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17414 U.S. PTO 080805

UTILITY PATENT APPLICATION TRANSMITTAL (ONLY FOR NEW NONPROVISIONAL APPLICATIONS UNDER 37 CFR 1.53(B))		
	Attorney Docket No.	68144/P014C1/10503148
	First Inventor	Xiaodong Li
	Title	OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING
	Express Mail Label No.	EV629198592US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

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113261 U.S PTO 11/199586 080805

1. [ ] **Fee Transmittal Form** (e.g., PTO/SB/17) *(Submit an original and a duplicate for fee processing)*
2. [X] **Applicant claims small entity status.** See 37 CFR 1.27.
3. [X] **Specification** [*Total Pages* 63] Both the claims and abstract must start on a new page *(For information on the preferred arrangement, see MPEP 608.01(a))*
4. [X] **Drawing(s)** *(35 U.S.C. 113)* [*Total Sheets* 7]
5. **Oath or Declaration** [*Total Sheets*]
   a. [ ] Newly executed (original or copy)
   b. [ ] A copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [X] **Application Data Sheet.** See 37 CFR 1.76
7. [ ] **CD-ROM or CD-R** in duplicate, large table or Computer Program *(Appendix)*
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   a. Computer Readable Form (CRF)
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ACCOMPANYING APPLICATION PARTS

9. [ ] **Assignment Papers** (cover sheet & document(s))
   Name of Assignee:
10. [ ] **37 CFR 3.73(b) Statement** *(when there is an assignee)* [ ] **Power of Attorney**
11. [ ] **English Translation Document** *(if applicable)*
12. [ ] **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
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18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

[X] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: 09/738,086

Prior application information: Examiner M. N. Zewdu *Art Unit:* 2683

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Utility Patent Application Transmittal

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Transmittal for Continuation Application (1 page)
Specification (47 pages)
Claims (15 pages)
Abstract (1 page)
7 Formal Drawing Sheets
First Preliminary Amendment (10 pages)
Application Data Sheet (3 pages)
Certificate of Mailing (1 page)
Return Postcard

UNITED STATES PATENT APPLICATION

for

OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

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Kemin Li
Wenzhong Zhang

OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

FIELD OF THE INVENTION

The invention relates to the field of wireless communications; more particularly, the invention relates to multi-cell, multi-subscriber wireless systems using orthogonal frequency division multiplexing (OFDM).

BACKGROUND OF THE INVENTION

Orthogonal frequency division multiplexing (OFDM) is an efficient modulation scheme for signal transmission over frequency-selective channels. In OFDM, a wide bandwidth is divided into multiple narrow-band subcarriers, which are arranged to be orthogonal with each other. The signals modulated on the subcarriers are transmitted in parallel. For more information, see Cimini, Jr., "Analysis and Simulation of a Digital Mobile Channel Using Orthogonal Frequency Division Multiplexing," IEEE Trans. Commun., vol. COM-33, no. 7, July 1985, pp. 665-75; Chuang and Sollenberger, "Beyond 3G: Wideband Wireless Data Access Based on OFDM and Dynamic Packet Assignment," IEEE Communications Magazine, Vol. 38, No. 7, pp. 78–87, July 2000.

One way to use OFDM to support multiple access for multiple subscribers is through time division multiple access (TDMA), in which each subscriber uses all the subcarriers within its assigned time slots. Orthogonal frequency division multiple access (OFDMA) is another method for multiple access, using the basic format of OFDM. In OFDMA, multiple subscribers simultaneously use different subcarriers, in a fashion similar to frequency division multiple access (FDMA). For more information, see Sari and Karam, "Orthogonal Frequency-Division Multiple Access and its Application to CATV Networks," European Transactions on Telecommunications, Vol. 9 (6), pp. 507-516, Nov./Dec. 1998 and Nogueroles, Bossert, Donder, and Zyablov, "Improved Performance of a Random OFDMA Mobile Communication System,", Proceedings of IEEE VTC'98, pp. 2502 –2506.

Multipath causes frequency-selective fading. The channel gains are different for different subcarriers. Furthermore, the channels are typically uncorrelated for different subscribers. The subcarriers that are in deep fade for one subscriber may provide high channel gains for another subscriber. Therefore, it is advantageous in an OFDMA system to adaptively allocate the subcarriers to subscribers so that each subscriber enjoys a high channel gain. For more information, see Wong et al., "Multiuser OFDM with

Adaptive Subcarrier, Bit and Power Allocation," IEEE J. Select. Areas Commun., Vol. 17(10), pp. 1747-1758, October 1999.

Within one cell, the subscribers can be coordinated to have different subcarriers in OFDMA. The signals for different subscribers can be made orthogonal and there is little intracell interference. However, with aggressive frequency reuse plan, e.g., the same spectrum is used for multiple neighboring cells, the problem of intercell interference arises. It is clear that the intercell interference in an OFDMA system is also frequency selective and it is advantageous to adaptively allocate the subcarriers so as to mitigate the effect of intercell interference.

One approach to subcarrier allocation for OFDMA is a joint optimization operation, not only requiring the activity and channel knowledge of all the subscribers in all the cells, but also requiring frequent rescheduling every time an existing subscribers is dropped off the network or a new subscribers is added onto the network. This is often impractical in real wireless system, mainly due to the bandwidth cost for updating the subscriber information and the computation cost for the joint optimization.

SUMMARY OF THE INVENTION

A method and apparatus for subcarrier selection for systems is described. In one embodiment, the system employs orthogonal frequency division multiple access (OFDMA). In one embodiment, a method for subcarrier selection comprises a subscriber measuring channel and interference information for subcarriers based on pilot symbols received from a base station, the subscriber selecting a set of candidate subcarriers, providing feedback information on the set of candidate subcarriers to the base station, and receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the invention, which, however, should not be taken to limit the invention to the specific embodiments, but are for explanation and understanding only.

Figure 1A illustrates subcarriers and clusters.

Figure 1B is a flow diagram of one embodiment of a process for allocating subcarriers.

Figure 2 illustrates time and frequency grid of OFDM symbols, pilots and clusters.

Figure 3 illustrates subscriber processing.

Figure 4 illustrates one example of Figure 3.

Figure 5 illustrates one embodiment of a format for arbitrary cluster feedback.

Figure 6 illustrates one embodiment of a partition the clusters into groups.

Figure 7 illustrates one embodiment of a feedback format for group-based cluster allocation.

Figure 8 illustrates frequency reuse and interference in a multi-cell, multi-sector network.

Figure 9 illustrates different cluster formats for coherence clusters and diversity clusters.

Figure 10 illustrates diversity clusters with subcarrier hopping.

Figure 11 illustrates intelligent switching between diversity clusters and coherence clusters depending on subscribers mobility.

Figure 12 illustrates one embodiment of a reconfiguration of cluster classification.

Figure 13 illustrates one embodiment of a base station.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

A distributed, reduced-complexity approach for subcarrier allocation is described. The techniques disclosed herein are described using OFDMA (clusters) as an example. However, they are not limited to OFDMA-based systems. The techniques apply to multi-carrier systems in general, where, for example, a carrier can be a cluster in OFDMA, a spreading code in CDMA, an antenna beam in SDMA (space-division multiple access), etc. In one embodiment, subcarrier allocation is performed in each cell separately. Within each cell, the allocation for individual subscribers (e.g., mobiles) is also made progressively as each new subscriber is added to the system as opposed to joint allocation for subscribers within each cell in which allocation decisions are made taking into account all subscribers in a cell for each allocation.

For downlink channels, each subscriber first measures the channel and interference information for all the subcarriers and then selects multiple subcarriers with good performance (e.g., a high signal-to-interference plus noise ratio (SINR)) and feeds back the information on these candidate subcarriers to the base station. The feedback may comprise channel and interference information (e.g., signal-to-interference-plus-noise-ratio information) on all subcarriers or just a portion of subcarriers. In case of providing information on only a portion of the subcarriers, a subscriber may provide a list of subcarriers ordered starting with those subcarriers which the subscriber desires to use, usually because their performance is good or better than that of other subcarriers.

Upon receiving the information from the subscriber, the base station further selects the subcarriers among the candidates, utilizing additional information available at the base station, e.g., the traffic load information on each subcarrier, amount of traffic requests queued at the base station for each frequency band, whether frequency bands are overused, and/or how long a subscriber has been waiting to send information. In one embodiment, the subcarrier loading information of neighboring cells can also be exchanged between base stations. The base stations can use this information in subcarrier allocation to reduce inter-cell interference.

In one embodiment, the selection by the base station of the channels to allocate, based on the feedback, results in the selection of coding/modulation rates. Such coding/modulation rates may be specified by the subscriber when specifying subcarriers that it finds favorable to use. For example, if the SINR is less than a certain threshold (e.g., 12 dB), quadrature phase shift keying (QPSK) modulation is used; otherwise, 16 quadrature amplitude modulation (QAM) is used. Then the base station informs the subscribers about the subcarrier allocation and the coding/modulation rates to use.

In one embodiment, the feedback information for downlink subcarrier allocation is transmitted to the base station through the uplink access channel, which occurs in a short period every transmission time slot, e.g., 400 microseconds in every 10-millisecond time slot. In one embodiment, the access channel occupies the entire frequency bandwidth. Then the base station can collect the uplink SINR of each subcarrier directly from the access channel. The SINR as well as the traffic load information on the uplink subcarriers are used for uplink subcarrier allocation.

For either direction, the base station makes the final decision of subcarrier allocation for each subscriber.

In the following description, a procedure of selective subcarrier allocation is also disclosed, including methods of channel and interference sensing, methods of information feedback from the subscribers to the base station, and algorithms used by the base station for subcarrier selections.

In the following description, numerous details are set forth to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring the present invention.

Some portions of the detailed descriptions which follow are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

The present invention also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein.

A machine-readable medium includes any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer). For example, a machine-readable medium includes read only memory ("ROM"); random access memory ("RAM"); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other form of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.); etc.

Subcarrier Clustering

The techniques described herein are directed to subcarrier allocation for data traffic channels. In a cellular system, there are typically other channels, pre-allocated for the exchange of control information and other purposes. These channels often include down link and up link control channels, uplink access channels, and time and frequency synchronization channels.

Figure 1A illustrates multiple subcarriers, such as subcarrier 101, and cluster 102. A cluster, such as cluster 102, is defined as a logical unit that contains at least one physical subcarrier, as shown in Figure 1A. A cluster can contain consecutive or disjoint subcarriers. The mapping between a cluster and its subcarriers can be fixed or reconfigurable. In the latter case, the base station informs the subscribers when the clusters are redefined. In one embodiment, the frequency spectrum includes 512 subcarriers and each cluster includes four consecutive subcarriers, thereby resulting in 128 clusters.

An Exemplary Subcarrier/Cluster Allocation Procedure

Figure 1B is a flow diagram of one embodiment of a process for allocation clusters to subscribers. The process is performed by processing logic that may comprise hardware (e.g., dedicated logic, circuitry, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 1B, each base station periodically broadcasts pilot OFDM symbols to every subscriber within its cell (or sector) (processing block 101). The pilot symbols, often referred to as a sounding sequence or signal, are known to both the base station and the subscribers. In one embodiment, each pilot symbol covers the entire OFDM frequency bandwidth. The pilot symbols may be different for different cells (or sectors). The pilot symbols can serve multiple purposes: time and frequency synchronization, channel estimation and signal-to-interference/noise (SINR) ratio measurement for cluster allocation.

Next, each subscriber continuously monitors the reception of the pilot symbols and measures the SINR and/or other parameters, including inter-cell interference and intra-cell traffic, of each cluster (processing block 102).

Based on this information, each subscriber selects one or more clusters with good performance (e.g., high SINR and low traffic loading) relative to each other and feeds back the information on these candidate clusters to the base station through predefined uplink access channels (processing block 103). For example, SINR values higher than 10 dB may indicate good performance. Likewise, a cluster utilization factor less than 50% may be indicative of good performance. Each subscriber selects the clusters with relatively better performance than others. The selection results in each subscriber selecting clusters they would prefer to use based on the measured parameters.

In one embodiment, each subscriber measures the SINR of each subcarrier cluster and reports these SINR measurements to their base station through an access channel. The SINR value may comprise the average of the SINR values of each of the subcarriers in the cluster. Alternatively, the SINR value for the cluster may be the worst SINR among the SINR values of the subcarriers in the cluster. In still another embodiment, a weighted averaging of SINR values of the subcarriers in the cluster is used to generate an SINR value for the cluster. This may be particularly useful in diversity clusters where the weighting applied to the subcarriers may be different.

The feedback of information from each subscriber to the base station contains a SINR value for each cluster and also indicates the coding/modulation rate that the subscriber desires to use. No cluster index is needed to indicate which SINR value in the feedback corresponds to which cluster as long as the order of information in the feedback is known to the base station. In an alternative embodiment, the information in the feedback is ordered according to which clusters have the best performance relative to each other for the subscriber. In such a case, an index is needed to indicate to which cluster the accompanying SINR value corresponds.

Upon receiving the feedback from a subscriber, the base station further selects one or more clusters for the subscriber among the candidates (processing block 104). The base station may utilize additional information available at the base station, e.g., the traffic load information on each subcarrier, amount of traffic requests queued at the base station for each frequency band, whether frequency bands are overused, and how long a subscriber has been waiting to send information. The subcarrier loading information of neighboring cells can also be exchanged between base stations. The base stations can use this information in subcarrier allocation to reduce inter-cell interference.

After cluster selection, the base station notifies the subscriber about the cluster allocation through a downlink common control channel or through a dedicated downlink traffic channel if the connection to the subscriber has already been established (processing block 105). In one embodiment, the base station also informs the subscriber about the appropriate modulation/coding rates.

Once the basic communication link is established, each subscriber can continue to send the feedback to the base station using a dedicated traffic channel (e.g., one or more predefined uplink access channels).

In one embodiment, the base station allocates all the clusters to be used by a subscriber at once. In an alternative embodiment, the base station first allocates multiple clusters, referred to herein as the basic clusters, to establish a data link between the base station and the subscriber. The base station then subsequently allocates more clusters, referred to herein as the auxiliary clusters, to the subscriber to increase the communication bandwidth. Higher priorities can be given to the assignment of basic clusters and lower priorities may be given to that of auxiliary clusters. For example, the base station first ensures the assignment of the basic clusters to the subscribers and then tries to satisfy further requests on the auxiliary clusters from the subscribers. Alternatively, the base station may assign auxiliary clusters to one or more subscribers before allocating basic clusters to other subscribers. For example, a base station may allocate basic and auxiliary clusters to one subscriber before allocating any clusters to other subscribers. In one embodiment, the base station allocates basic clusters to a new subscriber and then determines if there are any other subscribers requesting clusters. If not, then the base station allocates the auxiliary clusters to that new subscriber.

From time to time, processing logic performs retraining by repeating the process described above (processing block 106). The retraining may be performed periodically. This retraining compensates for subscriber movement and any changes in interference. In one embodiment, each subscriber reports to the base station its updated selection of clusters and their associated SINRs. Then the base station further performs the reselection and informs the subscriber about the new cluster allocation. Retraining can be initiated by the base station, and in which case, the base station requests a specific subscriber to report its updated cluster selection. Retraining can also be initiated by the subscriber when it observes channel deterioration.

Adaptive Modulation and Coding

In one embodiment, different modulation and coding rates are used to support reliable transmission over channels with different SINR. Signal spreading over multiple subcarriers may also be used to improve the reliability at very low SINR.

An example coding/modulation table is given below in Table 1.

Table 1

Scheme	Modulation	Code Rate
0	QPSK,1/8 Spreading	½
1	QPSK,¼ Spreading	½
2	QPSK,½ Spreading	½
3	QPSK	½
4	8PSK	2/3
5	16QAM	3/4
6	64QAM	5/6

In the example above, 1/8 spreading indicates that one QPSK modulation symbol is repeated over eight subcarriers. The repetition/spreading may also be extended to the time domain. For example, one QPSK symbol can be repeated over four subcarriers of two OFDM symbols, resulting also 1/8 spreading.

The coding/modulation rate can be adaptively changed according to the channel conditions observed at the receiver after the initial cluster allocation and rate selection.

Pilot Symbols and SINR Measurement

In one embodiment, each base station transmits pilot symbols simultaneously, and each pilot symbol occupies the entire OFDM frequency bandwidth, as shown in Figures 2A-C. Referring to Figure 2A-C, pilot symbols 201 are shown traversing the entire OFDM frequency bandwidth for cells A, B and C, respectively. In one embodiment, each of the pilot symbols have a length or duration of 128 microseconds with a guard time, the combination of which is approximately 152 microseconds. After each pilot period, there are a predetermined number of data periods followed by another set of pilot symbols. In one embodiment, there are four data periods used to transmit data after each pilot, and each of the data periods is 152 microseconds.

A subscriber estimates the SINR for each cluster from the pilot symbols. In one embodiment, the subscriber first estimates the channel response, including the amplitude and phase, as if there is no interference or noise. Once the channel is estimated, the subscriber calculates the interference/noise from the received signal.

The estimated SINR values may be ordered from largest to smallest SINRs and the clusters with large SINR values are selected. In one embodiment, the selected clusters have SINR values that are larger than the minimum SINR which still allows a reliable (albeit low-rate) transmission supported by the system. The number of clusters selected may depend on the feedback bandwidth and the request transmission rate. In one embodiment, the subscriber always tries to send the information about as many clusters as possible from which the base station chooses.

The estimated SINR values are also used to choose the appropriate coding/modulation rate for each cluster as discussed above. By using an appropriate SINR indexing scheme, an SINR index may also indicate a particular coding and modulation rate that a subscriber desires to use. Note that even for the same subscribers, different clusters can have different modulation/coding rates.

Pilot symbols serve an additional purpose in determining interference among the cells. Since the pilots of multiple cells are broadcast at the same time, they will interfere with each other (because they occupy the entire frequency band). This collision of pilot symbols may be used to determine the amount of interference as a worst case scenario. Therefore, in one embodiment, the above SINR estimation using this method is conservative in that the measured interference level is the worst-case scenario, assuming that all the interference sources are on. Thus, the structure of pilot symbols is such that it occupies the entire frequency band and causes collisions among different cells for use in detecting the worst case SINR in packet transmission systems.

During data traffic periods, the subscribers can determine the level of interference again. The data traffic periods are used to estimate the intra-cell traffic as well as the inter-cell interference level. Specifically, the power difference during the pilot and traffic periods may be used to sense the (intra-cell) traffic loading and inter-cell interference to select the desirable clusters.

The interference level on certain clusters may be lower, because these clusters may be unused in the neighboring cells. For example, in cell A, with respect to cluster A there is less interference because cluster A is unused in cell B (while it is used in cell C). Similarly, in cell A, cluster B will experience lower interference from cell B because cluster B is used in cell B but not in cell C.

The modulation/coding rate based on this estimation is robust to frequent interference changes resulted from bursty packet transmission. This is because the rate prediction is based on the worst case situation in which all interference sources are transmitting.

In one embodiment, a subscriber utilizes the information available from both the pilot symbol periods and the data traffic periods to analyze the presence of both the intra-cell traffic load and inter-cell interference. The goal of the subscriber is to provide an indication to the base station as to those clusters that the subscriber desires to use. Ideally, the result of the selection by the subscriber is clusters with high channel gain, low interference from other cells, and high availability. The subscriber provides feedback information that includes the results, listing desired clusters in order or not as described herein.

Figure 3 illustrates one embodiment of subscriber processing. The processing is performed by processing logic that may comprise hardware (e.g., dedicated logic, circuitry, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 3, channel/interference estimation processing block 301 performs channel and interference estimation in pilot periods in response to pilot symbols. Traffic/interference analysis processing block 302 performs traffic and interference analysis in data periods in response to signal information and information from channel/interference estimation block 301.

Cluster ordering and rate prediction processing block 303 is coupled to outputs of channel/interference estimation processing block 301 and traffic/interference analysis processing block 302 to perform cluster ordering and selection along with rate prediction.

The output of cluster ordering processing block 303 is input to cluster request processing block 304, which requests clusters and modulation/coding rates. Indications of these selections are sent to the base station. In one embodiment, the SINR on each cluster is reported to the base station through an access channel. The information is used for cluster selection to avoid clusters with heavy intra-cell traffic loading and/or strong interference from other cells. That is, a new subscriber may not be allocated use of a particular cluster if heavy intra-cell traffic loading already exists with respect to that cluster. Also, clusters may not be allocated if the interference is so strong that the SINR only allows for low-rate transmission or no reliable transmission at all.

The channel/interference estimation by processing block 301 is well-known in the art by monitoring the interference that is generated due to full-bandwidth pilot symbols being simultaneously broadcast in multiple cells. The interface information is forwarded to processing block 302 which uses the information to solve the following equation:

$$H_i S_i + I_i + n_i = y_i$$

where S_i represents the signal for subcarrier (freq. band) i, I_i is the interference for subcarrier i, n_i is the noise associated with subcarrier i, and y_i is the observation for subcarrier i. In the case of 512 subcarriers, i may range from 0 to 511. The I_i and n_i are not separated and may be considered one quantity. The interference/noise and channel gain H_i are not know. During pilot periods, the signal S_i representing the pilot symbols, and the observation y_i are knowns, thereby allowing determination of the channel gain H_i for the case where there is no interference or noise. Once this is known, it may be plugged back into the equation to determine the interference/noise during data periods since H_i, S_i and y_i are all known.

The interference information from processing blocks 301 and 302 are used by the subscriber to select desirable clusters. In one embodiment, using processing block 303, the subscriber orders clusters and also predicts the data rate that would be available using such clusters. The predicted data rate information may be obtained from a look up table with precalculated data rate values. Such a look up table may store the pairs of each SINR and its associated desirable transmission rate. Based on this information, the subscriber selects clusters that it desires to use based on predetermined performance criteria. Using the ordered list of clusters, the subscriber requests the desired clusters along with coding and modulation rates known to the subscriber to achieve desired data rates.

Figure 4 is one embodiment of an apparatus for the selection of clusters based on power difference. The approach uses information available during both pilot symbol periods and data traffic periods to perform energy detection. The processing of Figure 4 may be implemented in hardware, (e.g., dedicated logic, circuitry, etc.), software (such as is run on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 4, a subscriber includes SINR estimation processing block 401 to perform SINR estimation for each cluster in pilot periods, power calculation processing block 402 to perform power calculations for each cluster in pilot periods, and power calculation processing block 403 to perform power calculations in data periods for each cluster. Subtractor 404 subtracts the power calculations for data periods from processing block 403 from those in pilot periods from processing block 402. The output of subtractor 404 is input to power difference ordering (and group selection) processing block 405 that performs cluster ordering and selection based on SINR and the power difference between pilot periods and data periods. Once the clusters have been selected, the subscriber requests the selected clusters and the coding/modulation rates with processing block 406.

More specifically, in one embodiment, the signal power of each cluster during the pilot periods is compared with that during the traffic periods, according to the following:

$$P_P = P_S + P_I + P_N,$$

$$P_D = \begin{cases} P_N\text{, with no signal and interference} \\ P_S + P_N\text{, with signal only} \\ P_I + P_N\text{, with interference only} \\ P_S + P_I + P_N\text{, with both signal and interference} \end{cases}$$

$$P_P - P_D = \begin{cases} P_S + P_I\text{, with no signal and interference} \\ P_I\text{, with signal only} \\ P_S\text{, with interference only} \\ 0\text{, with both signal and interference} \end{cases}$$

where P_P is the measured power corresponding to each cluster during pilot periods, P_D is the measured power during the traffic periods, P_S is the signal power, P_I is the interference power, and P_N is the noise power.

In one embodiment, the subscriber selects clusters with relatively large $P_p/(P_P - P_D)$ (e.g., larger than a threshold such as 10dB) and avoids clusters with low $P_p/(P_P - P_D)$ (e.g., lower than a threshold such as 10dB) when possible.

Alternatively, the difference may be based on the energy difference between observed samples during the pilot period and during the data traffic period for each of the subcarriers in a cluster such as the following:

$$\Delta_i = \left|y_i^P\right| - \left|y_i^D\right|$$

Thus, the subscriber sums the differences for all subcarriers.

Depending on the actual implementation, a subscriber may use the following metric, a combined function of both SINR and $P_P - P_D$, to select the clusters:

$$\beta = f(\text{SINR}, P_P /(P_P - P_D)$$

where f is a function of the two inputs. One example of f is weighted averaging (e.g., equal weights). Alternatively, a subscriber selects a cluster based on its SINR and only uses the power difference $P_P - P_D$ to distinguish clusters with similar SINR. The difference may be smaller than a threshold (e.g., 1 dB).

Both the measurement of SINR and $P_P - P_D$ can be averaged over time to reduce variance and improve accuracy. In one embodiment, a moving-average time window is used that is long enough to average out the statistical abnormity yet short enough to capture the time-varying nature of channel and interference, e.g., 1 millisecond.

Feedback Format for Downlink Cluster Allocation

In one embodiment, for the downlink, the feedback contains both the indices of selected clusters and their SINR. An exemplary format for arbitrary cluster feedback is shown in Figure 5. Referring to Figure 5, the subscriber provides a cluster index (ID) to indicate the cluster and its associated SINR value. For example, in the feedback, the subscriber provides cluster ID1 (501) and the SINR for the cluster, SINR1 (502), cluster ID2 (503) and the SINR for the cluster, SINR2 (504), and cluster ID3 (505), and the SINR for the cluster, SINR3 (506), etc. The SINR for the cluster may be created using an average of the SINRs of the subcarriers. Thus, multiple arbitrary clusters can be selected as the candidates. As discussed above, the selected clusters can also be ordered in the feedback to indicate priority. In one embodiment, the subscriber may form a priority list of clusters and sends back the SINR information in a descending order of priority.

Typically, an index to the SINR level, instead of the SINR itself is sufficient to indicate the appropriate coding/modulation for the cluster. For example, a 3-bit field can be used for SINR indexing to indicate 8 different rates of adaptive coding/modulation.

