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(54) Title: RANDOMLY PHASED FEEDBACK ELEMENTS IN A SHARED FEEDBACK CHANNEL

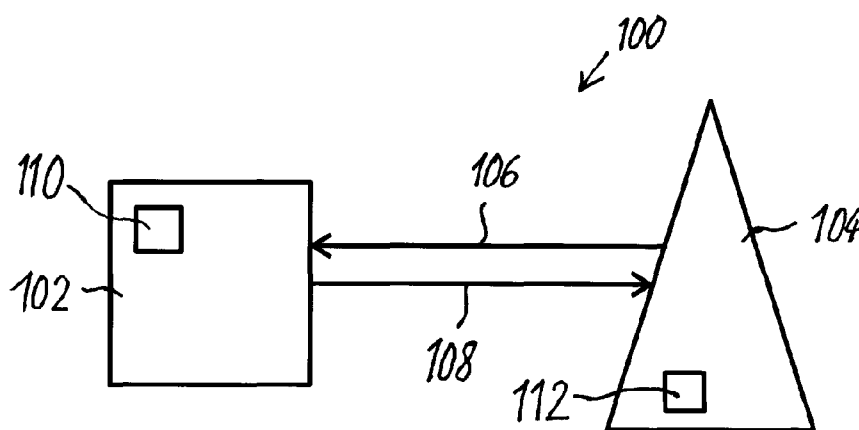


Fig. 1

(57) Abstract: A distributed transmission system is defined, whereby the distributed antennas are relaying feedback information to one or more receivers using random beam forming. According to an embodiment, a feedback message (108) is transmitted to a feedback receiving station (104) via a shared channel which is configured to be shared with at least one further feedback sending station (102). The feedback message (108) comprises at least two feedback elements (109, 109a, 109b, 109c) with a random phase, thereby reducing the likelihood of complete destructive interference of the whole feedback message at a feedback receiving station (104).



DESCRIPTION

Randomly phased feedback elements in a shared feedback channel

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Field of invention

The present invention relates to the field of communication systems and in particular communication systems which use a shared feedback channel for providing feedback to a feedback receiving station.

15 Art Background

In the document 3GPP TSG RAN1 No. 49b R1-072710 (3GPP = 3rd Generation Partnership Project), available from http://www.3gpp.org/ftp/tsg_ran/wg1_r11/tsg_r1_49b/docs, relates to an evolved multimedia broadcast/multicast service (MBMS) system, wherein common signalling is used for uplink feedback. For synchronized user equipments, a common uplink feedback channel is introduced. In this case, users transmit feedback using a common sequence and time frequency region reserved for this transmission in the uplink frame. Some energy aggregation and threshold comparison may be performed to also gauge the approximately number of responses which may aid in modulation and coding scheme (MCS) adaption. Multiple orthogonal sequences may be supported in the same common channel to provide more feedback possibilities.

In view of the above-described situation, there still exists a need for an improved technique that enables to provide feedback over a shared channel.

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Summary of the invention

The inventors have discovered that in a shared feedback channel, different users are interfering with each other
5 due to random phases introduced by the channel.

The need of providing an improved feedback technique over a shared channel may be met by the subject-matter according to the independent claims. Advantageous embodiments
10 of the herein disclosed subject-matter are described by the dependent claims.

According to a first aspect of the herein disclosed subject matter, there is provided a method of operating a
15 feedback sending station of a communication network, the method comprising transmitting a feedback message to a feedback receiving station via a shared channel. The shared channel is configured to be shared with at least one further feedback sending station. Further, the feedback
20 message of the method according to the first aspect comprises two or more feedback elements which have random phase. Hence, the feedback message may be considered as being relayed by using at least two random beams.

25 By providing a feedback element with a random phase, the likelihood of destructive interference of several messages/feedback elements received at a feedback receiving station is reduced. In this regard it is noted that the term "message" or "feedback element" embraces the physical
30 signals which correspond to the respective "message" or "feedback element". Hence "interference of feedback elements/messages" relates to the physical phenomena of interference of the respective physical signals, thus leading to destructive or constructive interference of
35 the signals (waves), depending on the phases and amplitudes of the individual signals. For example, in an embodiment where two or more feedback sending stations transmit the same signal (e.g. a negative acknowledgement

(NACK) message) over the shared channel, destructive interference may result in (almost) complete cancellation of the signals at the receiver if the phases are shifted by 180 degrees with respect to each other.

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A communication network may be for example a wireless communication network. According to an embodiment, a communication network as defined herein is a cellular communication network.

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According to an embodiment, the feedback sending station is a user equipment. For example, according to an embodiment, the user equipment is a mobile phone, a mobile computer, or any other portable or fixed device which is capable of feeding back a message to a feedback receiving station. According to an embodiment, a feedback receiving station is a base station of a wireless communication network.

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20 It is noted that the concept of the herein disclosed subject matter is applicable to and embraces any messaging where two or more sending stations transmit to the same receiving station by using a shared channel.

25 Further it is noted that in accordance with the first aspect not only a single shared channel, but also two or more shared channels may be provided in the communication system.

30 According to a further embodiment of the first aspect, the method further comprises providing a precursor of the feedback element, providing a random phase indicator, and modulating the precursor according to the random phase indicator, thereby generating the feedback element which
35 has a random phase, wherein the random phase corresponds to the random phase indicator.

According to an embodiment, the random phase indicator is a digital random phase indicator. According to other embodiments, the random phase indicator is an analog random phase indicator. According to a further embodiment, the random phase indicator is a random number. In any case, the random phase indicator is used to introduce randomness into the phase of the feedback element. As mentioned above, when having several feedback sending stations of the type described and when having a single sending station transmitting two or more feedback elements each of which has a random phase, the likelihood of destructive interference in the shared channel is reduced.

According to an embodiment, the feedback element is an anonymous feedback element, which means that the feedback element is free of any identifier which allows identification of the feedback sending station from the feedback element. According to a further embodiment, wherein the feedback message consists of one or more feedback elements, each of these feedback elements is an anonymous feedback element.

