the lowest subcarrier index in a resource block. This is shown in Figure 1A for First $f_{\text{offset}} = 2$. In the preferred case of two CQI-RS REs per resource block, First f_{offset} can take value from 0 – 5.

Figure 1B is identical to Figure 1A but illustrates a subframe 100 which includes two

extended Cyclic Prefix (CP) resource blocks 105, 110. The subframe 100 is shown with a frequency (f) axis and a time (t) axis. The resource blocks 105, 110 are transmission units which are one slot 130, 135 wide in time (t) and twelve subcarriers wide in frequency (f). Each of the slots 130, 135 are six symbols along the time axis for an extended Cyclic Prefix resource block 105, 110. In operation, the CQI-RS of a layer is transmitted in last OFDM symbol (i.e. OFDM symbol number 5 in the second slot 135).

Advantageously, by designing CQI-RS for all layers applicable to LTE-A operation to be placed in only one particular OFDM symbol within a subframe provides a simple way to avoid interference to/from Rel-8 CRS, Rel-8 DRS, and PBCH and synchronisation signals.

Figure 2 is shows a subframe 200 having two normal Cyclic Prefix (CP) resource blocks 205, 210 and further shows the preferred location of the CQI-RS for multiple layers for multiplexing via Frequency Division Multiplexing. Like Figures 1A and 1B, the subframe 200 is shown with a frequency (f) axis and a time (t) axis. The resource blocks 205, 210 are transmission units which are one slot 230, 235 wide in time (t) and twelve subcarriers wide in frequency (f). Each of the slots 230, 235 include seven symbols along the time axis for a normal Cyclic Prefix resource block 205, 210. A number of resource elements make up the resource block 205, 210 including cell-specific reference signals (CRS) 225 together with first LTE-A CQI-RS 240 (layer 1), second LTE-A CQI-RS 245 (layer 1), first LTE-A CQI-RS 250 (layer 2), second LTE-A CQI-RS 255 (for layer 2), first LTE-A CQI-RS 260 (layer 3), second LTE-A CQI-RS 265 (layer 3), first LTE-A CQI-RS 270 (layer 4) and second LTE-A CQI-RS 275 (layer 4).

In Figure 2, CQI-RS of all layers for LTE-A operation are transmitted in the same OFDM symbol (i.e. symbol number 6) for the case that the layers are multiplexed via FDM. The particular arrangement within the FDM framework is illustrative, other arrangements are possible.

Figure 3 shows a subframe 300 having two normal Cyclic Prefix (CP) resource blocks 305, 310 and further shows the preferred location of the CQI-RS for multiple layers for multiplexing via hybrid Frequency Division Multiplexing (FDM) and Code Division Multiplexing (CDM). A number of resource elements make up the resource block 305, 310 including cell-specific reference signals (CRS) 325 together with first LTE-A CQI-RS 315 (layer 1 and layer 2), second LTE-A CQI-RS 320 (layer 1 and layer 2), first LTE-A CQI-RS 340 (layer 3 and layer 4) and second LTE-A CQI-RS 345 (layer 3 and layer 4).

In Figure 3, CQI-RS of all layers for LTE-A operation are transmitted in the same OFDM symbol (i.e. symbol number 6) for the case that the layers are multiplexed hybrid via FDM and

CDM. The particular arrangement within the hybrid FDM and CDM framework is illustrative, other arrangements are possible.

Figure 4 shows a subframe 400 having two normal Cyclic Prefix (CP) resource blocks 405, 410 illustrating the location of the CQI-RS for multiple layers for CoMP cells multiplexed via hybrid FDM and CDM. In operation, the CQI-RS of a layer is transmitted in last OFDM symbol (i.e. OFDM symbol number 6 in the second slot 435), in order to mitigate CQI-RS intercell interference. The intercell interference is further reduced by including a first cell-specific subcarrier offset First f_{offset} and a second cell-specific subcarrier offset Second f_{offset} . First f_{offset} determines the Resource Element (RE) location offset of the CQI-RS from the lowest subcarrier index of a resource block for Cell-1. This is shown in Figure 4 for First $f_{\text{offset}} = 2$. Second f_{offset} determines the Resource Element (RE) location offset of the CQI-RS from the lowest subcarrier index of a resource block for Cell-2. This is shown in Figure 4 for Second $f_{\text{offset}} = 4$. Therefore, LTE-A CQI-RS are as follows: first LTE-A CQI-RS 440 (layer 1 and 2 for cell 1), second LTE-A CQI-RS 445 (layer 1 and 2 for cell 1), first LTE-A CQI-RS 450 (layer 3 and 4 for cell 1), second LTE-A CQI-RS 455 (layer 3 and 4 for cell 1), first LTE-A CQI-RS 460 (layer 1 and 2 for cell 2), second LTE-A CQI-RS 465 (layer 1 and 2 for cell 2), first LTE-A CQI-RS 470 (layer 3 and 4 for cell 2) and second LTE-A CQI-RS 475 (layer 3 and 4 for cell 2).

Advantageously, f_{offset} allows for robust intercell interference management for CoMP CQI-RS transmission.

Transmission period configuration of LTE-A only CQI-RS

Figure 5 is a schematic diagram of a series of subframes 500 illustrating use of a cell-specific subframe offset S_{offset} 510 and the CQI-RS transmission period, $T_{\text{CQI-RS.505}}$. $T_{\text{CQI-RS.505}}$ is the same as the CQI/PMI reporting period for LTE Rel-8, i.e. 2ms, 5ms, 10ms, 20ms, 40ms, 80ms and 160ms for Frequency Division Duplex (FDD), and 1ms, 5ms, 10ms, 20ms, 40ms, 80ms and 160ms for Time Division Duplex (TDD). However, $T_{\text{CQI-RS.505}}$ is cell-specific while the CQI/PMI reporting period is UE-specific, hence the configuration of $T_{\text{CQI-RS.505}}$ and CQI/PMI reporting period are independent. In practice, the CQI/PMI reporting period is generally not shorter than $T_{\text{CQI-RS.505}}$.