An Exemplary Base Station

The base station assigns desirable clusters to the subscriber making the request. In one embodiment, the availability of the cluster for allocation to a subscriber depends on the total traffic load on the cluster. Therefore, the base station selects the clusters not only with high SINR, but also with low traffic load.

Figure 13 is a block diagram of one embodiment of a base station. Referring to Figure 13, cluster allocation and load scheduling controller 1301 (cluster allocator) collects all the necessary information, including the downlink/uplink SINR of clusters specified for each subscriber (e.g., via SINR/rate indices signals 1313 received from OFDM transceiver 1305) and user data, queue fullness/traffic load (e.g., via user data buffer information 1311 from multi-user data buffer 1302). Using this information, controller 1301 makes the decision on cluster allocation and load scheduling for each user, and stores the decision information in a memory (not shown). Controller 1301 informs the subscribers about the decisions through control signal channels (e.g., control signal/cluster allocation 1312 via OFDM transceiver 1305). Controller 1301 updates the decisions during retraining.

In one embodiment, controller 1301 also performs admission control to user access since it knows the traffic load of the system. This may be performed by controlling user data buffers 1302 using admission control signals 1310.

The packet data of User 1 ~ N are stored in the user data buffers 1302. For downlink, with the control of controller 1301, multiplexer 1303 loads the user data to cluster data buffers (for Cluster 1 ~ M) waiting to be transmitted. For the uplink, multiplexer 1303 sends the data in the cluster buffers to the corresponding user buffers. Cluster buffer 1304 stores the signal to be transmitted through OFDM transceiver 1305 (for downlink) and the signal received from transceiver 1305. In one embodiment, each user might occupy multiple clusters and each cluster might be shared by multiple users (in a time-division-multiplexing fashion).

<u>Group-Based Cluster Allocation</u>

In another embodiment, for the downlink, the clusters are partitioned into groups. Each group can include multiple clusters. Figure 6 illustrates an exemplary partitioning. Referring to Figure 6, groups 1-4 are shown with arrows pointing to clusters that are in each group as a result of the partitioning. In one embodiment, the clusters within each group are spaced far apart over the entire bandwidth. In one embodiment, the clusters within each group are spaced apart farther than the channel coherence bandwidth, i.e. the bandwidth within which the channel response remains roughly the same. A typical value of coherence bandwidth is 100 kHz for many cellular systems. This improves frequency diversity within each group and increases the probability that at least some of the clusters within a group can provide high SINR. The clusters may be allocated in groups.

Goals of group-based cluster allocation include reducing the data bits for cluster indexing, thereby reducing the bandwidth requirements of the feedback channel (information) and control channel (information) for cluster allocation. Group-based cluster allocation may also be used to reduce inter-cell interference.

After receiving the pilot signal from the base station, a subscriber sends back the channel information on one or more cluster groups, simultaneously or sequentially. In one embodiment, only the information on some of the groups is sent back to the base station. Many criteria can be used to choose and order the groups, based on the channel information, the inter-cell interference levels, and the intra-cell traffic load on each cluster.

In one embodiment, a subscriber first selects the group with the best overall performance and then feedbacks the SINR information for the clusters in that group. The subscriber may order the groups based on their number of clusters for which the SINR is higher than a predefined threshold. By transmitting the SINR of all the clusters in the group sequentially, only the group index, instead of all the cluster indices, needs to be transmitted. Thus, the feedback for each group generally contains two types of information: the group index and the SINR value of each cluster within the group. Figure 7 illustrates an exemplary format for indicating a group-based cluster allocation. Referring to Figure 7, a group ID, ID1, is followed by the SINR values for each of the clusters in the group. This can significantly reduce the feedback overhead.

Upon receiving the feedback information from the subscriber, the cluster allocator at the base station selects multiple clusters from one or more groups, if available, and then assigns the clusters to the subscriber. This selection may be performed by an allocation in a media access control portion of the base station.

Furthermore, in a multi-cell environment, groups can have different priorities associated with different cells. In one embodiment, the subscriber's selection of a group is biased by the group priority, which means that certain subscribers have higher priorities on the usage of some groups than the other subscribers.

In one embodiment, there is no fixed association between one subscriber and one cluster group; however, in an alternative embodiment there may be such a fixed association. In an implementation having a fixed association between a subscriber and one or more cluster groups, the group index in the feedback information can be omitted, because this information is known to both subscriber and base station by default.

In another embodiment, the pilot signal sent from the base station to the subscriber also indicates the availability of each cluster, e.g., the pilot signal shows which clusters have already been allocated for other subscribers and which clusters are available for new allocations. For example, the base station can transmit a pilot sequence 1111 1111 on the subcarriers of a cluster to indicate that the cluster is available, and 1111 –1-1-1-1 to indicate the cluster is not available. At the receiver, the subscriber first distinguishes the two sequences using the signal processing methods which are well known in the art, e.g., the correlation methods, and then estimates the channel and interference level.

With the combination of this information and the channel characteristics obtained by the subscriber, the subscriber can prioritize the groups to achieve both high SINR and good load balancing.

In one embodiment, the subscriber protects the feedback information by using error correcting codes. In one embodiment, the SINR information in the feedback is first compressed using source coding techniques, e.g., differential encoding, and then encoded by the channel codes.

Figure 8 shows one embodiment of a frequency reuse pattern for an exemplary cellular set up. Each cell has hexagonal structure with six sectors using directional antennas at the base stations. Between the cells, the frequency reuse factor is one. Within each cell, the frequency reuse factor is 2 where the sectors use two frequencies alternatively. As shown in Figure 8, each shaded sector uses half of the available OFDMA clusters and each unshaded sector uses the other half of the clusters. Without loss of generality, the clusters used by the shaded sectors are referred to herein as odd clusters and those used by the unshaded sectors are referred to herein as even clusters.

Consider the downlink signaling with omni-directional antennas at the subscribers. From Figure 8, it is clear that for the downlink in the shaded sectors, Cell A interferes with Cell B, which in turn interferes with Cell C, which in turn interferes with Cell A, namely, A -> B -> C ->A. For the unshaded sectors, Cell A interferes with Cell C, which in turn interferes with Cell B, which in turn interferes with Cell A, namely, A -> C -> B ->A.

Sector A1 receives interference from Sector C1, but its transmission interferes with Sector B1. Namely, its interference source and the victims with which it interferes are not the same. This might cause a stability problem in a distributed cluster-allocation system using interference avoidance: if a frequency cluster is assigned in Sector B1 but not in Sector C1, the cluster may be assigned in A1 because it may be seen as clean in A1. However, the assignment of this cluster A1 can cause interference problem to the existing assignment in B1.

In one embodiment, different cluster groups are assigned different priorities for use in different cells to alleviate the aforementioned problem when the traffic load is progressively added to a sector. The priority orders are jointly designed such that a cluster can be selectively assigned to avoid interference from its interference source, while reducing, and potentially minimizing, the probability of causing interference problem to existing assignments in other cells.

Using the aforementioned example, the odd clusters (used by the shaded sectors) are partitioned into 3 groups: Group 1, 2, 3. The priority orders are listed in Table 2.

Table 2: Priority ordering for the downlink of the shaded sectors.

Priority Ordering	Cell A	Cell B	Cell C
1	Group 1	Group 3	Group 2
2	Group 2	Group 1	Group 3
3	Group 3	Group 2	Group 1

Consider Sector A1. First, the clusters in Group 1 are selectively assigned. If there are still more subscribers demanding clusters, the clusters in Group 2 are selectively assigned to subscribers, depending on the measured SINR (avoiding the clusters receiving strong interference from Sector C1). Note that the newly assigned clusters from Group 2 to Sector A1 shall not cause interference problem in Sector B1, unless the load in Sector B1 is so heavy that the clusters in both Group 3 and 1 are used up and the clusters in Group 2 are also used. Table 3 shows the cluster usage when less than 2/3 of all the available clusters are used in Sector A1, B1, and C1.

Table 3: Cluster usage for the downlink of the shaded sectors with less than 2/3 of the full load.

Cluster Usage	Cell A	Cell B	Cell C
1	Group 1	Group 3	Group 2
2	Group 2	Group 1	Group 3
3			

Table 4 shows the priority orders for the unshaded sectors, which are different from those for the shaded sectors, since the interfering relationship is reversed.

Table 4: Priority ordering for the downlink of the unshaded sectors.

Priority Ordering	Cell A	Cell B	Cell C
1	Group 1	Group 2	Group 3
2	Group 2	Group 3	Group 1
3	Group 3	Group 1	Group 2

Intelligent Switching between Coherence and Diversity Clusters

In one embodiment, there are two categories of clusters: coherence clusters, containing multiple subcarriers close to each other and diversity clusters, containing multiple subcarriers with at least some of the subcarriers spread far apart over the spectrum. The closeness of the multiple subcarriers in coherence clusters is preferably within the channel coherence bandwidth, i.e. the bandwidth within which the channel response remains roughly the same, which is typically within 100 kHz for many cellular systems. On the other hand, the spread of subcarriers in diversity clusters is preferably larger than the channel coherence bandwidth, typically within 100 kHz for many cellular systems. Of course, the larger the spread, the better the diversity. Therefore, a general goal in such cases is to maximize the spread.

Figure 9 illustrates exemplary cluster formats for coherence clusters and diversity clusters for Cells A-C. Referring to Figure 9, for cells A-C, the labeling of frequencies (subcarriers) indicates whether the frequencies are part of coherence or diversity clusters. For example, those frequencies labeled 1-8 are diversity clusters and those labeled 9-16 are coherence clusters. For example, all frequencies labeled 1 in a cell are part of one diversity cluster, all frequencies labeled 2 in a cell are part of another diversity cluster, etc., while the group of frequencies labeled 9 are one coherence cluster, the group of frequencies labeled 10 are another coherence cluster, etc. The diversity clusters can be configured differently for different cells to reduce the effect of inter-cell interference through interference averaging.

Figure 9 shows example cluster configurations for three neighboring cells. The interference from a particular cluster in one cell are distributed to many clusters in other cells, e.g., the interference from Cluster 1 in Cell A are distributed to Cluster 1, 8, 7, 6 in Cell B. This significantly reduces the interference power to any particular cluster in Cell B. Likewise, the interference to any particular cluster in one cell comes from many different clusters in other cells. Since not all cluster are strong interferers, diversity clusters, with channel coding across its subcarriers, provide interference diversity gain. Therefore, it is advantageous to assign diversity clusters to subscribers that are close (e.g., within the coherent bandwidth) to the cell boundaries and are more subject to inter-cell interference.

Since the subcarriers in a coherence cluster are consecutive or close (e.g., within the coherent bandwidth) to each other, they are likely within the coherent bandwidth of the channel fading. Therefore, the channel gain of a coherence cluster can vary significantly and cluster selection can greatly improve the performance. On the other hand, the average channel gain of a diversity cluster has less of a degree of variation due to the inherent frequency diversity among the multiple subcarriers spread over the spectrum. With channel coding across the subcarriers within the cluster, diversity clusters are more robust to cluster mis-selection (by the nature of diversification itself), while yielding possibly less gain from cluster selection. Channel coding across the subcarriers means that each codeword contains bits transmitted from multiple subcarriers, and more specifically, the difference bits between codewords (error vector) are distributed among multiple subcarriers.

More frequency diversity can be obtained through subcarrier hopping over time in which a subscriber occupies a set of subcarriers at one time slot and another different set of subcarriers at a different time slot. One coding unit (frame) contains multiple such time slots and the transmitted bits are encoded across the entire frame.

Figure 10 illustrates diversity cluster with subcarrier hopping. Referring to Figure 10, there are four diversity clusters in each of cells A and B shown, with each subcarrier in individual diversity clusters having the same label (1, 2, 3, or 4). There are four separate time slots shown and during each of the time slots, the subcarriers for each of the diversity clusters change. For example, in cell A, subcarrier 1 is part of diversity cluster 1 during time slot 1, is part of diversity cluster 2 during time slot 2, is part of diversity cluster 3 during time slot 3, and is part of diversity cluster 4 during time slot 4. Thus, more interference diversity can be obtained through subcarrier hopping over time, with further interference diversity achieved by using different hopping patterns for different cells, as shown in Figure 10.

The manner in which the subscriber changes the subcarriers (hopping sequences) can be different for different cells in order to achieve better interference averaging through coding.

For static subscribers, such as in fixed wireless access, the channels change very little over time. Selective cluster allocation using the coherence clusters achieves good performance. On the other hand, for mobile subscribers, the channel time variance (the variance due to changes in the channel over time) can be very large. A high-gain cluster at one time can be in deep fade at another. Therefore, cluster allocation needs to be updated at a rapid rate, causing significant control overhead. In this case, diversity clusters can be used to provide extra robustness and to alleviate the overhead of frequent cluster reallocation. In one embodiment, cluster allocation is performed faster than the channel changing rate, which is often measured by the channel Doppler rate (in Hz), i.e. how many cycles the channel changes per second where the channel is completely different after one cycle. Note that selective cluster allocation can be performed on both coherence and diversity clusters.

In one embodiment, for cells containing mixed mobile and fixed subscribers, a channel/interference variation detector can be implemented at either the subscriber or the base station, or both. Using the detection results, the subscriber and the base station intelligently selects diversity clusters to mobile subscribers or fixed subscribers at cell boundaries, and coherence clusters to fixed subscribers close to the base station. The channel/interference variation detector measures the channel (SINR) variation from time to time for each cluster. For example, in one embodiment, the channel/interference detector measures the power difference between pilot symbols for each cluster and averages the difference over a moving window (e.g., 4 time slots). A large difference indicates that channel/interference changes frequently and subcarrier allocation may be not reliable. In such a case, diversity clusters are more desirable for the subscriber.

Figure 11 is a flow diagram of one embodiment of a process for intelligent selection between diversity clusters and coherence clusters depending on subscribers mobility. The process is performed by processing logic that may comprise hardware (e.g., circuitry, dedicated logic, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 11, processing logic in the base station performs channel/interference variation detection (processing block 1101). Processing logic then tests whether the results of the channel/interference variation detection indicate that the user is mobile or in a fixed position close to the edge of the cell (processing block 1102). If the user is not mobile or is not in a fixed position close to the edge of the cell, processing transitions to processing block 1103 where processing logic in the base station selects coherence clusters; otherwise, processing transitions to processing block 1104 in which processing logic in the base station selects diversity clusters.

The selection can be updated and intelligently switched during retraining.

The ratio allocation of the numbers of coherence and diversity clusters in a cell depends on the ratio of the population of mobile and fixed subscribers. When the population changes as the system evolves, the allocation of coherence and diversity clusters can be reconfigured to accommodate the new system needs. Figure 12 illustrates a reconfiguration of cluster classification which can support more mobile subscribers than that in Figure 9.

Whereas many alterations and modifications of the present invention will no doubt become apparent to a person of ordinary skill in the art after having read the foregoing description, it is to be understood that any particular embodiment shown and described by way of illustration is in no way intended to be considered limiting. Therefore, references to details of various embodiments are not intended to limit the scope of the claims which in themselves recite only those features regarded as essential to the invention.

CLAIMS

We claim:

1. A method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA) comprising:

a subscriber measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station;

the subscriber selecting a set of candidate subcarriers;

the subscriber providing feedback information on the set of candidate subcarriers to the base station; and

the subscriber receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber.

2. The method defined in Claim 1 further comprising the subscriber continuously monitoring reception of the pilot symbols known to the base station and measuring signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

3. The method defined in Claim 2 further comprising the subscriber measuring inter-cell interference, wherein the subscriber selects candidate subcarriers based on the inter-cell interference.

4. The method defined in Claim 3 further comprising the base station selecting subcarriers for the subscriber based on inter-cell interference avoidance.

5. The method defined in Claim 2 further comprising the subscriber measuring intra-cell traffic, wherein the subscriber selects candidate subcarriers based on the intra-cell traffic load balancing.

6. The method defined in Claim 5 further comprising the base station selecting the subcarriers in order to balance intra-cell traffic load on each cluster.

7. The method defined in Claim 1 further comprising the subscriber submitting new feedback information after being allocated the set of subscribers to be allocated a new set of subcarriers and thereafter the subscriber receiving another indication of the new set of subcarriers.

8. The method defined in Claim 1 further comprising the subscriber using information from pilot symbol periods and data periods to measure channel and interference information.

9. The method defined in Claim 8 wherein the subscriber selects candidate subcarriers based on the SINR of a cluster of subcarriers and a difference between measured power corresponding to each cluster during pilot periods and measured power during data periods.

10. The method defined in Claim 9 further comprising the subscriber using the power difference to distinguish, during selection, clusters of subcarriers having substantially similar SINRs.

11. The method defined in Claim 8 further comprising the subscriber using information from pilot symbol periods and data traffic periods to analyze presence of intra-cell traffic load and inter-cell interference.

12. The method defined in Claim 1 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

13. The method defined in Claim 12 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

14. The method defined in Claim 1 further comprising the base station selecting the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

15. The method defined in Claim 14 wherein the additional information comprises traffic load information on each cluster of subcarriers.

16. The method defined in Claim 15 wherein the traffic load information is provided by a data buffer in the base station.

17. The method defined in Claim 1 wherein the indication of subcarriers is received via a downlink control channel.

18. The method defined in Claim 1 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

19. The method defined in Claim 1 wherein providing feedback information comprises arbitrarily ordering the set of candidate of subcarriers as clusters of subcarriers.

20. The method defined in Claim 19 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

21. The method defined in Claim 19 wherein the feedback information includes an index indication of a candidate cluster with its SINR value.

22. The method defined in Claim 21 wherein each index is indicative of a coding and modulation rate.

23. The method defined in Claim 1 wherein providing feedback information comprises sequentially ordering candidate clusters.

24. The method defined in Claim 1 further comprising the subscriber sending an indication of coding and modulation rates that the subscriber desires to employ for each cluster.

25. The method defined in Claim 24 wherein the indication of coding and modulation rates comprises an SINR index indicative of a coding and modulation rate.

26. The method defined in Claim 1 further comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

27. The method defined in Claim 26 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

28. The method defined in Claim 26 wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell subcarriers to establish their data link to the base station.

29. An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and

a first base station in the first cell, the first base station performing subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing in response to the feedback information.

30. An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and a first base station in the first cell, the first base station to allocate OFDMA subcarriers in clusters to the plurality of subscribers;

each of a plurality of subscribers to measure channel and interference information for the plurality of subcarriers based on pilot symbols received from the first base station and at least one of the plurality of subscribers to select a set of candidate subcarriers from the plurality of subcarriers, and the one subscriber to provide feedback information on the set of candidate subcarriers to the base station and to receive an indication of subcarriers from the set of subcarriers selected by the first base station for use by the one subscriber.

31. The apparatus defined in Claim 30 wherein each of the plurality of subscribers continuously monitors reception of the pilot symbols known to the base station and the plurality of subscribers and measures signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

32. The apparatus defined in Claim 31 wherein each of the plurality of subscribers measures inter-cell interference, wherein the at least one subscriber selects candidate subcarriers based on the inter-cell interference.

33. The apparatus defined in Claim 32 wherein the base station selects subcarriers for the one subscriber based on inter-cell interference avoidance.

34. The apparatus defined in Claim 31 wherein each of the plurality of subscribers measures intra-cell traffic, wherein the at least one subscriber selects candidate subcarriers based on the intra-cell traffic load balancing.

35. The apparatus defined in Claim 34 wherein the base station selects subcarriers in order to balance intra-cell traffic load on each cluster of subcarriers.

36. The apparatus defined in Claim 30 wherein the subscriber submits new feedback information after being allocated the set of subscribers to receive a new set of subcarriers and thereafter receives another indication of the new set of subcarriers.

37. The apparatus defined in Claim 30 wherein the at least one subscriber uses information from pilot symbol periods and data periods to measure channel and interference information.

38. The apparatus defined in Claim 30 wherein the at least one subscriber selects candidate subcarriers based on SINR of the cluster and a difference between measured power corresponding to each cluster during pilot periods and measured power during data periods.

39. The apparatus defined in Claim 38 wherein the one subscriber distinguishes, during selection, cluster of subcarriers having substantially similar SINRs based on the power difference.

40. The apparatus defined in Claim 38 wherein the at least one subscriber uses information from pilot symbol periods and data traffic periods to analyze presence of intra-cell traffic load and inter-cell interference.

41. The apparatus defined in Claim 38 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

42. The apparatus defined in Claim 41 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

43. The apparatus defined in Claim 30 wherein the base station selects the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

44. The apparatus defined in Claim 43 wherein the additional information comprises traffic load information on each cluster of subcarriers.

45. The apparatus defined in Claim 44 wherein the traffic load information is provided by a data buffer in the base station.

46. The apparatus defined in Claim 30 wherein the indication of subcarriers is received via a downlink control channel between the base station and the at least one subscriber.

47. The apparatus defined in Claim 30 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

48. The apparatus defined in Claim 30 wherein the plurality of subscribers provide feedback information that comprises an arbitrarily ordered set of candidate subcarriers as clusters of subcarriers.

49. The apparatus defined in Claim 48 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

50. The apparatus defined in Claim 48 wherein the feedback information includes an index indication of a candidate cluster with it SINR value.

51. The apparatus defined in Claim 50 wherein each index is indicative of a coding and modulation rate.

52. The apparatus defined in Claim 30 wherein providing feedback information comprises sequentially ordering candidate clusters.

53. The apparatus defined in Claim 30 wherein the one subscriber sends an indication of coding and modulation rates that the one subscriber desires to employ.

54. The apparatus defined in Claim 53 wherein the indication of coding and modulation rates comprises an SINR index indicative of a coding and modulation rate.

55. The apparatus defined in Claim 30 wherein the base station allocates a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then allocates a second portion of the subcarriers to the subscriber to increase communication bandwidth.

56. The apparatus defined in Claim 55 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

57. The apparatus defined in Claim 55 wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell subcarriers to establish their data link to the base station.

58. A method comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

59. The method defined in Claim 57 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

60. A base station comprising:

means for allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and

means for allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

61. The apparatus defined in Claim 60 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

62. An apparatus comprising:

a plurality of subscribers in a cell; and

a base station in the cell, the base station to perform subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing.

ABSTRACT OF THE DISCLOSURE

A method and apparatus for subcarrier selection for systems is described. In one embodiment, the system employs orthogonal frequency division multiple access (OFDMA). In one embodiment, a method for subcarrier selection comprises each of multiple subscribers measuring channel and interference information for subcarriers based on pilot symbols received from a base station, at least one of subscribers selecting a set of candidate subcarriers, providing feedback information on the set of candidate subcarriers to the base station, and the one subscriber receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the one subscriber.

