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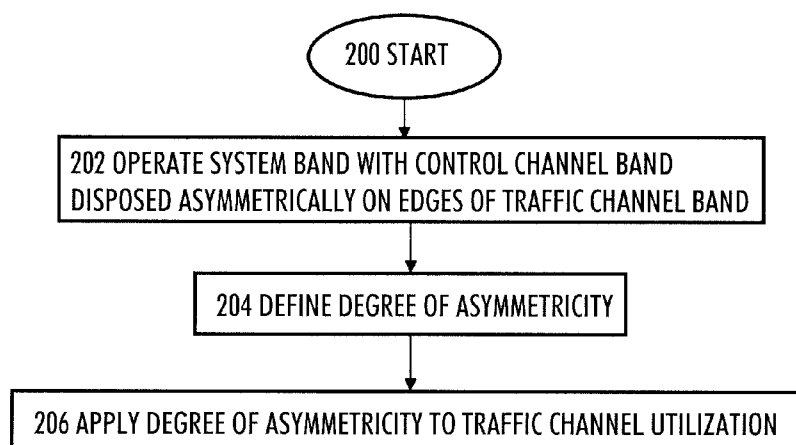


Fig 2

(57) **Abstract:** A method, apparatus, and computer program for controlling utilization of a system band in a cellular communication system are presented. In the system band, a control channel band is arranged asymmetrically at the edges of a traffic channel band in a frequency domain. The asymmetry is taken into account in the channel utilization by defining a degree of asymmetry describing an offset of a center frequency of the traffic channel band from a center frequency of the system band, and by controlling utilization of the traffic channel band according to the defined degree of asymmetry.

Controlling Cellular Communication Resources

Field

The invention relates to the field of cellular radio telecommunications and, particularly, to operating a system bandwidth having a specific structure.

5 Background

A communication system known as an evolved UMTS (Universal Mobile Telecommunication System) terrestrial radio access network (E-UTRAN, also referred to as UTRAN-LTE for its long-term evolution) is currently under development within the 3GPP. In this system, the downlink radio access
10 technique will be OFDMA (Orthogonal Frequency Division Multiple Access), and the uplink radio access technique will be Single-Carrier FDMA (SC-FDMA) which is a type of a linearly pre-coded OFDMA. The uplink system band has a structure where a Physical Uplink Control Channel (PUCCH) is arranged at both edges of a Physical Uplink Shared Channel (PUSCH) which is used for transmission of
15 uplink user traffic. The PUCCH carries uplink control information such as ACK/NACK messages, channel quality indicators (CQI) and scheduling request indicators (SRI). Efficient and flexible utilization in operating the system bandwidth is of paramount importance.

Brief description

20 According to an aspect of the present invention, there is provided a method as specified in claim 1.

According to another aspect of the present invention, there is provided an apparatus as specified in claim 13.

25 According to another aspect of the present invention, there is provided a user terminal of a cellular telecommunication system as defined in claim 25.

According to another aspect of the present invention, there is provided a base station of a cellular telecommunication system as defined in claim 26.

According to another aspect of the present invention, there is provided an apparatus as specified in claim 27.

30 According to yet another aspect of the present invention, there is provided a computer program product embodied on a computer readable distribution medium as specified in claim 28.

Embodiments of the invention are defined in the dependent claims.

List of drawings

Embodiments of the present invention are described below, by way of example only, with reference to the accompanying drawings, in which

Figure 1A illustrates communication between a mobile terminal and a
5 mobile telecommunication system in a cell;

Figure 1B illustrates an example of a structure of a system band in a system where embodiments of the invention may be implemented;

Figure 2 illustrates a process for controlling utilization of the system band according to an embodiment of the invention;

10 Figure 3 illustrates an asymmetric structure of the system band;

Figure 4 illustrates frequency hopping implemented in the asymmetric system band according to an embodiment of the invention;

Figure 5 illustrates a fragmented system band;

15 Figure 6 illustrates processing fragmented frequency resources according to an embodiment of the invention; and

Figure 7 illustrates an apparatus according to an embodiment of the invention.

Description of embodiments

20 The following embodiments are exemplary. Although the specification may refer to "an", "one", or "some" embodiment(s) in several locations, this does not necessarily mean that each such reference is to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

A general architecture of a cellular telecommunication system
25 providing voice and data transfer services to mobile terminals is illustrated in Figures 1A and 1B. Figure 1A illustrates a generic scenario of cellular communications where a base station 100 provides user terminals 110 to 122 with wireless communication services within a cell 102. The base station 100 may belong to a radio access network of a long-term evolution (LTE) of the
30 UMTS (Universal Mobile Telecommunication System) and, therefore, support OFDMA and SC-FDMA as radio access schemes for downlink and uplink, respectively. The base station is connected to other parts of the cellular telecommunication system, such as a mobility management entity (MME) controlling mobility of the user terminals, one or more gateway nodes through
35 which data is routed, and an operation and maintenance server configured to

control certain communication parameters, as is known in the art.

Figure 1B illustrates a generic structure of an uplink system band allocated to a network operator for providing uplink communication services according to LTE Releases 8 and 9. The system band is structured such that a traffic channel, i.e. a physical uplink shared channel (PUSCH), is allocated in the middle of the system band with a control channel, i.e. a physical uplink control channel (PUCCH), is allocated to both edges of the traffic channel band. The size of the control channel band is configurable by the base station 100 and, therefore, the base station may be configured to over-dimension the size of the control channel in the cell 102 and leave frequency resource blocks reserved for the control channel at the edges of the system band blank in order to accommodate other communication systems on neighboring bands or to assign a higher bandwidth to the PUSCH. In other words, more resource blocks is allocated to the control channel than what is actually needed, and a portion of the control channel resource blocks is left blank. Blanked resource blocks can be defined as PUCCH resource blocks not used as PUCCH resource blocks. A frequency resource block may comprise a determined number of subcarriers, e.g. 12. Blanking the outer frequency resource blocks has been introduced into Release 8 of the LTE as a symmetric operation, i.e. the same number of frequency resource blocks is left blank at both edges of the system band. Such a symmetric blanking is clearly sub-optimal in the case there is a need to blank one edge of the system band more than the other, e.g. due to the existence of another system on a neighboring band.

In order to better address these issues, support for asymmetric blanking is advantageous. There is, however, a problem with using asymmetric blanking or asymmetric channel allocation in general. Certain channel utilization algorithms are based on using a center frequency (and possibly a bandwidth) as a point of reference in current LTE versions. For example, frequency hopping algorithms (patterns) are implemented with respect to the center frequency of the system band, because the PUSCH is located at the center of the system band. The same applies to the allocation of a sounding reference signal (SRS) which is sharing the physical frequency domain resources with the PUSCH. SRS is used to provide information on uplink channel quality on a wider bandwidth than the current PUSCH transmission (PUSCH and PUCCH is not transmitted simultaneously in LTE) or when terminal has no transmissions on PUSCH. UE specific SRS bandwidth does not typically cover the whole SRS bandwidth. In

order to sound wider bandwidths, SRS transmission can also hop in frequency. This is particularly beneficial for the terminals on cell edge which cannot support wideband SRS transmissions. The hopping pattern of the SRS varies over sub-frames so that it may cover different set of sub-carriers in consecutive periodic transmissions. The SRS allocation algorithms are presented in 3GPP specification TS 36.211 (section 5.5.3).