Higher-layer configured cell-specific subframe offset S_{offset} 510 determines the subframe offset for CQI-RS transmission relative to subframe 0 within a frame. S_{offset} takes the value from 0ms to $(T_{\text{CQI-RS}} - 1)$ ms. Figure 5 shows a $T_{\text{CQI-RS.505}}$ of 2ms and S_{offset} of 1ms.

Advantageously, $T_{\text{CQI-RS.505}}$ is useful in controlling the CQI-RS overhead whereas

SFOffset 510 is useful for mitigating CQI-RS intercell interference among CoMP cells.

Figure 6 shows a series of subframes 600 and illustrates an example of how SFOffset can be used to avoid CQI-RS of different CoMP cells being transmitted in the same subframe. In this case Cell-1 SFOffset 625 has a value of 1ms and Cell-2 SFOffset 610 has a value of 0ms and a $T_{\text{CQI-RS},605}$ of 2ms.

Resource block allocation for LTE-A only CQI-RS

The CQI-RS subband which may be denoted k is defined in the similar way as the CQI-reporting subband for LTE Rel-8. The CQI-RS subband size or equivalently the total number of resource blocks that contain CQI-RS is determined based on the system bandwidth for a single component carrier, similar to the CQI-reporting subband size determination for LTE Rel-8. Specifically, the CQI-RS subband size is determined as shown in Table 1.

System Bandwidth of a single component carrier	CQI-RS Subband Size, k
6 - 7	Entire system bandwidth
8 - 10	4
11 - 26	4
27 - 63	6
64 - 110	8

Table 1: CQI-RS Subband Size k vs. System Bandwidth of a single component carrier

There is only one resource block in a CQI-RS subband that contains CQI-RS. With this in mind, Figure 7 shows a schematic diagram of bandwidth (20Mhz) of subframes 700 (having eight resource blocks in each subband 715) illustrating the use of the resource block offset parameter RBOffset_{710} . Each subband 715 includes a resource block 705 which contains CQI-RS (the subband size = 8 resource blocks). The exact location of the resource block that contains CQI-RS is determined by the parameter RBOffset_{710} . RBOffset ranges from 0 to $k-1$.

RBOffset_{710} can be either configured by a higher-layer or can cycle from the first resource block to the last resource block within the subband as subframe number increments (i.e. round-robin allocation of the CQI-RS to the resource blocks within the subband).

Advantageously, the parameter RBOffset can also be used to mitigate CQI-RS intercell

interference among CoMP cells as shown in Figure 8. In Figure 8 there shown a Cell-1 RBoffset 820 and a Cell-2 RBoffset 825 within a subband 815. The two offsets are used to avoid CQI-RS of different CoMP cells being transmitted in the same resource block. In case of the round-robin assignment, collision can be avoided by configuring different starting position for different
5 CoMP cell for the round-robin operation.

Advantageously, there is only one resource block in a CQI-RS subband that contains CQI-RS. The total number of resource blocks that contain CQI-RS is determined based on the system bandwidth for a single component carrier. Advantageously, the resource blocks containing CQI-RS are uniformly distributed over the system bandwidth which means it is able
10 to cover the entire system bandwidth (within a component carrier). This is known as the “wideband” requirement in LTE-A. In a further advantage, the arrangement minimises the impact on legacy User Equipment (e.g. LTE Rel-8) by minimising the number of resource blocks that contains CQI-RS within a subband.

Although the exemplary embodiments of the invention have been disclosed for
15 illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible without departing from the scope of the present invention. Therefore, the present invention is not limited to the above-described embodiments but is defined by the following claims.

This application is based upon and claims the benefit of priority from Australian
20 provisional patent application No. 2009901196 filed on March 19, 2009 the disclosure of which is incorporated herein in its entirety by reference.

Claims

1. A improved channel quality indicator method for determining and transmitting one or more Channel Quality Indicator Reference Signals from one or more subframes such that an associated User Equipment can use the Channel Quality Indicator Reference Signals to measure Channel Quality Indicator, the subframes including first and second slots, each of the first and second slots including a plurality of symbols, and each of the first and second slots forming a resource block, wherein the method comprising:
- generating one or more Reference Signals associated with the one or more Channel Quality Indicators;
- mapping the one or more Channel Quality Indicator-Reference Signals to the last symbol of the second slot of the one or more subframes.
2. The improved channel quality indicator method according to claim 1, comprising, before said mapping, providing one or more subcarrier frequency offsets for Channel Quality Indicator Reference Signals from the lowest subcarrier index in a resource block.
3. The improved channel quality indicator method according to claim 2, wherein the subcarrier frequency offset is an integer in the range of 0 to 5.
4. The improved channel quality indicator method according to claim 1, wherein two Channel Quality Indicator Reference Signals are included within the resource block.
5. The improved channel quality indicator method according to claim 4, wherein the two Channel Quality Indicator Reference Signals are uniformly distributed over the sub-carriers associated with the resource block.
6. The improved channel quality indicator method according to any of claims 1 to 5, wherein a Coordinated Multi-Point cell transmitted in the same resource block, and said method further comprising, before said mapping, providing a first subcarrier frequency offset for a first Coordinated Multi-Point cell and a second subcarrier frequency offset for a further Coordinated Multi-Point cell.
7. The improved channel quality indicator method according to any of claim 1 to 6, further

comprising providing the Channel Quality Indicator Reference Signals with a transmission period, $T_{\text{CQI-RS}}$.

8. The improved channel quality indicator method according to claim 7, wherein $T_{\text{CQI-RS}}$ is
5 equal to a CQI/PMI reporting period.

9. The improved channel quality indicator method according to claim 8, wherein the CQI/PMI reporting period is any of 2ms, 5ms, 10ms, 20ms, 40ms, 80ms and 160ms for Frequency Division Duplex.
10

10. The improved channel quality indicator method according to claim 8, wherein the CQI/PMI reporting period is any of 1ms, 5ms, 10ms, 20ms, 40ms, 80ms and 160ms for Time Division Duplex.