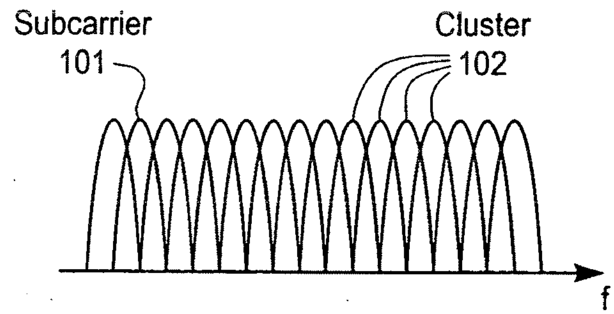

Subcarrier
101
Cluster
102
f

FIG. 1A

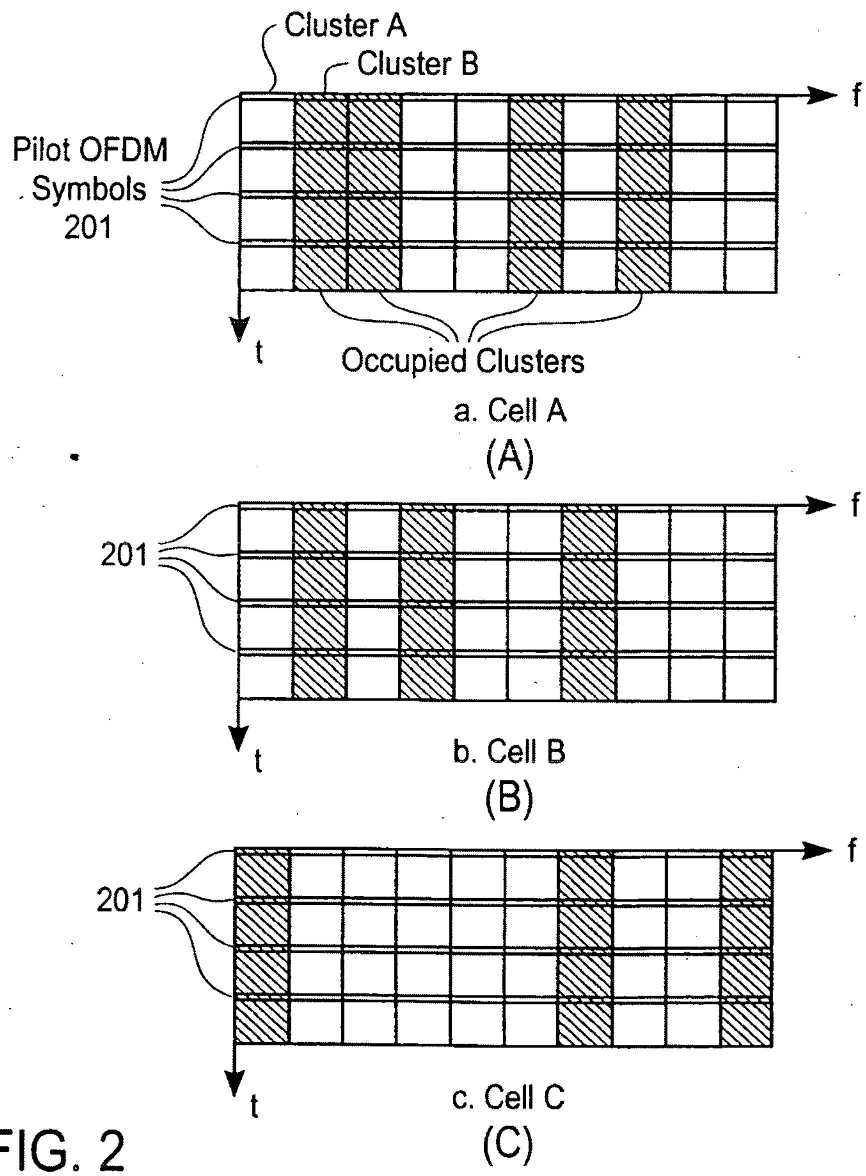

Cluster A
Cluster B
f
Pilot OFDM
Symbols
201
t
Occupied Clusters
a. Cell A
(A)
201
f
t
b. Cell B
(B)
201
f
t
c. Cell C
(C)

FIG. 2

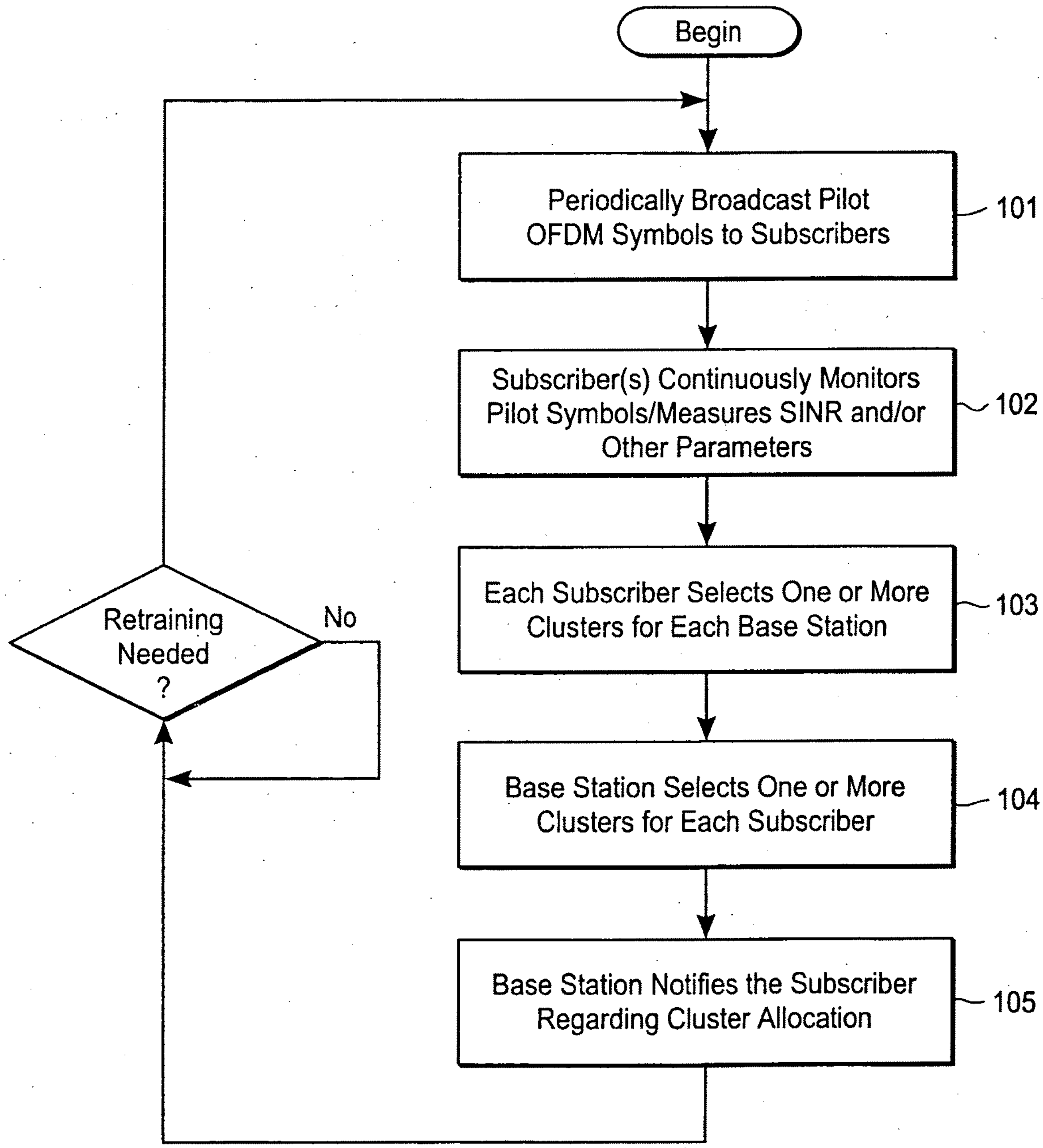

Begin
Periodically Broadcast Pilot OFDM Symbols to Subscribers
101
Subscriber(s) Continuously Monitors Pilot Symbols/Measures SINR and/or Other Parameters
102
Each Subscriber Selects One or More Clusters for Each Base Station
103
Base Station Selects One or More Clusters for Each Subscriber
104
Base Station Notifies the Subscriber Regarding Cluster Allocation
105
Retraining Needed ?
No

FIG. 1B

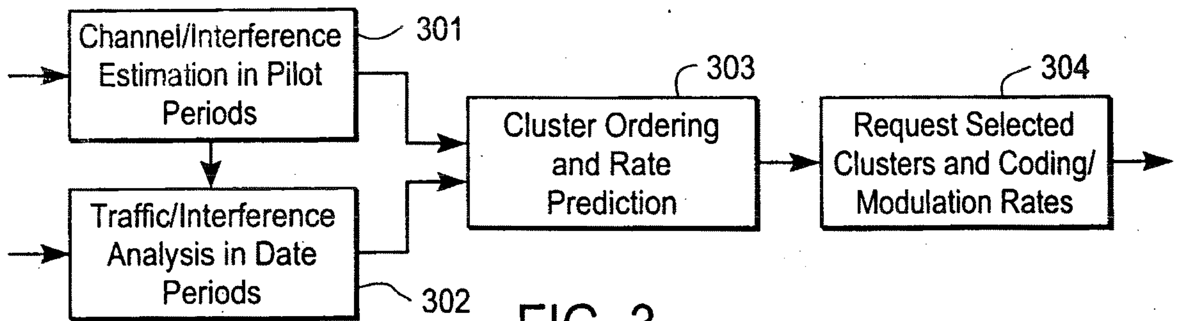


FIG. 3

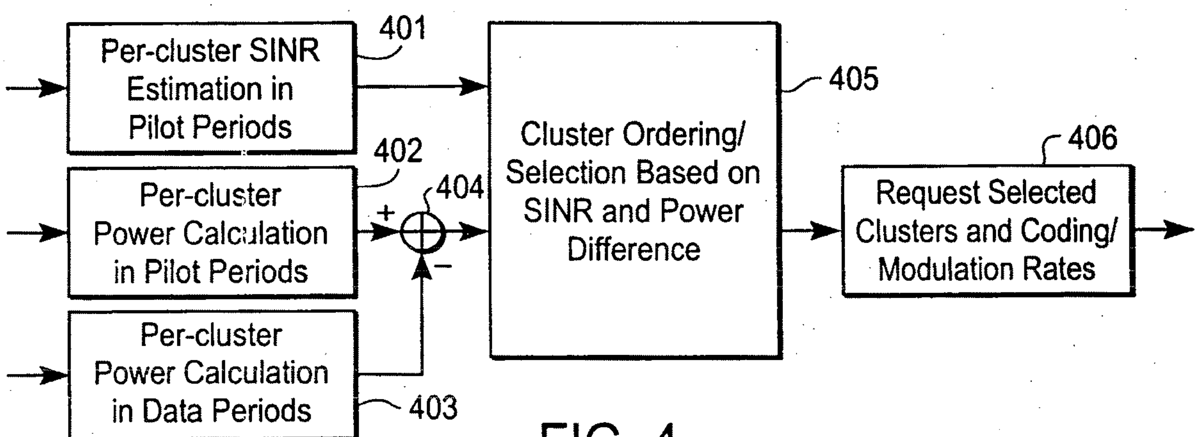


FIG. 4

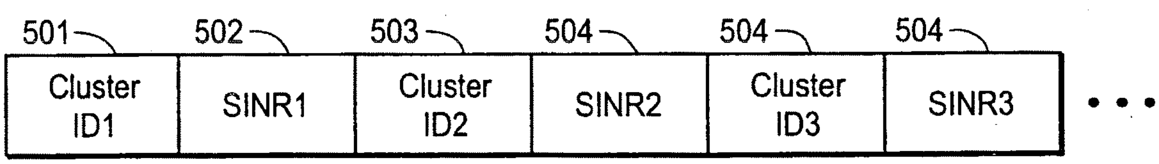


FIG. 5

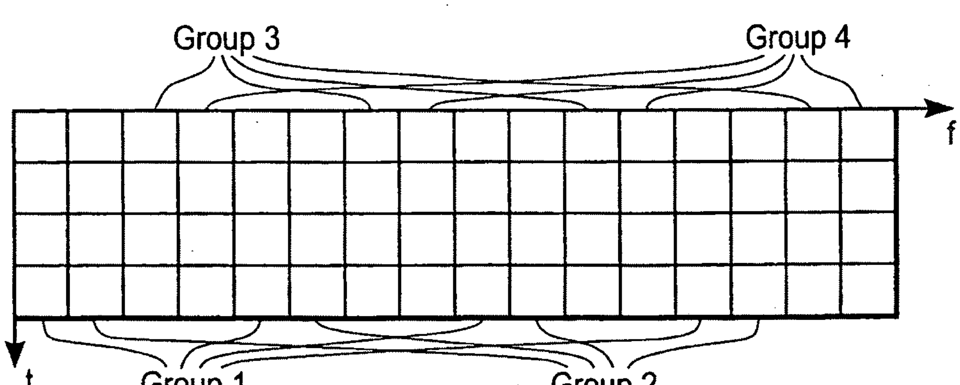


FIG. 6

Group ID1	SINR1	SINR2	SINR3	Group ID2	SINR1	SINR2	SINR3	• • •

FIG. 7

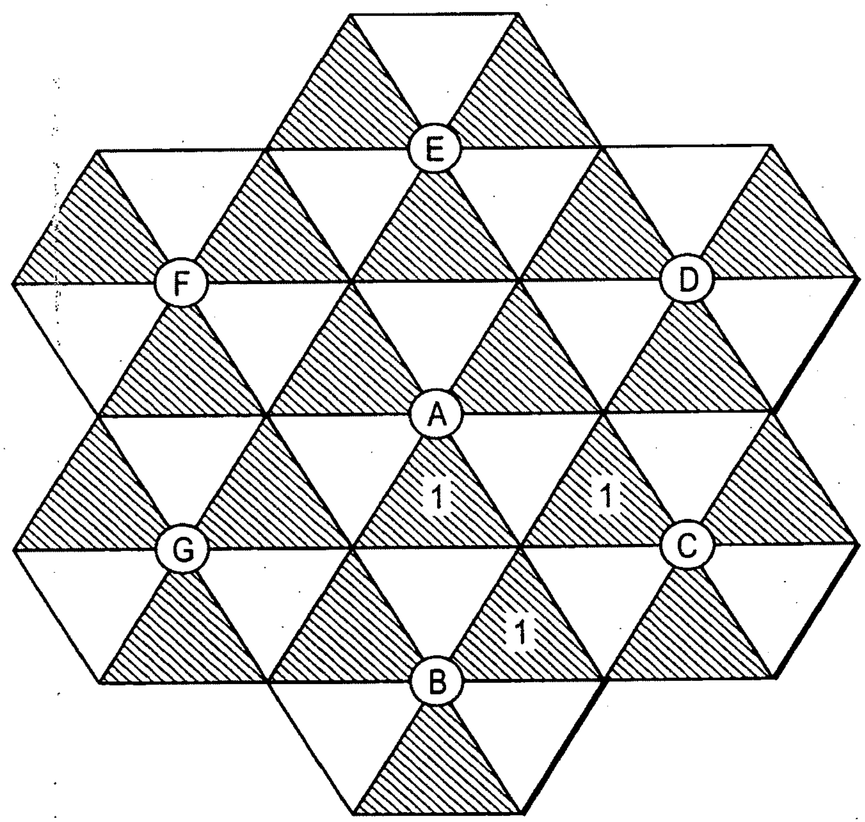


FIG. 8

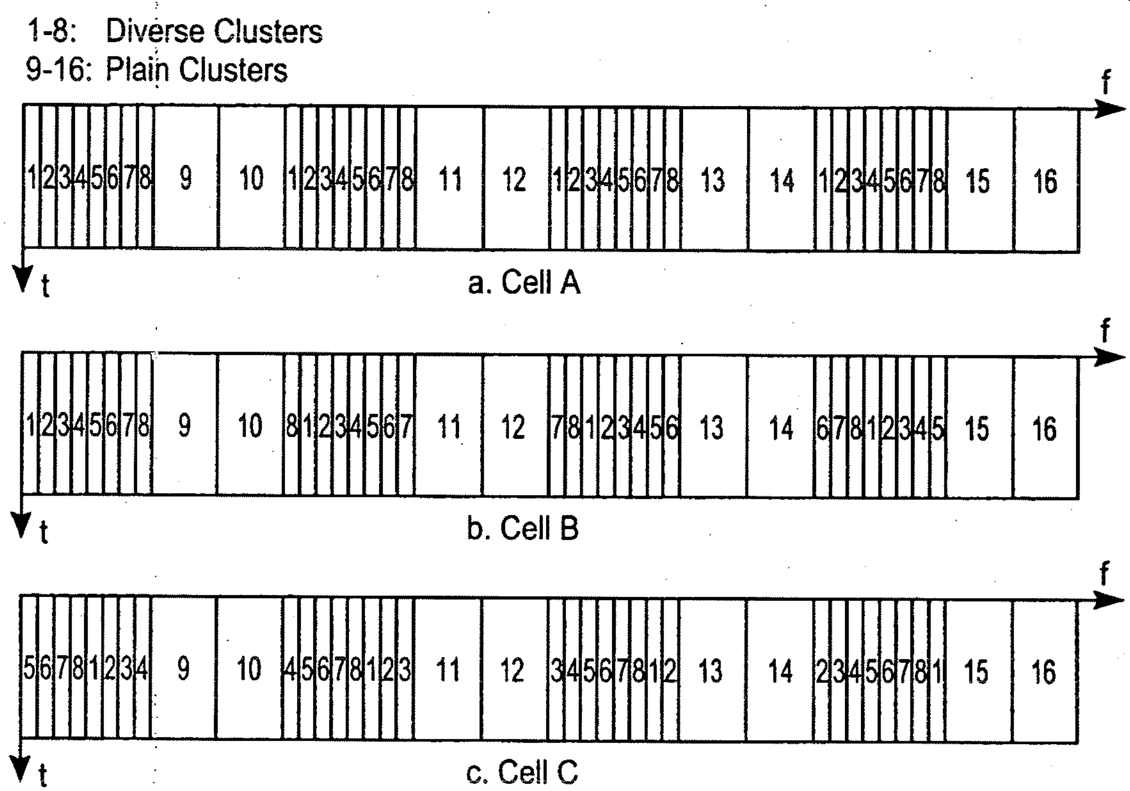

1-8: Diverse Clusters
9-16: Plain Clusters
f
t
1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 11 12 1 2 3 4 5 6 7 8 13 14 1 2 3 4 5 6 7 8 15 16
a. Cell A
1 2 3 4 5 6 7 8 9 10 8 1 2 3 4 5 6 7 11 12 7 8 1 2 3 4 5 6 13 14 6 7 8 1 2 3 4 5 15 16
b. Cell B
5 6 7 8 1 2 3 4 9 10 4 5 6 7 8 1 2 3 11 12 3 4 5 6 7 8 1 2 13 14 2 3 4 5 6 7 8 1 15 16
c. Cell C

FIG. 9

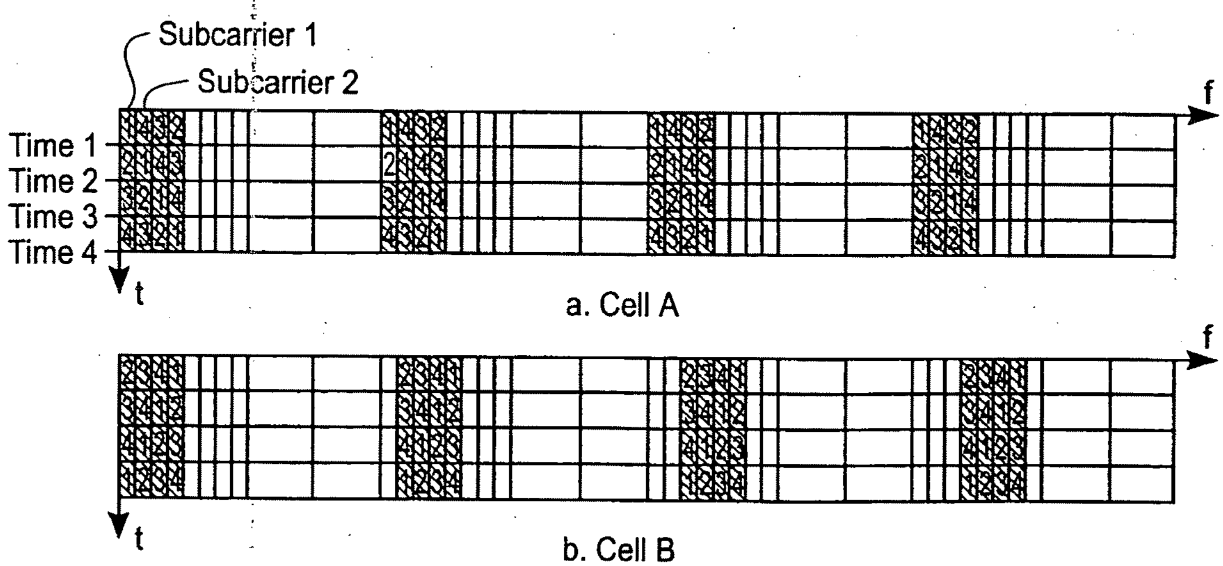

Subcarrier 1
Subcarrier 2
Time 1
Time 2
Time 3
Time 4
f
t
a. Cell A
b. Cell B

FIG. 10

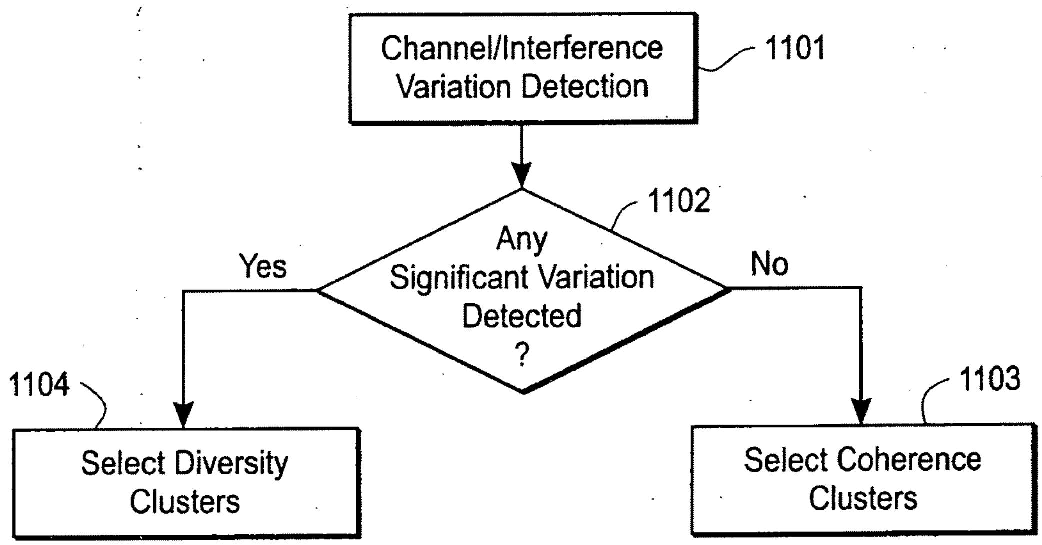
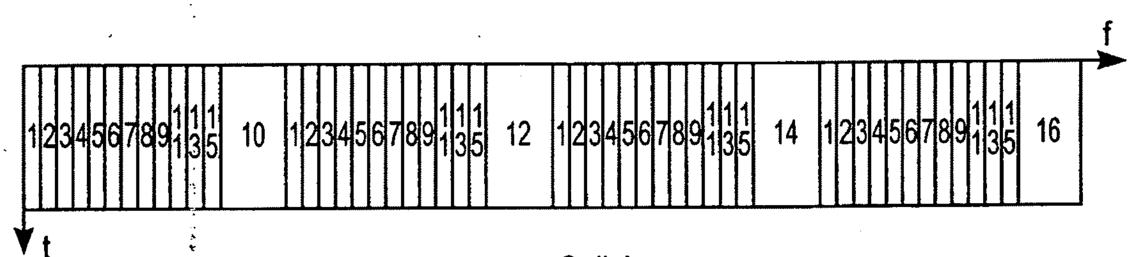


FIG. 11



a. Cell A

FIG. 12

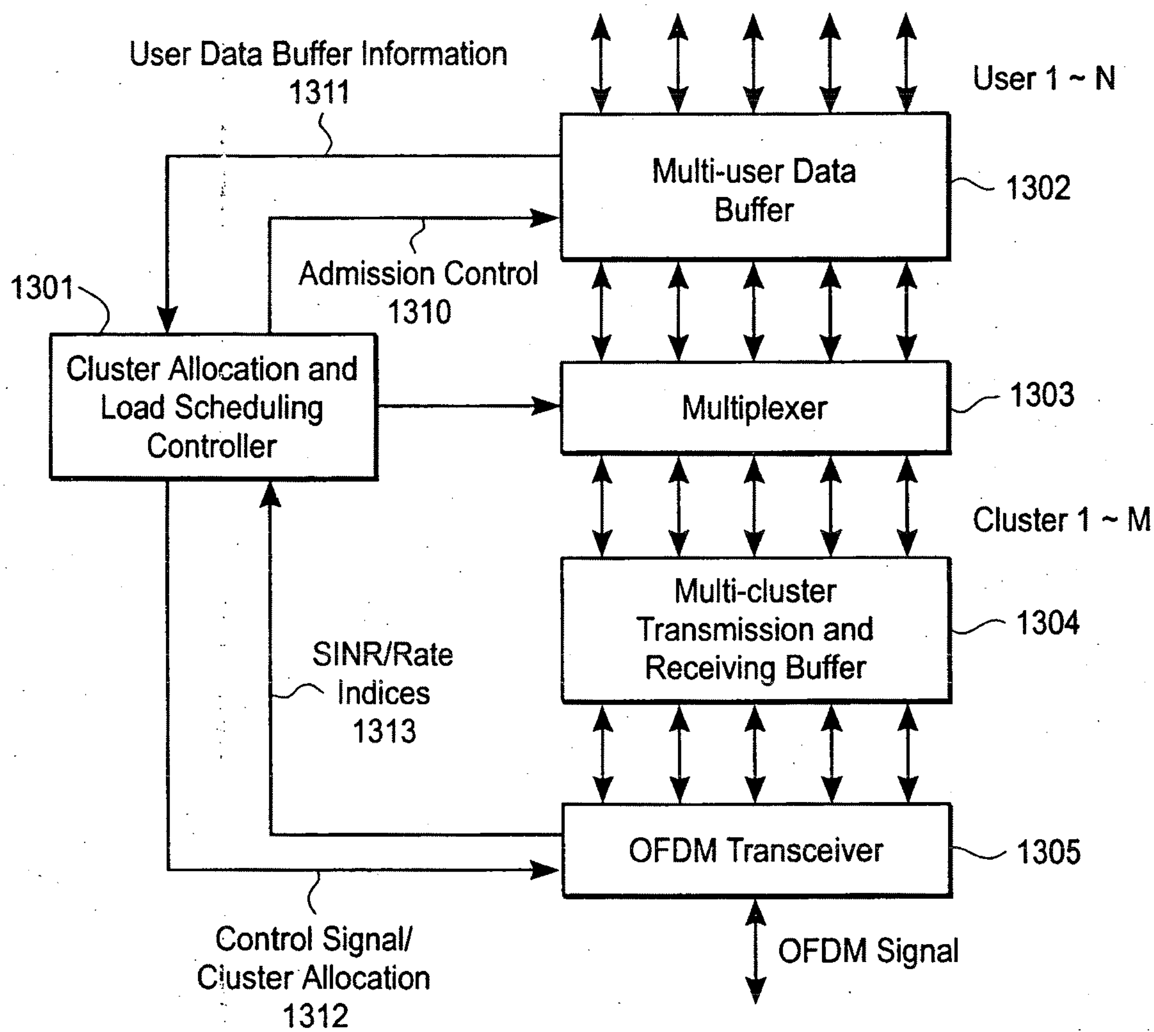

User Data Buffer Information
1311
User 1 ~ N
Multi-user Data Buffer
1302
Admission Control
1310
1301
Cluster Allocation and Load Scheduling Controller
Multiplexer
1303
Cluster 1 ~ M
Multi-cluster Transmission and Receiving Buffer
1304
SINR/Rate Indices
1313
OFDM Transceiver
1305
OFDM Signal
Control Signal/ Cluster Allocation
1312

FIG. 13

AMENDMENTS TO THE SPECIFICATION

After the Title and before the "FIELD OF INVENTION" section of the application please insert the heading "CROSS REFERENCE TO RELATED APPLICATION". After this heading please insert the following paragraph:

[0000] This is a continuing application of Application Serial No. 09/738,086, entitled "OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING," filed December 15, 2000, the disclosure of which is hereby incorporated herein by reference thereto.

I hereby certify that this correspondence is being deposited with the U.S. Postal Service as Express Mail, Airbill No. EV629198592US, in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on the date shown below.

Dated: August 8, 2005 Signature: Susan Bloomfield (Susan Bloomfield)

Docket No.: 68144/P014C1/10503148
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Xiaodong Li et al.

Application No.: Not Yet Assigned

Confirmation No.: N/A

Filed: Concurrently Herewith

Art Unit: N/A

For: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

Examiner: Not Yet Assigned

PRELIMINARY AMENDMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

INTRODUCTORY COMMENTS

Prior to examination on the merits, please amend the above-identified U.S. patent application as follows:

Amendments to the Specification begin on page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims which begins on page 3 of this paper.