According to a further embodiment of the first aspect, the feedback element is a symbol or group of symbols of a modulation scheme, wherein each symbol transmits at least one bit. For example, according to one embodiment, the feedback element consists of a single symbol of a modulation scheme. Further, according to another embodiment, a feedback element consists of a group of symbols, i.e. two or more symbols of a modulation scheme. A modulation scheme may be any suitable modulation scheme of a wireless communication system, e.g. orthogonal frequency division multiplexing (OFDM) or wide band code division multiple access (CDMA). According to a further embodiment of the first aspect, the feedback message comprises or consists of the feedback element and a further feedback element which also has a random phase wherein the random phase of the feedback element and the random phase of the

further feedback element are independent from each other. In such an embodiment, the likelihood of destructive interference of feedback messages or feedback message parts/feedback elements at the feedback receiving station
5 can be further reduced.

According to a further embodiment of the first aspect, the feedback message is configured solely for increasing the likelihood of receiving a minimal signal strength, where the
10 minimal signal strength is smaller than the mean signal strength corresponding to the number of transmitted feedback messages at a feedback receiving station. According to a still further embodiment of the first aspect, the feedback message is configured solely for increasing the
15 likelihood of receiving the mean signal strength corresponding to the number of transmitted feedback messages. In the latter two embodiments, distinguishing the transmitters for the feedback messages is not necessary and is not intended to be done. If the feedback messages are,
20 for example, acknowledgement messages or negative acknowledgement messages, the signal strength for the shared feedback channel at the feedback receiving station is an approximate measure for the number of feedback messages. Hence, the signal strength might be a sufficient
25 information in some embodiments, for example in a case where the only type of feedback message in the shared channel is a negative feedback message indicating that reception of data at the feedback sending station failed. An example configuration may be a broadcasting system,
30 where data are transmitted to a plurality of user equipments (feedback sending stations) and wherein a rough estimate of the number of failed data transmissions are sufficient feedback information.

According to a second aspect of the herein disclosed subject-matter, a method of operating a feedback receiving station is provided, the method comprising receiving at least two feedback elements having random phases via a shared channel which channel is configured to be shared among at least two feedback sending stations. Employing several feedback elements which have random phases at each transmitting station reduces the likelihood of destructive interference of the feedback elements at the receiving station. Thus, a more reliable feedback mechanism is provided.

According to a further embodiment of the second aspect, each of the feedback elements is an anonymous feedback element which is free of any identifier allowing identification of the feedback sending station from which the feedback element has been transmitted. By keeping the feedback element or feedback message free of any identifier, the load over the shared channel can be reduced. Further, depending on the application, according to some embodiments an identification of the feedback sending station from which the feedback element has been transmitted is not even necessary. For example, in a broadcasting application, it is not necessary to determine which user equipment failed to receive the broadcasted data, but only the number of user equipments for which the transmission failed is relevant e.g. for adjusting the transmission parameters (broadcast parameters) of the feedback receiving station, e.g. the base station.

According to an embodiment of the second aspect, the method comprises receiving a feedback message from at least two different feedback sending stations over the same, shared feedback channel. According to a further embodiment the content of the feedback messages from the at least two different feedback sending stations is identical. For example, according to an embodiment, the content

of the feedback messages is a negative acknowledgement (NACK).

According to a third aspect of the herein disclosed subject-matter, a feedback sending station of a communication network is provided, the feedback sending station being configured to carry out a method according to the first aspect or an embodiment thereof. For example, the feedback sending station comprises a feedback message generator for generating a feedback message, wherein the feedback message comprises at least two feedback elements which have random phase. Further, according to an embodiment, the feedback sending station comprises a transmitter for transmitting the feedback message to a feedback receiving station over a shared channel which is shared among at least two feedback sending stations.

According to a fourth aspect of the herein disclosed subject-matter, a feedback receiving station of communication network is provided, the feedback receiving station being configured for carrying out the method according to the second aspect or an embodiment thereof. For example, according to an embodiment, the feedback receiving station comprises a receiver configured for receiving feedback elements having random phases via a shared channel which is shared among at least two feedback sending stations.

According to a fifth aspect of the herein disclosed subject-matter, a communication system is provided, the communication system comprising at least two feedback sending stations according to the third aspect or an embodiment thereof and at least one feedback receiving station according to the fourth aspect or an embodiment thereof. It should be understood that in some embodiments, e.g. in case of a cellular communication system, the number of feedback sending stations may dynamically vary.

According to a sixth aspect of the herein disclosed subject-matter, a computer program for processing a physical object, namely a feedback element, is provided, the computer program, when being executed by a data processor is adapted for controlling the method according to the first aspect or an embodiment thereof.

According to an seventh aspect of the herein disclosed subject-matter, a computer program for processing a physical object, namely a feedback element, is provided, wherein the computer program, when being executed by a data processor, is adapted for controlling the method according to the second aspect or an embodiment thereof.

Aspects, embodiments and examples of the herein disclosed subject-matter may be realized by means of a computer program respectively software. However, aspects, embodiments and examples of the herein disclosed subject-matter may also be realized by means of one or more specific electronic circuits respectively hardware. Furthermore, the herein disclosed subject-matter may also be realized in a hybrid form, i.e. in a combination of software modules and hardware modules.

As used herein, reference to a computer program is intended to be equivalent to a reference to a program element and/or a computer-readable medium containing instructions for controlling a computer system to coordinate the performance of the above-described methods.

The computer program may be implemented as a computer-readable instruction code by use of any suitable programming language, such as, for example, JAVA, C++, and may be stored on a computer-readable medium (removable disk, volatile or non-volatile memory, embedded memory/processor, etc.). The instruction code is operable to program a computer or any other programmable device to carry out the intended functions. The computer program

may be available from a network, such as the World-WideWeb, from which it may be downloaded.

In the following, there will be described exemplary embodiments of the herein disclosed subject-matter with reference to a method of operating a feedback sending station and a method of operating a feedback receiving station. Other exemplary embodiments of the herein disclosed subject-matter are described hereinafter with reference to a feedback sending station and/or a feedback receiving station. It has to be pointed out that of course any combination of features relating to different aspects and embodiments of the herein disclosed subject-matter is also possible. In particular, some embodiments have been described with reference to apparatus type claims whereas other embodiments have been described with reference to method type claims. However, a skilled person will gather from the above and the following description that, unless otherwise notified, in addition to any combination of features belonging to one aspect also any combination between features relating to different aspects or embodiments, for example even between features of the apparatus type claims and features of the method type claims is considered to be disclosed with this application. Further, also a combination of features relating to a feedback sending station and features relating to a feedback receiving station is considered to be disclosed with this application. Further, while some features have been disclosed only for the feedback sending station or the feedback receiving station, also corresponding features relating to the respective other aspect are considered to be disclosed in this application.