Current 3GPP specifications for Release 8 describe a number of different frequency hopping schemes. The schemes are basically divided into two types of PUSCH hopping schemes (Type 1 and Type 2), as defined in the 3GPP specifications TS 36.213 (section 8.4.1) for Type 1 and TS 36.211 for Type 2 (section 5.3.4). Type 1 includes mirrored hopping where frequency hopping of a given user terminal is implemented between two sets of frequency resource blocks having an equal distance to the center frequency (or center frequency resource block in case of odd number of resource blocks) of the system band, i.e. located symmetrically with respect to the center frequency (resource block). Type 1 includes also another frequency hopping scheme including a number of different predefined frequency hopping patterns allocated by a base station with one or two bits (depending on the selected scheme and on the system bandwidth). Type 2 includes predefined configurable frequency hopping patterns. In a time domain, two frequency-hopping modes are defined that are configurable cell-specifically by higher layers. The frequency hopping may be implemented on a sub-frame level or even more rapidly within a sub-frame on a time slot level (a sub-frame includes two time slots). In other words, the transmission may occur in a different set of frequency resource block in consecutive sub-frames or time slots (according to the selected mode) according to the selected hopping pattern. In the case of inter sub-frame only frequency hopping, transmission may occur on a different set of frequency resource blocks in consecutive HARQ (hybrid automatic repeat request) (re-)transmission numbers of the same HARQ process so as to ensure that a retransmission does not use the same (fading) resources as the original transmission. Several of the current hopping patterns are arranged with respect to the center frequency of the system band and, therefore, the hopping patterns are not as such suitable for asymmetric blanking where the location of the PUSCH band (and/or PUCCH band) is asymmetric with respect to the system band. And even those patterns that are not always fully symmetrical with respect to the center frequency of the system band, do not take into account the asymmetric blanking. Therefore, some

of the hopping PUSCH resources located at the edge of the PUSCH band have to be excluded from frequency hopping in order to support blanking. This is sub-optimal.

With reference to a flow diagram of Figure 2, an embodiment of the present invention alleviates the asymmetry problem in a process for controlling utilization of the system band allocated to uplink communications in a cell. Naturally, the same procedure applies also to downlink direction in systems where similar problems are present. The process of Figure 2 starts in block 200. In block 202, a system band is operated, wherein a control channel band is arranged asymmetrically with respect to the system bandwidth at the edges of a traffic channel band by means of frequency domain multiplexing between traffic channel and control channel. In block 204, a degree of asymmetry describing an offset of the center frequency of the traffic channel band is defined from the center frequency of the system band. Alternatively, the asymmetry or offset of the traffic channel band may be counted as a number of non-traffic channel frequency resource blocks from upper and/or lower edges of the system bandwidth. In block 206, the utilization of the traffic channel band is controlled according to the defined degree of asymmetry.

This can be implemented by modifying the algorithms in the user terminal and the base station so as to support the asymmetric allocation of PUCCH and PUSCH bands with respect to the system band. Signaling and resource allocation may be kept intact and no modification to Release 8 control signaling is necessary. Additionally, utilization of the entire PUSCH band is available for frequency hopping, because the algorithms are modified to accommodate the degree of asymmetry between the PUSCH band and the system band. Moreover, the SRS may be allocated by taking into account the available PUSCH band.

The process or method described in Figure 2 may also be carried out in the form of a computer process defined by a computer program. The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in a carrier, which may be any entity or device capable of carrying the program. Such carriers include a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital processing unit or it may be distributed amongst a number of processing

units.

Figure 3 illustrates asymmetric allocation of PUSCH band and PUCCH band with respect to the system band. Each block represents an uplink frequency resource block, and the total number of resource blocks is N_{rb} , wherein the number of resource blocks depends on the system bandwidth, e.g. 6 for 1.4 MHz system bandwidth, 15 for 3 MHz system bandwidth, 25 for 5 MHz system bandwidth, 50 for 10 MHz system bandwidth, 75 for 15 MHz system bandwidth, and 100 for 20 MHz system bandwidth. An incrementally increasing number is assigned to frequency resource blocks of the system band, starting from one edge of the system band. As can be seen in Figure 3, resource blocks 0, 1, 2 at the lower edge of the system band are left blank, as is a resource block $N_{rb}-1$ at a higher edge of the system band. Obviously, the location of the PUCCH and PUSCH is now asymmetric with respect to the system band, because the center frequencies of the bands, i.e. system band and traffic channel band, are not the same. According to an embodiment of the invention, this asymmetry is taken into account in frequency hopping patterns and SRS allocation on the PUSCH band. PUSCH frequency hopping algorithms are modified so that offset terms determined according to the asymmetry are included in the algorithms. The offset terms may be defined by using the number of blanked frequency resource blocks at the upper edge of the system band $N_{RB}^{bl_upper}$ and the number of blanked frequency resource blocks at the lower edge of the system band $N_{RB}^{bl_lower}$ as offset terms. These offset terms may also be used when modifying an offset term defining the location of the SRS in the PUSCH band in an SRS allocation. Changes to each frequency hopping pattern type as well as to an SRS configuration are discussed in detail below.

A resource allocation field related to the configuration of the frequency hopping pattern and transmitted from the base station to a given user terminal comprises a resource indication value corresponding to a starting resource block (RB_{start}) and the size of the hopping resource in terms of contiguously allocated resource blocks (L_{CRBs}). RB_{start} defines the lowest frequency resource block of the frequency hopping band and L_{CRBs} defines the number of frequency resource blocks counted into the frequency hopping band, starting from the frequency resource block indicated by L_{CRBs} . In the case of asymmetric PUSCH and PUCCH configuration, a starting resource block for a first frequency hop is modified with an offset term determined according to the asymmetry as

$$RB'_{START} = RB_{START} + N_{RB}^{bl_lower} \quad (1)$$

Accordingly, the starting resource block for a first frequency hop is pushed from the lower edge of the system band by the number of blank resource blocks at the lower edge of the system band. The starting resource block for a second
 5 frequency hop is calculated as:

$$RB'_{START} = N_{RB} - L_{CRBs} - RB_{START} - N_{RB}^{bl_upper} \quad (2)$$

Similarly, the starting resource block for the second frequency hop is pushed from the higher edge of the system band by the number of blank resource blocks at the higher edge of the system band. Equations (1) and (2) define the
 10 frequency resources to be used in Type 1 mirrored frequency hopping. This is illustrated in Figure 4. In a conventional solution, the second frequency hop would use the frequency resource blocks mirrored with respect to the center frequency of the system band. This would result in one of the hopping resources being allocated to the PUCCH band, unless the hopping resources are limited at
 15 the edges of the PUSCH band (not desired). Once the algorithms have been corrected according to the asymmetry of the PUSCH band with respect to the system band, the mirrored frequency hopping is implemented with respect to the center frequency of the PUSCH band, which results in efficient utilization of the PUSCH band for frequency hopping.