Remarks begin on page 9 of this paper.

REMARKS

In view of the above amendment, applicant believes the pending application is in condition for allowance.

Applicant believes no fee is due with this response. However, if a fee is due, please charge our Deposit Account No. 06-2380, under Order No. 68144/P014C1/10503148 from which the undersigned is authorized to draw.

Dated: August 8, 2005

Respectfully submitted,

By________________

Jerry L. Mahurin
Registration No.: 34,661
FULBRIGHT & JAWORSKI L.L.P.
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Dallas, Texas 75201-2784
(214) 855-8000
(214) 855-8200 (Fax)
Attorney for Applicant

AMENDMENTS TO THE CLAIMS

1. (Original) A method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA) comprising:

a subscriber measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station;

the subscriber selecting a set of candidate subcarriers;

the subscriber providing feedback information on the set of candidate subcarriers to the base station; and

the subscriber receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber.

2. (Original) The method defined in Claim 1 further comprising the subscriber sending the indication to a base station.

3. (Original) The method defined in Claim 2 further comprising sending an indication of the group of clusters selected by the base station for use by the subscriber.

4. (Original) The method defined in Claim 3 further comprising the base station selecting subcarriers for the subscriber based on inter-cell interference avoidance.

5. (Canceled)

6. (Canceled)

7. (Original) The method defined in Claim 1 further comprising the subscriber submitting new feedback information after being allocated the set of subscribers to be allocated a new set of subcarriers and thereafter the subscriber receiving another indication of the new set of subcarriers.

8. (Original) The method defined in Claim 1 further comprising the subscriber using information from pilot symbol periods and data periods to measure channel and interference information.

9. (Canceled)

10. (Canceled)

11. (Canceled)

12. (Original) The method defined in Claim 1 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

13. (Original) The method defined in Claim 12 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

14. (Original) The method defined in Claim 1 further comprising the base station selecting the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

15. (Original) The method defined in Claim 14 wherein the additional information comprises traffic load information on each cluster of subcarriers.

16. (Original) The method defined in Claim 15 wherein the traffic load information is provided by a data buffer in the base station.

17. (Original) The method defined in Claim 1 wherein the indication of subcarriers is received via a downlink control channel.

18. (Original) The method defined in Claim 1 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

19. (Original) The method defined in Claim 1 wherein providing feedback information comprises arbitrarily ordering the set of candidate of subcarriers as clusters of subcarriers.

20. (Original) The method defined in Claim 19 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

21. (Canceled)

22. (Canceled)

23. (Original) The method defined in Claim 1 wherein providing feedback information comprises sequentially ordering candidate clusters.

24. (Canceled)

25. (Canceled)

26. (Original) The method defined in Claim 1 further comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

27. (Original) The method defined in Claim 26 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

28. (Canceled)

29. (Original) An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and

a first base station in the first cell, the first base station performing subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing in response to the feedback information.

30. (Original) An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and

a first base station in the first cell, the first base station to allocate OFDMA subcarriers in clusters to the plurality of subscribers;

each of a plurality of subscribers to measure channel and interference information for the plurality of subcarriers based on pilot symbols received from the first base station and at least one of the plurality of subscribers to select a set of candidate subcarriers from the plurality of subcarriers, and the one subscriber to provide feedback information on the set of candidate subcarriers to the base station and to receive an indication of subcarriers from the set of subcarriers selected by the first base station for use by the one subscriber.

31. (Original) The apparatus defined in Claim 30 wherein each of the plurality of subscribers continuously monitors reception of the pilot symbols known to the base station and the plurality of subscribers and measures signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

32. (Original) The apparatus defined in Claim 31 wherein each of the plurality of subscribers measures inter-cell interference, wherein the at least one subscriber selects candidate subcarriers based on the inter-cell interference.

33. (Original) The apparatus defined in Claim 32 wherein the base station selects subcarriers for the one subscriber based on inter-cell interference avoidance.

34. (Canceled)

35. (Canceled)

36. (Original) The apparatus defined in Claim 30 wherein the subscriber submits new feedback information after being allocated the set of subscribers to receive a new set of subcarriers and thereafter receives another indication of the new set of subcarriers.

37. (Original) The apparatus defined in Claim 30 wherein the at least one subscriber uses information from pilot symbol periods and data periods to measure channel and interference information.

39. – 42. (Canceled)

43. (Original) The apparatus defined in Claim 30 wherein the base station selects the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

44. (Original) The apparatus defined in Claim 43 wherein the additional information comprises traffic load information on each cluster of subcarriers.

45. (Original) The apparatus defined in Claim 44 wherein the traffic load information is provided by a data buffer in the base station.

46. (Original) The apparatus defined in Claim 30 wherein the indication of subcarriers is received via a downlink control channel between the base station and the at least one subscriber.

47. (Original) The apparatus defined in Claim 30 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

48. (Original) The apparatus defined in Claim 30 wherein the plurality of subscribers provide feedback information that comprises an arbitrarily ordered set of candidate subcarriers as clusters of subcarriers.

49. (Original) The apparatus defined in Claim 48 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

50. (Canceled)

51. (Canceled)

52. (Original) The apparatus defined in Claim 30 wherein providing feedback information comprises sequentially ordering candidate clusters.

53. (Canceled)

54. (Canceled)

55. (Original) The apparatus defined in Claim 30 wherein the base station allocates a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then allocates a second portion of the subcarriers to the subscriber to increase communication bandwidth.

56. (Original) The apparatus defined in Claim 55 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

57. (Canceled)

58. (Original) A method comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

59. (Original) The method defined in Claim 57 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

60. (Original) A base station comprising:

means for allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and

means for allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

61. (Original) The apparatus defined in Claim 60 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

62. (Original) An apparatus comprising:

a plurality of subscribers in a cell; and

a base station in the cell, the base station to perform subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing.

Application Data Sheet

Application Information

Application Type::	Regular
Subject Matter::	Utility
Suggested Group Art Unit::	N/A
CD-ROM or CD-R?::	None
Sequence submission?::	None
Computer Readable Form (CRF)?::	No
Title::	OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING
Attorney Docket Number::	68144/P014C1/10503148
Request for Early Publication?::	No
Request for Non-Publication?::	No
Total Drawing Sheets::	7
Small Entity?::	Yes
Petition included?::	No
Secrecy Order in Parent Appl.?::	No

Applicant Information

Applicant Authority Type::	Inventor
Primary Citizenship Country::	People's Republic of China
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State or Province of Residence::	WA
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Primary Citizenship Country::	People's Republic of China
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Family Name::	Liu
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City of mailing address::	Sammamish
State or Province of mailing address::	WA
Postal or Zip Code of mailing address::	98075
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Status::	Full Capacity
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State or Province of Residence::	WA
Country of Residence::	US
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City of mailing address::	Bellevue
State or Province of mailing address::	WA
Postal or Zip Code of mailing address::	98007
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Primary Citizenship Country::	People's Republic of China
Status::	Full Capacity
Given Name::	Wenzhong

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City of Residence::	Bellevue
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Street of mailing address::	4275 148th Avenue, NE, F20
City of mailing address::	Bellevue
State or Province of mailing address::	WA
Postal or Zip Code of mailing address::	98007

Correspondence Information

Correspondence Customer Number:: 000029053

Representative Information

Representative Customer Number:: 000029053

Domestic Priority Information

Application::	Continuity Type::	Parent Application::	Parent Filing Date::
This Application	Continuation	09/738,086	Dec. 15, 2000

Assignee Information

Assignee name::	Adaptix, Inc.
Street of mailing address::	605 – 5th Avenue S., Suite 800
City of mailing address::	Seattle
State or Province of mailing address::	WA
Postal or Zip Code of mailing address::	98104
Representative Customer Number::	000029053

PTO/SB/06 (12-04)
Approved for use through 7/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 11199586

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	150		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	250		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	100		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	40 minus 20 =	* 20	x 25 =	500	OR	x =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	6 minus 3 =	* 3	x 100 =	300		x =	
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			N/A			N/A	
			TOTAL	1300		TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371 (c) DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
11/199,586	08/08/2005	Xiaodong Li	68144/P014C1/10503148

CONFIRMATION NO. 1128

FORMALITIES LETTER

000029053
DALLAS OFFICE OF FULBRIGHT & JAWORSKI L.L.P.
2200 ROSS AVENUE
SUITE 2800
DALLAS, TX 75201-2784

Date Mailed: 09/12/2005

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  Applicant must submit $ **150** *to complete the basic filing fee for a small entity.*
- The oath or declaration is missing. *A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.*
  Note: If a petition under 37 CFR 1.47 is being filed, an oath or declaration in compliance with 37 CFR 1.63 signed by all available joint inventors, or if no inventor is available by a party with sufficient proprietary interest, is required.

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- Additional claim fees of $**800** as a small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- To avoid abandonment, a surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.16(f) of $65 for a small entity in compliance with 37 CFR 1.27, must be submitted with the missing items identified in this letter.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is **$1365** for a Small Entity

- **$150** Statutory basic filing fee.

- **$65** Surcharge.

- The application search fee has not been paid. Applicant must submit **$250** to complete the search fee.
- The application examination fee has not been paid. Applicant must submit $**100** to complete the examination fee for a small entity in compliance with 37 CFR 1.27

- Total additional claim fee(s) for this application is $**800**

    - **$300** for **3** independent claims over 3.
    - **$500** for **20** total claims over 20.

Replies should be mailed to: Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

A copy of this notice <u>MUST</u> be returned with the reply.

Office of Initial Patent Examination (571) 272-4000, or 1-800-PTO-9199, or 1-800-972-6382
PART 3 - OFFICE COPY

Attorney's Docket No.: 05158.P002 Patent

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled
OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

the specification of which

___ is attached hereto.
X was filed on (MM/DD/YYYY) 12/15/2000 as
United States Application Number 09/738,086
or PCT International Application Number ________
and was amended on (MM/DD/YYYY) ________.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
(Number)	(Country)	(Foreign Filing Date - MM/DD/YYYY)	Yes	No
(Number)	(Country)	(Foreign Filing Date - MM/DD/YYYY)	Yes	No
(Number)	(Country)	(Foreign Filing Date - MM/DD/YYYY)	Yes	No

I hereby claim the benefit under title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below:

(Application Number)	(Filing Date – MM/DD/YYYY)
(Application Number)	(Filing Date – MM/DD/YYYY)

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Number)	(Filing Date – MM/DD/YYYY)	(Status -- patented, pending, abandoned)
(Application Number)	(Filing Date – MM/DD/YYYY)	(Status -- patented, pending, abandoned)

I hereby appoint the persons listed on Appendix A hereto (which is incorporated by reference and a part of this document) as my respective patent attorneys and patent agents, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send correspondence to Michael J. Mallie (Name of Attorney or Agent), BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, 12400 Wilshire Boulevard 7th Floor, Los Angeles, California 90025 and direct telephone calls to Michael J. Mallie (Name of Attorney or Agent), (408) 720-8300.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of Sole/First Inventor Xiaodong Li

Inventor's Signature [signature] Date 6/19/2001

Residence Bellevue, Washington (City, State) Citizenship China (Country)

Post Office Address 13075 SE 26th, Apt. E208
Bellevue, Washington 98005

Full Name of Second/Joint Inventor Hui Liu

Inventor's Signature [signature] Date 6/19/2001

Residence Sammamish, Washington (City, State) Citizenship China (Country)

Post Office Address 2708 226th Ave., SE
Sammamish, Washington 98075

Full Name of Third/Joint Inventor Kemin Li

Inventor's Signature [signature] Date 6/19/2001

Residence Bellevue, Washington (City, State) Citizenship China (Country)

Post Office Address 14733 NE 1st Place #E6
Bellevue, Washington 98007

Full Name of Fourth/Joint Inventor Wenzhong Zhang

Inventor's Signature [signature] Date 6/19/2001

Residence Bellevue, Washington (City, State) Citizenship China (Country)

Post Office Address 4275 148th Avenue, NE, F20
Bellevue, Washington 98007

APPENDIX A

William E. Alford, Reg. No. 37,764; Farzad E. Amini, Reg. No. 42,261; William Thomas Babbitt, Reg. No. 39,591; Carol F. Barry, Reg. No. 41,600; Jordan Michael Becker, Reg. No. 39,602; Lisa N. Benado, Reg. No. 39,995; Bradley J. Bereznak, Reg. No. 33,474; Michael A. Bernadicou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; R. Alan Burnett, Reg. No. 46,149; Gregory D. Caldwell, Reg. No. 39,926; Andrew C. Chen, Reg. No. 43,544; Thomas M. Coester, Reg. No. 39,637; Donna Jo Coningsby, Reg. No. 41,684; Florin Corie, Reg. No. 46,244; Dennis M. deGuzman, Reg. No. 41,702; Stephen M. De Klerk, Reg. No. 46,503; Michael Anthony DeSanctis, Reg. No. 39,957; Daniel M. De Vos, Reg. No. 37,813; Sanjeet Dutta, Reg. No. 46,145; Matthew C. Fagan, Reg. No. 37,542; Tarek N. Fahmi, Reg. No. 41,402; George Fountain, Reg. No. 37,374; James Y. Go, Reg. No. 40,621; James A. Henry, Reg. No. 41,064; Libby N. Ho, Reg. No. 46,774; Willmore F. Holbrow III, Reg. No. 41,845; Sheryl Sue Holloway, Reg. No. 37,850; George W Hoover II, Reg. No. 32,992; Eric S. Hyman, Reg. No. 30,139; William W. Kidd, Reg. No. 31,772; Sang Hui Kim, Reg. No. 40,450; Walter T. Kim, Reg. No. 42,731; Eric T. King, Reg. No. 44,188; George Brian Leavell, Reg. No. 45,436; Kurt P. Leyendecker, Reg. No. 42,799; Gordon R. Lindeen III, Reg. No. 33,192; Jan Carol Little, Reg. No. 41,181; Robert G. Litts, Reg. No. 46,876; Joseph Lutz, Reg. No. 43,765; Michael J. Mallie, Reg. No. 36,591; Andre L. Marais, under 37 C.F.R. § 10.9(b); Paul A. Mendonsa, Reg. No. 42,879; Clive D. Menezes, Reg. No. 45,493; Chun M. Ng, Reg. No. 36,878; Thien T. Nguyen, Reg. No. 43,835; Thinh V. Nguyen, Reg. No. 42,034; Dennis A. Nicholls, Reg. No. 42,036; Robert B. O'Rourke, Reg. No. 46,972; Daniel E. Ovanezian, Reg. No. 41,236; Kenneth B. Paley, Reg. No. 38,989; Gregg A. Peacock, Reg. No. 45,001; Marina Portnova, Reg. No. 45,750; William F. Ryann, Reg. 44,313; James H. Salter, Reg. No. 35,668; William W. Schaal, Reg. No. 39,018; James C. Scheller, Reg. No. 31,195; Jeffrey Sam Smith, Reg. No. 39,377; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Judith A. Szepesi, Reg. No. 39,393; Vincent P. Tassinari, Reg. No. 42,179; Edwin H. Taylor, Reg. No. 25,129; John F. Travis, Reg. No. 43,203; Joseph A. Twarowski, Reg. No. 42,191; Tom Van Zandt, Reg. No. 43,219; Lester J. Vincent, Reg. No. 31,460; Glenn E. Von Tersch, Reg. No. 41,364; John Patrick Ward, Reg. No. 40,216; Mark L. Watson, Reg. No. 46,322; Thomas C. Webster, Reg. No. 46,154; and Norman Zafman, Reg. No. 26,250; my patent attorneys, and Firasat Ali, Reg. No. 45,715; Justin M. Dillon, Reg. No. 42,486; Thomas S. Ferrill, Reg. No. 42,532; and Raul Martinez, Reg. No. 46,904, my patent agents, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (310) 207-3800, and James R. Thein, Reg. No. 31,710, my patent attorney with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

APPENDIX B

Title 37, Code of Federal Regulations, Section 1.56
Duty to Disclose Information Material to Patentability

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclosure information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclosure all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) Prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) The closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made or record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application;

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.

PTO/SB/22 (12-04)
Approved for use through 7/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a) FY 2005 (Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).)	Docket Number (Optional) 68144/P014C1/10503148
Application Number 11/199,586-Conf. #1128	Filed August 8, 2005
For OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING	
Art Unit N/A	Examiner Not Yet Assigned

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above identified application.

The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):

		Fee	Small Entity Fee	
[x]	One month (37 CFR 1.17(a)(1))	$120	$60	$ 60.00
[ ]	Two months (37 CFR 1.17(a)(2))	$450	$225	$
[ ]	Three months (37 CFR 1.17(a)(3))	$1020	$510	$
[ ]	Four months (37 CFR 1.17(a)(4))	$1590	$795	$
[ ]	Five months (37 CFR 1.17(a)(5))	$2160	$1080	$

- [x] Applicant claims small entity status. See 37 CFR 1.27.
- [x] A check in the amount of the fee is enclosed.
- [ ] Payment by credit card. Form PTO-2038 is attached.
- [ ] The Director has already been authorized to charge fees in this application to a Deposit Account.
- [x] The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number 06-2380. I have enclosed a duplicate copy of this sheet.

I am the
- [ ] applicant/inventor.
- [ ] assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96).
- [ ] attorney or agent of record. Registration Number ______
- [x] attorney or agent under 37 CFR 1.34.
  Registration number if acting under 37 CFR 1.34 34,661.

Signature	December 12, 2005 Date
Jerry L. Mahurin Typed or printed name	(214) 855-8386 Telephone Number

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below.

[ ] Total of 1 forms are submitted.

12/14/2005 CNGUYEN2 00000026 11199586
07 FC:2251 60.00 OP

25604709.1

12/13/05

UNITED STATES PATENT AND TRADEMARK OFFICE

OIPE DEC 1 2 2005 PATENT & TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371 (c) DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
11/199,586	08/08/2005	Xiaodong Li	68144/P014C1/10503148

CONFIRMATION NO. 1128

FORMALITIES LETTER

000029053
DALLAS OFFICE OF FULBRIGHT & JAWORSKI L.L.P.
2200 ROSS AVENUE
SUITE 2800
DALLAS, TX 75201-2784

Date Mailed: 09/12/2005

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  Applicant must submit $ **150** *to complete the basic filing fee for a small entity.*
- The oath or declaration is missing. *A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.*
  Note: If a petition under 37 CFR 1.47 is being filed, an oath or declaration in compliance with 37 CFR 1.63 signed by all available joint inventors, or if no inventor is available by a party with sufficient proprietary interest, is required.

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- Additional claim fees of **$800** as a small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- To avoid abandonment, a surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.16(f) of $65 for a small entity in compliance with 37 CFR 1.27, must be submitted with the missing items identified in this letter.

12/14/2005 CNGUYEN2 00000026 11199586

01 FC:2011	150.00 OP
02 FC:2111	250.00 OP
03 FC:2311	100.00 OP
04 FC:2051	65.00 OP
05 FC:2201	300.00 OP
06 FC:2202	500.00 OP

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is **$1365** for a Small Entity

- **$150** Statutory basic filing fee.

- **$65** Surcharge.

- The application search fee has not been paid. Applicant must submit $**250** to complete the search fee.
- The application examination fee has not been paid. Applicant must submit $**100** to complete the examination fee for a small entity in compliance with 37 CFR 1.27

- Total additional claim fee(s) for this application is $**800**
  - $**300** for **3** independent claims over 3.
  - $**500** for **20** total claims over 20.

Replies should be mailed to: Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

A copy of this notice MUST be returned with the reply.

Office of Initial Patent Examination (571) 272-4000, or 1-800-PTO-9199, or 1-800-972-6382
PART 2 - COPY TO BE RETURNED WITH RESPONSE

PTO/SB/21 (09-04)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	11/199,586-Conf. #1128
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	2661
Examiner Name	Not Yet Assigned
Attorney Docket Number	68144/P014C1/10503148

Total Number of Pages in This Submission: 11

ENCLOSURES (*Check all that apply*)

- [ ] Fee Transmittal Form
  - [x] Fee Attached
- [ ] Amendment/Reply
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [x] Extension of Time Request
- [ ] Express Abandonment Request
- [ ] Information Disclosure Statement
- [ ] Certified Copy of Priority Document(s)
- [x] Reply to Missing Parts/ Incomplete Application
  - [x] Reply to Missing Parts under 37 CFR 1.52 or 1.53
- [ ] Drawing(s)
- [ ] Licensing-related Papers
- [ ] Petition
- [ ] Petition to Convert to a Provisional Application
- [ ] Power of Attorney, Revocation Change of Correspondence Address
- [ ] Terminal Disclaimer
- [ ] Request for Refund
- [ ] CD, Number of CD(s) ______
  - [ ] Landscape Table on CD
- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC (**Appeal Notice, Brief, Reply Brief**)
- [ ] Proprietary Information
- [ ] Status Letter
- [x] Other Enclosure(s) (please Identify below):

Declaration
Check - $1,425.00
Part 2 Notice of Missing Parts
Certificate of Mail
Return Postcard

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	FULBRIGHT & JAWORSKI L.L.P.		
Signature	[signature]		
Printed name	Jerry L. Mahurin		
Date	December 12, 2005	Reg. No.	34,661

Docket No.: 68144/P014C1/10503148
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Xiaodong Li et al.

Application No.: 11/199,586

Filed: August 8, 2005

For: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

Confirmation No.: 1128

Art Unit: N/A

Examiner: Not Yet Assigned

RESPONSE TO NOTICE TO FILE MISSING PARTS OF APPLICATION

MS Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In response to the Notice to File Missing Parts of Application – Filing Date Granted mailed September 12, 2005, Applicant respectfully submits Declaration and Power of Attorney, Petition for one month extension of time, and Part 2 Notice to File Missing Parts.

The required fee for this response is enclosed. If any additional fee is due, please charge Deposit Account No. 06-2380, under Order No. 68144/P014C1/10503148..

Dated: December 12, 2005

Respectfully submitted,

By ________________

Jerry L. Mahurin
Registration No.: 34,661
FULBRIGHT & JAWORSKI L.L.P.
2200 Ross Avenue, Suite 2800
Dallas, Texas 75201-2784
(214) 855-8000
(214) 855-8200 (Fax)
Attorney for Applicant

Application No. (if known): 11/199,586 Attorney Docket No.: 68144/P014C1/10503148

Certificate of Express Mailing Under 37 CFR 1.10

I hereby certify that this correspondence is being deposited with the United States Postal Service as Express Mail, Airbill No. EV 482723658US in an envelope addressed to:

MS Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

on December 12, 2005
Date

Signature

Gail Miller
Typed or printed name of person signing Certificate

Registration Number, if applicable

(214) 855-8379
Telephone Number

Note: Each paper must have its own certificate of mailing, or this certificate must identify each submitted paper.

Return Postcard
Transmittal – 1 page
Response to Missing Parts – 1 page
Petition for Ext. of Time – 1 page
Part 2 Notice to File Missing Parts – 2 pages
Check - $1,425.00
Declaration (copy) – 5 pages
Certificate of Mail – 1 page

PTO/SB/06 (12-04)
Approved for use through 7/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 11199586

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	150		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	250		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	100		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	40 minus 20 =	* 20	x 25 =	500	OR	x =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	6 minus 3 =	* 3	x 100 =	300	OR	x =	
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			N/A			N/A	
			TOTAL	1300		TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

1/30/06

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Application No. (if known): 11/199,586 Attorney Docket No.: DO-068144/P014C1/10503148

Certificate of Express Mailing Under 37 CFR 1.10

I hereby certify that this correspondence is being deposited with the United States Postal Service as Express Mail, Airbill No. EV 628782365US in an envelope addressed to:

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

on March 9, 2006
Date

Gail Miller
Signature

Gail Miller
Typed or printed name of person signing Certificate

Registration Number, if applicable

(214) 855-8379
Telephone Number

Note: Each paper must have its own certificate of mailing, or this certificate must identify each submitted paper.

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Power of Attorney – 1 page
Statement Under 37 CFR 3.73(b) – 2 pages
Certificate of Mail – 1 page

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03/10/06

 IFW

PTO/SB/21 (09-04)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	11/199,586-Conf. #1128
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	N/A
Examiner Name	Not Yet Assigned
Attorney Docket Number	DO-068144/P014C1/10503148
Total Number of Pages in This Submission	5

ENCLOSURES (*Check all that apply*)

- [ ] Fee Transmittal Form
  - [ ] Fee Attached
- [ ] Amendment/Reply
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
- [ ] Express Abandonment Request
- [ ] Information Disclosure Statement
- [ ] Certified Copy of Priority Document(s)
- [ ] Reply to Missing Parts/ Incomplete Application
  - [ ] Reply to Missing Parts under 37 CFR 1.52 or 1.53
- [ ] Drawing(s)
- [ ] Licensing-related Papers
- [ ] Petition
- [ ] Petition to Convert to a Provisional Application
- [x] Power of Attorney, Revocation Change of Correspondence Address
- [ ] Terminal Disclaimer
- [ ] Request for Refund
- [ ] CD, Number of CD(s) ______
  - [ ] Landscape Table on CD
- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC (Appeal Notice, Brief, Reply Brief)
- [ ] Proprietary Information
- [ ] Status Letter
- [x] Other Enclosure(s) (please Identify below):

Statement Under 37 CFR 3.73(b)
Return Postcard
Certificate of Mail

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	FULBRIGHT & JAWORSKI L.L.P.		
Signature	[signature]		
Printed name	Jody C. Bishop		
Date	March 9, 2006	Reg. No.	44,034

25633180.1

PTO/SB/81 (04-05)
Approved for use through 11/30/2005. OMB 0651-0035
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

POWER OF ATTORNEY and CORRESPONDENCE ADDRESS INDICATION FORM

Application Number	11/199,586
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Title	OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND, etc.
Art Unit	N/A
Examiner Name	Not Yet Assigned
Attorney Docket No.	68144/P014C1/10503148

I hereby revoke all previous powers of attorney given in the above-identified application.