The aspects and embodiments defined above and further aspects and embodiments of the herein disclosed subject-matter are apparent from the examples to be described hereinafter and are explained with reference to the drawings, but to which the invention is not limited.

Brief description of the drawings

5 Fig. 1 shows a wireless communication system in accordance with embodiments of the herein disclosed subject-matter.

10 Fig. 2 shows schematically a feedback message in accordance with embodiments of the herein disclosed subject-matter.

15 Fig. 3 schematically shows in part a feedback sending station in accordance with embodiments of the herein disclosed subject-matter.

20 Fig. 4 schematically shows in part feedback receiving station in accordance with embodiments of the herein disclosed subject-matter.

25 Fig. 5 shows a cumulative distribution function $P(x < X)$ over the cumulative amplitude x at the feedback receiving station for four feedback sending stations transmitting feedback elements with constant amplitude and constant phase.

30 Fig. 6 shows a cumulative distribution function over amplitude for a case which is identical to that of Fig. 4 except that the feedback elements have random phases.

35 Fig. 7 shows schematically a further feedback message in accordance with embodiments of the herein disclosed subject-matter.

Detailed description

The illustration in the drawings is schematic. It is noted that in different figures, similar or identical elements are provided with the same reference signs or with reference signs which are different from the corresponding reference signs only within the first digit or an appended character.

Examples of the herein disclosed subject-matter are applicable to systems where shared negative acknowledgement channels are employed and where the negative acknowledgement channel can carry more than one feedback element. The feedback element may be a data symbol in an OFDMA system, or a spread symbol in a CDMA system. Examples for such systems are WiMAX (802.16E and 802.16M) and LTE, and UMTS.

The downlink multicast transmission can solve efficiently a problem of scarce wireless resources when a number of stations receive the same data stream, e.g. radio or TV. Since the wireless transmission is broadcast by its nature, the base station can send only one data stream that will be received by several stations. The wireless transmission is prone to errors that may occur due to a faded channel. As a result one or several stations may fail to receive correctly data transmitted over the shared multicast channel. Even though it may not be a severe problem with services such as radio or TV, a user may experience a bad quality. Furthermore some services, such as emergency services are more critical and may require that all the data are delivered properly.

On the one hand, the base station can solve the problem by using the most robust modulation and coding scheme (MCS) overall the stations that belong to the same multicast group or even a more robust one to ensure a correct data reception. However, such an approach leads to a very

bad spectral efficiency. Furthermore, there is no guarantee that a channel does not fade suddenly resulting in a bad data reception. Thus, a possible solution is deploying some retransmission mechanism that can improve the spectral efficiency and correct random reception errors due to a fading channel.

For informing the base station about reception errors, feedback is necessary from the user equipment to the base station. In this embodiment, the user equipment is an example of a feedback sending station and the base station is an example of a feedback receiving station.

The typical way of acknowledging received data is to use a dedicated feedback channel. In certain situations, such as multicast and broadcast, where many users benefit from retransmissions or where the payload has low volume and the feedback is comparatively costly, shared negative acknowledgement feedback mechanisms can be advantageous.

The trade of between retransmission cost for assigning fewer users to one shared negative acknowledgement (NACK) channel but using more shared NACK channels can be assessed analytically. This is possible under certain simplifying assumptions, such as equal (resource allocation) mapping message (MAP) size for all users and negligible impact of the amount of shared channel access on NACK reception error probability. It is noted that the simplified assumptions provide a good starting point for handling more complex cases of mixed MAP message sizes.

The inventors found that one problem that may arise is that in the shared NACK feedback channel different users are interfering with each other due to random phases introduced by the channel. Thus, with a few users sharing simultaneously the NACK channel, NACK reception may fail because of the destructive interference.

To avoid such problems, according to an embodiment it is proposed, to employ complete randomness of the data symbol phases, i.e. the phases are not bound to e.g. codes or code values. This does not mean that complete randomness could not be implemented as pseudo random codes.

However, features of embodiments of the herein disclosed subject-matter relate to one or more of the following features: a) The length of codes can be near infinite if they are used only for generating random numbers; b) The codes might express a phase rotation only (similar to CAZAC sequences); and c) Codes are not used for separating users or groups of users.

It should be pointed out that a mobile station transmitting with random phases to a base station can be understood as an (uplink) beam forming system, creating random phased "beams". This is in fact similar to codebook based beam forming in downlink. These techniques aim at exploiting diversity.

According to an embodiment of the herein disclosed subject-matter, a distributed transmission system is defined, whereby distributed antennas (of one or more feedback sending stations) are relaying information to one or more receivers (feedback receiving stations) using random beam forming. The distributed transmitters are using a number of successive transmission opportunities to transmit feedback elements of random phase and, according to an embodiment, of constant amplitude.

The number of distinct transmission opportunities within allocated channel resources is given to satisfy a minimal signal to interference noise ratio (SINR) or is given by system design constraints such as achieving a certain likelihood to reach a minimum receive amplitude or a certain likelihood to receive the mean amplitude. For instance, in OFDMA the transmission opportunities may be the data symbols within a time-frequency tile.

Fig. 1 shows a wireless communication system 100 in accordance with embodiments of the herein disclosed subject-matter. The communication system 100 comprises a user equipment 102 and a base station 104. The base station 104 is configured for broadcasting a data stream 106 to a plurality of user equipments, of which one user equipment 102 is exemplarily shown in Fig. 1. According to an embodiment, the user equipment 102 transmits to the base station 104 a feedback message 108 in the case that reception or decoding of the data stream 106 has failed. In this way, the base station 104 is informed about reception failures of the user equipments 102, thus allowing the base station to retransmit the data stream 106 to the user equipments, possibly by using different parameters for transmission.

Transmission of the feedback message 108 is effected over a shared channel which is configured to be shared among a plurality of user equipments. As the user equipment 102 is sending the feedback message 108 and the base station is receiving the feedback message 108, the user equipment 102 is a feedback sending station and the base station 104 is a feedback receiving station in the sense of the herein disclosed subject-matter. The feedback message 108 comprises one or more feedback elements having a random phase, i.e. the phases of the feedback elements are independent from each other.

The feedback sending station 102 comprises a controller 110 for controlling operation of the feedback sending station 102. Likewise, the feedback receiving station 104 comprises a controller 112 for controlling operation of the feedback receiving station 104.