20 This idea could be generalized as a process where the location of the traffic channel band in the system band is defined by the number of non-traffic channel frequency resource blocks or blank control channel frequency blocks at each edge of the system band. In the latter example using the number of blank control channel frequency blocks, it is assumed that the number of actual (non-
 25 blanked) control channel frequency resource blocks at each edge of the traffic channel band is known.

The other frequency hopping algorithms are modified in a similar manner by taking into account the number of blank PUCCH resource blocks at upper and lower edges of the system band. For example, the other Type 1 frequency
 30 hopping algorithm is modified as follows. First, the maximum number of frequency resource blocks available for the frequency hopping is defined as $\lfloor 2^y / N_{RB} \rfloor$, where y is the number of bits used for indicating the pattern (y equals one or two). As in the mirrored hopping, the set of frequency resource blocks to be used for frequency hopping is defined by RB_{start} and L_{CRBs} , and the starting
 35 resource block for a first frequency hop may be calculated as:

$$RB'_{START} = RB_{START} + \left\lfloor N_{RB}^{PUCCH} / 2 \right\rfloor + N_{RB}^{bl_lower}, \quad (3)$$

where RB_{start} is the starting or virtual resource block received in resource allocation. Accordingly, the resource allocation itself need not be modified. In this scheme, RB_{start} is first pushed by the number of PUCCH resource blocks at the lower edge of the system band (division by two indicates that symmetric PUCCH placement with respect to the PUSCH band is assumed) and then pushed again by the number of blank resource blocks at the lower edge of the system band. The second hopping PUSCH frequency resource is calculated as:

$$RB'_{START} = \tilde{n}_{PRB} + \left\lfloor N_{RB}^{PUCCH} / 2 \right\rfloor + N_{RB}^{bl_lower}, \quad (4)$$

where $\tilde{n}_{PRB}$ is the starting or virtual resource block determined from the RB_{start} according to the applied frequency hopping pattern for the second hopping resource.

Type 2 PUSCH frequency hopping may be modified accordingly. In the case of asymmetric PUSCH and PUCCH configuration, the size of the frequency-hopping sub-band, i.e. the number of frequency resource blocks used in the frequency hopping, may be re-defined by considering the number of blank resource blocks at each edge of the system band. First, the maximum number of frequency resource blocks available for the frequency hopping is defined as $\min(\left\lfloor 2^y / N_{RB} \right\rfloor, \left\lfloor N_{RB}^{PUSCH} / N_{sb} \right\rfloor)$, where y is the number of bits used for indicating the pattern (y equals one or two), N_{sb} is the number of frequency-hopping sub-bands configured by the higher layer, and N_{RB}^{PUSCH} is the number of frequency resource blocks on the hopping PUSCH band defined as:

$$N_{RB}^{PUSCH} = N_{RB} - N_{RB}^{PUCCH} - N_{RB}^{bl_lower} - N_{RB}^{bl_upper}, \quad (5)$$

where N_{RB}^{PUCCH} is the number of frequency resource blocks on the PUCCH band.

The size of each sub-band may be defined as:

$$N_{RB}^{sb} = \begin{cases} N_{RB} - N_{RB}^{bl_lower} - N_{RB}^{bl_upper} & N_{sb} = 1 \\ \left\lfloor (N_{RB} - N_{RB}^{PUCCH} - N_{RB}^{PUCCH} - N_{RB}^{bl_lower} - N_{RB}^{bl_upper} \bmod 2) / N_{sb} \right\rfloor & N_{sb} > 1 \end{cases} \quad (6)$$

Here, the frequency resource blocks associated with the PUCCH may also be used in the frequency hopping when $N_{sb}=1$, when no PUCCH is transmitted. As in the case of Type 1 PUSCH hopping, the number of PUSCH resource blocks used for frequency hopping are reconfigured to take into account the number of blank resource blocks at both edges of the system band. This is carried out

according to the following equation:

$$N_{RB}^{PUSCH} = N_{RB} - N_{RB}^{PUCCH} - N_{RB}^{bl_lower} - N_{RB}^{bl_upper} \quad (7)$$

The actual pattern type of Type 2 frequency hopping may be kept intact, i.e. it may be implemented in a conventional manner as

$$\begin{aligned} \tilde{n}_{PRB}(n_s) &= (\tilde{n}_{VRB} + f_{hop}(i) \cdot N_{RB}^{sb} + ((N_{RB}^{sb} - 1) - 2(\tilde{n}_{VRB} \bmod N_{RB}^{sb})) \cdot f_m(i)) \bmod N_{RB}^{sb} \cdot N_{sb} \\ 5 \quad i &= \begin{cases} \lfloor n_s/2 \rfloor & \text{inter-subframe hopping} \\ n_s & \text{intra and inter-subframe hopping} \end{cases} \end{aligned} \quad (8)$$

where f_{hop} defines the frequency hopping function, and f_m defines whether or not to use mirroring with respect to the center frequency (of the PUSCH in the embodiments considering the asymmetry). The definitions for a physical frequency resource block n_{PRB} and a virtual resource block $\tilde{n}_{VRB}$ may, however be redefined. LTE specifications of 3GPP define the merits of both physical and virtual frequency blocks and mapping tables showing how they are linked to each other, so it will not be discussed herein in greater detail. The physical resource block n_{PRB} and the virtual resource block $\tilde{n}_{VRB}$ for the Type 2 frequency hopping algorithm is re-defined as

$$\begin{aligned} n_{PRB}(n_s) &= \begin{cases} \tilde{n}_{PRB}(n_s) + N_{RB}^{bl_lower} & N_{sb} = 1 \\ \tilde{n}_{PRB}(n_s) + \lceil N_{RB}^{PUCCH}/2 \rceil + N_{RB}^{bl_lower} & N_{sb} > 1 \end{cases} \\ \tilde{n}_{VRB} &= \begin{cases} n_{VRB} - N_{RB}^{bl_lower} & N_{sb} = 1 \\ n_{VRB} - \lceil N_{RB}^{PUCCH}/2 \rceil - N_{RB}^{bl_lower} & N_{sb} > 1 \end{cases} \end{aligned} \quad (9)$$

where n_s is a time slot index, $\tilde{n}_{PRB}$ is the virtual PUSCH resource block after a frequency hop, and n_{VRB} is the virtual resource block obtained from the initial resource allocation.

