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(54) Title: SUB-CARRIER ALLOCATION FOR MULTI-ANTENNA TRANSMISSION IN CELLULAR TELECOMMUNICATION SYSTEM

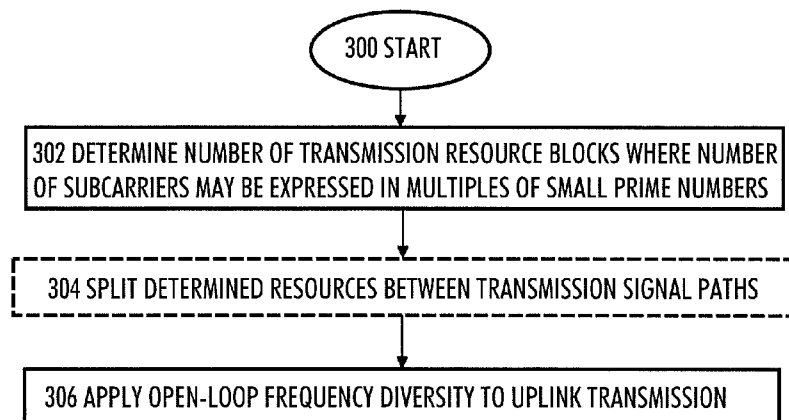


Fig 3

(57) Abstract: A method, apparatus, and computer program for implementing uplink multi-antenna transmission in a cellular telecommunication system are provided. A number of transmission resource blocks for use in uplink multi-antenna transmission is determined, wherein each transmission resource block is associated with a fixed number of subcarriers and wherein the determined number of transmission resource blocks includes a number of subcarriers that is expressible in multiples of small prime numbers that are suitable for efficient Fourier transform implementation. The uplink multi-antenna transmission is applied with a plurality of spatial uplink transmission signal paths and with transmit diversity utilizing the determined transmission resource blocks.

SUB-CARRIER ALLOCATION FOR MULTI-ANTENNA TRANSMISSION IN CELLULAR
TELECOMMUNICATION SYSTEM

Field

The invention relates to the field of cellular radio
5 telecommunications and, particularly, to multi-antenna transmission in a
modern cellular telecommunication system.

Background

A communication system known as an evolved UMTS (Universal
Mobile Telecommunication System) terrestrial radio access network (E-
10 UTRAN, also referred to as UTRAN-LTE for its long-term evolution or LTE-A
for long-term evolution – Advanced) is currently under development within the
3GPP. In this system, the downlink radio access 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
15 pre-coded OFDMA. The uplink system band has a structure where a Physical
Uplink Control Channel (PUCCH) is used for transferring uplink control
messages, and a Physical Uplink Shared Channel (PUSCH) is used for
transmission of uplink user traffic. Additional control messages may be
transmitted in resources initially allocated to the PUSCH. The PUCCH carries
20 uplink control information, such as ACK/NACK messages, channel quality
indicators (CQI), scheduling request indicators (SRI), channel rank indicators,
downlink pre-coding information, etc. Two types of reference signals, namely
sounding reference signals and demodulation reference signals, are
transmitted in the PUSCH resources in order to facilitate channel impulse
25 response estimation (demodulation reference signal) and uplink resource
allocation (sounding reference signal).

It has been envisaged that multi-antenna transmission will be
utilized in LTE-A uplink. To support multi-antenna transmission, e.g. single
user MIMO (multiple-input-multiple-output) transmission, a user terminal may
30 be equipped with multiple antennas. The uplink multi-antenna transmission
may be utilized in numerous manners to improve the quality of
communications and data rates. However, efficient utilization of the multi-
antenna transmission should take into account the current characteristics of
the LTE system according to earlier releases of the LTE and efficient
35 implementation.

Brief description

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
5 provided an apparatus as specified in claim 15.

According to another aspect of the present invention, there is provided a user terminal of a cellular telecommunication system as specified in claim 29.

According to another aspect of the present invention, there is
10 provided a base station of a cellular telecommunication system as specified in claim 30.

According to another aspect of the present invention, there is provided an apparatus as specified in claim 31.

According to yet another aspect of the present invention, there is
15 provided a computer program product embodied on a computer readable distribution medium as specified in claim 32.

Embodiments of the invention are defined in the dependent claims.

List of drawings

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

Figure 1 illustrates communication between a mobile terminal and a mobile telecommunication system;

Figure 2 illustrates a block diagram of a transmitter suitable for single-carrier frequency division multiple access transmission;

25 Figure 3 illustrates a procedure for applying uplink transmission according to an embodiment of the invention;

Figures 4A to 4D illustrate different embodiments for using frequency diversity in uplink transmission according to embodiments of the invention;

30 Figure 5 is a signaling diagram illustrating a procedure for determining a diversity scheme for uplink transmission;

Figure 6 is a signaling diagram illustrating another procedure for determining a diversity scheme for uplink transmission;

Figure 7 illustrates another embodiment of uplink transmission with
35 frequency diversity;

Figure 8 is a block diagram of elements in a base station of the mobile telecommunication system.

Description of embodiments

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 providing voice and data transfer services to mobile terminals is illustrated in Figure 1. Figure 1 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) or LTE-advanced (LTE-A) of the UMTS (Universal Mobile Telecommunication System) specified within 3GPP (3rd Generation Partnership Project) and, therefore, support at least OFDMA and SC-FDMA as radio access schemes for downlink and uplink, respectively. The base station 100 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 which data is routed, and an operation and maintenance server configured to control certain communication parameters, as is known in the art.

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 and a control channel, i.e. a physical uplink control channel (PUCCH), is allocated to both edges of the traffic channel band. In current scenarios of the LTE system, uplink L1/L2 control signaling is divided into two classes in the LTE system: control signaling in the absence of UL data, which takes place on the PUCCH, and control signaling in the presence of UL data, which takes place on the PUSCH. However, the present invention is applicable also in a case where PUSCH and PUCCH are transmitted simultaneously. PUCCH is a shared frequency/time resource reserved exclusively for user terminals transmitting only L1/L2 control signals. The base station schedules transmission resource blocks on the PUSCH to user terminals served by the base station. A transmission resource

block is associated with 12 sub-carriers wherein each sub-carrier of a SC-FDMA symbol carries one information symbol. Accordingly, the number of scheduled resource blocks effectively defines the bandwidth of the SC-FDMA symbol and the number of sub-carriers or information symbols in the SC-FDMA symbol. At this stage, it should be noted that an SC-FDMA is not a multi-carrier symbol in the same sense as an OFDM symbol, because a Fourier transform calculated in a transmitter spreads the information symbol on each sub-carrier over the whole frequency band currently scheduled. However, the term 'sub-carrier' is still widely used in the context of SC-FDMA transmission, because the sub-carriers are clearly localized in the frequency domain in stages between the Fourier and inverse Fourier transforms.