The feedback elements with random phase provide for random beam forming which in turn provides diversity gain in a non-coherent fashion. In a more concrete setting of

shared channel access, an embodiment of the herein disclosed subject-matter shapes the cumulative distribution function (CDF) of the interfered signal received at the feedback receiving station 104, when incoherent detection is employed at the feedback receiving station 104. The CDF is shaped such that a) the mean reception value which is given by the number of mobile stations accessing the channel, becomes more likely; and/or b) it becomes less likely that the received amplitude falls below a certain threshold.

In other embodiments, each data symbol may have its own random phase which is independent from the phases of the other data symbols in the same message as well as from the data symbols in other messages. In such cases a feedback element may consist of a single data symbol.

Fig. 2 shows an example of a feedback message 108 in accordance with illustrative embodiments of the herein disclosed subject-matter. According to an embodiment, the feedback message 108 is an OFDMA tile, as shown in Fig. 2. Herein, the bold circles indicate data symbols 113. According to an embodiment, the symbols 113 are quadrature amplitude modulation (QAM) symbols. Further, the first line of four symbols corresponds to a first feedback element 109a, the second line of four symbols of the OFDMA tile 108 corresponds to a second feedback element 109b and the third line of four symbols corresponds to a third feedback element 109c of the OFDMA tile / feedback message 108. According to other embodiments, each single QAM symbol is one feedback element (having a random phase). The OFDMA tile shown in Fig. 2 is in some respect similar to known examples of OFDMA tiles, as disclosed e.g. in IEEE 802.16E Ref 2D9, chapter 8.4.6.2.1. However, in accordance with embodiments of the herein disclosed subject-matter, each of the three feedback elements 109a, 109b, 109c (each of which is defined by one line of the OFDMA tile in Fig. 2) has a random, i.e. usually a dif-

ferent phase. In other words, the example feedback message 108 in Fig. 2 consists of three feedback elements 109a, 109b, 109c, each of which has a random phase that is independent from the random phases of the other two
5 feedback elements. However, other configurations and numbers of data symbols per feedback element are possible. According to a further embodiment, the data symbols of a group of data symbols, which belong to one feedback element, are modulated so as to have the same phase. The
10 number of data symbols in a group may be four, as shown in Fig. 2. However, other numbers of data symbols in a group are also contemplated.

Fig. 3 shows a feedback message generator 114 for generating the feedback message 108 comprising the one or more
15 feedback elements 109a, 109b, 109c having a random phase. The feedback message generator 114 receives a precursor 116a, 116b, 116c of the feedback element 109a, 109b, 109c. Further, the message generator 114 receives random
20 phase indicators 118a, 118b, 118c. In order to not obscure the illustration in Fig. 3, feedback elements 109a, 109b, 109c have been denoted for short as 109a,b,c, the precursors have been denoted as 116a,b,c and the random phase indicators have been denoted as 118a,b,c in Fig. 3.
25 In operation, the feedback message generator modulates the precursors 116a, 116b, 116c by taking into account the random phase indicators 118a, 118b, 118c, e.g. random numbers, thereby generating the feedback elements 108a, 108b, 108c each having a random phase corresponding to
30 the respective random phase indicator 118a, 118b, 118c. Changing the phase of a precursor signal 116a can be done in any suitable way, e.g. by modulation, which is well-known to those skilled in the art. The partially shown feedback sending station 102 in Fig. 3 further comprises
35 a transmitter 120 for transmitting the feedback message 108 comprising the one or more feedback elements 109a, 109b, 109c.

Fig. 4 shows in part the feedback receiving station 104 of Fig. 1. As shown in Fig. 4, according to an embodiment, the feedback receiving station comprises an antenna 122 and a corresponding receiver 124, which are operatively coupled, indicated at 126 in Fig. 4. The receiver 124 is configured for receiving feedback messages 108a, 108b, 108c and 108d.. Each of the feedback messages 108a, 108b, 108c, 108d comprises two or more feedback elements each of which has a random phase.

Further, the feedback receiving station 104 comprises a signal strength measuring unit 128 operatively coupled, as indicated at 130, with the receiver 124. In one embodiment, the signal strength measuring unit 128 is provided for measuring a cumulative signal strength of the received feedback elements/feedback messages. In this way, the number of user equipments 102, for which reception of the data stream 106 has failed, can be estimated by the feedback receiving station (base station) 104.

According to an embodiment, the feedback receiving station 104 is configured for only determining the cumulative signal strength of the received feedback elements, without further using the received feedback elements. According to other embodiments, further processing/use of the received feedback elements is performed by the feedback receiving station 104.

It should be understood, that all components of the feedback sending station, e.g. the feedback message generator 114 or the transmitter 120 is controlled by a respective control unit, e.g. control unit 110. Also, any component of the feedback receiving station 104, e.g. the receiver 124 and the signal strength measuring unit 128 are controlled by a respective control unit, e.g. control unit 112. As disclosed herein, any suitable component of the feedback sending station 102 or the feedback receiving station 104 may be provided in the form of respective

computer programs which enable a processor to provide the functionality of the respective elements as disclosed herein. Further it should be understood, that according to other embodiments, any component of the feedback sending station 102 or the feedback receiving station 104 may be provided in hardware. This includes embodiments wherein some of the components are provided in software whereas some of the components are provided in hardware.

In the following, it is intended to illustrate the effect of random phases of the feedback elements. These considerations are valid for the exemplary feedback message 108 shown in Fig. 2 as well as for any other configuration.

In a first consideration, where all the phases of the feedback elements of a feedback message are assumed to be the same, for the power control system the received signal at the feedback receiving station 104 can be described as

$$r = \left| \sum_{k=1}^n a_k e^{j\varphi_k} \right| = |x|, \quad (1)$$

where n is the number of interferences, each arriving at the feedback receiving station 104 with amplitude a_k and random phase φ_k which comes about by the channel. The notation $|x|$ denotes the magnitude of the complex variable x .

Next, the case is considered that the feedback elements (corresponding in this example to data symbols) are chosen with a random phase at the transmitter, in accordance with embodiments of the herein disclosed subject-matter. If there are D data symbols in one slot, the received amplitude is again the expression of equation (1), but summed over the data symbols:

$$r = \sum_{d=1}^D \frac{1}{D} \left| \sum_{k=1}^n a_k e^{j\varphi_{k,d}} \right| \quad (2).$$

We observe that now D times more random variables are summed compared to equation (1). Here $\varphi_{k,d}$ is a superposition of the random user specific channel phase and the randomly chosen data symbol phase. For a constant amplitude a of the feedback element, we can no longer expect a Rayleigh but a Gaussian distribution in the limit.