As mentioned above, the SRS allocation may also be adjusted to take into account the asymmetric location of the PUSCH and PUCCH bands with respect to the system band. This can be achieved by including the number of blank resource blocks in the upper and lower edges of the system band in the SRS configuration algorithm. This effectively narrows the bandwidth of the SRS in proportion to the total number of blank resource blocks and shifts the location of the SRS signal according to the distribution of the blank resource blocks to the upper and lower edge of the system band. The frequency domain starting position k_0 of the SRS is defined according to the LTE specifications as:

$$k_0 = k'_0 + \sum_{b=0}^{B_{SRS}} 2M_{sc,b}^{RS} n_b \quad (10)$$

where $M_{sc,b}^{RS}$ is the length of the SRS sequence, n_b is a frequency position index, B_{SRS} is a user terminal specific SRS bandwidth defined by the base station. Now, k'_0 is defined as

$$k'_0 = \left(\left\lfloor (N_{RB} - N_{RB}^{bl_lower} - N_{RB}^{bl_upper}) / 2 \right\rfloor + N_{RB}^{bl_lower} - m_{SRS,0} / 2 \right) N_{SC}^{RB} + k_{TC} \quad (11)$$

where $m_{SRS,0}$ is defined according to the number of uplink resource blocks available for PUSCH, N_{SC}^{RB} is the resource block size in the frequency domain, expressed as a number of subcarriers, and k_{TC} is an offset value given to each user terminal by the higher layers according to the shape of the SRS sequence ("transmission comb" referring to the comb-shaped spectrum of SRS). With respect to the equations (10) and (11), the frequency domain starting position k_0 of the SRS is offset according to the number of blank resource blocks at both the upper and lower edge of the system band.

The embodiments described above describe the PUSCH frequency hopping and SRS configuration in the case of an asymmetric PUSCH and PUCCH configuration and only a single PUSCH band in the system band. The embodiments may be modified to support a structure of the system band where the PUSCH band is fragmented into a plurality of fragments. As mentioned above, the blanked frequency resource blocks at the edge of the system band may be used as additional PUSCH bands, or the PUSCH may be fragmented into a plurality of fragments for other reasons. One or more PUCCH bands and/or blank frequency resource blocks may be disposed between the PUSCH fragments, as illustrated in Figure 5.

The asymmetry of the PUSCH and PUCCH bands may be considered in this case of fragmented PUSCH bands by defining a degree of asymmetry of each PUSCH fragment, the degree of asymmetry describing an offset of the center frequency of the PUSCH fragment from the center frequency of the system band, and by controlling utilization of the PUSCH fragment according to the defined degree of asymmetry. Alternatively, the offset can be counted for upper or lower edges of the PUSCH fragment from the upper or lower edges of the system bandwidth.

With respect to frequency hopping patterns, each PUSCH may be processed separately by applying to each fragment an offset value offsetting the

fragment from the center frequency of the system band, or by offsetting the lower and/or upper edges of the fragment from the corresponding edges of the system band. In this case, the number of blank resource blocks at upper and lower edges of the first fragment may be removed from the equations above. As a consequence, when considering the first traffic channel fragment of Figure 5, i.e. the one in the highest frequency resource blocks, an offset value corresponding to the offset of the center frequency of the first fragment band from the center frequency of the system band may be applied to the frequency hopping patterns, thereby replacing $N_{RB}^{bl_upper}$ and $N_{RB}^{bl_lower}$ in the frequency hopping equations.

The third fragment is processed in a similar manner but the offset is naturally applied to the other direction from the center frequency of the system band.

The second fragment in the middle of the system band may be processed by considering the other fragments as blank resource blocks and, thereby, adding the number of resource blocks in the first fragment to $N_{RB}^{bl_upper}$ and the number of resource blocks in the third fragment to $N_{RB}^{bl_lower}$.

In an alternative embodiment, the fragments are considered as a single logical PUSCH fragment. First, the PUSCH fragments are combined to form a single fragment, as illustrated in Figure 6. The order of the fragments may be arranged according to the numbering of the resource blocks. Then, the combined PUSCH resource blocks may be mapped to have a new numbering as illustrated in Figure 6. The original numbering is on the left hand side of the PUSCH resource blocks, and the renumbering is illustrated on the right hand side of the resource blocks. The renumbering may take into account the number of blank and/or PUCCH resource blocks and, thus, the lowest renumbered PUSCH resource block may have a number other than zero, and the numbering may increase incrementally from that to $N_{rbv}-1$, which represents the highest PUSCH resource block. Now, the frequency hopping pattern may be applied to the combined PUSCH band and, thereafter, the mapping may be removed by restoring the original numbering of the resource blocks.

Similarly, the SRS configuration may be carried out individually for each PUSCH fragment or over multiple fragments. Let us first consider configuration of the SRS for each fragment individually. The frequency domain starting position k_0 is modified according to the location of each fragment on the system band. For the first fragment at the higher frequencies, equations (10) and (11) take the following form:

$$k_0 = k'_{0,upper} + \sum_{b=0}^{B_{SRS}} 2M_{sc,b}^{RS} n_b \quad (12)$$

$$k'_{0,upper} = \left(\left\lfloor N_{RB}^{PUSCH_upper} / 2 \right\rfloor + N_{RB}^{UL} - N_{RB}^{PUSCH_upper} - m_{SRS_upper,0} / 2 \right) N_{SC}^{RB} + k_{TC} \quad (13)$$

where $m_{SRS_upper,0}$ is configured for the first segment by the base station according to the number of uplink resource blocks in the third fragment from the available SRS bandwidth sets, as defined in the LTE specifications. Further, $M_{sc,b}^{RS}$ values are also defined according to the SRS bandwidth set configured for the first segment. The second fragment in the middle of the system band is processed by assuming the resource blocks of the first and third fragment as blank resource blocks, as was done when describing the frequency hopping for the second fragment above. The third resource block at the lower edge of the system band is configured with the following equations:

$$k_0 = k'_{0,lower} + \sum_{b=0}^{B_{SRS}} 2M_{sc,b}^{RS} n_b \quad (14)$$

$$k'_{0,lower} = \left(\left\lfloor N_{RB}^{PUSCH_lower} / 2 \right\rfloor - m_{SRS_lower,0} / 2 \right) N_{SC}^{RB} + k_{TC} \quad (15)$$

where $m_{SRS_lower,0}$ is configured for the third segment by the base station according to the number of uplink resource blocks in the third fragment from the available SRS bandwidth sets as defined in the LTE specifications. Further, $M_{sc,b}^{RS}$ values are also according to the SRS bandwidth set configured for the third segment, as defined in the LTE specifications.

On a broadcast channel, the base station may broadcast information about on which PUSCH fragments cell-specific SRS region is supported, as well as the SRS bandwidth set for each PUSCH fragment. This information defines, for example, the values for m_{SRS_upper} and m_{SRS_lower} parameters according to specified table values stored in the user terminals. The base station may broadcast the SRS bandwidth set separately for each fragment, or the bandwidth set of the other fragments may be signaled in relation to the bandwidth set of the central fragment. In other words, the bandwidth set of the central fragment may be signaled explicitly, and the bandwidth set of the other fragments may be signaled as a difference from the bandwidth set of the central fragment or as a difference from a maximum bandwidth left available for the upper/lower fragments. An SRS configuration specific to a given user terminal and transmitted by the base station may indicate to which fragment the user terminal is allocated, so the user terminal may calculate the SRS configuration according

to the corresponding equation.