Figure 2 illustrates a basic structure of an SC-FDMA transmitter supporting multi-antenna transmission. It has been envisaged that future Releases of the LTE-A system utilize multi-antenna transmission in uplink. In other words, user terminals will be equipped with a capability to support single-user multiple-input-multiple-output transmission (SU-MIMO) in uplink transmission, wherein the uplink transmission is multiplexed spatially to achieve higher data rates and better spectral efficiency. Referring to Figure 2, bits to be transmitted are first modulated and channel-coded according to a determined modulation and coding scheme in block 200. Then, the resulting information symbols are divided between two transmission signal paths in an antenna segmentation block 201, wherein each transmission signal path corresponds to a signal path leading to a different transmission antenna element. The number of transmission signal paths may equal the number of transmission signal elements, and the user terminal may comprise 2, 3, or 4 antenna elements. The antenna segmentation block may split the information symbols to the transmission signal paths, for example, by multiplexing a first block of symbols to a first path, a subsequent second block of symbols to a second path, a subsequent third block of symbols to a first path, and so on. In each transmission signal path, the information symbols are transformed into a frequency domain with a discrete Fourier transform (DFT) in blocks 202 and 214. In connection with the Fourier transform, the symbols may be converted from a serial form into a parallel form as illustrated in Figure 2. Information symbols are allocated to corresponding frequency resource elements in resource element mapping blocks 204 and 216 according to a determined criterion. The resource element may be a sub-carrier or a virtual sub-carrier,

which is the term widely used in the context of SC-FDMA transmission. Then, inverse DFT is calculated in blocks 206 and 218, the signal is converted from the parallel form into a serial one, a cyclic prefix is added in blocks 210 and 220, and the signal is transformed into an analog form and transmitted through
5 radio frequency (RF) parts 212 and 222 of the transmitter. In the receiver, reversed operations are carried out. A radio signal is received through antennas and RF parts of the receiver and the received signals are transformed into a digital domain. The cyclic prefix is then removed and DFT
10 calculated before extraction of information symbols from their resource elements, inverse DFT, and demodulation, detection and decoding operations. Before the resource element mapping, the receiver chain may comprise a signal processing block, e.g. a MIMO equalizer, which processes the received signals in multiple reception paths, each comprising signal components from all transmission signal paths, such that a signal corresponding to one
15 transmission signal path is obtained for each output of the equalizer. This is common knowledge in the field of MIMO communications and will not be discussed herein in greater detail.

Blocks 200 to 210 and 214 to 220 can be implemented by one or more digital signal processors realized by one or more processors configured
20 with suitable software or by one or more ASICs (Application-Specific Integrated Circuit). Other implementations known in the art as suitable for radio transmitters are naturally possible, and one skilled in the art selects a suitable implementation according to the required computational complexity, power consumption limits, etc.

25 Figure 3 is a flow diagram illustrating a process for assigning resource blocks to uplink transmission. The process starts in block 300. In block 302, a number of transmission resource blocks for use in multi-antenna transmission are determined. Each transmission resource block is associated with a fixed number of subcarriers, and the determined number of transmission
30 resource blocks includes a number of subcarriers that can be expressed in multiples of small prime numbers so as to enable efficient Fourier transform implementation.

In block 304, the determined number of transmission resource blocks are split between a plurality of transmission signal paths such that
35 a number of transmission resource blocks allocated to each transmission signal path includes a number of subcarriers that can be expressed in multiples of

small prime numbers, wherein each transmission signal path is linked to a different transmission antenna element. If the Fourier transforms are calculated separately for each transmission signal path in the transmitter, as in Figure 2, all Fourier transforms can be calculated efficiently. Step 304 is, however, optional, because the signal paths use the same frequency band in some embodiments, as will be described later.

In a current LTE-A specification, each transmission resource block consists of 12 subcarriers, i.e. the total number of sub-carriers is a multiple of 12. On the other hand, a fast Fourier transform (FFT) algorithm is based on the prime numbers, and the FFT can be calculated more efficiently when the length of the FFT can be expressed in multiples of small prime numbers. For example, FFT of length 64 can be calculated very efficiently because 64 can be expressed in multiples of two. However, 64 is not a multiple of 12 so it does not directly fit into the LTE-A specification. From the multiples of 12, 48 equaling four transmission resource blocks can be expressed as $2 \times 2 \times 2 \times 2 \times 3$, while 60 equaling to five transmission resource blocks can be expressed as $2 \times 3 \times 5$. In general, the larger the number of different prime factors, the higher the complexity of the FFT. With a transmission resource block size of 12 subcarriers, the factors 2 and 3 are already implicitly included as factors in the FFT and, from the point of view of implementation, a factor of 5 is found acceptable as well, while larger prime factors increase the complexity. However, in some implementations, a prime factor of 7 has been found acceptable. In the LTE-A system, it has been proposed to limit uplink scheduling grants to allocations corresponding to FFT sizes that can be written as a product of the numbers 2, 3, and 5.

Since the possible transmission block numbers that can be allocated in current LTE-A systems are based on the fact that the number of allocated sub-carriers can be expressed as multiples of prime numbers 2, 3, 5, demodulation reference signals (DM RS) transmitted in the same resources are also defined on the same basis.

In block 306, transmit diversity is applied to the uplink transmission. In an embodiment, the transmission signal paths are transmitted on different frequency bands in consecutive time periods. The transmit diversity may be an open-loop frequency diversity scheme wherein the frequency diversity for each uplink transmission signal path is applied without information on an uplink channel state. Accordingly, the transmitter does not necessarily have

knowledge about the channel state in each frequency band or resource block. It is noted that an open-loop diversity transmission technique may be needed besides the closed loop techniques, because instantaneous channel state information required by closed loop schemes may not be available, particularly when using frequency-hopping (FH) in the PUSCH. Naturally, the open loop scheme may be used when the frequency hopping is not in use. The open loop diversity transmission can be arranged by means of Alamouti scheme / space-time block codes (STBC) used in a downlink of a Wideband Code Division Multiple Access (W-CDMA) system, CDD (Cyclic Delay Diversity), or frequency selection transmit diversity (FSTD). The problem with using STBCs is that an efficient single-carrier based realization requires that the number of SC-FDMA symbols should be an even number. This is not always the case in LTE-A uplink, because there exist two different time slot formats: one with six SC-FDMA data symbols per slot (normal cyclic prefix) and the other with five SC-FDMA data symbols per slot (extended cyclic prefix). Furthermore, the number of SC-FDMA data symbols is reduced in the last slot of the sub-frame by one symbol in a case when a sounding reference signal (SRS) block is configured for transmission in the current sub-frame. The problem with CDD, where the same data is transmitted with a cyclic delay, is that it effectively increases multipath propagation, resulting in additional inter-symbol interference for a single-carrier signal. Therefore, FSTD based open loop transmit diversity schemes that are not limited by the number of SC-FDMA symbols per slot are particularly attractive.

In addition to the above, FSTD can be seen as a promising candidate in user terminals equipped with more than two antennas, either as the only diversity scheme or as combined with another open loop transmit diversity technique, e.g. STBCs. As an example of a combination of two open-loop techniques, a user terminal with four transmission antennas may be configured to group the transmission antennas into two pairs and to apply to each pair STBC accordingly. As a consequence, antennas of transmission signal paths of each group transmit the same payload data but encoded with space-time block codes according to the state of the art STBC techniques for two antennas. Then, the same FSTD is applied to each antenna of the same group in the same manner, i.e. the antennas of the same group transmit in the same frequency resources, and the antennas of different groups transmit in different frequency resources.

In another embodiment, the FSTD is applied together with a closed-loop diversity technique, e.g. antenna selection. In this embodiment, the base station measures frequency-selective uplink channel state information (CSI) for each uplink transmission antenna from an uplink reference signal received from the user terminal and carries out scheduling of resource blocks on the basis of the CSI. The base station may schedule the resources separately for each transmission antenna (transmission signal path) on the basis of the CSI. As a consequence, the base station selects the resource blocks separately for each uplink transmission signal path and signals the scheduled transmission resources to the user terminal. In practice, the base station may schedule two sets of resource blocks and indicate with one or two bits (depending on the number of antennas) which set is scheduled to which antenna. The number of resource blocks scheduled to each antenna fulfill the criterion that the number of sub-carriers in the resource blocks scheduled to an antenna can be expressed in multiples of small prime numbers. Then, the user terminal divides the frequency resources to the transmission antennas in block 304 according to the received scheduling information.

The process of Figure 3 may be executed in an apparatus comprising a processing unit configured to carry out the steps of Figure 3 and an interface to enable the processing unit to communicate with other parts of a radio device including the apparatus and with other radio devices. Basically, the process of Figure 3 may be carried out in both the base station and the user terminal but efficient implementation of the FFT is particularly advantageous in the user terminal having limited computational and power resources. Referring to Figure 2, the utilization of the resource mapping according to the embodiment of the invention prevents a complexity increase in DFT blocks 202, 214 and inverse DFT blocks 206, 218. Additionally, the use of multi-antenna transmission with transmit diversity improves both tolerance against interference and overall quality of communications in the uplink. Moreover, allocation of resource blocks in the above-described manner enables use of DM RS sequences currently specified for the LTE-A systems using single-antenna transmissions in the uplink. Therefore, modifications needed to accommodate multi-antenna uplink transmissions are reduced, which facilitates implementation.