15 11. The improved channel quality indicator method according to any of claims 1 to 10, further comprising providing a subframe offset for higher-layers wherein the subframe offset for Channel Quality Indicator Reference Signals transmission is relative to subframe 0 within a frame.

20 12. The improved channel quality indicator method according to claim 11, wherein said subframe offset takes the value from 0ms to $(T_{\text{CQI-RS}} - 1)$ ms.

13. The improved channel quality indicator method according to any of claims 1 to 12, further comprising:

25 determining the total number of resource blocks that contain Channel Quality Indicator Reference Signals;

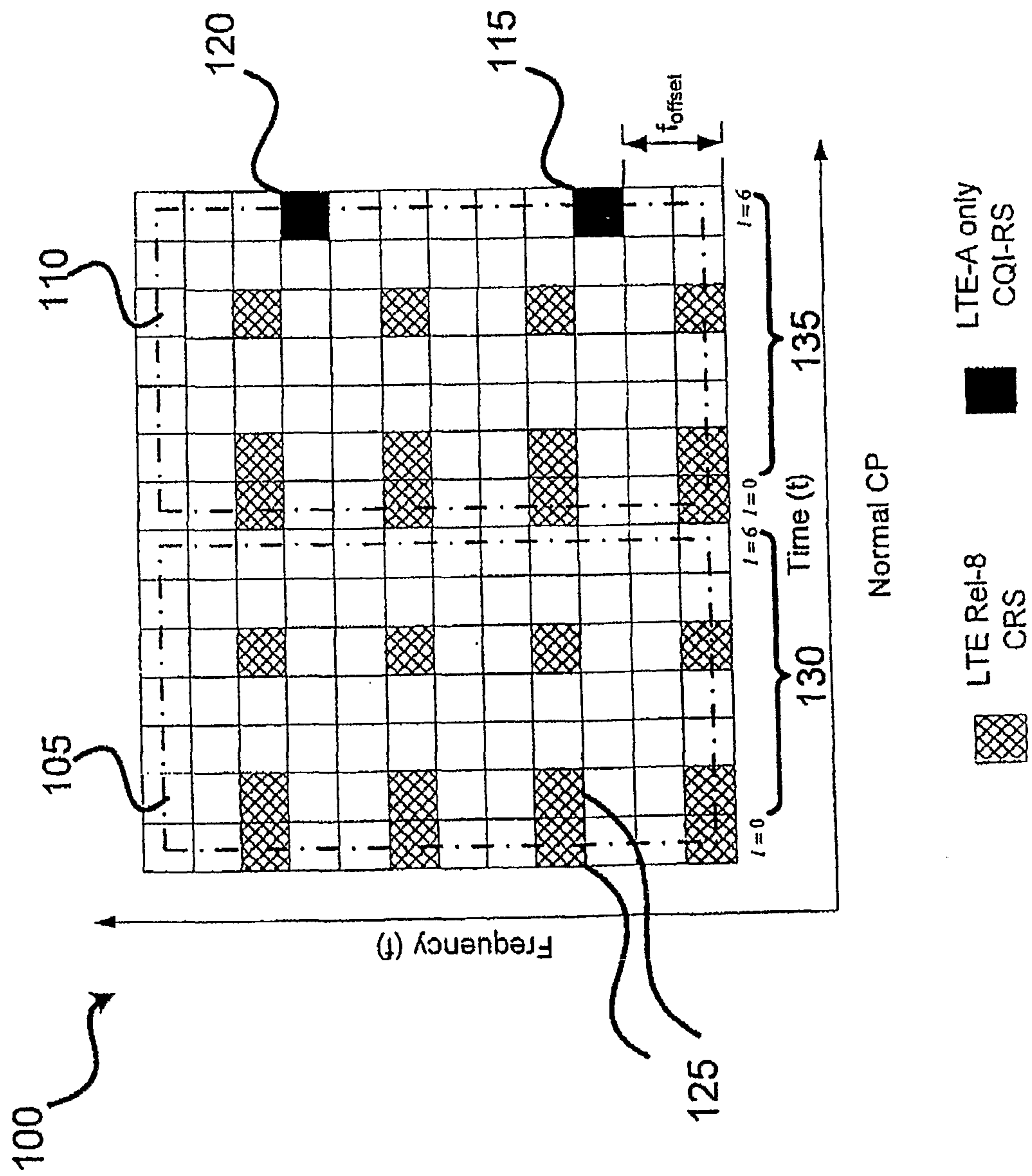
determining the total number of resource blocks that contain Channel Quality Indicator Reference Signals based on the system bandwidth for a single component carrier, wherein the location of the resource block that contains Channel Quality Indicator Reference Signals is
30 determined by a parameter $\text{RB}_{\text{offset}}$