For the configuration of the SRS over multiple fragments, the frequency domain starting position k_0 may be calculated, as described above with respect to the separate processing of fragments. As is known in relation to the transmission of the SRS, a cell-specific sub-frame offset is defined relative to a frame. The sub-frame offset defines the transmission periods of the SRS in the sub-frames. In the case of a fragmented PUSCH, each fragment may be assigned a different sub-frame offset so that the transmission of the SRS occurs in different sub-frames in different PUSCH fragments. For example, a sub-frame offset of '0' may be assigned to the central (second) fragment, sub-frame offset of '1' may be assigned to the upper (first) fragment, and sub-frame offset of '2' may be assigned to the lower (third) fragment. On the user terminal side, this fragment-specific sub-frame offset may be predetermined and applied to the cell-specific and terminal-specific sub-frame offsets received from the base station depending on which fragment the user terminal is configured to use. Therefore, there is no need to change the existing signaling scheme in this context.

Figure 7 illustrates the structure of an apparatus in which embodiments of the invention may be implemented. The apparatus may be configured to operate in a base station or in a user terminal, and the actual implementation may be modified accordingly. In its most basic form, the apparatus may be considered as a processor controlling communications in a cellular communication system. The apparatus comprises an interface 706 to transmit and receive signals from external components. The interface 706 may be considered as a physical interface which exchanges signals between two separate physical components, e.g. between two signal processing units. Alternatively, the interface 706 may be an interface between two software modules communicating with each other. The apparatus further comprises a memory unit 702 configured to store communication parameters and other operational parameters needed in controlling the communications.

The apparatus further comprises a frequency hop controller 704 and a radio resource allocation controller 700. These two controllers 700, 704 may be included in a logically single communication controller configured to carry out the process of Figure 2. The radio resource allocation controller 700 may be configured to determine utilization of the radio resources on the system band. When the apparatus is implemented in the base station, the radio resource allocation controller 700 may be configured to determine the number of blanked

resource blocks at the edges of the system band and to send corresponding information through the interface 706 to user terminals. Additionally, the radio resource allocation controller 700 may determine fragmentation of the PUSCH bands and broadcast corresponding information, as described above. The radio resource allocation controller 700 may also allocate the user terminals to PUSCH bands and to select SRS configurations for the user terminals. Consequently, the radio resource allocation controller 700 configures the signal reception components of the base station to receive SRS signals from the user terminals according to the SRS configurations. When the apparatus is implemented in the user terminal, the radio resource allocation controller 700 receives through the interface 700 information on the structure of the system band, PUSCH allocation for the user terminal, and the SRS configuration. Accordingly, the radio resource allocation controller 700 configures the user terminal to transmit the SRS on the basis of the received information by taking into account the asymmetry of the PUSCH and PUCCH bands, as described above.

When the apparatus is implemented in the base station, the frequency hop controller 702 allocates frequency hopping patterns to the user terminals. Furthermore, the frequency hop controller 702 configures receiver components of the base station to apply the selected frequency hopping pattern for each user terminal by taking into account the asymmetric location of the PUSCH and PUCCH with respect to the system band, as described above. Accordingly, the frequency hop generator may select a hopping pattern of Type 1 or Type 2 and then select a corresponding hopping algorithm and appropriate equations (1) to (9) so as to configure the receiver to receive signals from correct resource blocks at correct time instants with respect to a given user terminal.

When the apparatus is implemented in the user terminal, the frequency hop controller 702 receives a frequency hopping pattern from the base station in a control message. Furthermore, the frequency hop controller 702 configures transmitter components of the user terminal to apply the selected frequency hopping pattern by taking into account the asymmetric location of the PUSCH and PUCCH with respect to the system band, as described above. Accordingly, the frequency hop generator 702 may select a hopping algorithm corresponding to the allocated hopping pattern and select appropriate equations (1) to (9) so as to configure the transmitter to transmit signals in correct resource blocks at correct time instants.

The apparatus of Figure 7 may be implemented by one or more

processors. In practice, even the memory unit 702 may be external to the apparatus and replaced with an additional signaling link to the external memory unit in the interface 706. The term 'processor' refers to a device that is capable of processing data. The processor may comprise an electronic circuit implementing the required functionality, and/or a microprocessor running a computer program implementing the required functionality. When designing the implementation, a person skilled in the art will consider the requirements set for the size and power consumption of the apparatus, the necessary processing capacity, production costs, and production volumes, for example. The processor may comprise logic components, standard integrated circuits, microprocessor(s), and/or application-specific integrated circuits (ASIC).

The microprocessor implements functions of a central processing unit (CPU) on an integrated circuit. The CPU is a logic machine executing a computer program, which comprises program instructions. The program instructions may be coded as a computer program using a programming language, which may be a high-level programming language, such as C, Java, etc., or a low-level programming language, such as a machine language, or an assembler. The CPU may comprise a set of registers, an arithmetic logic unit (ALU), and a control unit. The control unit is controlled by a sequence of program instructions transferred to the CPU from a program memory. The control unit may contain a number of microinstructions for basic operations. The implementation of the microinstructions may vary, depending on the CPU design. The microprocessor may also have an operating system (a dedicated operating system of an embedded system, or a real-time operating system), which may provide the computer program with system services.

The present invention is applicable to the cellular or mobile telecommunication system defined above but also to other suitable telecommunication systems. The protocols used, the specifications of mobile telecommunication systems, their network elements and subscriber terminals develop rapidly. Such development may require extra changes to the described embodiments. Therefore, all words and expressions should be interpreted broadly and they are intended to illustrate, not to restrict, the embodiment. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Claims

1. A method comprising:
operating a system band where a control channel band is arranged
asymmetrically at the edges of a traffic channel band in a frequency domain;
5 defining a degree of asymmetry describing an offset of a center
frequency of the traffic channel band from a center frequency of the system
band; and
controlling utilization of the traffic channel band according to the
defined degree of asymmetry.
- 10 2. The method of claim 1, further comprising: configuring utilization of
the traffic channel band with respect to the center frequency of the traffic channel
band offset from the center frequency of the system band by the degree of
asymmetry.
- 15 3. The method of claim 1 or 2, further comprising: defining a location
of the traffic channel band in the system band by the number of non-traffic
channel frequency resource blocks at each edge of the system band.
4. The method of claim 3, further comprising: defining the location of
the traffic channel band in the system band by the number of blank control
channel frequency resource blocks at each edge of the system band.
- 20 5. The method according to any one of claims 1 to 4, further
comprising: applying the degree of asymmetry to a frequency-hopping pattern
defining frequency resource allocation for one or more user terminals.
6. The method of claim 5, wherein the frequency-hopping resources
for a given user terminal are allocated symmetrically with respect to the center
25 frequency of the traffic channel band.
7. The method of claim 5 or 6, wherein frequency hopping of a given
user terminal is implemented between two sets of frequency resource blocks
having an equal minimum distance of the frequency resource block allocation to
an edge of the traffic channel band.
- 30 8. The method according to any one of claims 1 to 7, further
comprising: applying the degree of asymmetry to allocation of a reference signal
to a traffic channel band, wherein the reference signal is used for defining an
uplink channel quality in uplink communications.
- 35 9. The method according to any one of claims 1 to 8, wherein the
traffic channel band is split into a plurality of traffic channel fragments, the
method further comprising:

defining a degree of asymmetry of each traffic channel fragment describing an offset of a center frequency of the traffic channel fragment from the center frequency of the system band; and

controlling utilization of the traffic channel fragment according to the
5 defined degree of asymmetry.