Moreover, the process of Figure 2 may be carried out by a computer program embodied on a computer-readable medium, wherein the computer

program comprises one or more software modules in the medium for each step of Figure 2. Each module is configured to control a computer or a processor executing the computer program to carry out the corresponding step.

Figures 4A to 4C illustrate embodiments applying the FSTD in the
 5 uplink transmission when the user terminal is configured to have two transmission signal paths. Let us first denote that in an LTE-A system, each transmission resource block is identified with an index. The base station carries out the resource allocation by indicating in a scheduling grant message a resource block index RB_{START} and a number of contiguous transmission
 10 resource blocks L_{CRB} counted from the indicated resource block index. If the user terminal applies frequency hopping to the uplink transmission, the frequency hopping pattern is known to both the user terminal and the base station before the scheduling grant message. Then, the user terminal splits the allocated resource blocks between the transmission signal paths such that the
 15 resource blocks allocated to each signal path maintains the requirement that the number of sub-carriers can be expressed with small prime numbers.

Referring to Figure 4A, the resource split and the order of the resource blocks allocated to different signal paths are maintained in consecutive frequency hops. In a time period denoted by $i=0$, resource
 20 allocation to the first signal path starts from a resource block denoted by RB_{START} received from the base station, and $L_{CRB}(1)$ resource blocks are allocated to the first signal path. Resource allocation to the second signal path starts from a resource block denoted by $RB_{START} + L_{CRB}(1)$, and $L_{CRB}(2)$ resource blocks are allocated to the first signal path. The resource block
 25 allocation to the other signal paths (if any) is carried out in a similar manner continuing from $RB_{START} + L_{CRB}(1) + L_{CRB}(2)$. In a time period denoted by $i=1$, resource allocation to the first signal path starts from a resource block denoted by RB_{START_HOP} defined by RB_{START} received from the base station and the used frequency hopping pattern, and $L_{CRB}(1)$ resource blocks are allocated to
 30 the first signal path. Resource allocation to the second signal path starts from a resource block denoted by $RB_{START_HOP} + L_{CRB}(1)$, and $L_{CRB}(2)$ resource blocks are allocated to the first signal path. The resource block allocation to the other signal paths (if any) is carried out in a similar manner, continuing from $RB_{START_HOP} + L_{CRB}(1) + L_{CRB}(2)$. The scheme illustrated in Figure 4A provides
 35 frequency diversity to combat interference in PUSCH transmission.

Referring to Figure 4B, the resource split and the order of the resource blocks allocated to different signal paths are mirrored in consecutive frequency hops. In a time period denoted by $i=0$, resource allocation to the signal paths similar as in Figure 4A in time period $i=0$. In a time period denoted by $i=1$, resource allocation to the N^{th} signal path starts from a resource block denoted by $RB_{\text{START_HOP}}$ defined by RB_{START} received from the base station and the used frequency hopping pattern, wherein N is the number of transmission signal paths. $L_{\text{CRB}}(N)$ resource blocks are allocated to the N^{th} signal path. Resource allocation to the $N-1^{\text{th}}$ signal path starts from a resource block denoted by $RB_{\text{START_HOP}} + L_{\text{CRB}}(N)$, and $L_{\text{CRB}}(N-1)$ resource blocks are allocated to the $N-1^{\text{th}}$ signal path. The resource block allocation to the other signal paths (if any) is carried out in a similar manner continuing from $RB_{\text{START_HOP}} + L_{\text{CRB}}(N) + L_{\text{CRB}}(N-1)$. The scheme illustrated in Figure 4A provides an alternative method to improve frequency diversity to combat interference in PUSCH transmission.

In the embodiment of Figure 4C, the allocated and the hopping resource blocks are both used in both time periods $i=0, 1$. The resource blocks are exchanged between the signal paths in consecutive time periods $i=0, 1$, as illustrated in Figure 4C. Resource elements may be allocated to the first signal path according to the original frequency hopping pattern, i.e. the first signal path utilizes resource blocks from RB_{START} to $RB_{\text{START}} + L_{\text{CRB}}(1) - 1$. Resource elements may be allocated to the second signal path such that the second signal path utilizes the frequency hopping resources of the first signal path in the first time period $i=0$ and the resources allocated to the first signal path in the consecutive time period $i=1$, when the first signal path utilizes the frequency hopping resources. In general, the second signal path utilizes resource blocks of the first signal path calculated for the next hop ($i+1$) in even time periods $i=0, 2, 4$, etc. and resource blocks of the first signal path calculated for the previous hop ($i-1$) in odd time periods $i=1, 3, 5$, etc. This type of resource mapping minimizes frequency spectrum fragmentation amongst multiple user terminals, because a single user terminal uses the same frequency resources in consecutive time periods.

In Figures 4A to 4C, the time period i may be a sub-frame, as in current LTE-A specifications where a frequency hop occurs on a sub-frame level, but it may be another time period, e.g. a time slot (there are two time slots in a sub-frame) or a 10 ms radio frame comprising 10 sub-frames. The

frequency-hopping may also be coupled with the transmission number of predefined HARQ (re-)transmissions such that odd HARQ transmissions (original transmission, 2nd retransmission, 4th retransmission, etc.) occur in the first transmission resources and even HARQ transmissions (1st retransmission, 3rd retransmission, etc.) occur in the second transmission resources different from the first ones.

Referring to Figure 4D, the latest versions of the LTE-A support also clustered mapping of resource blocks. Clustered mapping means that, unlike in Figures 4A to 4C where a number of contiguous resource blocks are allocated, the resource block allocation is fragmented into a number of resource block clusters. Figure 4D illustrates the scheme of Figure 4C in the case of a clustered resource block mapping, wherein a scheduling grant message indicates the starting resource block RB_{START} and the number of resource blocks L_{CRB} for each cluster. Reduction in the amount of signaling information may be achieved, for example, by allocating equal amount of resource blocks to each cluster and, therefore, it is possible to signal L_{CRB} to a plurality of clusters jointly. The number of sub-carriers in each cluster may fulfill the criterion that it can be expressed in multiples of the small prime numbers to enable the efficient Fourier transform. The user terminal may then calculate the Fourier transforms not only separately for each transmission signal path but also separately for each cluster. However, one cluster per transmission signal path may be preferred for the sake of simplicity of implementation. The clustered mapping is obviously applicable to any one of the above-mentioned diversity schemes.

Referring to block 304 of Figure 3, the resource blocks may be split between the transmission signal paths evenly, or a different number of transmission resource blocks may be allocated to the signal paths. However, efficient implementation of the Fourier transform should be borne in mind. Referring to Figure 2, the Fourier transform(s) is calculated separately for each signal path and, therefore, the number of resource blocks allocated to each signal path should be such that the length of the Fourier transform, i.e. the number of sub-carriers in the allocated resource blocks, can be expressed in multiples of small prime numbers. Of course, if the Fourier transforms are calculated jointly for the signal paths, it suffices that the total number of allocated transmission resource blocks (L_{CRB}) fulfills this criterion. However, let us now concentrate on an embodiment where the transforms are calculated

separately for each signal path. Table 1 below shows suitable resource splits between the signal paths in the case where an equal number of resource blocks (RB) is allocated to the signal paths and in the case where an unequal number of resource blocks is allocated to the signal paths. In the case of an equal split, the number of signal paths is from one to four (N=1 to 4), where the column under N=1 shows possible numbers of resource blocks that can be allocated according to the current specification of the LTE-A. In Table 1, “-” indicates that the resource allocation is not possible, “x” indicates even resource split between the antenna elements, and “a+b” indicates that “a” resource blocks are allocated to the first signal path and “b” resource blocks are allocated to the second signal path. For example, 3 resource blocks can be split evenly only when N=3 and, in the case of an unequal resource block allocation and a total of 25 resource blocks allocated to the user terminal, the split is 15+10 because both 15 and 10 can be expressed in multiples of prime numbers 2, 3, and 5 ($2 \times 5 = 10$ and $3 \times 5 = 15$). For example, 13+12 is not allowed, because 13 is a prime number that would result in an inefficient FFT. However, the number of resource blocks allocated to different signal paths in the unequal allocation may be as close to one another as possible according to the criterion for efficient FFT. For example, 15+10 is preferred in this embodiment over 20+5.