To illustrate the effect of the random phases, a simulation for an exemplary system has been carried out, where four users (four feedback sending stations) transmit in one shared negative acknowledgement channel and where the feedback messages are identical and are composed of 36 data symbols. For example, the message may be composed of three tiles of the type shown in Fig. 2.

In one scenario, the 36 data symbol phases are kept constant, hence equation (1) applies and the respective result is shown in Fig. 5 where the probability of measuring an amplitude x that is smaller than a limit X ($P(x < X)$) is depicted over the limit X normalized by an amplitude a of a single message (X/a). In order to introduce further realism in the simulation, the user amplitudes are varied in a range of -2 dB to +2 dB. It should be noted that in the system, on which the simulation of Fig. 5 is based, all 36 data symbols of one user's feedback message slot have the same value (same amplitude and phase). As can be seen from Fig. 5, there is a 16% chance that the received NACK signal is below the amplitude a of a single user.

Fig. 6 shows the result for the same simulation parameters as used for the simulation shown in Fig. 5, except that for Fig. 6 each of the 36 data symbols is randomly phased and hence equation (2) applies. As can be seen

from Fig. 6, mean and median coincide and are at about 2.05 times a . In a simulation where only phases are random and the received amplitudes are constant the mean for the chosen example would be 2 times a . There is an about 5 0% chance that the received NACK signal is below amplitude 1 times a . Again it should be noted that for the simulation of Fig. 6 all 36 symbols have the same amplitude a but random phase.

10 Comparing the results of Fig. 5 and Fig. 6, while the mean will be similar, the median will shift to the right for the case of random phases. This leads to less missed negative acknowledgements due to the switch-like behaviour of the link level packet error rate (PER) curve. The 15 more data symbols can be used the higher the likelihood that at least an amplitude of A is reached for incoherent detection at the feedback receiving station. Mean μ of x refers here to the expected value of x , whereas the median of x refers to the 50%tile of the CDF. Mean and median 20 are identical for symmetric distributions.

In the following, the improvement of mean estimation is quantified. If we interpret r of equation (1) as a random variable which for a given n has realizations $r_{i,n}$, we can 25 express equation (2) as

$$r_{n,D} = \sum_{i=1}^D \frac{r_{i,n}}{D} \quad (3)$$

and consequently

$$\text{var}(r_{n,D}) = \text{var}\left(\sum_{i=1}^D \frac{r_{i,n}}{D}\right) = D \text{var}\left(\frac{r_n}{D}\right) = \frac{\text{var}(r_n)}{D} \quad (4).$$

30

As known, the probability mass around the mean scales with the variance for the Gaussian distribution. It can be shown that the probability mass within a certain interval around the mean μ scales with $\sqrt{D}$ for parameters as 35 in the chosen examples. That is, there will be a $\sqrt{D}$

higher likelihood to observe the mean at the receiver when using D random phased data symbols compared to the data symbols having constant phase.

5 Next, an implementation of the herein disclosed subject-matter in WiMAX (IEEE 802.16M) is described. IEEE 802.16M specifies the resource for fast feedback channels similar to 802.16E Rev. 2 D9. For instance, hybrid automatic repeat request (HARQ) feedback is assigned to feedback mini
10 tiles (FMT) and several FMTs make one feedback channel. Depending on the level of error protection wanted, one or more of those FMTs taken together can be used also for shared NACK feedbacks. For instance, one feedback channel may comprise three FMTs in the time(t)-frequency(f)
15 plane, each FMT having two OFDMA subcarriers and six OFDMA symbols as shown in Fig. 7. The whole channel can thus hold 36 data symbols. This structure shown in Fig. 7 may be used for a shared NACK channel and transmittance of feedback messages according to the herein disclosed
20 subject-matter. According to an embodiment, the shared NACK channel is accessed in case a negative acknowledgement is to be sent. In case of positive acknowledgement nothing is transmitted on the channel.

25 One shared NACK channel may comprise one, two, or more FMTs, e.g. three FMTs as shown in Fig. 7. Each of symbols $C_{0,0} \dots C_{2,11}$ is modulated with the constant amplitude and random phases. According to an embodiment, the amplitude is constant for all messages. Hence, each of symbols $C_{0,0}$
30 $\dots C_{2,11}$ corresponds to a feedback element, some of which are indicated at 109 in Fig. 7. A pseudo random phasing may be employed, using the mobile ID as a seed for the random number generator. A feedback sending station (e.g. user equipment or mobile station) may always use the same
35 seed and hence the same random phasing. According to other embodiments, different seeds for the random number generator may be used.

As already stated above, reference to an OFDMA system is made only for illustrative purposes. Besides OFDMA, embodiments and aspects of the herein disclosed subject-matter may also be implemented in other existing or future technologies, e.g. in long-term evolution (LTE). However, LTE uses a single carrier frequency division multiple access (SC-FDMA) and the implementation may differ from WiMAX therefore only in the arrangement of the data symbols on the time-frequency (symbol-subcarrier) plane. Feedback channel ACK-NACK signals in LTE may be implemented as both computer generated (CG) CAZAC (constant amplitude zero auto-correlation) sequences with different cyclic shift values and Walsh-DFT (discrete Fourier transform) orthogonal sequences. Thus, certain randomness is present. However, sequence length appear to be limited to three or four values and the amount of different sequences is limited to about 16 in one embodiment. This leads to the conclusion that those channels were not designed for improving the likelihood of receiving a minimal amplitude, or exploiting diversity in the feedback channel.

Further, in CDMA, the feedback elements (or symbols or "transmission opportunities") are realized as scrambling or spreading codes. Hence for employing the herein disclosed subject matter in CDMA, as in OFDMA several symbols are random phased and then those several symbols are scrambled or spread with different codes in order to achieve a reduced destructive interference likelihood at the receiver.

In a CDMA system as UMTS this can be done as follows: In HSUPA, a scrambling code or set of scrambling codes for the feedback channel or set of feedback channels is reserved. The feedback sending station needs to have the capability to add the feedback scrambling code(s) to their normal mobile station specific scrambled signal. The power of the feedback code can be a bit lower, as low

as noise floor considerations allow. For signalling, a feedback sending station either random phases segments of the scrambled code within the frame or, when using several scrambling codes, the feedback sending station applies random phases to these scrambling codes.