I hereby appoint:

[X] Practitioners associated with the Customer Number: 000029053

OR

[ ] Practitioner(s) named below:

Name	Registration Number	Name	Registration Number

as my/our attorney(s) or agent(s) to prosecute the application identified above, and to transact all business in the United States Patent and Trademark Office connected therewith.

Please recognize or change the correspondence address for the above-identified application to:

[X] The address associated with the above-mentioned Customer Number:

OR

[ ] The address associated with Customer Number:

OR

[ ] Firm or Individual Name					
Address					
City		State		Zip	
Country		Telephone		Email	

I am the:

[ ] Applicant/Inventor.

[X] Assignee of record of the entire interest. See 37 CFR 3.71.
Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)

SIGNATURE of Applicant or Assignee of Record

Signature	[signature]	Date	3/8/06
Name	Byron Young		(206) 384-2580
Title and Company	Vice Pres. Marketing & Product Management, Adaptix, Inc.		

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

[ ] *Total of 1 forms are submitted.

25583103.1

Docket No. 68144/P014C1/10503148

PTO/SB/96 (12-05)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Xiaodong Li, et al.

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Entitled: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

Adaptix, Inc. (Name of Assignee), a Corporation (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

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The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

[signature] (Signature) 3/8/06 (Date)

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STATEMENT UNDER 37 CFR 3.73(b) - Supplemental Sheet

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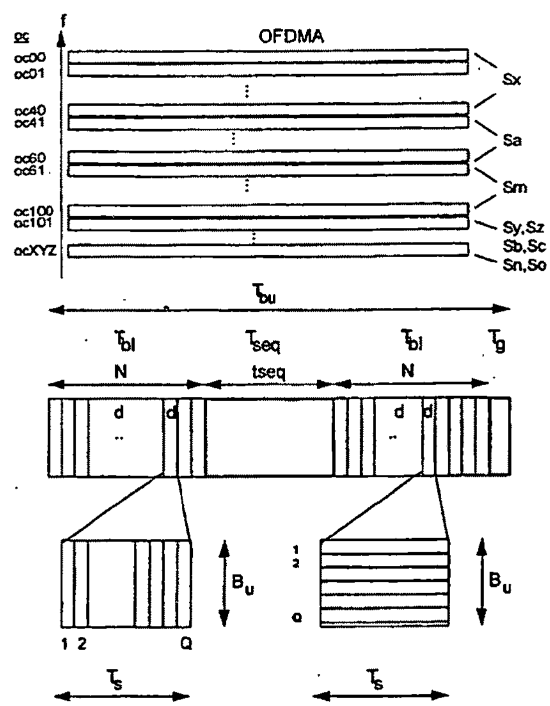
DE 44 41 323 A1
KAMMEYER, K.D.: Nachrichtenübertragung, Teubner Verlag, Stuttgart, 1996, 2. Aufl., ISBN-3-519-16142-7, S. 611-613;

(54) Verfahren und Funk-Kommunikationssystem zur Zuteilung von Funkressourcen einer Funkschnittstelle

(57) Das erfindungsgemäße Verfahren und Funk-Kommunikationssystem geht aus von einem OFDMA-Multiträgerverfahren und der Nutzung einer Anzahl von Subträgern (oc), die für die Kommunikationsverbindung zwischen Basisstation (BS) und Mobilstation (MS) zugeteilt werden, und umfaßt folgende Schritte:
- Messen der Qualität unterschiedlicher Segmente (S...) des Frequenzspektrums durch jede Mobilstation (MS),
- Bestimmen zumindest eines für die eigene Kommunikationsverbindung bevorzugt geeigneten Segments (Sx...Sa...Sm...) durch jede Mobilstation (MS) und Senden einer entsprechenden Information zur Basisstation (BS),
- Auswerten der von den Mobilstationen (MS) empfangenen Informationen durch die Basisstation (BS) und Zuteilen eines Segments (Sx, Sa, Sm) für die jeweilige Kommunikationsverbindung an jede Mobilstation (MS) abhängig von der Auswertung,
- Senden einer Information über das zugeteilte Segment (Sx, Sa, Sm) zu jeder Mobilstation (MS) durch die Basisstation (BS).



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Beschreibung

Die Erfindung betrifft ein Verfahren zur Zuteilung von Funkressourcen einer Funkschnittstelle eines Funk-Kommunikationssystem sowie ein entsprechendes Funk-Kommunikationssystem.

Bekanntlich weisen Funk-Kommunikationssysteme eine Funkschnittstelle auf, über die Datensymbole zwischen einer ortsfesten Basisstation und üblicherweise mehreren, im Funkversorgungsbereich – z. B. einer Funkzelle – der Basisstation befindlichen beweglichen Mobilstationen übertragen werden. Dabei finden Vielfachzugriffsverfahren Anwendung, um die Funkressourcen der Funkschnittstelle möglichst effektiv ausnutzen zu können. Ein klassisches Vielfachzugriffsverfahren ist das für Zeitmultiplex (TDMA, Time Division Multiple Access), bei dem die Datensymbole als Funkblock (bursts) in einem Zeitschlitz (time slot) enthalten sind. Ein weiteres Vielfachzugriffsverfahren ist das für Kodemultiplex (CDMA, Code Division Multiple Access), bei dem jedes Datensymbol mit mehreren Kodesymbolen auf eine bestimmte Bandbreite gespreizt wird.

Darüber hinaus gibt es das OFDMA-Multiträgerverfahren (Orthogonal Frequency Division Multiple Access), das zur Übertragung der Datensymbole das OFDM-Prinzip gemäß Kapitel 15.3.2 von "Nachrichtenübertragung", K. D. Kammeyer, Teubner Verlag, Stuttgart, 2. Auflage 1996 nutzt. Nahezu rechteckförmige Sende- und Empfangsfilter-Impulsantworten ermöglichen eine FFT-(Fast Fourier Transformation) bzw. IFFT- (Inverse Fast Fourier Transformation) basierte Signalverarbeitung im Sender und Empfänger, was hohe Datenraten bei relativ geringer Komplexität erlaubt. Darüber hinaus ist vorteilhaft, daß schmalbandige Subträger (OFDMA carriers), die beispielsweise nur einige wenige Kilohertz voneinander getrennt sein können, eine feine Granularität der Datenraten abhängig von der jeweiligen Anwendung ermöglichen. So kann eine Anzahl von Subträgern und damit ein Segment eines Frequenzspektrums für die Kommunikationsverbindung zwischen Basisstation und Mobilstation zugewiesen werden.

Aus der deutschen Offenlegungsschrift DE 44 41 323 A1 ist ein Verfahren zur Übertragung von OFDM-Signalen in einem mobilen Kommunikationssystem bekannt, bei dem für hohe Übertragungsraten dynamikreduzierte OFDM-Signale durch einen Sendeverstärker innerhalb seines im wesentlichen linearen Verstärkungsbereichs verstärkt werden.

Der Erfindung liegt die Aufgabe zugrunde, ein verbessertes Verfahren und Funk-Kommunikationssystem zur Zuteilung von Funkressourcen bei Anwendung des OFDMA-Multiträgerverfahrens anzugeben.

Diese Aufgabe wird gemäß der Erfindung durch das Verfahren mit den Merkmalen des Patentanspruchs 1 und durch das Funk-Kommunikationssystem mit den Merkmalen des Patentanspruchs 12 gelöst. Weiterbildungen der Erfindung sind den Unteransprüchen zu entnehmen.

Das erfindungsgemäße Verfahren geht aus von dem OFDMA-Multiträgerverfahren und der Nutzung einer Anzahl von Subträgern, die für die Kommunikationsverbindung zwischen Basisstation und Mobilstationen zugeteilt werden, und umfasst folgende Schritte:

- Messen der Qualität unterschiedlicher Segmente des Frequenzspektrums durch jede Mobilstation,
- Bestimmen zumindest eines für die eigene Kommunikationsverbindung bevorzugt geeigneten Segments durch jede Mobilstation und Senden einer entsprechenden Information zur Basisstation,
- Auswerten der von den Mobilstationen empfangenen Informationen durch die Basisstation und Zuteilen eines Segments für die jeweilige Kommunikationsverbindung an jede Mobilstation abhängig von der Auswertung,
- Senden einer Information über das zugeteilte Segment zu jeder Mobilstation durch die Basisstation.

Das erfindungsgemäße Funk-Kommunikationssystem geht ebenfalls aus von dem OFDMA-Multiträgerverfahren und der Nutzung einer Anzahl von Subträgern, die für die Kommunikationsverbindung zwischen Basisstation und Mobilstation zugeteilt werden, und umfasst folgende Mittel:

- Steuermittel in jeder Mobilstation zum Messen der Qualität unterschiedlicher Segmente des Frequenzspektrums und zum Bestimmen zumindest eines für die eigene Kommunikationsverbindung bevorzugt geeigneten Segments,
- Sendemittel in jeder Mobilstation zum Senden einer entsprechenden Information zur Basisstation,
- Steuermittel in jeder Basisstation zum Auswerten der von den Mobilstationen empfangenen Informationen und zum Zuteilen eines Segments für die jeweilige Kommunikationsverbindung an jede Mobilstation abhängig von der Auswertung, sowie
- Sendemittel in jeder Basisstation zum Senden einer Information über das zugeteilte Segment zu jeder Mobilstation.

Durch das geschilderte Zuteilungsverfahren können die Vorteile des OFDMA-Multiträgerverfahrens genutzt und möglichst optimale Frequenzressourcen für alle von einer Basisstation betreuten Kommunikationsverbindungen mit Hilfe der flexiblen Zuweisung mehrerer Subträger bzw. eines dadurch definierten Segments des Frequenzspektrums vergeben werden. Dabei spielt die Qualität der eigenen Kommunikationsverbindung im Hinblick auf die Frequenzsituation eine entscheidende Rolle, die entsprechend dem erfindungsgemäßen Verfahren individuell nach Bestimmen der am besten geeigneten Segmente in jeder von der Basisstation betreuten Mobilstation geändert und damit verbessert wird.

Ein weiterer wichtiger Vorteil besteht darin, daß durch die Erfindung die Interferenzen, insbesondere die in Funk-Kommunikationssystemen kritischen Interzellinterferenzen und die Intersymbolinterferenzen, berücksichtigt und ausgeglichen werden können.

Es wird durch das erfindungsgemäße Verfahren und Funk-Kommunikationssystem auch eine kosteneffektive und gegenüber einer Breitband-Kommunikation (wideband communication) leistungssteigernde – vor allem für höhere Frequenzen im MHz-Bereich – Zuteilung der Frequenzressourcen bei Anwendung des OFDMA-Multiträgerverfahrens erzielt. Das verbesserte OFDMA-Multiträgerverfahren kann mit anderen Vielfachzugriffsverfahren, die Datensymbole endlicher Dauer in Zeitschlitzen übertragen, zu einem noch effektiveren Funksystem kombiniert werden. So ist das verbesserte OFDMA-Multiträgerverfahren gemäß einer besonders bevorzugten Ausgestaltung in ein TDMA/CDMA-Funksystem integrierbar, was für Anwendungen mit geringeren Leistungsanforderungen – z. B. Mikrozellensysteme – oder für TDD-Anwendungen (Time Division Duplex) oder für Anwendungen bei höheren Datenraten – z. B. für Indoor-Systeme, Schnurlos-Systeme (residential cordless) – oder für Anwendungen mit geringen Bewegungsgeschwindigkeiten besonders vorteilhaft sich auswirkt.

Die Flexibilität des erfindungsgemäßen Verfahrens wird besonders vorteilhaft ausgenutzt, wenn den Mobilstationen von der Basisstation Segmente des Frequenzspektrums zugeteilt werden, deren Bandbreiten sich unterscheiden, oder eine unterschiedliche Anzahl von Zeitschlitzen für die Übertragung der Datensymbole in den zugeteilten Segmenten zugeteilt wird. Damit können für individuelle Kommunikationsverbindungen, die sich voneinander unterscheiden, die am besten geeigneten Segmente zur Kommunikation jederzeit bestimmt und bei Bedarf geändert werden.

Gemäß einer weiteren Ausgestaltung der Erfindung wird von den Mobilstationen jeweils eine Prioritätenliste an die Basisstation gesendet, die Informationen über ein für die eigene Kommunikationsverbindung am besten geeignetes Segment sowie über weitere, für die eigene Kommunikationsverbindung bevorzugt geeignete Segmente enthält. Dadurch erhält die Basisstation anhand der eintreffenden Listen Kenntnis von den Wünschen aller Mobilstationen hinsichtlich des oder der für sie am besten geeigneten Segmente, und kann entsprechende Neuzuordnungen der Segmente des Frequenzspektrums zu allen Mobilstationen – besser angepasst an deren übermittelte Bedürfnisse – vornehmen.

Es hat sich als günstig erwiesen, daß für jede Mobilstation die Anzahl der zugeteilten Subträger in einem Zeitschlitz von der Basisstation variabel einstellbar ist, um bei Bedarf nicht nur die Segmente wechseln, sondern auch deren Bandbreite ändern zu können.

Eine vorteilhafte Weiterbildung der Erfindung zum Messen der Qualität der Segmente des Frequenzspektrums sieht vor, daß die Mobilstation alle Subträger in dem ihr zugewiesenen Zeitschlitz empfängt, für jeden Subträger überprüft, ob eine Amplitudenmodulation der im Zeitschlitz übertragenen Datensymbole vorliegt, und einen Mittelwert aus den Ergebnissen der Überprüfung für alle zu dem jeweiligen Segment gehörigen Subträger bildet. Der Vorteil liegt in dem Zweistufen-Verfahren, bei dem zunächst jeweils die Qualität für die individuellen Subträger ermittelt und anschließend zur Festlegung der Qualität des spezielle untersuchten Segments die Qualitäten der Subträger gemittelt werden.

Eine besonders einfache Methode zum Messen der Qualität besteht darin, relative Abweichungen der Amplituden der Datensymbole dadurch zu ermitteln, daß die absolute Amplitudendifferenz von Datensymbol zu Datensymbol aufaddiert und das Additionsresultat mit der mittleren Amplitude aller auf einem vorgebbaren Subträger übertragenen Datensymbole normiert wird.

Gemäß einer Weiterbildung der Erfindung weist das Funk-Kommunikationssystem eine Mobilstation mit Steuermittel zum Messen der Qualität unterschiedlicher Segmente des Frequenzspektrums und zum Bestimmen zumindest eines für die eigene Kommunikationsverbindung bevorzugt geeigneten Segments, sowie mit Sendemittel zum Senden einer entsprechenden Information zur Basisstation auf.

Gemäß einer anderen Weiterbildung der Erfindung weist das Funk-Kommunikationssystem eine Einrichtung, die gemäß alternativer Ausgestaltungen als Teil einer Basisstation oder einer Basisstationssteuerung ausgeprägt ist, mit Steuermittel zum Auswerten der von den Mobilstationen empfangenen Informationen und zum Zuteilen eines Segments für die jeweilige Kommunikationsverbindung an jede Mobilstation abhängig von der Auswertung, sowie mit Sendemittel zum Senden einer Information über das zugeteilte Segment zu jeder Mobilstation auf.

Im folgenden wird der Erfindungsgegenstand anhand eines Ausführungsbeispielen unter Bezugnahme auf zeichnerische Darstellungen näher erläutert.

Dabei zeigen

Fig. 1 ein Blockschaltbild eines Mobilfunksystems mit mehreren von einer Basisstation betreuten Mobilstationen,

Fig. 2 eine schematische Darstellung der Struktur eines Funkblocks mit Datensymbolen in einem Zeitschlitz sowie der OFDMA-Subträger zur Bildung von Segmenten eines Frequenzspektrums,

Fig. 3 einen Nachrichtenfluß zur Zuteilung der Frequenzressourcen zu den Mobilstationen,

Fig. 4 eine schematische Darstellung der Amplitudenmodulation der übertragenen Datensymbole auf einem OFDMA-Subträger zum Messen der Qualität der Segmente,

Fig. 5 ein Blockschaltbild einer Mobilstation, und

Fig. 6 ein Blockschaltbild einer Basisstation/Basisstationssteuerung.

Das in **Fig.** 1 dargestellte Funk-Kommunikationssystem entspricht in seiner Struktur einem bekannten Mobilfunksystem, das Netzeinrichtungen eines Mobilfunknetzes wie z. B. Mobilvermittlungsstellen MSC, die untereinander vernetzt sind bzw. den Zugang zu einem Festnetz PSTN herstellen, und mit den Mobilvermittlungsstellen MSC verbundene Basisstationssteuerungen BSC und mit jeweils einer Basisstationssteuerung BSC verbundene Basisstationen BS aufweist. Eine solche Basisstation BS ist eine ortsfeste Funkstation, die über eine Funkschnittstelle Kommunikationsverbindungen zu Mobilstationen MS aufbauen, abbauen und aufrechthalten kann. In **Fig.** 1 sind beispielhaft drei Funkverbindungen zwischen drei Mobilstationen MS und einer Basisstation BS dargestellt. Ein Operations- und Wartungszentrum OMC realisiert Kontroll- und Wartungsfunktionen für das Mobilfunksystem bzw. für Teile davon. Das Operations- und Wartungszentrum OMC und die Basisstationssteuerung BSC realisieren üblicherweise die Funktionen der Einstellung und Anpassung der Zuteilung von funktechnischen Ressourcen innerhalb der Funkzellen der Basisstationen BS. Die Funktionalität des Funk-Kommunikationssystems ist auch auf andere Funk-Kommunikationssysteme übertragbar, ggf. auch mit ortsfesten Mobilstationen MS. Auch bei diesen Funk-Kommunikationssystemen kann das erfindungsgemäße Verfahren zum Einsatz kommen.

Die Kommunikationsverbindungen zwischen der Basisstation BS und den Mobilstationen MS unterliegen einer Mehrwegeausbreitung, die durch Reflektionen beispielsweise an Gebäuden oder Bepflanzungen zusätzlich zum direkten Ausbreitungsweg hervorgerufen werden. Geht man von einer Bewegung der Mobilstationen MS aus, dann führt die Mehrwegeausbreitung zusammen mit weiteren Störungen dazu, daß bei der empfangenden Basisstation BS sich die Signalkomponenten der verschiedenen Ausbreitungswege eines Teilnehmersignals zeithängig überlagern. Weiterhin wird davon ausgegangen, daß ein OFDMA-Multiträgerverfahren zur Übertragung von Datensymbolen in Zeitschlitzen benutzt wird, das den Mobilstationen jeweils eine Anzahl von Subträgern und damit ein Segment eines Frequenzspektrums für die Kommunikationsverbindung zwischen Basisstation BS und Mobilstation MS zuteilt.

Gemäß dem Erfindungsgegenstand misst jede Mobilstation MS die Qualität unterschiedlicher Segmente des Frequenzspektrums, wobei sie alle Subträger in dem ihr zugewiesenen Zeitschlitz empfängt, für jeden individuellen Subträger dessen Qualität überprüft und anschließend die ermittelten Qualitäten der Subträger mittelt. Danach bestimmt jede Mobilstation zumindest ein für die eigene Kommunikationsverbindung bevorzugt geeignetes Segment und sendet eine entsprechende Information zur Basisstation BS. Im vorliegenden Beispiel ermittelt die erste Mobilstation ein Segment Sx mit den Subträgern oc00... oc40 als das für sie am besten geeignete Segment. Darüber hinaus bestimmt sie Segmente Sy, Sz als weitere, für die eigene Kommunikationsverbindung bevorzugt geeignete Segmente. In eine Prioritätenliste PL1 werden Informationen über die Segmente

Sx, Sy, Sz eingetragen, entsprechend ihrer Eignung für die Kommunikationsverbindung numeriert und zur Basisstation BS gesendet.

In gleicher Weise ermittelt die zweite Mobilstation ein Segment Sa mit den Subträgern oc41...oc60 als das für sie am besten geeignete Segment. Darüber hinaus bestimmt sie Segmente Sb, Sc als weitere, für die eigene Kommunikationsverbindung bevorzugt geeignete Segmente. In eine Prioritätenliste PL2 werden Informationen über die Segmente Sa, Sb, Sc eingetragen, entsprechend ihrer Eignung für die Kommunikationsverbindung numeriert und ebenfalls zur Basisstation BS gesendet.

Auch die dritte, von der Basisstation BS betreute Mobilstation MS bestimmt ein Segment Sm mit den Subträgern oc61...oc100 als das für ihre kommunikationsverbindung am besten geeignete Segment. Darüber hinaus gibt sie Segmente Sn, So als weitere, für die eigene Kommunikationsverbindung bevorzugt geeignete Segmente in einer Prioritätenliste PL3 an. Die Informationen über diese drei Segmente Sm, Sn, So, die entsprechend ihrer Eignung für die Kommunikationsverbindung in der Prioritätenliste PL3 numeriert sind, werden von ihr anschliessend ebenfalls zur Basisstation BS gesendet. Aus den Beispielen ist entnehmbar, daß die Anzahl der Subträger co... und damit die Bandbreite der Segmente S... unterschiedlich gewählt werden kann.

Die Basisstation BS wertet alle von den Mobilstationen MS empfangenen Informationen aus und teilt abhängig von der Auswertung jeder Mobilstation ein Segment für die jeweilige Kommunikationsverbindung zu. Eine Information über das jeweils zugeteilte Segment sendet die Basisstation zu jeder Mobilstation. Im vorliegenden Beispiel sei angenommen, daß jeder Mobilstation MS das von ihr gewünschte am besten geeignete Segment zugeteilt werden konnte. Dies hängt auch von den Übertragungsbedingungen und/oder der Auslastung der von der Basisstation BS versorgten Funkzelle nach Vorgaben des Operations- und Wartungszentrums OMC oder der Basisstationssteuerung BSC zum Funkressourcenmanagement ab. So erhalten die erste Mobilstation MS das Segment Sx, die zweite Mobilstation MS das Segment Sa und die dritte Mobilstation MS das Segment Sm, jeweils mit den entsprechenden OFDMA-Subträgern co..., von der Basisstation BS zugeteilt. Den individuellen Mobilstationen MS kann auch eine unterschiedliche Anzahl von Zeitschlitzen zur Übertragung der Datensymbole in den zugeteilten Segmenten zugewiesen werden.

Die Flexibilität des erfindungsgemäßen Verfahrens wird besonders vorteilhaft ausgenutzt, wenn den Mobilstationen MS von der Basisstation BS Segmente des Frequenzspektrums zugeteilt sind, deren Bandbreiten sich unterscheiden, oder eine unterschiedliche Anzahl von Zeitschlitzen für die Übertragung der Datensymbole in den zugeteilten Segmenten vorgesehen ist. Damit können für individuelle Kommunikationsverbindungen, die sich voneinander unterscheiden, die am besten geeigneten Segmente zur Kommunikation jederzeit bestimmt und bei Bedarf geändert werden.

In **Fig.** 2 sind die Struktur eines Funkblocks mit Datensymbolen in einem Zeitschlitz sowie die OFDMA-Subträger zur Bildung der Segmente gemäß den Beispielen in **Fig.** 1 schematisch dargestellt. So stehen beispielsweise einige hundert Subträger oc – mit einem Abstand von einigen Kilohertz zwischen jeweils zwei benachbarten Träger – in der Funkzelle der in **Fig.** 1 mit den drei Mobilstationen MS in Verbindung stehenden Basisstation BS zur Verfügung. Davon sind die Subträger oc00...oc40 zur Definition des Segments Sx, die Subträger oc41...oc60 zur Definition des Segments Sa, und die Subträger oc61...oc100 zur Definition des Segments Sm entsprechend der Zuweisung durch die Basisstation auf die Mobilstationen verteilt. Weitere Subträger oc101...ocXYZ sind in dem insgesamt für einen Netzbetreiber nutzbaren Frequenzband verfügbar, das auch die von den Mobilstationen als ebenfalls geeignet eingestuften Segmente Sy, Sz und Sb, Sc und Sn, So mit einer Anzahl von Subträgern enthält. Nach **Fig.** 2 wird für die Segmente Sx, Sm eine identische Bandbreite angenommen. Dies ist jedoch für ein Funk-Kommunikationssystem im Sinne der Erfindung keine Voraussetzung.

Der in **Fig.** 2 beispielhaft gezeigte Funkblock wird in einem Zeitschlitz einer TDMA-Rahmenstruktur übertragen. In jedem Rahmen ist zumindest ein Zeitschlitz für ein oder mehrere Teilnehmersignale vorgesehen. Von der Basisstation wird in jedem Zeitschlitz eine vorgebbare Anzahl von Subträgern benutzt, auf denen jeweils eine vorgebbare Anzahl von Datensymbolen übertragen wird. Darüber hinaus ist für jede Mobilstation die Anzahl der zugeteilten Subträger in einem Zeitschlitz von der Basisstation variabel einstellbar.

Die Dauer des Funkblocks wird mit Tbu bezeichnet. Der Funkblock umfaßt zwei Blöcke mit jeweils N Datensymbolen d, wobei jeder Block die Länge T_{bl} hat. Beide Blöcke sind durch eine Trainingssequenz tseq mit der Dauer T_{seq} getrennt. Den Abschluß des Funkblocks bildet eine Schutzzeit T_g, die die Laufzeitunterschiede aufgrund unterschiedlicher Entfernungen der Mobilstationen MS von der Basisstation BS ausgleichen soll. Weiterhin wird in **Fig.** 2 gezeigt, wie ein einzelnes Datensymbol d nach einem reinen CDMA-Verfahren – linke Darstellung – oder nach einem reinen Mehrträger-Verfahren – rechte Darstellung – übertragen werden kann. Beim CDMA-Verfahren wird jedes Datensymbol d mit Q Kodesymbolen auf die Bandbreite B_u gespreizt. Beim Mehrträger-Verfahren wird jedes Datensymbole d auf Q Träger moduliert, wobei die Summe der Bandbreiten der Träger die Bandbreite B_u ergibt. In beiden Fällen dauert die Übertragung eines Datensymbols die Symboldauer T_S. Damit ist das Funk-Kommunikationssystem als TDMA/CDMA-Mobilfunksystem ausgebildet, bei dem in durch die Zeitschlitze gebildeten Frequenzkanälen gleichzeitig die Datensymbole d mehrerer Kommunikationsverbindungen übertragen werden, wobei die Informationen unterschiedlicher Verbindungen gemäß einer verbindungsindividuellen Feinstruktur – beispielsweise durch Spreizung der Datensymbole – unterscheidbar sind.