While Table 1 illustrates an unequal resource split for only two transmission signal paths, one skilled in the art may derive the corresponding unequal resource splits for a higher number of signal paths by keeping in mind the required criterion that each signal path has the number of sub-carriers that can be expressed in multiples of 2, 3, and 5. In practical implementations, the number of MIMO paths is two even when the user terminal employs four transmission antennas, because use of four separate signal paths does not usually result in significant additional gains. Therefore, it is often more advantageous to bundle two transmission antennas together and transmit the same signals from them by using beamforming processing in order to control the transmission direction of the signal. Alternatively, in many cases it is possible to support STBC only with two antennas. In such cases, it is natural to apply FSTD between two STBC pairs.

Resource block allocation to N antenna elements		
Equal number of RBs to all signal paths		Unequal number of RBs

N=1	N=2	N=3	N=4		N=1	N=2
1	-	-	-		1	-
2	x	-	-		2	x
3	-	x	-		3	2+1
4	x	-	x		4	x
5	-	-	-		5	3+2
6	x	x	-		6	x
8	x	-	x		8	x
9	-	x	-		9	5+4
10	x	-	-		10	x
12	x	x	x		12	x
15	-	x	-		15	9+6
16	x	-	x		16	x
18	x	x	-		18	x
20	x	-	x		20	x
24	x	x	x		24	x
25	-	-	-		25	15+10
27	-	x	-		27	15+12
30	x	x	-		30	x
32	x	-	x		32	x
36	x	x	x		36	x
40	x	-	x		40	x
45	-	x	-		45	25+20
48	x	x	x		48	x
50	x	-	-		50	x
54	x	x	-		54	x
60	x	x	x		60	x
64	x	-	x		64	x
72	x	x	x		72	x
75	-	x	-		75	45+30
80	x	-	x		80	x
81	-	x	-		81	45+36
90	x	x	-		90	x
96	x	x	x		96	x
100	x	-	x		100	x

108	x	x	x		108	x
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Table 1

The resource split between the transmission signal paths must be known not only to user terminal but also to the base station so as to enable a correct combination of the transmission signal paths in the receiver (the base station). The resource split between the signal paths may be derived from the number of allocated transmission resource blocks and the knowledge of transmission signal paths used in the uplink. In the case of two transmission signal paths, all the possible numbers of resource blocks can be allocated, either evenly or unevenly. Note that if the equal resource split is not possible in Table 1, Table 1 provides an allowed unequal resource. If the resource split cannot be deduced from the number of allocated resource blocks alone, e.g. when there are multiple options for the number of allocated resource blocks, the resource split may be signaled separately.

There are several numbers of resource blocks that cannot be allocated according to the current specification. For example, seven resource blocks cannot be allocated to a single user terminal, because it results in a number of sub-carriers that cannot be expressed in multiples of 2, 3, and 5. However, when a user terminal uses SU-MIMO with two transmission signal paths, seven resource blocks could be allocated to the user terminal, if the user terminal divides the seven blocks to the transmission signal paths in an allowed manner, i.e. two resource blocks to the first path and five to the second. According to an embodiment, the base station may be configured to apply special rules to user terminals known to apply SU-MIMO transmission in the uplink. The base station may allocate to such user terminals a number of resource blocks that contain a number of sub-carriers that cannot be expressed in multiples small prime numbers, if the number of resource blocks can be divided into two, three, or four sets (depending on the number of antennas in the user terminal), wherein the number of sub-carriers in each set can be expressed in multiples of small prime numbers. The base station may also indicate the division into the sets.

The description above describes the division of the resource blocks to the transmission signal paths, wherein the resource blocks acts as an allocation unit, i.e. the allocation is carried out in units of resource blocks. In an embodiment of the invention, transmission of one resource block is split between multiple transmission signal paths such that one transmission signal

path transmits a portion of the resource block and another transmission signal path transmits another portion. The number of sub-carriers of the resource block allocated to each transmission signal path may be 12 divided by the number of transmission signal paths: 6 with two paths, 4 with three paths, and 3 or 6 with four paths (depending on whether or not the grouping of signal paths is applied). 3, 4, and 6 can all be expressed in multiples of 2 and/or 3 so this embodiment fulfills the criterion for efficient FFT implementation when the FFT (or IFFT) is calculated separately for each signal path. The sub-carrier allocation may be contiguous (a number of contiguous sub-carriers are allocated to each signal path) or interleaved. In this embodiment, the demodulation reference signal may be transmitted by using any one of the following exemplary embodiments. In a first embodiment, each signal path conveys a reference signal designed for the length of one resource block, and the reference signal of the different signal paths are discriminated with a different cyclic shift of the reference signal applied to each signal path. In a second embodiment, a reference signal designed for the length of one resource block is cut according to the sub-carrier allocation, i.e. divided into portions equal in number to the transmission signal paths, and a different portion of the reference signal is assigned to different signal paths. In a third embodiment, new reference signals may be designed, e.g. reference signals of length 6 symbols, and a different reference signal is assigned to each signal path.

The utilization of the frequency hopping resources should also be known to both the user terminal and the base station. In other words, both base station and the user terminal should know which one of the exemplary FSTD schemes of Figures 4A to 4C is currently in use. Both the base station and the user terminal may support multiple FSTD schemes and select one of the schemes according to a predetermined criterion. For example, the FSTD scheme to be used may be configured as a higher layer signaling, e.g. on a radio resource control layer. The selection of the FSTD scheme to be used in each cell of the cellular telecommunication system may be a part of operation and maintenance (O&M) functionality in the system, wherein an O&M server selects the FSTD scheme for predetermined cells and signals the selected FSTD schemes to the base stations. Then, the base stations signal the FSTD schemes to the predetermined user terminals they serve. The O&M server may be configured to select a different FSTD scheme for neighboring cells so

as to provide more interference diversity in the system. This prevents two user terminals in neighboring cells from transmitting in the same frequency resources continuously, because the frequency utilization pattern is different.

Figure 5 is a signaling diagram illustrating a procedure for
5 determining the FSTD scheme by using the higher layer signaling. In S1, the base station determines the FSTD scheme and signals the FSTD scheme to the user terminal as higher layer signaling information. The user terminal receives the FSTD scheme and configures its transmission elements to apply the scheme. In S2, the base station schedules the uplink transmission
10 resource blocks to the user terminal. In S3, the user terminal divides the scheduled resource blocks to the transmission signal paths according to the applied FSTD scheme, applied frequency-hopping scheme, and scheduled resource blocks. In S4, the user terminal performs transmission signal processing on each transmission signal path, including a fast Fourier
15 transform, resource element allocation, and the inverse FFT, wherein the FFTs can both be implemented efficiently according to an embodiment of the invention. In S5, the user terminal performs the uplink transmission in the scheduled resources. In S6, the base station receives the uplink transmission and performs reception signal processing in order to discriminate the
20 transmission signal paths and correctly detect the transmitted information.