It should be noted that the term "comprising" does not exclude other elements or steps and that "a" or "an" does not exclude a plurality. Also elements described in association with different embodiments may be combined.

It should also be noted that reference signs in the claims should not be construed as limiting the scope of the claims.

In order to recapitulate the above-described embodiments of the present invention one can state: A distributed transmission system is defined, whereby the distributed antennas are relaying feedback information to one or more receivers using random beam forming. According to an embodiment, a feedback message is transmitted to a feedback receiving station via a shared channel which is configured to be shared with at least one further feedback sending station. The feedback message of each transmitting station comprises at least two feedback elements with random phase, thereby reducing the likelihood of complete destructive interference of the whole feedback message at a feedback receiving station.

30

List of reference signs:

	100	communication system	
5	102	feedback sending station	
	104	feedback receiving station	
	106	data stream	
	108, 108a, 108b, 108c, 108d	feedback message	
	109, 109a, 109b, 109c	feedback element	
10	110	controller	
	112	controller	
	113	data symbols	
	114	feedback message generator	
	116a, 116b, 116c	precursor of feedback element	
15	118a, 118b, 118c	random phase indicator	
	120	transmitter	
	122	antenna	
	124	receiver	
	126	operative coupling	
20	128	signal strength measuring unit	
	130	operative coupling	

25

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CLAIMS:

1. A method of operating a feedback sending station (102) of communication network (100), the method comprising:

- 5 - transmitting a feedback message (108) to a feedback receiving station (104) via a shared channel which is configured to be shared with at least one further feedback sending station (102);
- the feedback message (108) comprising at least two feedback
10 elements (109, 109a, 109b, 109c, 109d) wherein each feedback element has a random phase;
- thereby relaying said feedback message using at least two random beams.

15 2. Method according to claim 1, further comprising:

- providing a precursor (116a, 116b, 116c) of each feedback element (109a, 109b, 109c);
- providing a random phase indicator (118a, 118b, 118c) for each feedback element;
- 20 - modulating said precursor according to said random phase indicator, thereby generating said at least two feedback elements (109, 109a, 109b, 109c, 109d) having a random phase corresponding to respective random phase indicator (118a, 118b, 118c).

25

3. Method according to claim 2, wherein said random phase indicator (118a, 118b, 118c) is a random number.

4. Method according to one of the preceding claims, wherein
30 each feedback element (109, 109a, 109b, 109c) is an anonymous feedback element (109, 109a, 109b, 109c) which is free of any identifier allowing identification of the feedback sending station (102).

5. Method according to one of the preceding claims, wherein each feedback element (109, 109a, 109b, 109c) is a symbol or group of symbols of a modulation scheme, wherein each symbol transmits at least one bit.

6. Method according to one of the preceding claims, wherein feedback message (108) is configured solely for increasing the likelihood of receiving a minimal signal strength, where the minimal signal strength is smaller than the mean signal strength corresponding to the number of transmitted feedback messages at a feedback receiving station (104).

7. Method of operating a feedback receiving station (104), the method comprising:

- receiving feedback elements (109, 109a, 109b, 109c) having random phases via a shared channel which configured to be shared among at least two feedback sending stations (102).

8. Method according to claim 7, further comprising:

- measuring a cumulative signal strength of said received feedback elements (109, 109a, 109b, 109c).

9. Method according to one of claims 7 or 8, wherein each of said feedback elements (109, 109a, 109b, 109c) is an anonymous feedback element (109, 109a, 109b, 109c) which is free of any identifier allowing identification of the feedback sending station (102) from which the feedback element (109, 109a, 109b, 109c) has been transmitted.

10. Method according to one of claims 7 to 9, wherein each feedback element (109, 109a, 109b, 109c) is a symbol or group

of symbols of a modulation scheme, wherein each symbol transmits at least one bit.

11. A computer program for processing a physical object,
5 namely a feedback element (109, 109a, 109b, 109c), the computer program, when being executed by a data processor, is adapted for controlling the method as set forth in any one of the claims 1 to 6.

10 12. A computer program for processing a physical object, namely a feedback element (109, 109a, 109b, 109c), the computer program, when being executed by a data processor, is adapted for controlling the method as set forth in any one of the claims 7 to 10.

15 13. Feedback sending station (102) of a communication network (100), the feedback sending station (102) comprising:

- a feedback message generator (114) for generating a feedback message (108) comprising at least two feedback elements (109, 109a, 109b, 109c) wherein each feedback element has a random phase; and
- a transmitter (120) for transmitting the feedback message (108) to a feedback receiving station (104).

25 14. Feedback receiving station (104) of a communication network (100), the feedback receiving station (104) comprising:

- a receiver (124) configured for receiving over a shared channel feedback elements (109, 109a, 109b, 109c) having random phases.

30 15. Communication system (100) comprising at least one feedback sending stations (102) according to one of claims 13 and

at least one feedback receiving station (104) according to claim 14.