Gerade bei Kombination des TDMA/CDMA-Mobilfunksystem mit dem OFDMA-Multiträgerverfahren können möglichst optimale Frequenzressourcen für alle von einer Basisstation betreuten Kommunikationsverbindungen mit Hilfe der flexiblen Zuweisung mehrerer Subträger bzw. eines dadurch definierten Segments des Frequenzspektrums gemäß der Erfindung vergeben werden. Dies wirkt sich für Anwendungen mit geringeren Leistungsanforderungen – z. B. Mikrozellensysteme – oder für TDD-Anwendungen (Time Division Duplex) oder für Anwendungen bei höheren Datenraten – z. B. für Indoor-Systeme, Schnurlos-Systeme (residential cordless) – oder für Anwendungen mit geringen Bewegungsgeschwindigkeiten besonders vorteilhaft aus. Durch das verbesserte Frequenzressourcen-Zuteilungsverfahren (smart frequency hopping approach) gemäß der Erfindung werden Interferenzen, insbesondere die in Funk-Kommunikationssystemen kritischen Interzellinterferenzen (inter-cell interference) und die Intersymbolinterferenzen, berücksichtigt und zumindest vermindert oder gar ausgeglichen. Dies ist deshalb von Bedeutung, da für nahezu alle Funk-Kommunikationssysteme es ein typisches Merkmal ist, daß sie in Abwärtsrichtung (downlink) leistungsbegrenzt sind, was durch Interferenzen noch verstärkt wird.

Fig. 3 zeigt den Nachrichtenfluß über die Funkschnittstelle für die Zuteilung der Frequenzressourcen zu den Mobilstationen MS durch die Basisstation BS. An Stelle der Basisstation BS kann auch eine Basisstationssteuerung BSC die Zuteilung steuern, jedoch kommuniziert immer die Basisstation BS über die Luft mit den Mobilstationen MS. In einem ersten Schritt (1) empfangen die Mobilstationen MS parallel alle Subträger oc in dem ihnen jeweils zugewiesenen Zeitschlitz ts. Für jeden Subträger oc überprüft die Mobilstation MS in einem weiteren Schritt (2), ob eine Amplitudenmodulation der im Zeitschlitz ts übertragenen Datensymbole vorliegt, und hat damit ein Messergebnis über die Qualität des jeweiligen Subträgers oc. Sie bildet danach einen Mittelwert aus den Ergebnissen der Überprüfung für alle zu einem ausgewählten Segment gehörigen Subträger oc, was zu einem Qualitätsergebnis für das gesamte Segment führt. Dies kann sie für mehrere Segmente – vorzugsweise parallel – durchführen. Jede Mobilstation MS bestimmt nach Kenntnis der Qualität unterschiedlicher Segmente in einem weiteren Schritt (3) zumindest ein bevorzugt geeignetes Segment, im Beispiel das Segment Sx bzw. Sa bzw. Sm.

Im Schritt (4) senden die Mobilstationen MS ihre Prioritätenlisten PL1...PL3 mit den Informationen über vorzugsweise mehrere bevorzugt geeignete Segmente, d. h. über die Segmente Sx, Sy, Sz bzw. Sa, Sb, Sc bzw. Sm, Sn, So, für die eine Reihenfolge hinsichtlich ihrer Eignung von der Mobilstation MS festgelegt wurde, über die Funkschnittstelle zu der Basisstation BS.

In einem Schritt (5) wertet die Basisstation BS die eintreffenden Prioritätenlisten PL1...PL3 mit den Informationen über die gewünschten Segmente aus und entscheidet – gegebenenfalls in Rücksprache mit der Basisstationssteuerung BSC –, welches Segment der jeweiligen Mobilstation MS zuzuweisen ist. Im genannten Beispiel ordnet die Basisstation BS die Segmente Sx, Sa und Sm, die allesamt als die am besten geeigneten Segmente mobilstationsseitig ausgewählt wurden, den drei Mobilstationen zu. Für den Fall, daß nicht das gewünschte Segment zugeordnet werden kann, wird eines der anderen, von der Mobilstation MS alternativ angegebenen Segmente ausgewählt. Im Schritt (6) werden schließlich die Informationen über die zugeteilten Segmente Sx, Sa und Sm zu den Mobilstationen MS über die Funkschnittstelle übertragen, die die empfangenen neuen Frequenzressourcen im Frequenzspektrum für ihre individuellen Kommunikationsverbindungen nutzen. Zur Überwachung eines möglichst breiten Frequenzspektrums verfügen die Mobilstationen MS jeweils über Breitband-Empfänger, was bei Anwendung des OFDMA-Multiträgerverfahrens der Fall ist. Der Zeitpunkt und damit die Geschwindigkeit der Änderung der Zuteilung der Funkressourcen bzw. Frequenzressourcen kann abhängig von den Übertragungsbedingungen und/oder der Auslastung einer Funkzelle erfolgen. Grundsätzlich ist es pro Sekunde in einer der Anzahl der übertragenen TDMA-Rahmen entsprechenden Häufigkeit möglich. Bei einem auf dem GSM-Standard basierenden Mobilfunksystem werden beispielsweise circa 217 Rahmen in der Sekunde übertragen.

Fig. 4 zeigt eine schematische Darstellung der Amplitudenmodulation der übertragenen Datensymbole auf einem OFDMA-Subträger zum Messen der Qualität der Segmente durch jede Mobilstation. Durch Umsetzen möglicherweise auftretender Interferenzen oder Rauschen in eine Amplitudenmodulation von Datensymbol zu Datensymbol kann auf einfache, aber effektive Weise die Qualität der einzelnen Subträger und damit auch des gesamten Segments über alle zugehörigen Subträger mobilstationsseitig gemessen werden. Für jedes übertragene Datensymbol im Zeitschlitz wird eine FFT-Signalverarbeitung durchgeführt, und die Signalverarbeitung trägerselektiv für die Subträger des Segments fortgesetzt. So entsteht aus einem Nutzsignal ss durch ein Interferenzsignal- oder ein Rauschsignal is ein resultierendes Signal rs mit einer bestimmten Amplitude, die zwischen einer minimalen Amplitude Amin und einer maximalen Amplitude Amax liegt. Liegt Interferenz oder Rauschen vor, variieren die Amplituden der individuellen auf einem bestimmten Subträger Datensymbole von Datensymbol zu Datensymbol. Gibt es keine Interferenz oder kein Rauschen, weisen die Amplituden aller Datensymbole denselben Wert auf. Am einfachsten können relative Abweichungen der Amplituden der Datensymbole dadurch ermittelt werden, daß die absolute Amplitudendifferenz von Datensymbol zu Datensymbol aufaddiert und das Additionsresultat mit der mittleren Amplitude aller auf einem vorgebbaren Subträger übertragenen Datensymbole normiert wird. Im Beispiel werden beispielsweise die Qualitätsergebnisse aller 40 Subträger des Segments Sx gemittelt und ein entsprechender Qualitätswert für das Segment Sx ermittelt. Dies wird für eine Mehrzahl anderer Segmente ebenfalls ausgeführt, und eine Anzahl von Segmenten bester Qualität hinsichtlich der eigenen Kommunikationsverbindung festgelegt.

Eine Mobilstation MS zur Unterstützung des erfindungsgemäßen Verfahrens und Funk-Kommunikationssystems ist in **Fig.** 5 dargestellt, während **Fig.** 6 eine entsprechende Basisstation bzw. Basisstationssteuerung BSC zeigt. Dabei sind nur die für den Erfindungsgegenstand wesentlichen Mittel und Einrichtungen dargestellt.

Die Mobilstation MS weist Steuermittel MSE mit einer Speichereinrichtung MSP und einer FFT-Einrichtung FFT, Modulationsmittel MOD bzw. Demodulationsmittel DEM und Sende/Empfangsmittel MHF auf.

In Abwärtsrichtung wie in Aufwärtsrichtung (uplink) werden Datensymbole d der Teilnehmersignale übertragen. Für die Übertragung in Aufwärtsrichtung werden sie von den Steuermitteln MSE aufbereitet und für das Senden den Modulationsmitteln MOD zugeführt. Dagegen werden in Abwärtsrichtung die Datensymbole d von den Sende/Empfangsmitteln MHF empfangen, von den Demodulationsmitteln DEM aufbereitet und an die Steuermittel MSE weitergeleitet. In einem Teil der Modulationsmittel MOD wird eine Datenmodulation, Fehlersicherung, Verschachtelung u. ä. durchgeführt. Zusätzlich werden die Datensymbole d eines Funkblockes in einem Teil der Modulationsmittel MOD entsprechend der Kombination von TDMA- und CDMA-Verfahren zur Realisierung der verbindungsindividuellen Feinstruktur für die Unterscheidung der Teilnehmersignale in einem Zeitschlitz gespreizt. Nach Analog/Digital-Wandlung werden die Funkblöcke in den Sende/Empfangsmitteln MHF verstärkt und über die Funkschnittstelle zu der Basisstation gesendet.

In Abwärtsrichtung empfangen die Sende/Empfangsmittel MHF über die Luft alle Subträger oc in dem der Mobilstation MS zugewiesenen Zeitschlitz – siehe Schritt (1) in **Fig.** 3. Die Steuermittel MSE werden über die Subträger oc informiert und führen eine Messung der Qualität unterschiedlicher Segmente entsprechend obiger Ausführungen durch. Die Steuermittel MSE bestimmen die für die eigene Kommunikationsverbindung bevorzugt geeigneten Segmente S..., tragen sie in die Prioritätenliste ein, und veranlassen die Sende/Empfangsmittel MHF zum Aussenden entsprechender Informationen über die Luft an die Basisstation – siehe Schritt (4) in **Fig.** 3.

Auch in Abwärtsrichtung empfangen die Sende/Empfangsmittel MHF – aber zu einem späteren Zeitpunkt nach erfolgter Auswertung der übermittelten Segmente aller Mobilstationen durch die Basisstation – die Information über das individuell von der Basisstation zugewiesene Segment S... – siehe Schritt (6) in **Fig.** 3. Entsprechend der zugeteilten Frequenzressourcen nehmen die Steuermittel MSE eine Änderung der funktechnischen Parameter in der Funkzelle für die Mobilstation MS vor.

Gleichzeitig kann durch das verbesserte Zuteilungsverfahren den Bedürfnissen einzelner Mobilstationen MS entsprochen werden, die besondere Übertragungsbedingungen (kein CDMA oder ein Mehrträger-Verfahren nur innerhalb einer bestimmten Bandbreite) und besondere Datenraten anfordern.

Die Einrichtung gemäß **Fig.** 6 – als Basisstation BS oder als Basisstationssteuerung BSC ausgeprägt – weist Steuermittel BSE mit einer Speichereinrichtung BSP und einer FFT-Einrichtung FFT, Modulationsmittel MOD bzw. Demodulationsmittel DEM und Sende/Empfangsmittel BHF auf. Von den Steuermitteln BSE werden die Sende/Empfangsmittel BHF veranlaßt, die Subträger oc über die Luft in Abwärtsrichtung zu den Mobilstationen zu senden. In der Gegenrichtung empfangen die Sende/Empfangsmittel BHF die Informationen über die von den Mobilstationen bestimmten Segmenten S... und leiten sie an die Steuermittel BSE weiter. Anhand der Auswertung der Gesamtheit der eintreffenden Informationen teilt die Steuermittel BSE ein Segment S... jeder von ihr versorgten Mobilstation zu und veranlaßt die Sende/Empfangsmittel BHF zum Aussenden entsprechender Informationen über die Luft an die jeweilige Mobilstation.

Die Änderung der Segmente des Frequenzspektrums berücksichtigt auch die Übertragungsbedingungen (starke Störungen und Interferenzen) und die Auslastung der funktechnischen Ressourcen (Zeitschlitze, Frequenzen, Spreizkodes) in der Funkzelle. Diese Bedingungen werden den Steuermitteln BSE vom Basisstationscontroller BSC bzw. vom Operations- und Wartungszentrum OMC signalisiert. Daraufhin wählen die Steuermittel BSE die Subträger zur Definition des Segments nach Qualitätsmerkmalen für jede Kommunikationsverbindung aus.

Die Signalverarbeitung bei Anwendung des OFDMA-Multiträgerverfahrens durch die FFT-Einrichtung FFT sowie die Modulationsmittel MOD bzw. Demodulationsmittel DEM arbeiten in der Basisstation BS in gleicher Weise wie in der Mobilstation MS, sodaß obige Ausführungen zu **Fig.** 5 entsprechend gelten. In der Speichereinrichtung BSP sind u. a. die von den Mobilstationen kommenden Prioritätenlisten mit den als bevorzugt geeignet gekennzeichneten Segmenten gespeichert.

Zum Erreichen einer möglichst einfachen Synchronisation in Bezug auf Zeit und Frequenz wird ein Anfangs-Synchronisationsschritt ausgeführt, bei dem Symbole mit halber Übertragungsrate gesendet werden, sodaß die übertragenen Symbole auch bei vollständig unsynchronisierten Bedingungen in einem Zeitfenster sicher empfangen werden. Bei Mikrozellen-Anwendungen ist lediglich eine Synchronisation der Mobilstationen auf die Basisstation erforderlich.

Zur Identifikation der Basisstation BS kann ein Basisstationskode gebildet werden, wobei die Phasen zwischen den auf zumindest zwei benachbarten Subträgern an erster Stelle im Funkblock übertragenen Datensymbolen verwendet werden. Vorzugsweise sind dies die beiden Subträger, die in der Mitte eines Datenstroms mit mehreren Subträgern liegen. So wird dem ersten Datensymbol auf dem Subträger mit der niedrigeren Frequenz die Phase 0 Grad zugeordnet. Die Phase des ersten Datensymbols des bebachbarten Subträgers mit der höheren Frequenz bildet den Basisstationskode, d. h. mit den Werten 0 Grad, 90 Grad, 180 Grad und 270 Grad. Die Phasen der ersten Symbole der beiden bebachbarten Subträger kann auch als Phasenreferenz zum Detektieren der Informationen auf allen Subträgern benutzt werden.

Aus obigen Bemerkungen ergibt sich, daß sich das erfindungsgemäße Verfahren insbesondere für einen Einsatz in zukünftigen Funk-Kommunikationssystemen, wie UMTS (Universal Mobile Communications System) oder FPLMTS (Future Public Land Mobile Telecommunication System) eignet.

Patentansprüche

1. Verfahren zur Zuteilung von Funkressourcen einer Funkschnittstelle eines Funk-Kommunikationssystems, wobei
   - Datensymbole (d) in Zeitschlitzen (ts) über die Funkschnittstelle zwischen einer Basisstation (BS) und mehreren von der Basisstation (BS) betreuten Mobilstationen (MS) übertragen werden, und
   - ein OFDMA-Multiträgerverfahren zur Übertragung der Datensymbole (d) benutzt wird, das den Mobilstationen (MS) jeweils eine Anzahl von Subträgern (oc) und damit ein Segment (S...) eines Frequenzspektrums für die Kommunikationsverbindung zwischen Basisstation (BS) und Mobilstation (MS) zuteilt,

   mit den folgenden Verfahrensschritten:
   - Messen der Qualität unterschiedlicher Segmente (S...) des Frequenzspektrums durch jede Mobilstation (MS),
   - Bestimmen zumindest eines für die eigene Kommunikationsverbindung bevorzugt geeigneten Segments (Sx... Sa... Sm...) durch jede Mobilstation (MS) und Senden einer entsprechenden Information zur Basisstation (BS),
   - Auswerten der von den Mobilstationen (MS) empfangenen Informationen durch die Basisstation (BS) und Zuteilen eines Segments (Sx, Sa, Sm) für die jeweilige Kommunikationsverbindung an jede Mobilstation (MS) abhängig von der Auswertung, sowie
   - Senden einer Information über das zugeteilte Segment (Sx, Sa, Sm) zu jeder Mobilstation (MS) durch die Basisstation (BS).
2. Verfahren nach Anspruch 1, bei dem zumindest zwei Mobilstationen (MS) von der Basisstation (BS) Segmente (Sx, Sa) des Frequenzspektrums zugeteilt werden, deren Bandbreiten sich unterscheiden.
3. Verfahren nach Anspruch 1 oder 2, bei dem den Mobilstationen (MS) von der Basisstation (BS) eine unterschiedliche Anzahl von Zeitschlitzen (ts) für die Übertragung der Datensymbole (d) in den zugeteilten Segmenten zugeteilt wird.
4. Verfahren nach einem der vorhergehenden Ansprüche, bei dem von den Mobilstationen (MS) jeweils eine Prioritätenliste (PL1, PL2, PL3) an die Basisstation (BS) gesendet wird, die Informationen über ein für die eigene Kommunikationsverbindung am besten geeignetes Segment (Sx, Sa, Sm) sowie über weitere, für die eigene Kommunikationsverbindung bevorzugt geeignete Segmente (Sy, Sz; Sb, Sc; Sn, So) enthält.
5. Verfahren nach einem der vorhergehenden Ansprüche, bei dem von der Basisstation (BS) in jedem Zeitschlitz (ts) eine vorgebbare Anzahl von Subträgern (oc) benutzt wird, auf denen jeweils eine vorgebbare Anzahl von Datensymbolen (d) übertragen wird.
6. Verfahren nach einem der vorhergehenden Ansprüche, bei dem für jede Mobilstation (MS) die Anzahl der zugeteilten Subträger (oc) in einem Zeitschlitz (ts) von der Basisstation (BS) variabel einstellbar ist.
7. Verfahren nach einem der vorhergehenden Ansprü-

che, bei dem zum Messen der Qualität der Segmente (S...) des Frequenzspektrums von der Mobilstation (MS)

- alle Subträger (oc) in dem ihr zugewiesenen Zeitschlitz (ts) empfangen werden,
- für jeden Subträger (oc) überprüft wird, ob eine Amplitudenmodulation der im Zeitschlitz übertragenen Datensymbole (d) vorliegt, und ein Mittelwert aus den Ergebnissen der Überprüfung für alle zu dem jeweiligen Segment (S...) gehörigen Subträger (oc) gebildet wird.

8. Verfahren nach Anspruch 7, bei dem relative Abweichungen der Amplituden der Datensymbole (d) dadurch ermittelt werden, daß die absolute Amplitudendifferenz von Datensymbol zu Datensymbol aufaddiert und das Additionsresultat mit der mittleren Amplitude aller auf einem vorgebbaren Subträger (oc) übertragenen Datensymbole normiert wird.

9. verfahren nach Anspruch 7 oder 8, bei dem von der Mobilstation (MS) mehrere Segmente (z. B. Sx, Sy, Sz) bester Qualität bestimmt und entsprechend einer ansteigenden Amplitudenmodulation in einer Prioritätenliste (z. B. PL1) numeriert werden.

10. Verfahren nach einem der Ansprüche 7 bis 9, bei dem eine Amplitudenmodulation dann ermittelt wird, wenn die Amplituden der auf einem bestimmten Subträger (oc) übertragenen Datensymbole (d) auf Grund von Interferenzen oder von Rauschen sich von Datensymbol zu Datensymbol unterscheiden.

11. Verfahren nach einem der vorhergehenden Ansprüche, bei dem das Funk-Kommunikationssystem als TDMA/CDMA-Mobilfunksystem ausgeprägt ist, bei dem in durch Zeitschlitze gebildeten Frequenzkanälen gleichzeitig Datensymbole (d) mehrerer Kommunikationsverbindungen übertragen werden, wobei die Informationen unterschiedlicher Verbindungen gemäß einer verbindungsindividuellen Feinstruktur unterscheidbar sind.

12. Funk-Kommunikationssystem zur Zuteilung von Funkressourcen einer Funkschnittstelle, wobei

- Datensymbole (d) in Zeitschlitzen (ts) über die Funkschnittstelle zwischen einer Basisstation (BS) und mehreren von der Basisstation (BS) betreuten Mobilstationen (MS) übertragen werden, und
- ein OFDMA-Multiträgerverfahren zur Übertragung der Datensymbole (d) benutzt wird, das den Mobilstationen (MS) jeweils eine Anzahl von Subträgern (oc) und damit ein Segment (S...) eines Frequenzspektrums für die Kommunikationsverbindung zwischen Basisstation (BS) und Mobilstation (MS) zuteilt,

mit

- Steuermittel (MSE) in jeder Mobilstation (MS) zum Messen der Qualität unterschiedlicher Segmente (S...) des Frequenzspektrums und zum Bestimmen zumindest eines für die eigene Kommunikationsverbindung bevorzugt geeigneten Segments (Sx... Sa... Sm...).
- Sendemittel (MHF) in jeder Mobilstation (MS) zum Senden einer entsprechenden Information zur Basisstation (BS),
- Steuermittel (BSE) in jeder Basisstation (BS) zum Auswerten der von den Mobilstationen (MS) empfangenen Informationen und zum Zuteilen eines Segments (Sx, Sa, Sm) für die jeweilige Kommunikationsverbindung an jede Mobilstation (MS) abhängig von der Auswertung, sowie
- Sendemittel (HF) in jeder Basisstation (BS) zum Senden einer Information über das zugeteilte Segment (Sx, Sa, Sm) zu jeder Mobilstation (MS).

13. Funk-Kommunikationssystem nach Anspruch 12, mit einer Mobilstation (MS), die aufweist

- Steuermittel (MSE) zum Messen der Qualität unterschiedlicher Segmente (S...) des Frequenzspektrums und zum Bestimmen zumindest eines für die eigene Kommunikationsverbindung bevorzugt geeigneten Segments (Sx, Sa, Sm), und
- Sendemittel (MHF) zum Senden einer entsprechenden Information zur Basisstation (BS).

14. Funk-Kommunikationssystem nach Anspruch 12 oder 13, mit einer Einrichtung, die aufweist

- Steuermittel (BSE) zum Auswerten der von den Mobilstationen (MS) empfangenen Informationen und zum Zuteilen eines Segments (Sx, Sa, Sm) für die jeweilige Kommunikationsverbindung an jede Mobilstation (MS) abhängig von der Auswertung, sowie
- Sendemittel (BHF) zum Senden einer Information über das zugeteilte Segments (Sx, Sa, Sm) zu jeder Mobilstation (MS).

15. Funk-Kommunikationssystem nach Anspruch 14, bei dem die Steuermittel (BSE) das Auswerten der von den Mobilstationen (MS) empfangenen Informationen und das Zuteilen der Segmente (Sx, Sa, Sm) für die jeweiligen Kommunikationsverbindungen an die Mobilstationen (MS) entsprechend den Übertragungsbedingungen und/oder der Auslastung einer Funkzelle nach Vorgaben einer Einrichtung (BSC, OMC) zum Funkressourcenmanagement durchführen.

16. Funk-Kommunikationssystem nach Anspruch 14 oder 15, bei dem die Einrichtung als Teil einer Basisstation (BS) ausgebildet ist.

17. Funk-Kommunikationssystem nach Anspruch 14 oder 15, bei dem die Einrichtung als Teil einer Basisstationssteuerung (BSC) ausgebildet ist.