Alternatively, the used FSTD scheme may be fixed for each cell and determined with no the need for exchanging signaling between the user terminal and the base station. Figure 6 is a signaling diagram illustrating this embodiment. Referring to Figure 6, both the base station and the user terminal
25 determine independently the FSTD scheme to be used in the uplink transmission in S11. The FSTD scheme may be determined, for example, from a cellular identifier of the base station in a determined manner. The identifier of the base station may be a cellular radio network temporary identifier (C-RNTI) or another identifier, and the FSTD scheme may be determined by processing
30 the identifier with a specific algorithm. For example, if the system supports two FSTD schemes, e.g. those of Figures 4A and 4B, the FSTD scheme may be determined by calculating a mod 2 sum of the identifier. If the result is 0, the scheme of Figure 4A is selected, and the scheme of Figure 4B is selected when the result is 1. Modulo of the sum operation corresponds to the number
35 of supported FSTD schemes.

In the FSTD schemes illustrated in Figures 4A to 4C, a number of consecutive resource blocks is assigned to each transmission signal path, and each transmission signal path is transmitted in different frequency resource blocks. As a consequence, orthogonality between the signal paths is obtained.

5 The orthogonality can be maintained in another manner as well, as is illustrated in Figure 7. According to this embodiment, the same transmission resource blocks may be allocated to both (or all) signal paths in block 304 of Figure 3. Referring to Figure 7, let us assume that the base station has scheduled resource blocks #10 and #11 to the user terminal for uplink

10 transmission. The user terminal then assigns both resource blocks #10 and #11 to the two transmission signal paths, i.e. to both transmission branches in Figure 2. Then, the user terminal configures the resource element mapping blocks 204, 216 to carry out mapping of information symbols to the sub-carriers as illustrated in Figure 7. Accordingly, the first resource element

15 mapping block 204 on the first signal path allocates the information symbols to odd subcarriers on both resource blocks #10 and #11, and the second resource element mapping block 216 on the second signal path allocates the information symbols to even subcarriers on both resource blocks #10 and #11. Now, every second sub-carrier (sub-carriers 1, 3, 5, etc.) in resource blocks

20 #10 and #11 belongs to the first signal path, and every second sub-carrier (sub-carriers 2, 4, 6, etc.) in resource blocks #10 and #11 belongs to the second signal path. Then, the inverse FFT spreads the sub-carriers over the frequency band covering the band of the resource blocks #10 and #11. While both signal paths transmit on the same frequency band, the orthogonality is

25 maintained because the receiver (the base station) transforms the signals into a frequency domain where the signal paths are orthogonal.

Figure 8 illustrates a block diagram of the base station carrying out the allocation of transmission resource blocks and FSTD scheme, if the applied FSTD scheme is signaled to the user terminals, and reception signal

30 processing of signals received through multiple MIMO paths from a given user terminal. The base station comprises a radio resource controller 800 configured to carry out higher layer radio resource control in both uplink and downlink communications with the user terminals. As mentioned above, the radio resource controller 800 may select the FSTD scheme to be applied to

35 uplink communications. The same FSTD scheme may be selected for every user terminal in the cell served by the base station, or the radio resource

controller 800 may select the FSTD scheme individually for each user terminal on the basis of the FSTD schemes supported by each user terminal, for example. The radio resource controller 800 may include a scheduler 802 which carries out uplink and downlink resource scheduling to the user terminals. The
5 radio resource controller has a communication connection with an O&M server controlling radio resources and other communication parameters in a wider geographical area in the cellular system. The radio resource controller 800 and the scheduler transmit and receive control signaling to/from the user terminals through transmitter and receiver components 804 carrying out the signal
10 processing needed for transmission and reception of signals. The transmitter and receiver components 804 communicate also with a data processing unit 806 so as to convey payload data.

With respect to downlink transmission, the transmitter and receiver components 804 multiplex control information (including uplink scheduling
15 grant messages) received from the radio resource controller 800 and scheduler 802 with payload data and transmit them according to the OFDM transmission scheme. With respect to uplink transmission, the transmitter and receiver components 804 receive the transmission of a given user terminal in the transmission resources allocated to the user terminal in the scheduling
20 grant message, separate the two transmission signal paths from the received signals remove the mapping of the information symbols to the resource elements in the separated transmission signal paths, and demultiplex or combine the two transmission signal paths for demodulation, detection and decoding. Then, the control information contained in the received message is
25 transferred to the radio resource controller 800, and the payload data in the received message is transferred to the data processing unit 806. The radio resource controller 800 uses the received control data for scheduling and radio resource control of the user terminal, while the data processing unit 806 conveys the payload data through the data routers towards the destination
30 address of the data.

The processes or methods described above in connection with Figures 3 to 7 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
35 some sort of 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.

5 The description describes the embodiments of the invention as implemented in a system configured according to the LTE-A specifications, but it should be appreciated that the embodiments may be easily modified for application to other systems, e.g. WiMAX. The protocols used, the specifications of mobile telecommunication systems, their network elements
10 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
15 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:

determining a number of transmission resource blocks for use in
uplink multi-antenna transmission in a cellular telecommunication system,
5 wherein each transmission resource block is associated with a fixed number of
subcarriers and wherein the determined number of transmission resource
blocks includes a number of subcarriers that is expressible in multiples of small
prime numbers that are suitable for efficient Fourier transform implementation;
and
10 applying the uplink multi-antenna transmission with a plurality of
spatial uplink transmission signal paths utilizing the determined transmission
resource blocks.

2. The method of claim 1, further comprising: assigning the
determined number of transmission resource blocks to a plurality of
15 transmission signal paths such that a number of transmission resource blocks
allocated to each transmission signal path includes a number of subcarriers
that can be expressed in multiples of said small prime numbers, wherein each
transmission signal path is linked to a different transmission antenna element.

3. The method of claim 1 or 2, wherein the number of subcarriers is
20 expressible in multiples of prime numbers lower than 8.

4. The method according to any one of claims 1 to 3, wherein an
equal number of transmission resource blocks is assigned to the transmission
signal paths and wherein different resource blocks are assigned to each
transmission signal path in consecutive transmission time units in order to
25 provide protection against interference.

5. The method according to any one of claims 1 to 3, wherein an
unequal number of transmission resource blocks is assigned to the
transmission signal paths and wherein the number of transmission resource
blocks allocated to a transmission signal path includes the number of
30 subcarriers that can be expressed in multiples of the small prime numbers.

6. The method of claim 6, wherein the numbers of transmission
resource blocks allocated to the different transmission signal paths are as
close to one another as possible and fulfill the criterion that the number of
transmission resource blocks allocated to each transmission signal path
35 includes the number of subcarriers that can be expressed in multiples of the
small prime numbers.

7. The method of any preceding claim, further comprising:
applying a frequency hopping pattern to the transmission; and
allocating transmission resource blocks to the transmission signal
paths in an ascending order starting from the resource block and a signal path
5 having the lowest index.

8. The method of claim 7, wherein the transmission resource blocks
are allocated to the transmission signal paths in an ascending order in the first
frequency hop by starting from the resource block and transmission signal path
having the lowest index, and wherein the transmission resource blocks are
10 allocated to the transmission signal paths in an order starting from a resource
block having the highest index and from a transmission signal path having the
lowest index in a second frequency hop.

9. The method of claim 7, wherein the transmission resource blocks
are exchanged mutually between at least two transmission signal paths in
15 consecutive frequency hops.

10. The method of any preceding claim 7 to 9, wherein the resource
allocation to the transmission signal paths for the applied frequency hopping
pattern is selected from a plurality of supported resource allocation patterns
according to a predetermined criterion.

20 11. The method of any preceding claim 7 to 10, wherein the
resource allocation to the transmission signal paths for the applied frequency
hopping pattern has a cell-specific pattern different from a resource allocation
pattern of at least one neighboring cell.

12. The method of any preceding claim, further comprising:
25 calculating a Fourier transform separately for each transmission signal path,
wherein the Fourier transform has a length that is expressible in multiples of
small prime numbers so as to provide efficient Fourier transform
implementation.