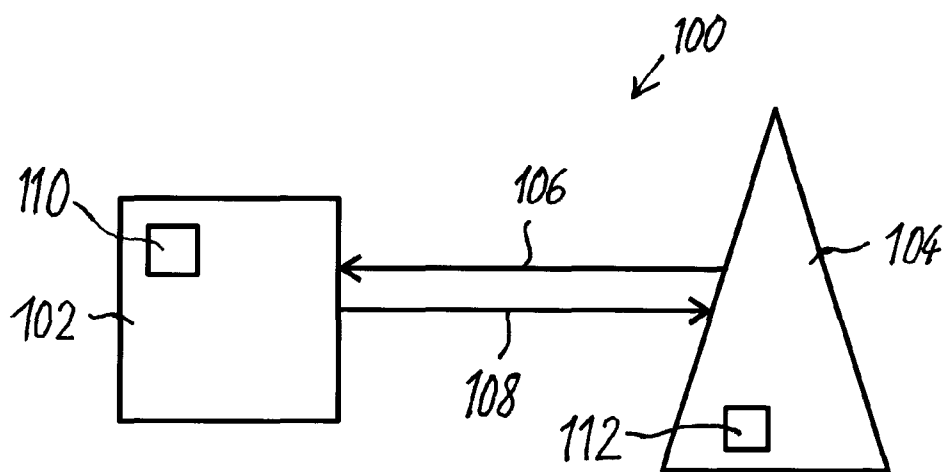


Fig. 1

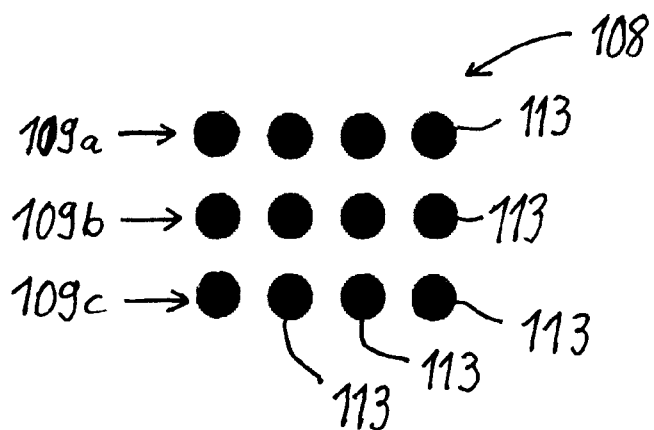


Fig. 2

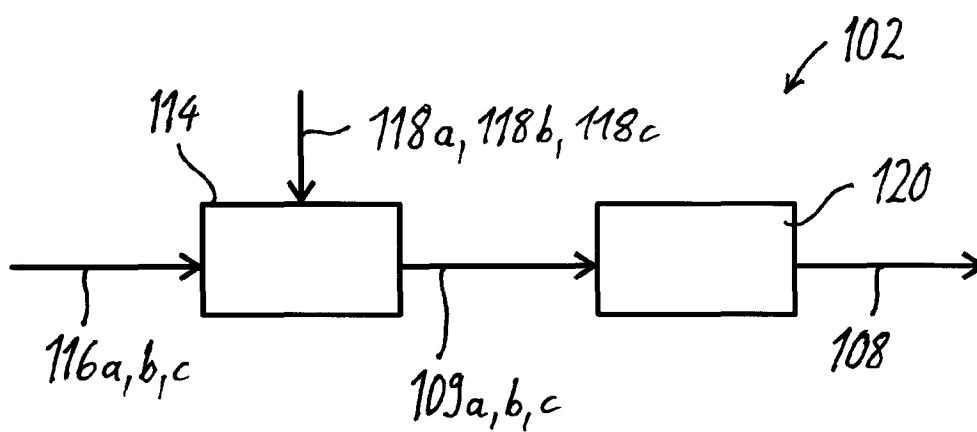


Fig. 3

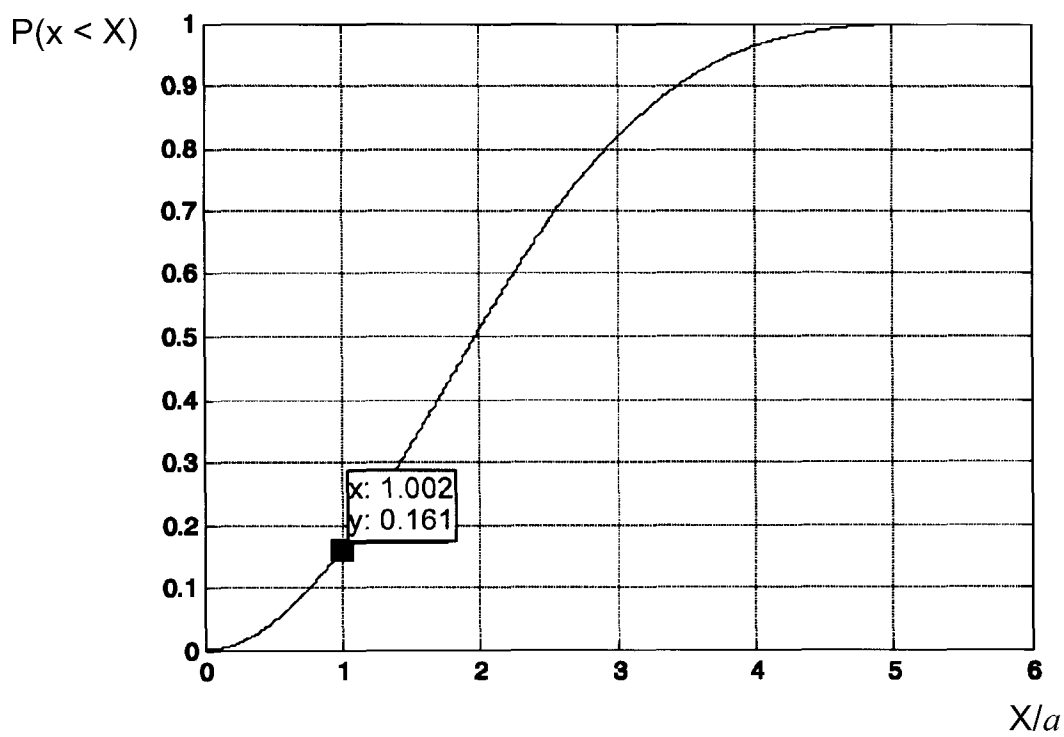
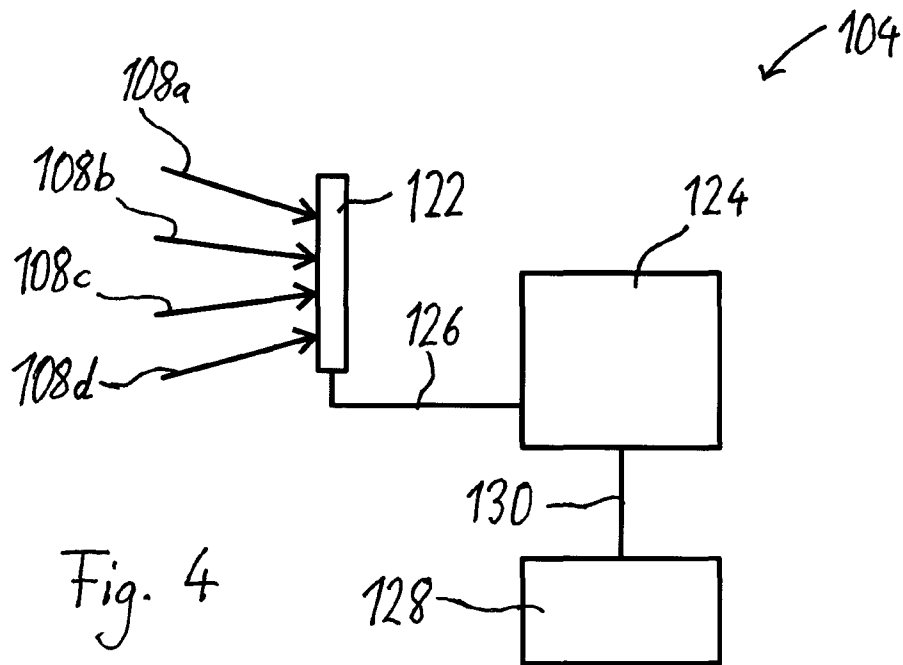