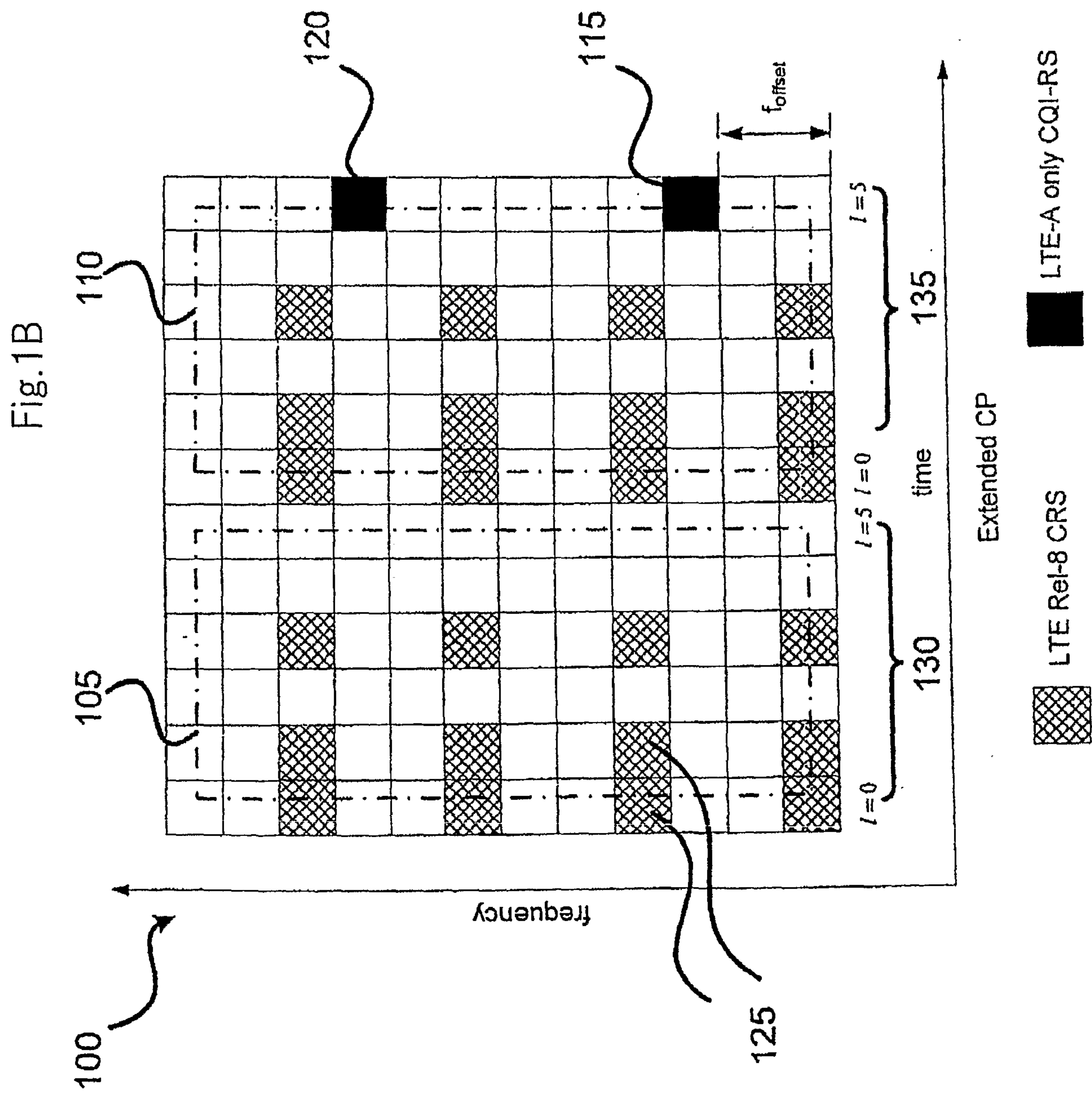
14. The improved channel quality indicator method according to claim 13, wherein $\text{RB}_{\text{offset}}$ ranges from 0 to $k-1$, where k is the hannel Quality Indicator Reference Signals subband size.

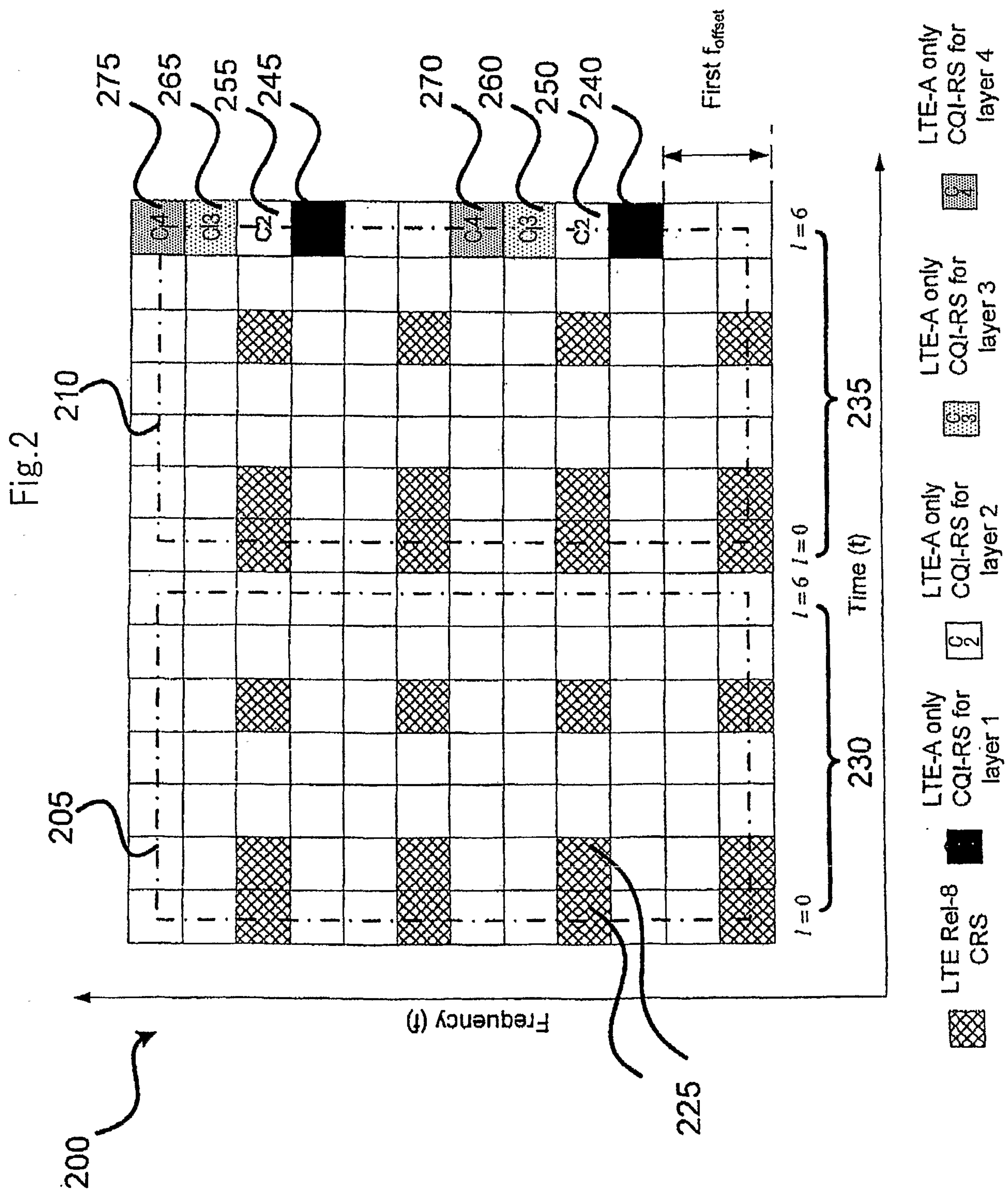
15. The improved channel quality indicator method according to claim 14, wherein RB_{offset} is configured by a higher-layer.
16. The improved channel quality indicator method according to claim 14, wherein RB_{offset} is
5 configured by cycling from the first resource block to the last resource block within the subband as subframe number increments.