13. The method of any preceding claim, wherein a user terminal
30 carrying out uplink transmission is equipped with four transmission antennas,
the method further comprising:

grouping the transmission antennas into two groups, each
comprising two antennas;

determining for both antenna groups a number of transmission
35 resource blocks for use in the uplink transmission, wherein the determined
number of transmission resource blocks for each antenna group includes a

number of subcarriers that is expressible in multiples of small prime numbers;
and

applying a space-time block code to each antenna group separately.

5 14. The method of any preceding claim, wherein one transmission resource block is allocated to the uplink transmission, the method further comprising: dividing sub-carriers of the allocated transmission resource blocks amongst the transmission signal paths, wherein the number of subcarriers in each transmission signal path is expressible in multiples of small prime
10 numbers that are suitable for efficient Fourier transform implementation.

15. An apparatus comprising:

a processor configured to determine a number of transmission resource blocks for use in uplink multi-antenna transmission in a cellular telecommunication system, wherein each transmission resource block is
15 associated with a fixed number of subcarriers and wherein the determined number of transmission resource blocks includes a number of subcarriers that is expressible in multiples of small prime numbers that are suitable for efficient Fourier transform implementation, and to apply uplink multi-antenna transmission with a plurality of spatial uplink transmission signal paths utilizing
20 the determined transmission resource blocks.

16. The apparatus of claim 15, wherein the processor is further configured to assign the determined number of transmission resource blocks to a plurality of transmission signal paths such that a number of transmission resource blocks allocated to each transmission signal path includes a number
25 of subcarriers that can be expressed in multiples of said prime numbers, wherein each transmission signal path is linked to a different transmission antenna element.

17. The apparatus of claim 15 or 16, wherein the number of subcarriers is expressible in multiples of prime numbers lower than 8.

30 18. The apparatus according to any one of claims 15 to 17, wherein the processor is further configured to assign an equal number of transmission resource blocks to the transmission signal paths and to assign different resource blocks to each transmission signal path in consecutive transmission time units in order to provide protection against interference.

35 19. The apparatus according to any one of claims 15 to 18, wherein the processor is further configured to assign an unequal number of

transmission resource blocks to the transmission signal paths, wherein the number of transmission resource blocks allocated to a transmission signal path includes the number of subcarriers that can be expressed in multiples of the prime numbers.

5 20. The apparatus of claim 19, wherein the numbers of transmission resource blocks allocated to the different transmission signal paths are as close to one another as possible and fulfill the criterion that the number of transmission resource blocks allocated to each transmission signal path includes the number of subcarriers that can be expressed in multiples of the
10 small prime numbers.

 21. The apparatus according to any one of claims 15 to 20, wherein the processor is further configured to apply a frequency hopping pattern to the transmission, and to allocate transmission resource blocks to the transmission signal paths in an ascending order starting from the resource block and a
15 signal path having the lowest index.

 22. The apparatus of claim 21, wherein the processor is further configured to allocate the transmission resource blocks to the transmission signal paths in an ascending order in a first frequency hop by starting from the resource block and transmission signal path having the lowest index, and to
20 allocate the transmission resource blocks to the transmission signal paths in an order starting from a resource block having the highest index and from a transmission signal path having the lowest index in a second frequency hop.

 23. The apparatus of claim 21, wherein the processor is further configured to exchange the transmission resource blocks mutually between at
25 least two transmission signal paths in consecutive frequency hops.

 24. The apparatus of any preceding claim 21 to 23, wherein the processor is further configured to select the resource allocation to the transmission signal paths for the applied frequency hopping pattern from a plurality of supported resource allocation patterns according to a
30 predetermined criterion.

 25. The apparatus of any preceding claim 21 to 24 wherein the processor is further configured to arrange the resource allocation to the transmission signal paths for the applied frequency-hopping pattern as a cell-specific pattern different from a resource allocation pattern of at least one
35 neighboring cell.

26. The apparatus of any preceding claim 15 to 25, wherein the processor is further configured to calculate a Fourier transform separately for each transmission signal path, wherein the Fourier transform has a length that is expressible in multiples of small prime numbers so as to provide efficient
5 Fourier transform implementation.

27. The apparatus of any preceding claim 15 to 26, wherein one transmission resource block is allocated to the uplink transmission and wherein the processor is further configured to divide sub-carriers of the allocated transmission resource blocks amongst the transmission signal paths, wherein
10 the number of subcarriers in each transmission signal path is expressible in multiples of small prime numbers that are suitable for efficient Fourier transform implementation.

28. The apparatus of any preceding claim 15 to 27, wherein the apparatus is applicable to a user terminal carrying out uplink transmission and
15 comprising four transmission antennas and wherein the processor is further configured to group the transmission antennas into two groups, each comprising two antennas, to determine for both antenna groups a number of transmission resource blocks for use in the uplink transmission, wherein the determined number of transmission resource blocks for each antenna group
20 includes a number of subcarriers that is expressible in multiples of small prime numbers, and to apply a space-time block code to each antenna group separately.

29. A user terminal of a cellular telecommunication system, comprising the apparatus according to any one of claims 15 to 28.

25 30. A base station of a cellular telecommunication system, comprising the apparatus according to any one of claims 15 to 27.

31. An apparatus, comprising:

means for determining a number of transmission resource blocks for use in uplink multi-antenna transmission in a cellular telecommunication
30 system, wherein each transmission resource block is associated with a fixed number of subcarriers and wherein the determined number of transmission resource blocks includes a number of subcarriers that is expressible in multiples of small prime numbers that are suitable for efficient Fourier transform implementation; and

means for applying the uplink multi-antenna transmission with a plurality of spatial uplink transmission signal paths utilizing the determined transmission resource blocks.

32. A computer program product embodied on a distribution medium
5 readable by a computer and comprising program instructions which, when loaded into an apparatus, execute the method according to any preceding claim 1 to 14.