Fig. 5

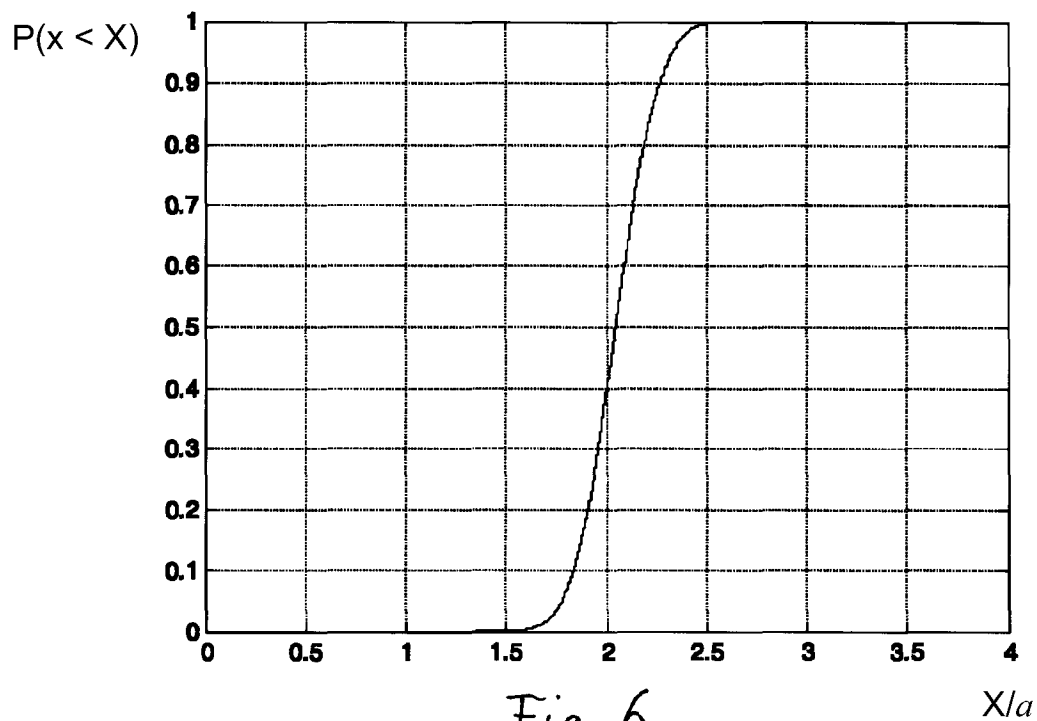


Fig. 6

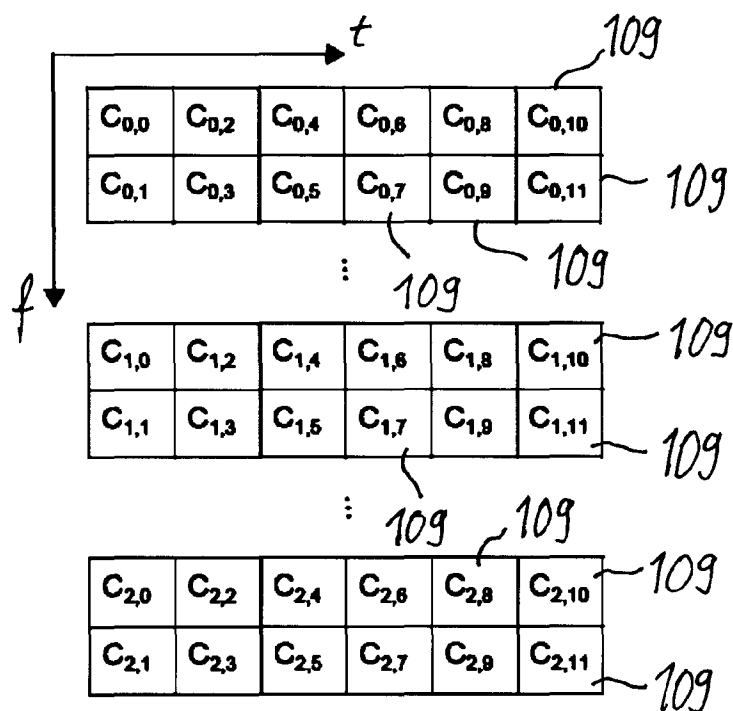


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/059321

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04L25/03
ADD.

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)
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, WPI Data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2009/023730 A2 (QUALCOMM INC [US]; MALLADI DURGA PRASAD [US]; KIM BYOUNG-HOON [US]; MO) 19 February 2009 (2009-02-19)	1-7, 9-15
Y	paragraphs [0045], [0062] - [0064] -----	8
X	LG ELECTRONICS: "Clarification on channel coding for UCI HARQ-ACK" 3GPP DRAFT; R1-090997 DRAFT CR36.212 ACKNACK MAPPING, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, no. Athens, Greece; 20090216, 16 February 2009 (2009-02-16), XP050318825 [retrieved on 2009-02-16] section 5.2.2.6 ----- -/--	1, 2, 4-6, 9-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

1 November 2010

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2009/059321

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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X	TEXAS INSTRUMENTS: "Transmission of Downlink CQI in E-UTRA Uplink" 3GPP DRAFT; R1-072212-CQI, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Kobe, Japan; 20070502, 2 May 2007 (2007-05-02), XP050105948 [retrieved on 2007-05-02] page 1 -----	1,2,5,6, 10-15
Y	Raghuraman Mudumbai, Ben Wild, Upamanyu Madhow, Kannan Ramchandran: "Distributed Beamforming using 1 Bit Feedback: from Concept to Realization" Proc. of 44'th Allerton Conference on Communication Control and computing September 2006 (2006-09), pages 1020-1027, XP002607570 Retrieved from the Internet: URL: http://www.ece.ucsb.edu/{raghu/research/allerton06.pdf [retrieved on 2010-10-29] section II, part A, step 1 -----	8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2009/059321

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