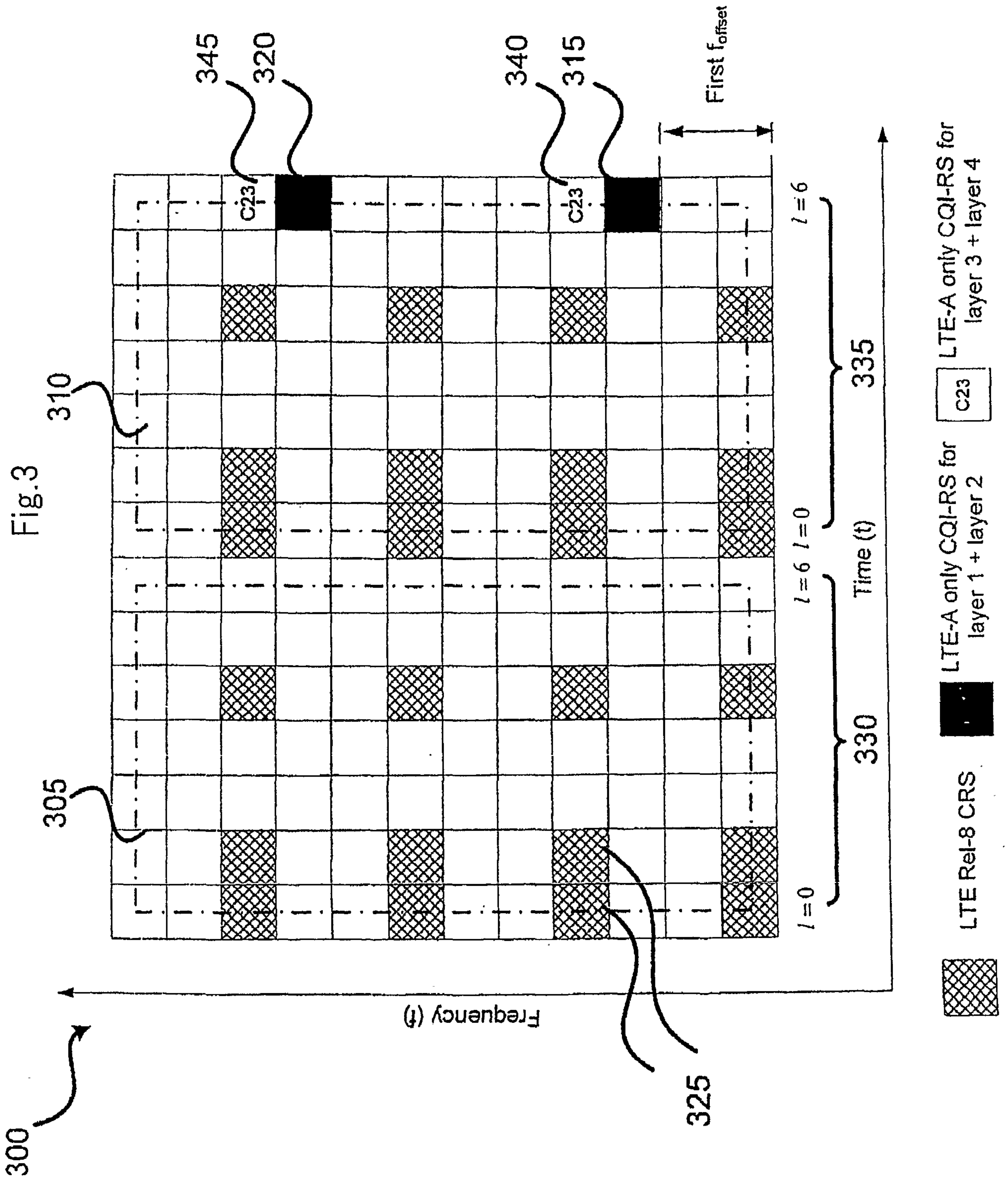
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Fig. 1A