1/4

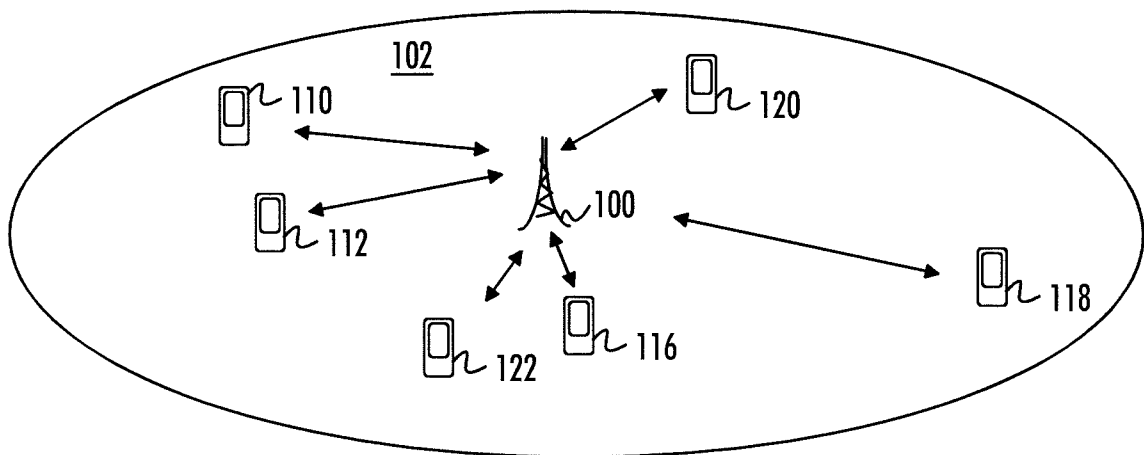


Fig 1

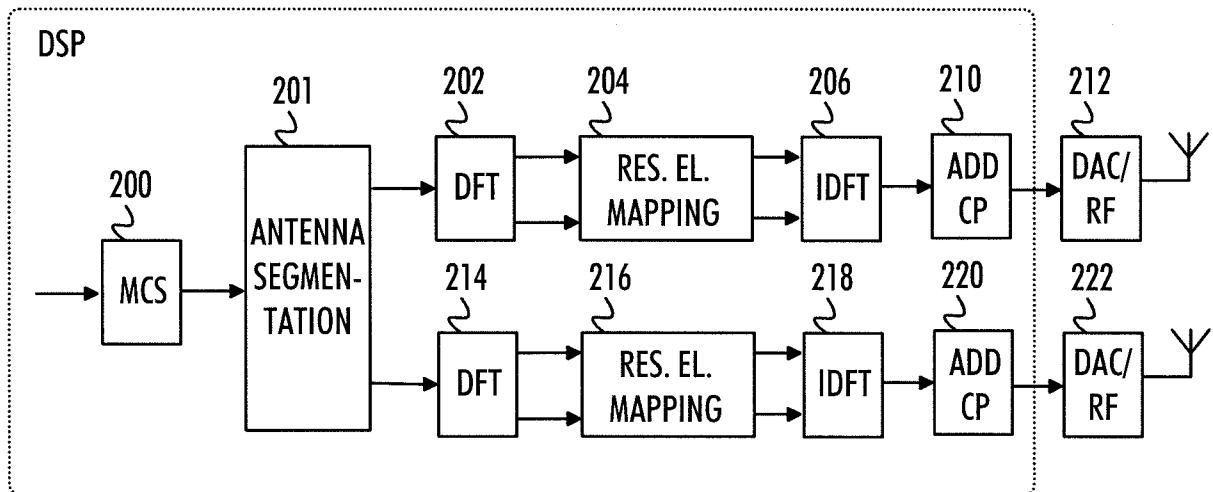


Fig 2

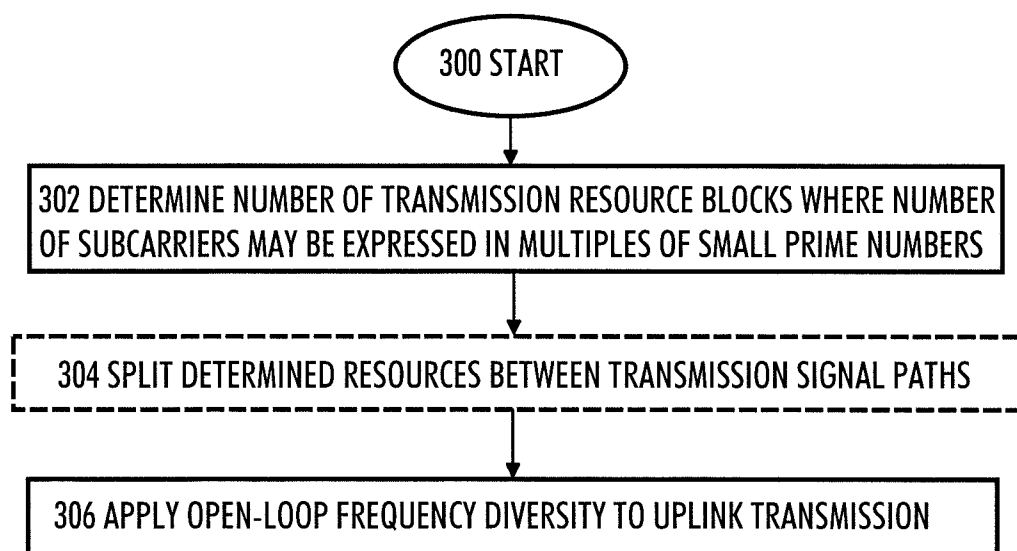


Fig 3

2/4

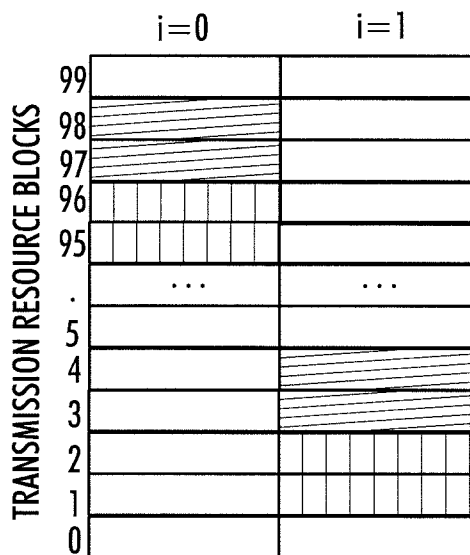


Fig 4A

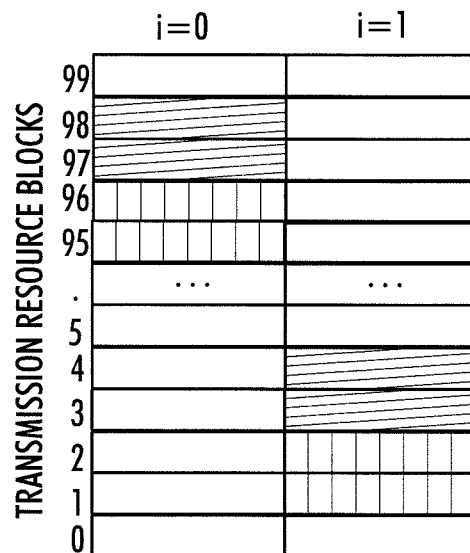


Fig 4B

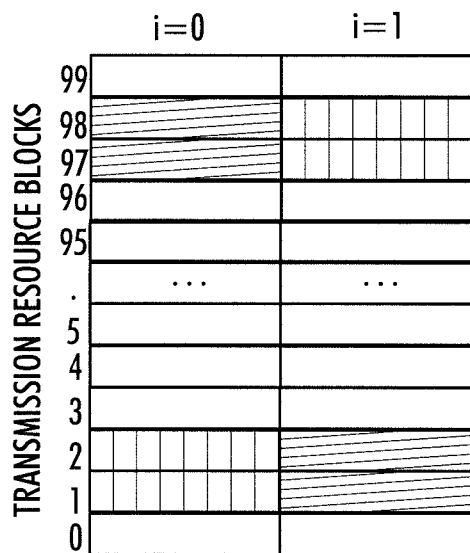


Fig 4C

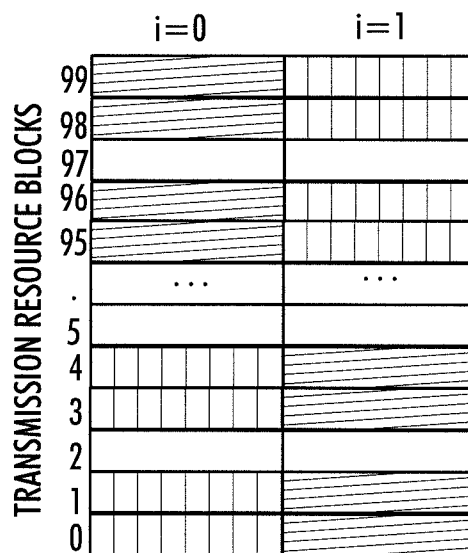
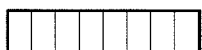