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FIG 1

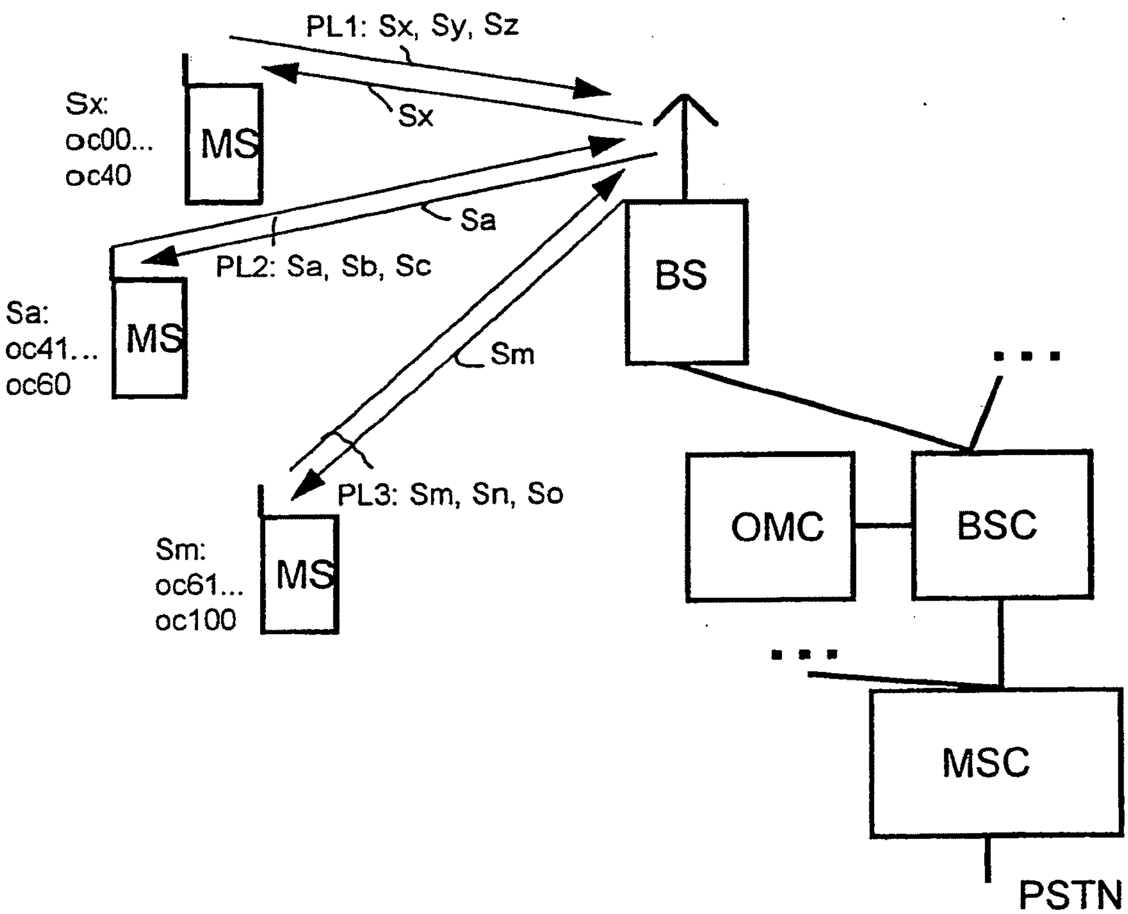

FIG 4

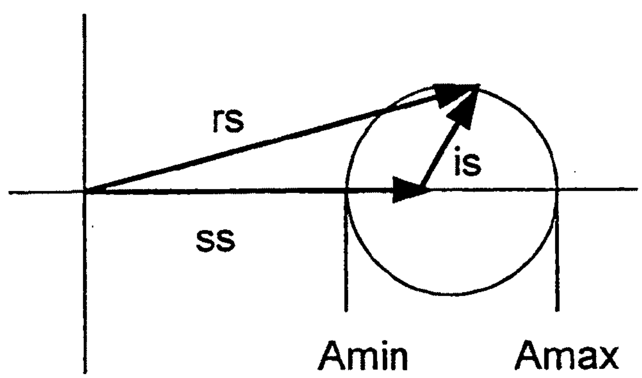

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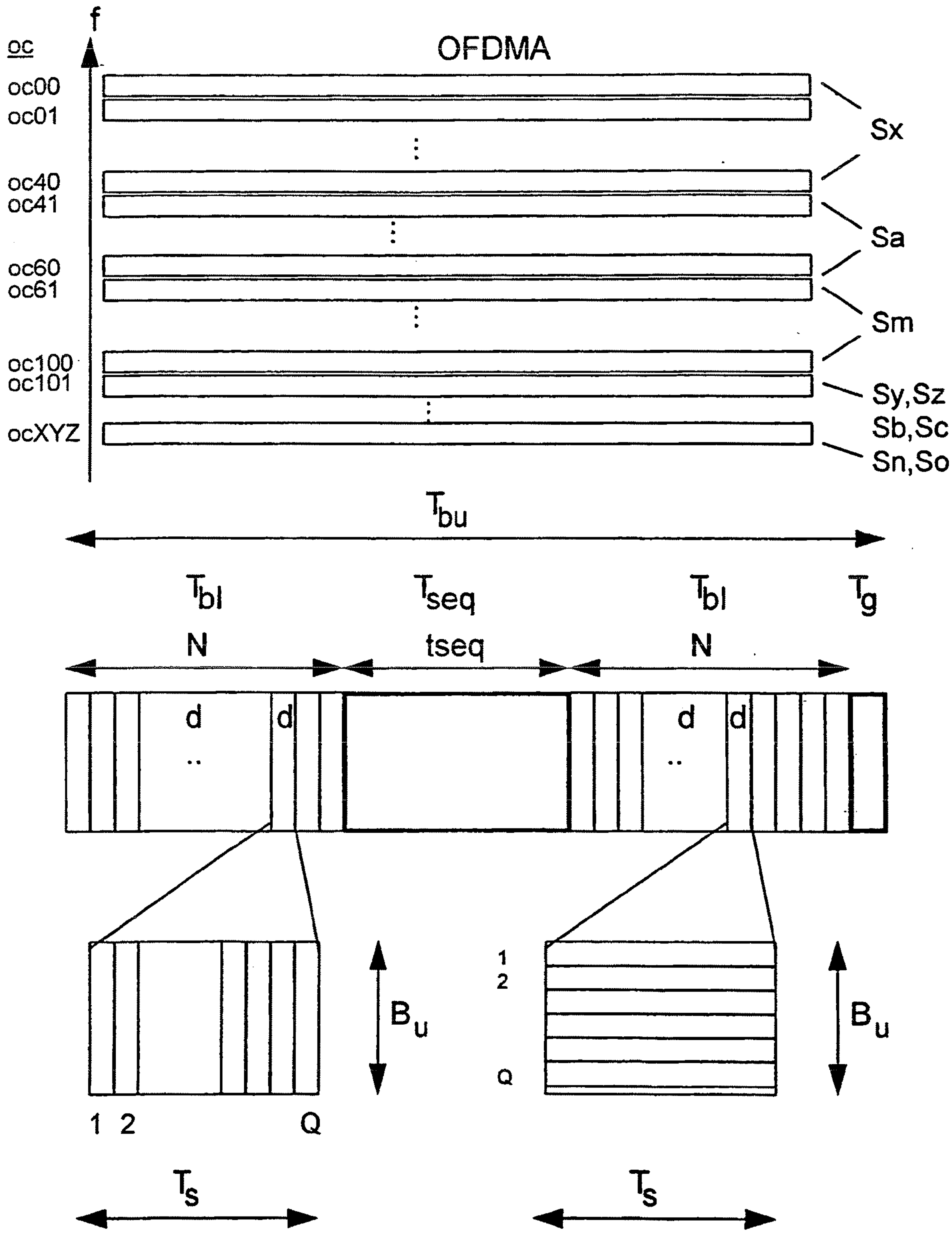
FIG 2



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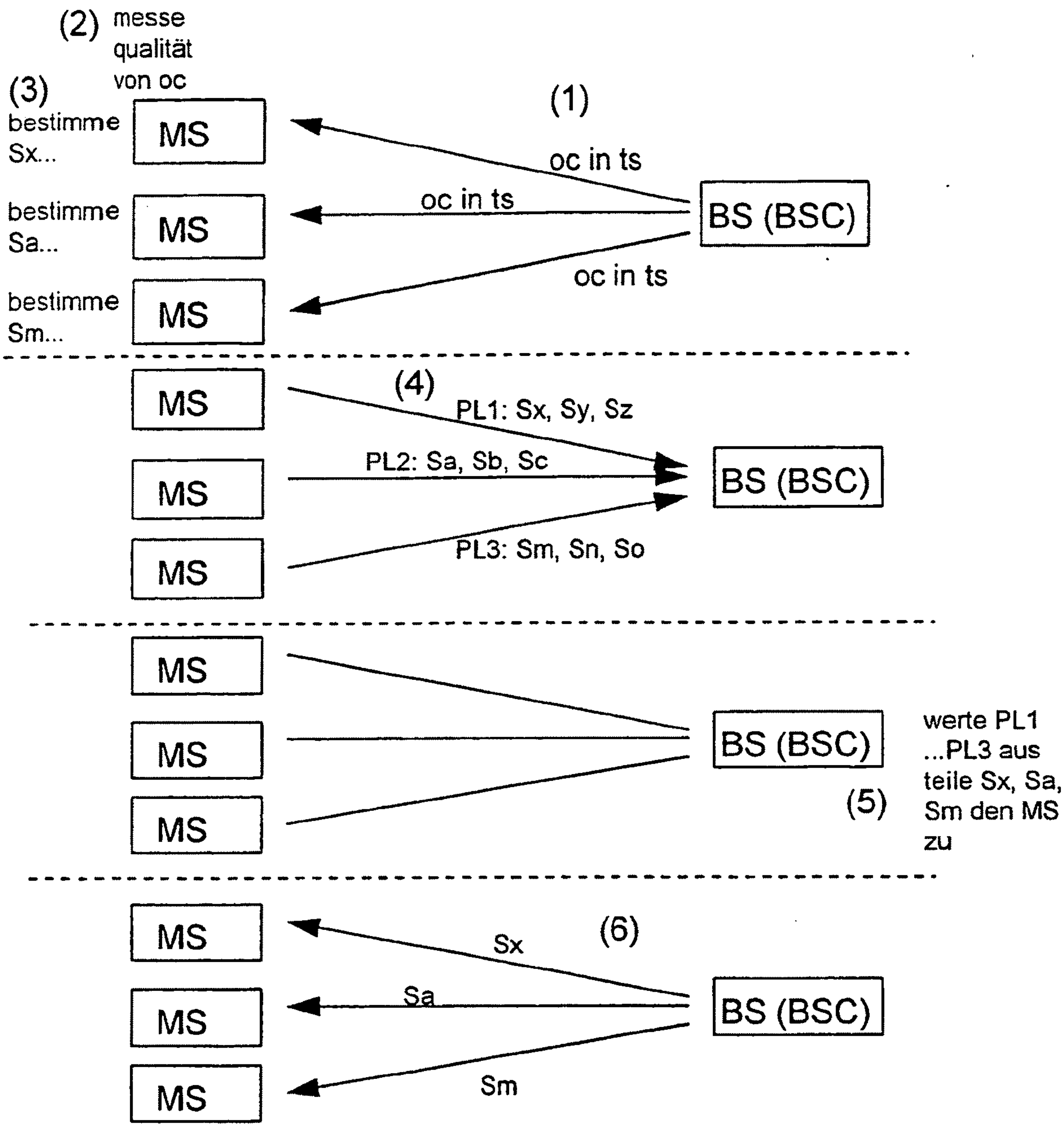

FIG 3

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FIG 5

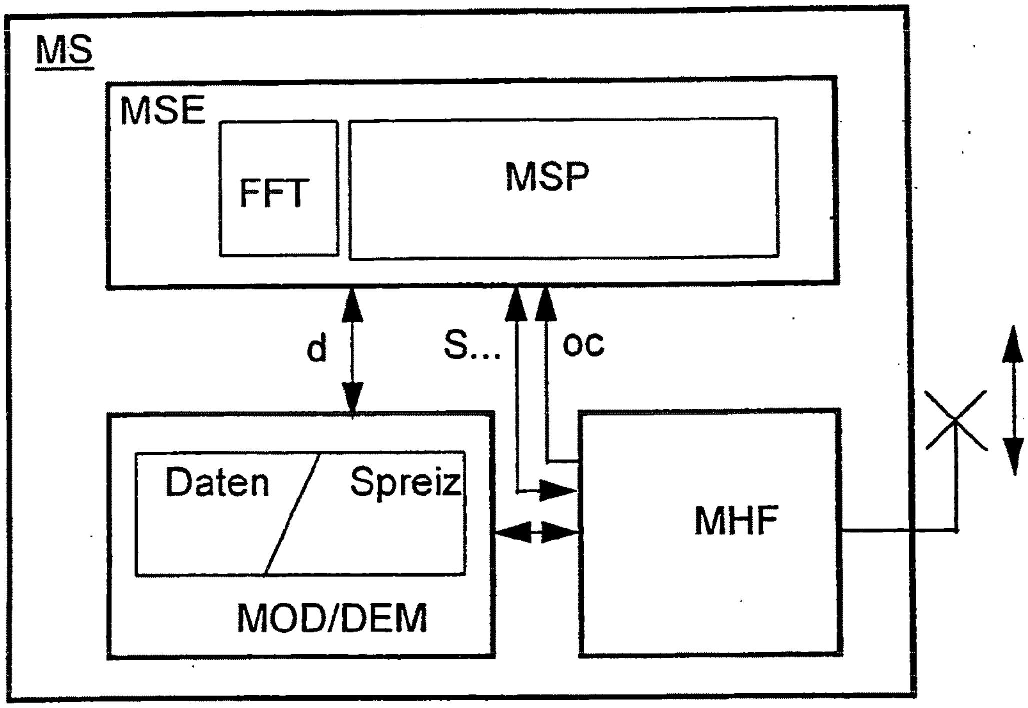
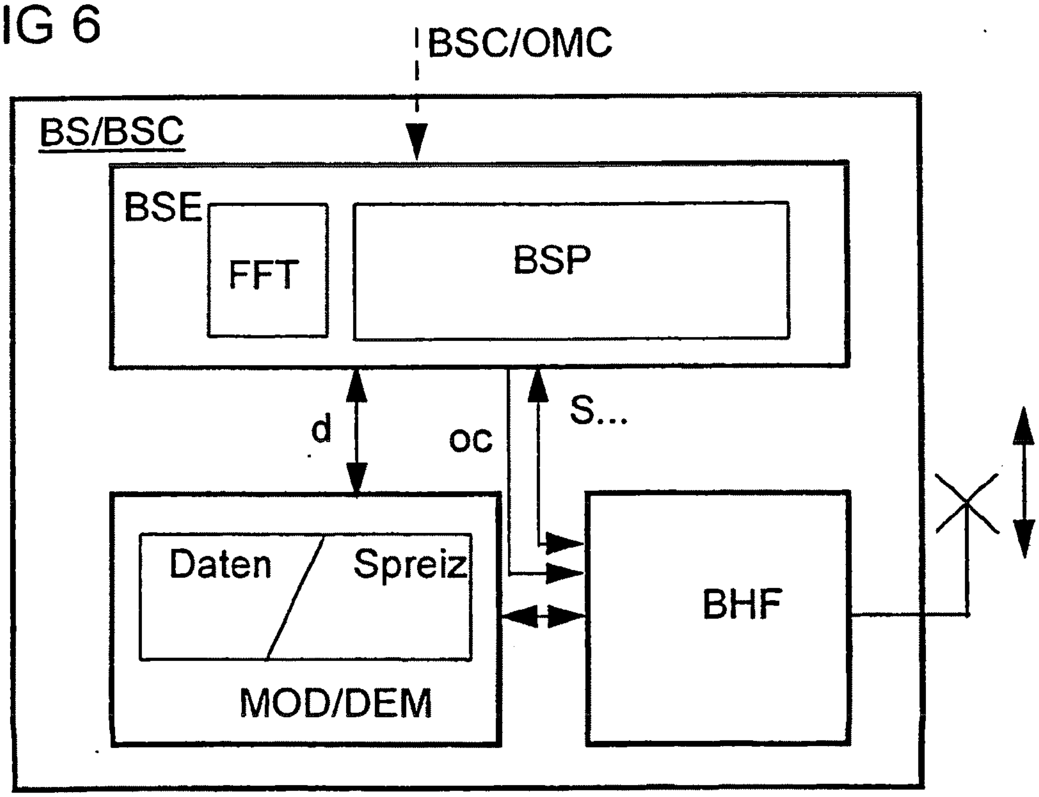


FIG 6



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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	11/199,586-Conf. #1128
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	2617
Examiner Name	M. N. Zewdu
Attorney Docket Number	68144/P014C1/10503148
Total Number of Pages in This Submission	5

ENCLOSURES (*Check all that apply*)

- [ ] Fee Transmittal Form
  - [ ] Fee Attached
- [ ] Amendment/Reply
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
- [ ] Express Abandonment Request
- [x] Information Disclosure Statement
- [ ] Certified Copy of Priority Document(s)
- [ ] Reply to Missing Parts/ Incomplete Application
  - [ ] Reply to Missing Parts under 37 CFR 1.52 or 1.53
- [ ] Drawing(s)
- [ ] Licensing-related Papers
- [ ] Petition
- [ ] Petition to Convert to a Provisional Application
- [ ] Power of Attorney, Revocation Change of Correspondence Address
- [ ] Terminal Disclaimer
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- [ ] CD, Number of CD(s) ______
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- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
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- [ ] Status Letter
- [x] Other Enclosure(s) (please Identify below):

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Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	FULBRIGHT & JAWORSKI L.L.P.		
Signature	R. Ross		
Printed name	R. Ross Viguet		
Date	April 25, 2006	Reg. No.	42,203

Application No.: 11/199,586 Attorney Docket No.: 68144/P014C1/10503097

Certificate of Express Mailing Under 37 CFR 1.10

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Docket No.:
68144/P014C1/10503148
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Xiaodong Li et al.

Application No.: 11/199,586 | Confirmation No.: 1128

Filed: August 8, 2005 | Art Unit: 2617

For: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING | Examiner: M. N. Zewdu

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT (IDS)

MS Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In accordance with 37 CFR 1.97, Applicant(s) hereby make of record the following additional documents. A PTO Form SB/08 and a full copy of each of the documents required under 37 CFR 1.98(a)(2) accompany this statement.

Applicant(s) have become aware of the following documents, cited in a Mexican Office Action issued March 31, 2006, during the prosecution of Mexican application no. PA/a/2003/005311, which corresponds to US 09/837,701 which is related to the above referenced application, and in accordance with 37 CFR 1.97(c) and (e)(1) or (b)(3), hereby submit(s) these documents for the Examiner's consideration. These documents are cited on the enclosed PTO Form SB/08, and a copy of the Mexican Office Action and of each document required under 37 CFR 1.98(a)(2) cited thereon are enclosed as well. An english language translation of DE 198 00 953 and the Mexican Office Action is not readily available.

This statement is not to be interpreted as a representation that the cited documents are material, that an exhaustive search has been conducted, or that no other relevant information exists. Nor shall the citation of any document herein be construed *per se* as a representation that such document is prior art. Moreover, Applicant(s) understand(s) the Examiner will make an independent evaluation of the cited documents.

This Information Disclosure Statement is filed before the mailing date of a first Office Action on the merits as far as is known to the undersigned (37 CFR 1.97(b)(3)).

Furthermore, in accordance with 37 CFR 1.704(d), Applicant(s) note(s) that to our knowledge this communication was not received by any individual designated in 1.56(c) more than thirty days prior to the filing of this statement.

Applicant believes no fee is due. However, if a fee is due, the Director is hereby authorized to charge any deficiency in the fees filed, asserted to be filed or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our Deposit Account No. 06-2380, under Order No. 68144/P014C1/10503148.

Dated: April 25, 2006

Respectfully submitted,

By ________________

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PTO/SB/08A (10-01)
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Substitute for form 1449A/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(use as many sheets as necessary)

Sheet	1	of	1

Complete if Known	
Application Number	11/199,586
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	2617
Examiner Name	M. N. Zewdu
Attorney Docket Number	68144/P014C1/10503148

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]-Number[4]-Kind Code[5] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
	BA	DE 198 00 953	July 29, 1999	Siemens AG		

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

[1] Applicant's unique citation designation number (optional). [2] See attached Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the application number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	CA	Wong et al. "Multiuser OFDM with Adaptive Subcarrier, Bit, and Power Allocation", IEEE Journal on Selected Areas in Communications. IEEE. New York, US, 1999, Vol. 17. NR. 10, pp. 1747-1758	
	CB	Mexican Office Action issued for PA/a/2003/005311 dated March 31, 2006.	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] Applicant's unique citation designation number (optional). [2] Applicant is to place a check mark here if English language Translation is attached.

25649312 .1		Date Considered	

Instituto Mexicano de la Propiedad Industrial

"2006, Año del Bicentenario del natalicio del Benemérito de las Américas, Don Benito Juárez García"

DIRECCION DIVISIONAL DE PATENTES
SUBDIRECCION DIVISIONAL DE EXAMEN DE FONDO DE PATENTES
COORDINACION DEPARTAMENTAL DE EXAMEN DE FONDO AREA ELECTRICA
Expediente **PA/a/2003/005311** de Patente PCT.

Asunto: Se comunica el resultado del examen de fondo.

1er. requisito

México, D.F., a 31 de marzo de 2006

MA. ANGELICA PARDAVELL JUAREZ.*
Apoderado de
ADAPTIX INC.
San Francisco 310
Col. Del Valle
03100, , Distrito Federal

No. de Folio: **23433**

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Fecha:
Firma:

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ANTONIA H. RAMIREZ C.
I.F.E. FOLIO 8081120
SAN FRANCISCO No. 310 COL. DEL VALLE
03100 MEXICO, D. F.

REF: Su solicitud No. PA/a/2003/005311 de Patente PCT presentada el 13 de Diciembre de 2001.

Como resultado del examen de fondo, realizado con fundamento en los artículos 53 de la Ley de la Propiedad Industrial (LPI) y 42 del Reglamento de la Ley de la Propiedad Industrial (RLPI), se le comunica lo siguiente:

El examen fue realizado en base a los siguientes documentos de la solicitud:

Descripción: No. 1 al 59, como originalmente fueron presentadas.

Reivindicaciones: No. 1 al 47, como originalmente fueron presentadas.

Figuras: No. 1 al 13, como originalmente fueron presentadas.

1) Durante el proceso de búsqueda practicado a su solicitud de patente se encontraron documentos que contienen características técnicas esenciales que coinciden con lo que se pretende proteger, en las prioridades **E.U.A. 09/738,086** de fecha 15 de Diciembre de 2000, **E.U.A. 09/837,701** de fecha 17 de Abril de 2001 y que corresponde con la publicación No. **WO0249385 A3** de fecha del 20 de Junio del 2002.

- DE 198 00 953 (SIEMENS AG), del 29 de July de 1999 (1999-07-29).
- WONG C.Y. ET AL: "MULTIUSER OFDM WITH ADAPTIVE SUBCARRIER, BIT, AND POWER ALLOCATION", IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE INC. NEW YORK, US, VOL. 17, NR. 10, PAGE(S) 1747-1758 XP000854075, ISSN: 0733-8716.

En cumplimiento en lo dispuesto en los artículos 55 y 179 de la LPI y 43 del RLPI, deberá presentar, los documentos señalado anteriormente con su respectiva traducción al español, para valorar la patentabilidad de la invención.

Las aclaraciones o modificaciones realizadas ya sea en la descripción, en los dibujos y/o en las reivindicaciones, no deberán contener materia adicional con mayor alcance que la materia presentada originalmente en la solicitud y/o elementos que den soporte a reivindicaciones adicionales, de tal manera que se cumpla con lo establecido en el artículo 55 BIS LPI.

Asimismo deberá efectuar el pago que establece la tarifa vigente y exhibir el comprobante correspondiente.

PA/2006/23433

Instituto Mexicano de la Propiedad Industrial

Para que satisfaga estos requisitos, se le concede un plazo de dos meses contados a partir del día siguiente a la fecha en que se le notifique el presente oficio, apercibido que de no cumplir este requerimiento en el plazo señalado se considerará abandonada su solicitud de Patente de conformidad con lo dispuesto por los arts. 55 y 58 de la Ley de la Propiedad Industrial.

El suscrito firma el presente oficio con fundamento en los artículos 6° fracciones III y XI y 7° bis 2 de la Ley de la Propiedad Industrial; artículos 1°, 3°, 4°, 7° fracciones III, V, IX, XV y XVI, 8° fracciones I, II, III, IV y V, 11° y 12° fracciones I, II, III, IV y VI del Reglamento del Instituto Mexicano de la Propiedad Industrial (D.O.F. 14 de diciembre de 1999); artículos 5°, 11° fracciones III, V, IX y XVI, 12° fracción II, 15° y 16° fracciones I, II, III, IV y VI del Estatuto Orgánico del Instituto Mexicano de la Propiedad Industrial (D.O.F. 27 de diciembre de 1999); artículos 1°, 2° y 5° incisos e), l) y párrafos antepenúltimo y penúltimo de este artículo, del Acuerdo por el que se delegan facultades en los Directores Generales Adjuntos, Coordinador, Directores Divisionales, Titulares de las Oficinas Regionales, Subdirectores Divisionales, Coordinadores Departamentales y otros Subalternos del Instituto Mexicano de la Propiedad Industrial (D.O.F. 15 de diciembre de 1999); y artículo tercero transitorio del Decreto por el que se reforma el Reglamento Interior de la Secretaría de Comercio y Fomento Industrial publicado en el Diario Oficial de la Federación el 14 de septiembre de 1994.

A T E N T A M E N T E
EL COORDINADOR DEPARTAMENTAL

ING. PEDRO DAVID FRAGOSO LOPEZ

JMH/DDP.6.2006.2

UN. 8272 Multiuser OFDM with Adaptive Subcarrier, Bit, and Power Allocation

Cheong Yui Wong, Roger S. Cheng, *Member, IEEE*, Khaled Ben Letaief, *Senior Member, IEEE*, and Ross D. Murch, *Senior Member, IEEE*

XP-000854075 p1747-1758 = (12) PD. 00/10/99

***Abstract*—Multiuser orthogonal frequency division multiplexing (OFDM) with adaptive multiuser subcarrier allocation and adaptive modulation is considered. Assuming knowledge of the instantaneous channel gains for all users, we propose a multiuser OFDM subcarrier, bit, and power allocation algorithm to minimize the total transmit power. This is done by assigning each user a set of subcarriers and by determining the number of bits and the transmit power level for each subcarrier. We obtain the performance of our proposed algorithm in a multiuser frequency selective fading environment for various time delay spread values and various numbers of users. The results show that our proposed algorithm outperforms multiuser OFDM systems with static time-division multiple access (TDMA) or frequency-division multiple access (FDMA) techniques which employ fixed and predetermined time-slot or subcarrier allocation schemes. We have also quantified the improvement in terms of the overall required transmit power, the bit-error rate (BER), or the area of coverage for a given outage probability.**

***Index Terms*—Adaptive modulation, frequency selective fading channel, multiaccess communication, multiuser channel, orthogonal frequency division multiplexing (OFDM), resource management.**

I. Introduction

RECENTLY, intense interest has focused on modulation techniques which can provide broadband transmission over wireless channels for applications including wireless multimedia, wireless Internet access, and future-generation mobile communication systems. One of the main requirements on the modulation technique is the ability to combat intersymbol interference (ISI), a major problem in wideband transmission over multipath fading channels. There are many methods proposed to combat the ISI, e.g., [1]–[3]. Multicarrier modulation techniques, including orthogonal frequency division multiplex (OFDM), (e.g., [4]) are among the more promising solutions to this problem.

Assuming that the transmitter knows the instantaneous channel transfer functions of all users, many papers [5]–[7] have demonstrated that significant performance improvement can be achieved if adaptive modulation is used with OFDM. In particular, subcarriers with large channel gains employ higher order modulation to carry more bits/OFDM symbol, while subcarriers in deep fade carry one or even zero bits/symbol. Integrated design of forward error correcting code and adaptive modulation has also been studied using BCH code and trellis coded modulation (TCM) in [8] and [9], respectively. Although both references considered only time-varying flat fading channels, the same coded adaptive modulation design can be easily applied to OFDM systems. As different subcarriers experience different fades and transmit different numbers of bits, the transmit power levels must be changed accordingly. The problem of optimal power allocation has also been studied in [10].