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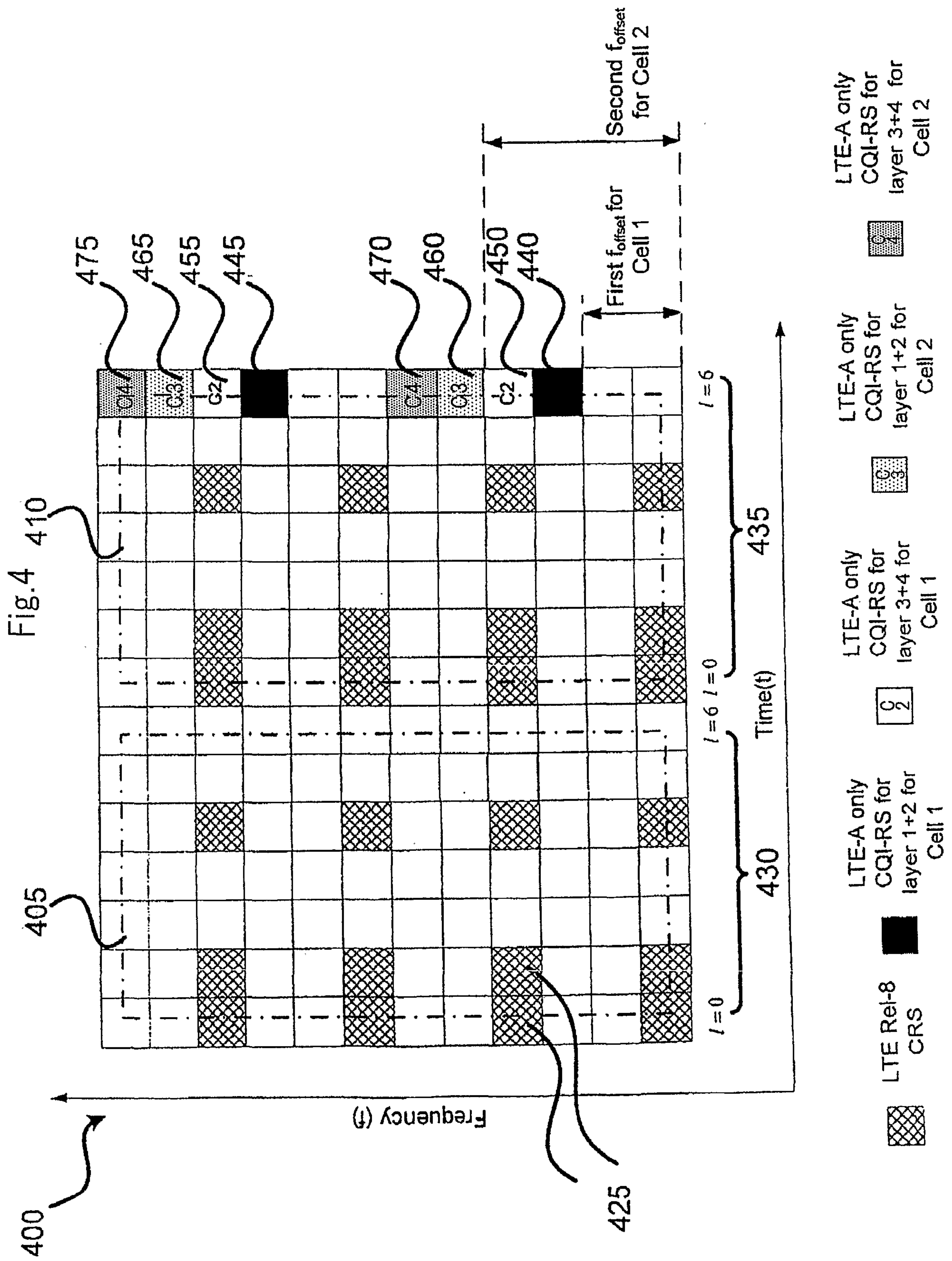
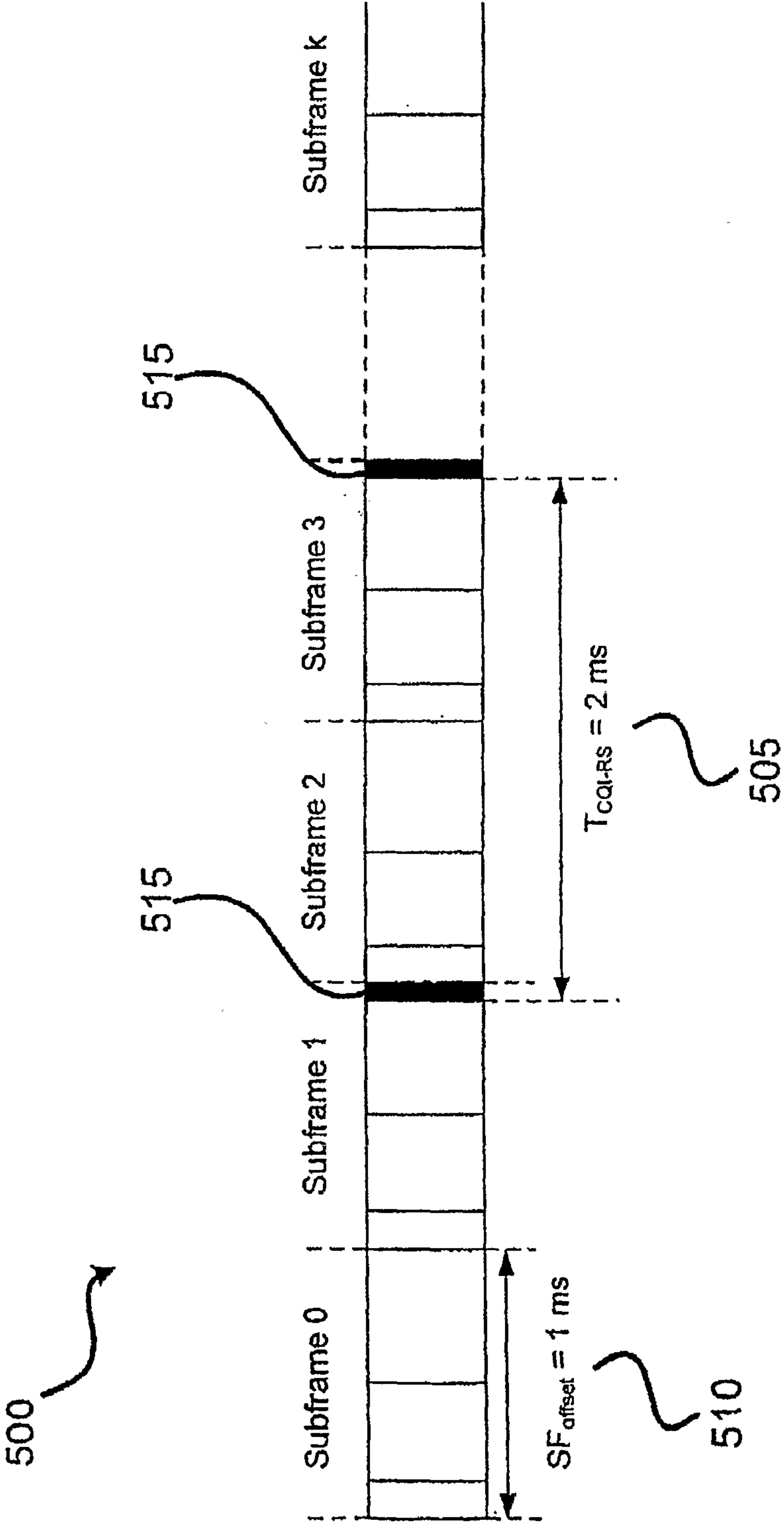