Fig 4D



= SIGNAL PATH #1



= SIGNAL PATH #2

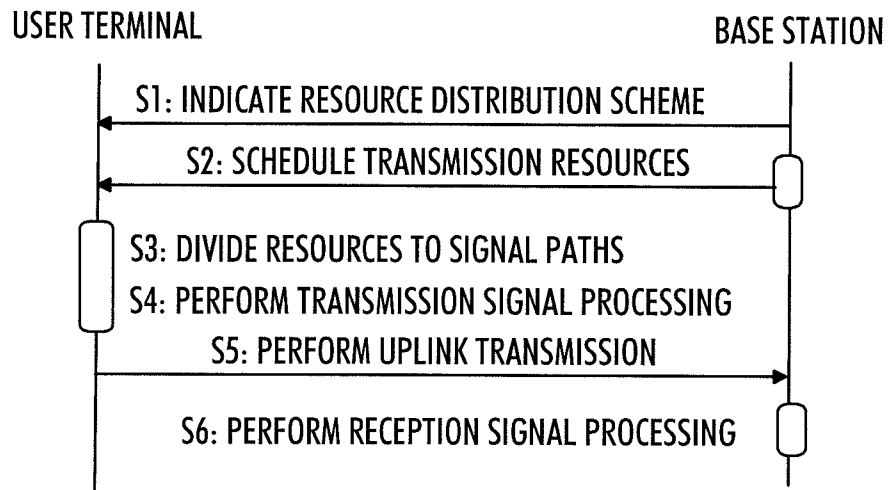


Fig 5

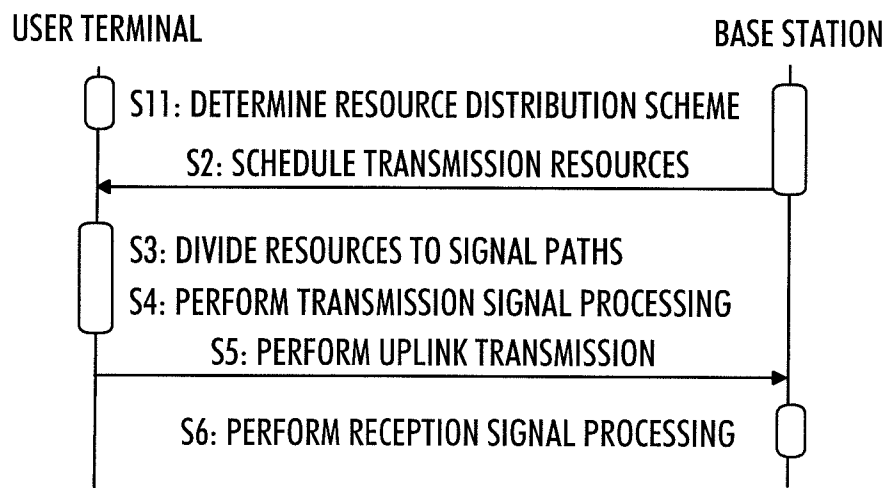


Fig 6

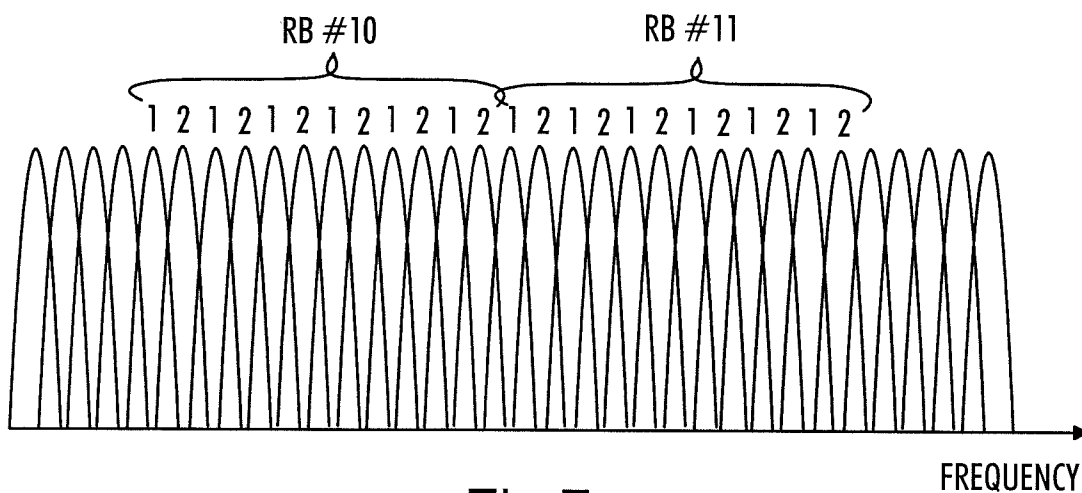


Fig 7

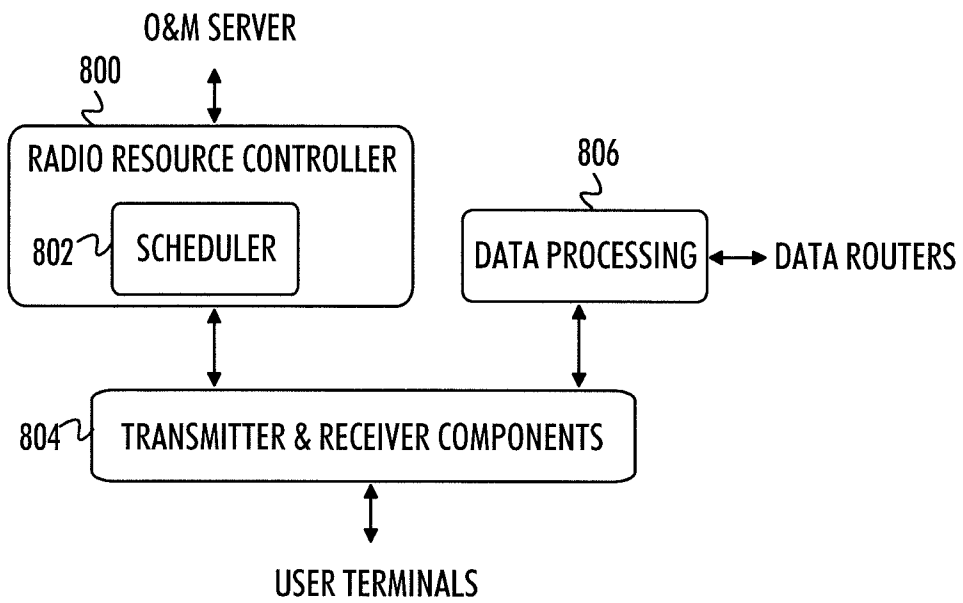


Fig 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/051136

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04B7/06 H04B7/12 H04L5/00 H04B1/713

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)

H04B H04L

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	3GPP DRAFT; 25814-150, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Shanghai, China; 20060526, 26 May 2006 (2006-05-26), XP050102001 pages 71,77,78 ----- -/--	1-11, 14-25, 28-32

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

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

25 January 2010

Date of mailing of the international search report

01/02/2010

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
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Fax: (+31-70) 340-3016

Authorized officer

Franz, Volker

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2009/051136

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ERICSSON: "DFT size for uplink transmissions" 3GPP DRAFT; R1-070461, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Sorrento, Italy; 20070110, 10 January 2007 (2007-01-10), XP050104492 page 1	1-3, 15-17, 29-32
A	EP 1 959 700 A1 (MATSUSHITA ELECTRIC IND CO LTD [JP] PANASONIC CORP [JP]) 20 August 2008 (2008-08-20) claim 4	7,21
A	INTEL CORPORATION: "Downlink OFDMA resource allocation and mapping rules for distributed mode users in E-UTRA" 3GPP DRAFT; R1-060873 DL OFDMA MULTIPLEXING AND RESOURCE ALLOCATION, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Athens, Greece; 20060321, 21 March 2006 (2006-03-21), XP050101783 [retrieved on 2006-03-21] page 2	6,20
A	NORTEL: "RE Mapping of SFBC+FSTD Based TxD for Shared Data Channel" 3GPP DRAFT; R1-073080(NORTEL DATA_MAPPING_4-TX TXD), 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Orlando, USA; 20070620, 20 June 2007 (2007-06-20), XP050106735 [retrieved on 2007-06-20] page 2 - page 3	4-6,14, 18-19,28

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2009/051136

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

1-11, 14-25, 28-32
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-3, 15-17, 29-32

to determine a number of subcarriers per resource block based on multiples of prime numbers lower than 8.

2. claims: 4, 7-11, 18, 21-25

to change the resource block allocation in consecutive transmission time units to provide protection against interference.

3. claims: 5-6, 14, 19-20, 28

to assign unequal number of transmission resource blocks to the transmission signal paths.

4. claims: 12, 26

to calculate a Fourier transform separately for each transmission signal path.

5. claims: 13, 27

to group four transmission antennas into two groups and to apply a space-time block code to each antenna group separately.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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