10. The method of claim 9, wherein a control channel is disposed between the traffic channel fragments in the frequency domain, the method further comprising: implementing frequency hopping between at least two traffic channel fragments.

11. The method of claim 10, further comprising:
combining the traffic channel fragments into a single logical traffic channel fragment;

applying the frequency hopping pattern to the logical traffic channel fragment;

15 restoring fragmentation of the traffic channel fragments with a frequency hopping pattern applied to the traffic channel fragments.

12. The method according to any one of claims 9 to 11, further comprising: determining a bandwidth of the reference signal for each traffic channel fragment separately according to a bandwidth of each traffic channel
20 fragment.

13. An apparatus comprising a processor configured to operate with respect to a system band where a control channel band is arranged asymmetrically at the edges of a traffic channel band in a frequency domain, to define a degree of asymmetry describing an offset of a center frequency of the traffic channel band from a center frequency of the system band, and to control utilization of the traffic channel band according to the defined degree of asymmetry.
25

14. The apparatus of claim 13, wherein the processor is further arranged to configure utilization of the traffic channel band with respect to the center frequency of the traffic channel band offset from the center frequency of the system band by the degree of asymmetry.
30

15. The apparatus of claim 13 or 14, wherein the processor is further configured to define a location of the traffic channel band in the system band by the number of non-traffic channel frequency resource blocks at each edge of the system band.
35

16. The apparatus of claim 15, wherein the processor is further

configured to define the location of the traffic channel band in the system band by the number of blank control channel frequency resource blocks at each edge of the system band, wherein a blank control channel frequency resource block refers to a control channel frequency resource block not used as a control channel frequency resource block.

17. The apparatus according to any one of claims 13 to 16, wherein the processor is further configured to apply the degree of asymmetry to a frequency-hopping pattern defining frequency resource allocation for one or more user terminals.

18. The apparatus of claim 17, wherein the frequency-hopping resources for a given user terminal are allocated symmetrically with respect to the center frequency of the traffic channel band.

19. The apparatus of claim 17 or 18, wherein frequency hopping of a given user terminal is implemented between two sets of frequency resource blocks having an equal minimum distance of the frequency resource block allocation to an edge of the traffic channel band..

20. The apparatus according to any one of claims 13 to 19, wherein the processor is further configured to apply the degree of asymmetry to allocation of a reference signal to a traffic channel band, wherein the reference signal is used for defining an uplink channel quality in uplink communications.

21. The apparatus according to any one of claims 13 to 20, wherein the traffic channel band is split into a plurality of traffic channel fragments, and wherein the processor is further configured to define a degree of asymmetry of each traffic channel fragment describing an offset of a center frequency of the traffic channel fragment from a center frequency of the system band, and to control utilization of the traffic channel fragment according to the defined degree of asymmetry.

22. The apparatus of claim 21, wherein a control channel is disposed between the traffic channel fragments in the frequency domain, and wherein the processor is further configured to implement frequency hopping between at least two traffic channel fragments.

23. The apparatus of claim 22, wherein the processor is further configured to combine the traffic channel fragments into a single logical traffic channel fragment, to apply the frequency hopping pattern to the logical traffic channel fragment, and to restore fragmentation of the traffic channel fragments with the frequency hopping pattern applied to the traffic channel fragments.

24. The apparatus according to any one of claims 21 to 23, wherein the processor is further configured to determine a bandwidth of the reference signal for each traffic channel fragment separately according to a bandwidth of each traffic channel fragment.

5 25. A user terminal of a cellular telecommunication system, comprising the apparatus according to any one of claims 13 to 24.

26. A base station of a cellular telecommunication system, comprising the apparatus according to any one of claims 13 to 24.

27. An apparatus comprising:

10 means for operating with respect to a system band where a control channel band is arranged asymmetrically at the edges of a traffic channel band in a frequency domain;

 means for defining a degree of asymmetry describing an offset of a center frequency of the traffic channel band from a center frequency of the system band; and

15 means for controlling utilization of the traffic channel band according to the defined degree of asymmetry.

28. A computer program product embodied on a distribution medium readable by a computer and comprising program instructions which, when loaded
20 into an apparatus, execute the method according to any preceding claim 1 to 12.

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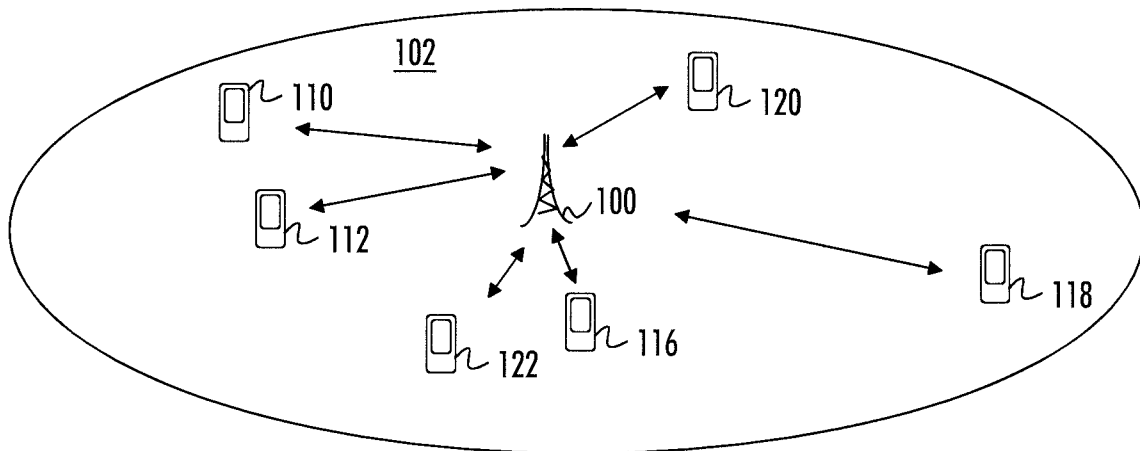