Fig.5



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Fig.6

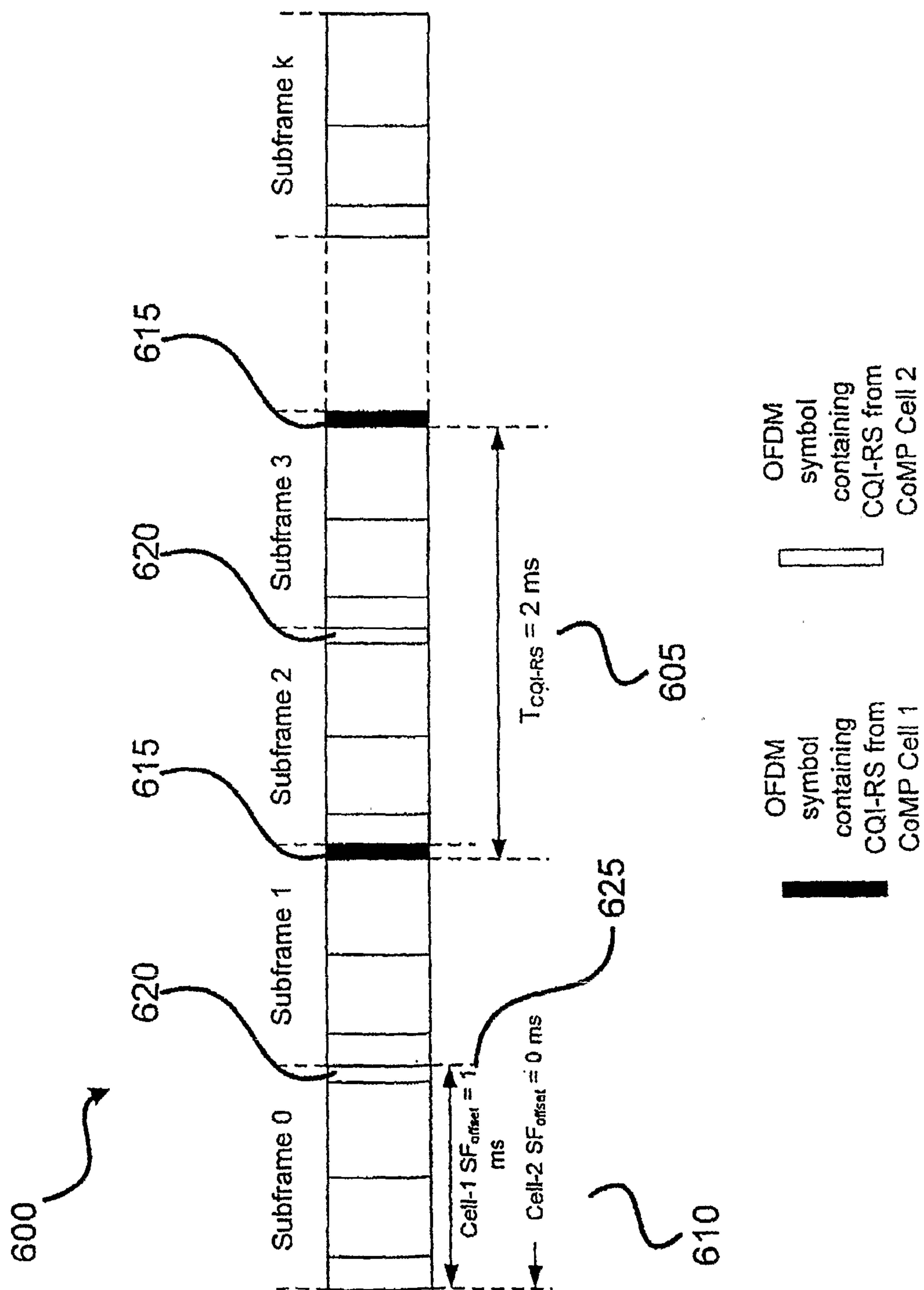
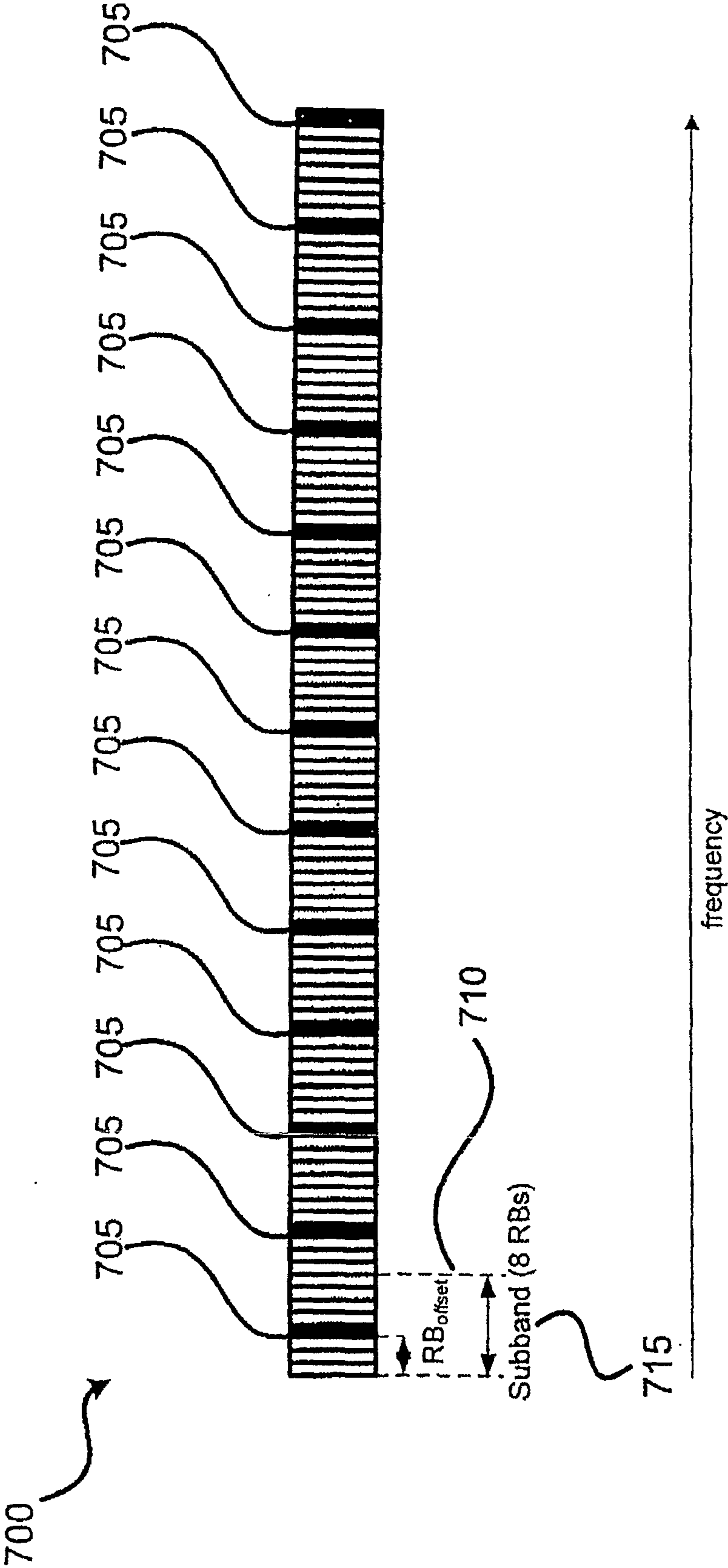