Fig 1A



Fig 1B

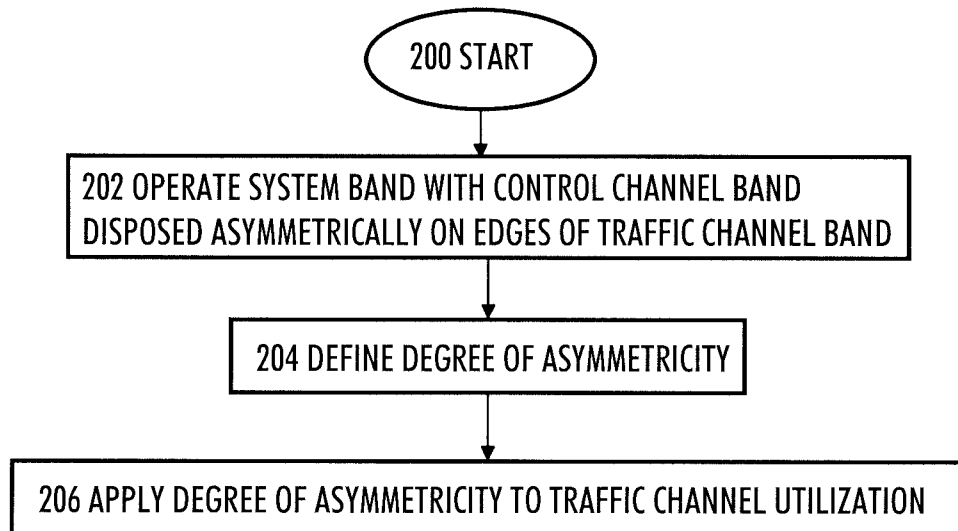


Fig 2

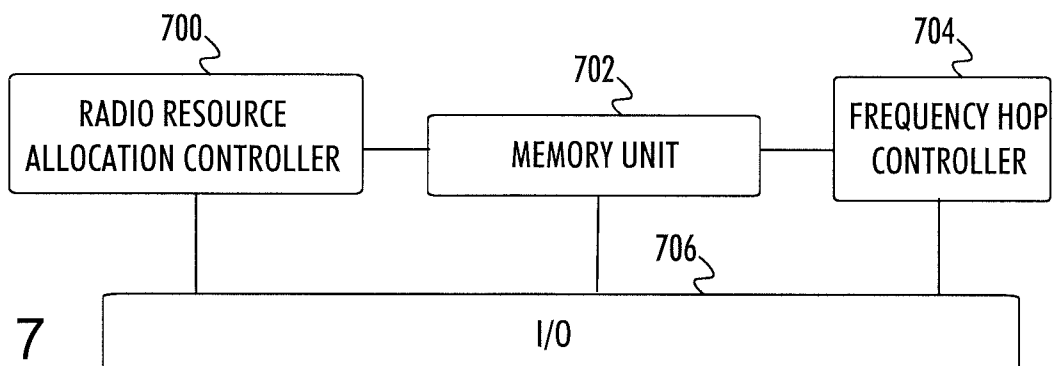


Fig 7

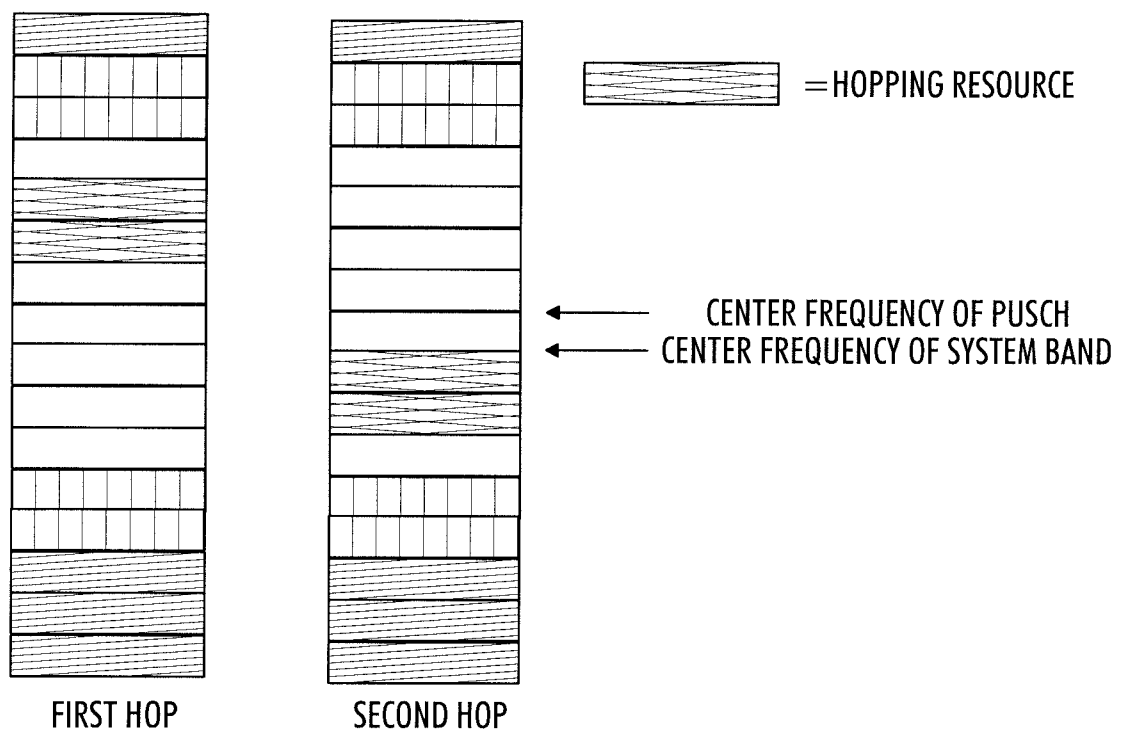
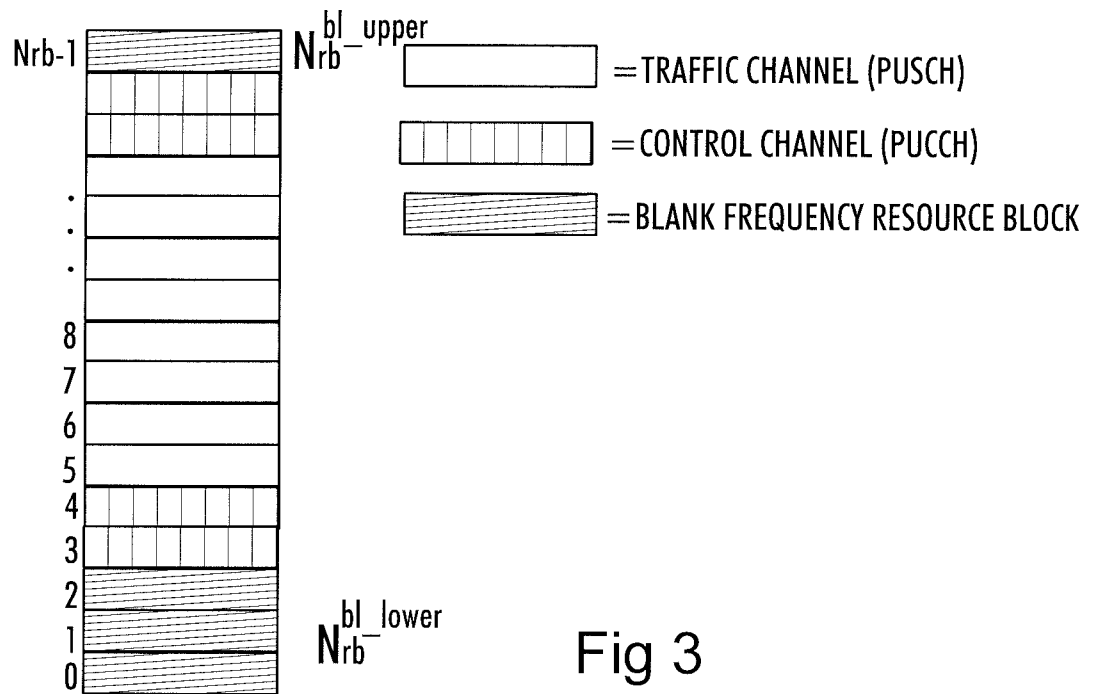
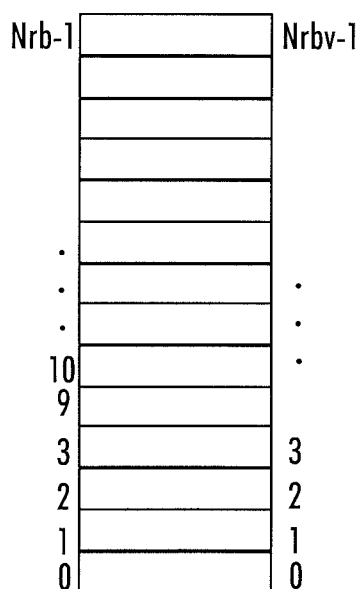
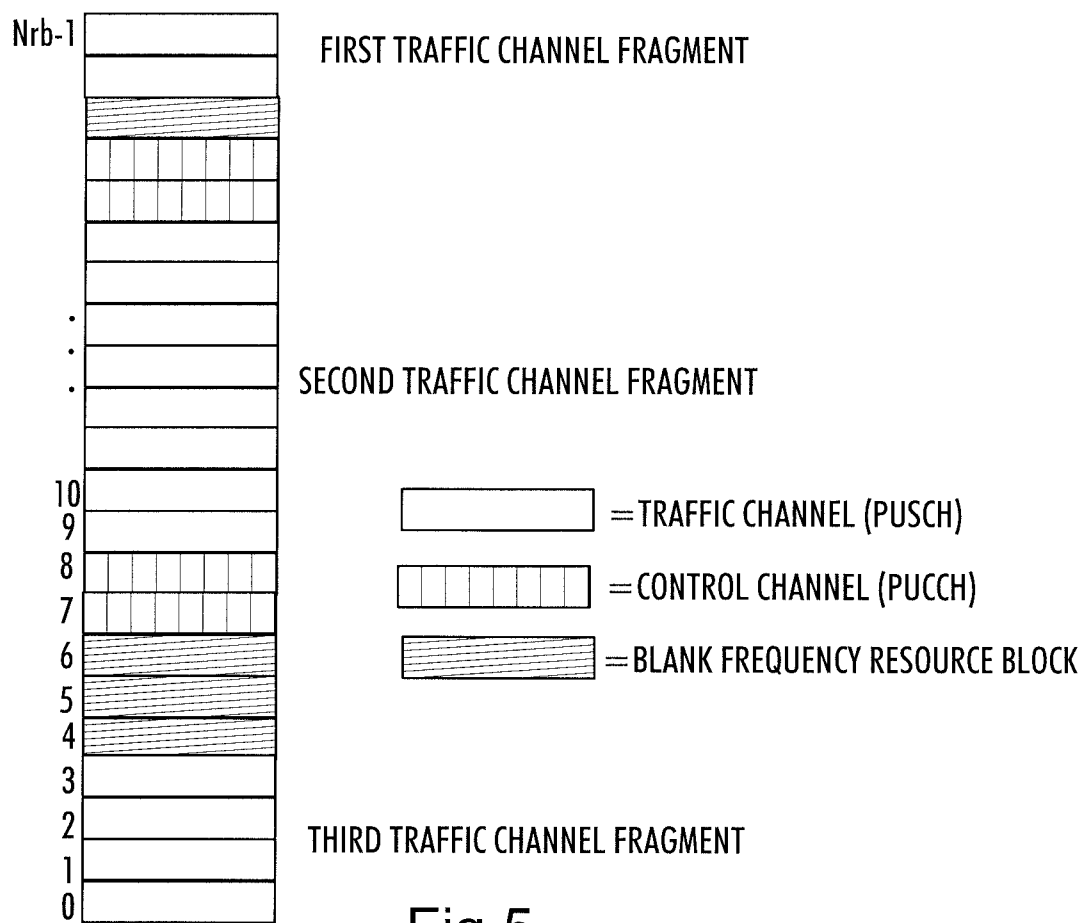


Fig 4

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2008/065569

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W72/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MOTOROLA: "PUCCH options to address UL/DL co-existence" 3GPP DRAFT; R4-082561_ PUCCH OPTION TO ADDRESS CO-EXISTANCE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, no. Scotland; 20080929, 3 October 2008 (2008-10-03), XP050325812 [retrieved on 2008-09-25] page 1, paragraph 1 page 3, paragraph 3 page 3, paragraph 3.1 page 3, paragraph 3.2 page 3; figures 3.2-1 page 4, paragraph 4.1.2 - page 5 page 5, paragraph 4.2 - pages 4.2-1 page 4, line 25 - line 26	1-4, 9, 13-16, 21, 25-28
Y	-/--	5, 6, 8, 12, 17,

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

☒ See patent family annex.

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- *S* document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2008/065569

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	----- PANASONIC: "Discussion on the handling of UE emission control issue" 3GPP DRAFT; R1-083661, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, no. Prague, Czech Republic; 20080929, 29 September 2008 (2008-09-29), XP050317013 [retrieved on 2008-09-23] page 2, paragraph 2.2	8, 12, 20, 24
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A	----- 3RD GENERATION PARTNERSHIP PROJECT: "3GPP TS 36.211 V8.4.0 - Physical Channels and Modulation"[Online] 30 September 2008 (2008-09-30), XP002538749 650 Route des Lucioles - Sophia Antipolis Valbonne - FRANCE Retrieved from the Internet: URL: http://www.3gpp.org/ftp/Specs/html-inf/o/36211.htm [retrieved on 2009-07-24] page 27, paragraph 5.5.3 - page 33 ----- -/--	1-28

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2008/065569

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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information on patent family members

International application No

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