Fig.7



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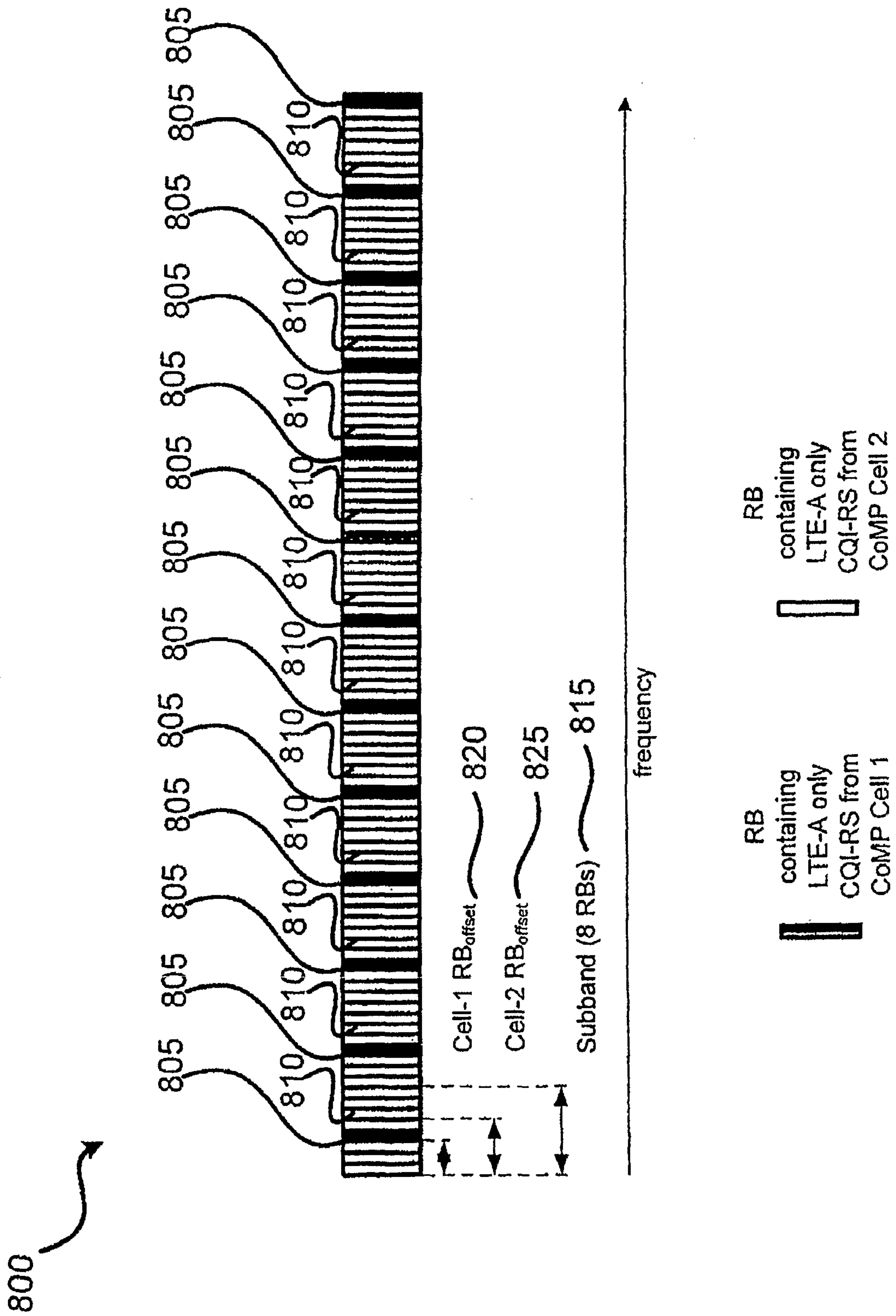


Fig.1A