In this paper, we consider extending OFDM with adaptive modulation to multiuser frequency selective fading environments. When OFDM with adaptive modulation is applied in a frequency selective fading channel, a significant portion of the subcarriers may not be used. These are typically subcarriers which experience deep fade and are not power efficient to carry any information bit. In multiuser systems using static time-division multiple access (TDMA) or frequency-division multiple access (FDMA) as multiaccess schemes, each user is allocated a predetermined time slot or frequency band to apply OFDM with adaptive modulation. Consequently, these unused subcarriers (as a result of adaptive modulation) within the allocated time slot or frequency band of a user are wasted and are not used by other users. However, the subcarriers which appear in deep fade to one user may not be in deep fade for other users. In fact, it is quite unlikely that a subcarrier will be in deep fade for all users, as the fading parameters for different users are mutually independent. This motivates us to consider an adaptive multiuser subcarrier allocation scheme where the subcarriers are assigned to the users based on instantaneous channel information. This approach will allow all the subcarriers to be used more effectively because a subcarrier will be left unused only if it appears to be in deep fade to all users.

We consider a multiuser subcarrier, bit, and power allocation scheme where all users transmit in all the time slots. Our objective is to minimize the overall transmit power by allocating the subcarriers to the users and by determining the number of bits and the power level transmitted on each subcarrier based on the instantaneous fading characteristics of *all* users. In this paper, we formulate the multiuser subcarrier, bit, and power allocation problem and propose an iterative algorithm to perform the multiuser subcarrier allocation. Once

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the subcarrier allocation is determined, the bit and power allocation algorithm can be applied to each user on its allocated subcarriers. We also compare the performance of our proposed solution to various other static subcarrier allocation schemes.

The results of the work can be applied, for instance, to the downlink transmission in a time division duplex (TDD) wireless communication system to improve the downlink capacity. In such a system, the base station (BS) can estimate the instantaneous channel characteristics of all the BS-to-mobile links based on the received uplink transmissions. The multiuser subcarrier, bit, and power allocation can then be used. It is clear that there is a certain amount of transmission overhead as the BS has to inform the mobiles about their allocated subcarriers and the number of bits assigned to each subcarrier.[1] However, this overhead can be relatively small, especially if the channels vary slowly (e.g., in an indoor low mobility environment), and the assignment is done once every many OFDM symbols. To further reduce the overhead, we can assign a contiguous band of subcarriers with similar fading characteristics as a group, instead of assigning each individual subcarrier. In this paper, we will not focus on how the subcarrier allocation information is transmitted. Instead, we will focus on how— and by how much—this new strategy can reduce the required transmit power, or how and by how much this new scheme can improve the bit-error rate (BER) for a fixed transmit power. Alternately, we also consider how and by how much this new scheme can increase the area of coverage for a given transmit power and target BER.

While the bit allocation algorithm can be viewed as a practical implementation of the water-pouring interpretation for achieving the Shannon capacity of an ISI channel [13], the multiuser subcarrier and bit allocation algorithm presented in this paper is the counterpart of the multiuser water-pouring solution given in [14]. In information theoretic studies, the usual approach is to maximize the capacity (or information rate) under the power constraint. In this study, we focus on deriving practical algorithms that can support real-time multimedia data whose bit rates are generally fixed by the compression algorithms. Hence, we assume a given set of user data rates and attempt to minimize the total transmit power under a fixed performance requirement.

The organization of this paper is as follows. In Section II, we will first give the system model and formulate the minimum overall transmit power problem. The optimization problem seeks to minimize the overall transmit power using combined subcarrier, bit, and power allocation schemes for multiuser OFDM systems. The bit and power allocation algorithm for a single-user system is studied in Section III. In Section IV, we derive a lower bound to the minimum overall transmit power by relaxing some of the constraints in the original problem. We also derive a suboptimal subcarrier allocation algorithm. In Section V, we compare the performance between our proposed method and other static approaches via Monte Carlo simulations. Finally, we conclude in Section VI.

[1] Note that the power level used does not need to be transmitted to the receiver in such a TDD system. As the subcarrier gain is known to the transmitter, it can adjust the transmit power level to achieve a predetermined receiver power level based on the number of bits allocated to that subcarrier. However, in FDD systems, the transmit power levels determined by the receiver have to be sent back to the transmitter. In such systems, the additional performance gain achieved by power allocation may not justify the cost of sending the transmit power level information to the transmitter.

II. SYSTEM MODEL

The configuration of our multiuser adaptive OFDM system is shown in Fig. 1. We assume that the system has K users and the kth user has a data rate equal to R_k bit per OFDM symbol. In the transmitter, the serial data from the K users are fed into the subcarrier and bit allocation block which allocates bits from different users to different subcarriers. We assume that each subcarrier has a bandwidth that is much smaller than the coherence bandwidth of the channel and that the instantaneous channel gains on all the subcarriers of all the users are known to the transmitter. Using the channel information, the transmitter applies the combined subcarrier, bit, and power allocation algorithm to assign different subcarriers to different users and the number of bits/OFDM symbol to be transmitted on each subcarrier. Depending on the number of bits assigned to a subcarrier, the adaptive modulator will use a corresponding modulation scheme, and the transmit power level will be adjusted according to the combined subcarrier, bit, and power allocation algorithm. We define $c_{k,n}$ to be the number of bits of the kth user that are assigned to the nth subcarrier. As we do not allow more than one user to share a subcarrier, it follows that for each n, if $c_{k',n} \neq 0$, $c_{k,n} = 0$ for all $k \neq k'$. We also assume that the adaptive modulator allows $c_{k,n}$ to take values in the set $D = \{0, 1, 2, \ldots, M\}$ where M is the maximum number of information bits/OFDM symbol that can be transmitted by each subcarrier.

The complex symbols at the output of the modulators are transformed into the time domain samples by inverse fast Fourier transform (IFFT). Cyclic extension of the time domain samples, known as the guard interval, is then added to ensure orthogonality between the subcarriers, provided that the maximum time dispersion is less than the guard interval. The transmit signal is then passed through different frequency selective fading channels to different users.

We assume that the subcarrier and bit allocation information is sent to the receivers via a separate control channel. At the receiver, the guard interval is removed to eliminate the ISI, and the time samples of the kth user are transformed by the FFT block into modulated symbols. The bit allocation information is used to configure the demodulators while the subcarrier allocation information is used to extract the demodulated bits from the subcarriers assigned to the kth user.

In the frequency selective fading channel, different subcarriers will experience different channel gains. We denote by $\alpha_{k,n}$ the magnitude of the channel gain (assuming coherent reception) of the nth subcarrier as seen by the kth user. We assume that the single-sided noise power spectral density (PSD) level N_0 is equal to unity (i.e., $N_0 = 1$), for all

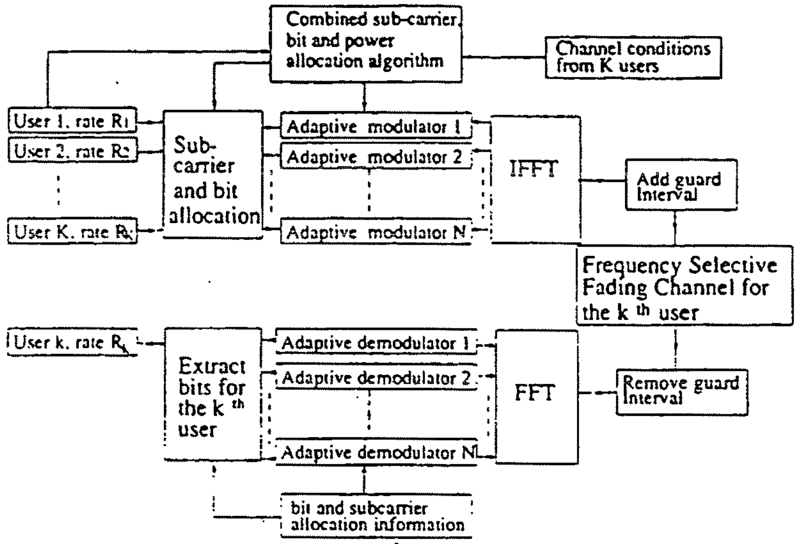

Fig. 1. Block diagram of a multiuser OFDM system with subcarrier, bit, and power allocation.

subcarriers and is the same for all users. Furthermore, we denote by $f_k(c)$ the required received power (in energy per symbol) in a subcarrier for reliable reception of c information bits/symbol when the channel gain is equal to unity. Note that the function $f_k(c)$ depends on k, and this allows different users to have different quality-of-service (QoS) requirements and/or different coding and modulation schemes. In order to maintain the required QoS at the receiver, the transmit power, allocated to the nth subcarrier by the kth user must equal

$$P_{k,n} = \frac{f_k(c_{k,n})}{\alpha_{k,n}^2}. \tag{1}$$

Using these transmit power levels, the receiver can demodulate the modulated symbols at the output of the FFT processor and achieve the desired QoS's of all users.

The goal of the combined subcarrier, bit, and power allocation algorithm is then to find the best assignment of $c_{k,n}$ so that the overall transmit power, the sum of $P_{k,n}$ over all subcarriers and all users, is minimized for given transmission rates of the users and given QoS requirements specified through $f_k()$, $k = 1, \ldots, K$. In order to make the problem tractable, we further require that $f_k(c)$ is a convex and increasing function with $f_k(0) = 0$. This condition essentially means that no power is needed when no bit is transmitted and that the required additional power to transmit an additional bit increases with c [i.e., $f_k(c+1) - f_k(c)$ is increasing in c]. Almost all popular coding and modulation schemes satisfy this condition.

It is important to note that even though the problem is formulated to minimize the overall transmit power for given QoS requirements, the same solution can be applied to improve the QoS's of the users for a given overall transmit power. The latter can simply be achieved by increasing the power proportionally for all the subcarriers, while using the same set of $c_{k,n}$.

Mathematically, we can formulate the problem as

$$P_T^* = \min_{c_{k,n} \in \mathrm{D}} \sum_{n=1}^{N} \sum_{k=1}^{K} \frac{1}{\alpha_{k,n}^2} f_k(c_{k,n}) \tag{2}$$

and the minimization is subjected to the constraints

$$\text{C1: For all } k \in \{1, \ldots, K\},\ R_k = \sum_{n=1}^{N} c_{k,n} \tag{3}$$

and

$$\text{C2: For all } n \in \{1, \ldots, N\}, \text{ if there exists } k' \text{ with } c_{k',n} \neq 0, \text{ then } c_{k,n} = 0,\ \forall k \neq k'. \tag{4}$$

Note that constraint (3) is the data rate requirement and constraint (4) ensures that each subcarrier can only be used by one user. Moreover, $\mathrm{D} = \{0, 1, 2, \ldots, M\}$ is the set of all possible values for $c_{k,n}$, and $c_{k,n} = 0$ means that the kth user does not use the nth subcarrier to transmit any information.

III. Bit Allocation Algorithm for Single User Channel

Before we try to solve the multiuser allocation problem, we will first derive the bit allocation algorithm for the single-user environment. The single-user problem not only gives better understanding of the issues involved, but also provides a bit allocation algorithm that we will use in our multiuser solution.

We can rewrite the optimization problem in (2) for the single-user case as

$$P_T^* = \min_{c_n \in \mathrm{D}} \sum_{n=1}^{N} \frac{1}{\alpha_n^2} f(c_n) \tag{5}$$

and the minimization is under the constraint

$$R = \sum_{n=1}^{N} c_n. \tag{6}$$

Note that we have dropped the subscript k, which denotes the user in all notations.

As the power needed to transmit a certain number of bits in a subcarrier is independent of the numbers of bits allocated to other subcarriers, it turns out that a greedy approach is optimal. A greedy algorithm assigns bits to the subcarriers one bit at a time, and in each assignment, the subcarrier that requires the least additional power is selected. The bit allocation process will be completed when all R bits are assigned. Several papers (e.g., [15] and [16]) have provided various algorithms for this problem, and the basic structure of most algorithms are similar and can be described as follows:

Initialization:
For all n, let $c_n = 0$ and $\Delta P_n = [f(1) - f(0)]/\alpha_n^2$;
Bit Assignment Iterations:
Repeat the following R times:
$\hat{n} = \arg\min_n \Delta P_n$;
$c_{\hat{n}} = c_{\hat{n}} + 1$;
$\Delta P_{\hat{n}} = [f(c_{\hat{n}} + 1) - f(c_{\hat{n}})]/\alpha_{\hat{n}}^2$;
End;
Finish:
$\{c_n\}_{n=1}^{N}$ is the final bit allocation solution.

The initialization stage computes, for each subcarrier, the additional power needed to transmit an additional bit. For each bit assignment iteration, the subcarrier that needs the minimum additional power is assigned one more bit, and the new additional power for that subcarrier is updated. After R iterations, the final bit assignment gives the optimal bit allocation for each subcarrier. It is important to note that the bit allocation is optimal only for the given function $f(c)$, which depends on the selected modulation scheme. Different modulation schemes will lead to different $f(c)$, different bit allocation, and possibly lower transmit power P_T^*.

The concept of this algorithm is fairly simple, and many similar algorithms based on the same principle have been obtained before. In particular, there exist faster and less complex algorithms which can speed up the bit allocation process significantly (e.g., [15] and [16]). In our simulations, we use the algorithm given in [16].

IV. Multiuser Subcarrier and Bit Allocation

We have observed that, in the single-user case, a greedy approach which assigns one bit at a time to the subcarrier that requires the least additional power gives the optimal allocation in the sense of minimizing the overall transmit power. Unfortunately, the problem becomes more difficult in the multiuser environment. As users cannot share the same subcarrier, allocating bits to a subcarrier essentially prevents other users from using that subcarrier. This dependency makes any greedy algorithm a nonoptimal solution. It turns out that the optimal solution may not assign any of a user's bits to the best subcarrier seen by that user. This may happen when the best subcarrier of a user is also the best subcarrier of another user who happens to have no other good subcarriers. Hence, the multiuser subcarrier and bit allocation problem is much more complicated to solve than that of the single-user case.

It turns out that the optimization problem in (2) is a combinatorial optimization problem. To make the problem tractable, we consider a different but similar optimization problem. We relax the requirement $c_{k,n} \in D$ to allow $c_{k,n}$ to be a real number within the interval $[0, M]$. Moreover, in order to deal with constraint (4), K variables, $\rho_{k,n}$, $k = 1, \ldots, K$ with values within the interval [0, 1], are introduced to the cost function as sharing factors of the nth subcarrier. The new optimization problem becomes

$$\underline{P}_T = \min_{\substack{c_{k,n} \in [0, M] \\ \rho_{k,n} \in [0, 1]}} \sum_{n=1}^{N} \sum_{k=1}^{K} \frac{\rho_{k,n}}{\alpha_{k,n}^2} f_k(c_{k,n}) \tag{7}$$

where $c_{k,n}$ and $\rho_{k,n}$ have to satisfy

$$R_k = \sum_{n=1}^{N} \rho_{k,n} c_{k,n}, \qquad \text{for all } k \in \{1, \ldots, K\} \tag{8}$$

and

$$1 = \sum_{k=1}^{K} \rho_{k,n}, \qquad \text{for all } n \in \{1, \ldots, N\}. \tag{9}$$

For any valid set of $c_{k,n} \in D$ satisfying the constraints (3) and (4) in the original optimization problem, we can let

$$\rho_{k,n} = \begin{cases} 1, & \text{if } c_{k,n} \neq 0, \\ 0, & \text{if } c_{k,n} = 0. \end{cases} \tag{10}$$

Then, it is easy to show that the same set of $c_{k,n}$ and the corresponding $\rho_{k,n}$ defined in (10) satisfy the constraints (8) and (9) in the new optimization problem. Moreover, with $\rho_{k,n}$ defined in (10), the new cost function in (7) is equal to the cost function in (2). Hence, the minimization problem in (7) is the same as the original optimization problem, except that the minimization is done over a larger set. Consequently, the minimum power obtained in (7) $\underline{P}_T$ is a lower bound to the minimum power obtained in (2), P_T^*.

Another way to interpret the optimization in (7) is to consider $\rho_{k,n}$ as the time-sharing factor for the kth user of the nth subcarrier. For example, in every L OFDM symbol (L being a very large number), user k uses the nth subcarrier in $L\rho_{k,n}$ symbols. Clearly, the average (over L symbols) information data rate and the average transmit power has to be scaled by the same factor $\rho_{k,n}$. Hence, we can consider (7) as the optimization problem when the users are allowed to time-share each subcarrier over a large number of OFDM symbols. However, most wireless communication channels are time varying, and the channels may not stay unchanged long enough for timesharing to be feasible. Hence, in this paper, we will continue to consider the original problem in (2) and use the optimization problem in (7) as a lower bound, even though it has its own physical interpretation.

The modified optimization problem in (7) is more tractable. However, even though the function $f_k(c)$ is convex in c, the terms in the cost function have the form $\rho f_k(c)$, and as a function of (ρ, c), $\rho f_k(c)$ is not convex in (ρ, c). To proceed further, we let $r_{k,n} = c_{k,n}\rho_{k,n}$ and rewrite the cost function in terms of $r_{k,n}$ and $\rho_{k,n}$. The constraint on $r_{k,n}$

becomes $r_{k,n} \in [0, M\rho_{k,n}]$, and it can be easily shown that $\rho f_k(c) = \rho f_k(r/\rho)$ is convex in (ρ, r) within the triangular region specified by $\rho \in [0, 1]$ and $r \in [0, M\rho]$. In particular, the Hessian evaluated at any point within this region is a positive semidefinite matrix. Hence, we can reformulate the optimization problem in (7) as a convex minimization problem over a convex set. That is

$$\underline{P}_T = \min_{\substack{r_{k,n} \in [0, M\rho_{k,n}] \\ \rho_{k,n} \in [0,1]}} \sum_{n=1}^{N} \sum_{k=1}^{K} \frac{\rho_{k,n}}{\alpha^2_{k,n}} f_k\left(\frac{r_{k,n}}{\rho_{k,n}}\right) \qquad (11)$$

where $r_{k,n}$ and $\rho_{k,n}$ have to satisfy

$$R_k = \sum_{n=1}^{N} r_{k,n}, \qquad \text{for all } k \in \{1, \ldots, K\} \qquad (12)$$

and

$$1 = \sum_{k=1}^{K} \rho_{k,n} \qquad \text{for all } n \in \{1, \ldots, N\}. \qquad (13)$$

Using standard optimization techniques in [17], we obtain the Lagrangian

$$L = \sum_{n=1}^{N} \sum_{k=1}^{K} \frac{\rho_{k,n}}{\alpha^2_{k,n}} f_k\left(\frac{r_{k,n}}{\rho_{k,n}}\right) - \sum_{k=1}^{K} \lambda_k \left(\sum_{n=1}^{N} r_{k,n} - R_k\right) - \sum_{n=1}^{N} \beta_n \left(\sum_{k=1}^{K} \rho_{k,n} - 1\right) \qquad (14)$$

where λ_k and β_n are the Lagrangian multipliers for the constraints (12) and (13), respectively.

After differentiating L with respect to $r_{k,n}$ and $\rho_{k,n}$, respectively, we obtain the necessary conditions for the optimal solution, $r^*_{k,n}$ and $\rho^*_{k,n}$. Specifically, if $\rho^*_{k,n} \neq 0$, we have

$$\left.\frac{\partial L}{\partial r_{k,n}}\right|_{(r_{k,n}, \rho_{k,n}) = (r^*_{k,n}, \rho^*_{k,n})} = \frac{1}{\alpha^2_{k,n}} f_k'\left(\frac{r^*_{k,n}}{\rho^*_{k,n}}\right) - \lambda_k \begin{cases} > 0, & \text{if } r^*_{k,n} = 0 \\ = 0, & \text{if } r^*_{k,n} \in (0, M\rho^*_{k,n}) \\ < 0, & \text{if } r^*_{k,n} = M\rho^*_{k,n} \end{cases} \qquad (15)$$

and

$$\left.\frac{\partial L}{\partial \rho_{k,n}}\right|_{(r_{k,n}, \rho_{k,n}) = (r^*_{k,n}, \rho^*_{k,n})} = \frac{1}{\alpha^2_{k,n}} \left[f_k\left(\frac{r^*_{k,n}}{\rho^*_{k,n}}\right) - f_k'\left(\frac{r^*_{k,n}}{\rho^*_{k,n}}\right)\frac{r^*_{k,n}}{\rho^*_{k,n}} \right] - \beta_n \begin{cases} = 0, & \text{if } \rho^*_{k,n} \in (0, 1) \\ < 0, & \text{if } \rho^*_{k,n} = 1. \end{cases} \qquad (16)$$

On the other hand, if $\rho^*_{k,n} = 0$, then $r^*_{k,n} = 0$; and we have

$$r_{k,n}\frac{\partial L}{\partial r_{k,n}} + \rho_{k,n}\frac{\partial L}{\partial \rho_{k,n}} \geq 0, \quad \text{for all } \rho_{k,n} \in (0, 1] \text{ and } r_{k,n} \in (0, M\rho_{k,n}]. \qquad (17)$$

These necessary conditions can be interpreted by the fact that if the minimum occurs within the constrained region [(0, 1) for $\rho_{k,n}$ and $(0, M\rho_{k,n})$ for $r_{k,n}$], then the derivative evaluated at the minimum point must be zero. On the other hand, if the optimal solution occurs at a boundary point, then the derivative must be positive along all directions pointing toward the interior of the constraint set. Then, (17) follows from considering the boundary point at $(r^*_{k,n}, \rho^*_{k,n}) = (0, 0)$.

From (15) and (17), we can conclude that

$$r^*_{k,n} = \rho^*_{k,n} f_k'^{-1}(\lambda_{q,k}\alpha^2_{k,n}) \qquad (18)$$

where

$$\lambda_{q,k} = \begin{cases} f_k'(0)/\alpha^2_{k,n}, & \text{if } f_k'^{-1}(\lambda_k\alpha^2_{k,n}) < 0; \\ \lambda_k, & \text{if } 0 \leq f_k'^{-1}(\lambda_k\alpha^2_{k,n}) \leq M; \\ f_k'(M)/\alpha^2_{k,n}, & \text{if } f_k'^{-1}(\lambda_k\alpha^2_{k,n}) > M. \end{cases}$$

Moreover, from (16) and (17), it follows that

$$\rho^*_{k,n} = \begin{cases} 0, & \text{if } \beta_n < H_{k,n}(\lambda_{q,k}) \\ 1, & \text{if } \beta_n > H_{k,n}(\lambda_{q,k}) \end{cases} \qquad (19)$$

where

$$H_{k,n}(\lambda) = \frac{1}{\alpha^2_{k,n}}\left[f_k(f_k'^{-1}(\lambda\alpha^2_{k,n})) - \lambda\alpha^2_{k,n} f_k'^{-1}(\lambda\alpha^2_{k,n})\right]. \qquad (20)$$

Since constraint (13) must be satisfied, we find from (19) that for each n, if $H_{k,n}(\lambda_{q,k})$ for $k = 1, \ldots, K$ are all different, then only the user with the smallest $H_{k,n}(\lambda_{q,k})$ can use that subcarrier. In other words, for the nth subcarrier, if $H_{k,n}(\lambda_{q,k})$ are different for all k, then

$$\rho^*_{k',n} = 1, \quad \rho^*_{k,n} = 0, \qquad \text{for all } k \neq k' \qquad (21)$$

where

$$k' = \arg\min_k H_{k,n}(\lambda_{q,k}). \qquad (22)$$

Hence, it follows that for a fixed set of Lagrange multipliers λ_k, $k = 1, \ldots, K$, we can use them to determine k' for each n using (22). The $r^*_{k,n}$ and $\rho^*_{k,n}$ obtained will then form an optimal solution for the optimization problem; however, the individual rate constraint (12) may not be satisfied.

In order to find the set of λ_k such that the individual rate constraints are satisfied, we have obtained an iterative searching algorithm. Starting with some small values for all λ_k, this iterative procedure increases one of the λ_k until the data rate constraint (12) for user k is satisfied. Then, we switch to another user and go through the users one at a time. This process repeats for all users until the data rate constraint for all users are satisfied. This algorithm converges because for a given k, as λ_k increases, $H_{k,n}(\lambda_{q,k})$ for all n decreases, and more $\rho^*_{k,n}$ in (19) become one while $r^*_{k,n}$ in (18) increases for those n where $\rho^*_{k,n} > 0$. Hence, $\sum_{n=1}^{N} r^*_{k,n}$ increases. During this process, some of the other $\rho^*_{k',n}$ may change from one to zero and consequently decrease the total data rate for other users. However, as all the λ_k increase, $r^*_{k,n}$ increases accordingly. As long as the total data rate is less than MN bits/symbol, which is the total number of bits possibly transmitted within an OFDM symbol, the algorithm will converge to a solution that satisfies all the constraints. Since the optimization problem is a convex optimization problem over a convex set, the set of necessary conditions is also sufficient, and the solution that satisfies all the necessary conditions is the unique optimal solution.

In the process of adjusting λ_k for $k = 1, \ldots, K$, the situation where, for a fixed n, more than one $H_{k,n}(\lambda_{q,k})$ has the same values cannot be ignored. In that case, $\rho^*_{k,n}$ has to take values within the interval (0, 1). This solution suggests that the subcarrier should be shared by multiple users. In practice, this can be done by having these users with $\rho^*_{k,n} > 0$ time share the nth subcarrier, and the ratio of the symbols used by different users are set proportionally to $\rho^*_{k,n}$. The detailed flow chart of the algorithm is given in the Appendix.

Now, we have an algorithm to obtain the optimal values of $\rho^*_{k,n}$ and

$$c^*_{k,n} = \begin{cases} r^*_{k,n}/\rho^*_{k,n}, & \text{if } \rho^*_{k,n} \neq 0 \\ 0, & \text{otherwise.} \end{cases} \quad (23)$$

This solution, when substituted in (7), gives a lower bound to the minimum overall transmit power. However, we cannot use these results immediately in (2). One problem is that $c^*_{k,n}$ may not be in D, and the other is that some $\rho^*_{k,n}$ may be within (0, 1), indicating a time-sharing solution. Furthermore, simply quantizing $c^*_{k,n}$ and $\rho^*_{k,n}$ will not satisfy the individual rate constraints in (3).

To solve this problem, we propose a multiuser adaptive OFDM (MAO) scheme where the subcarrier allocation follows essentially the solution to the lower bound in (7), and then the single-user bit allocation algorithm given in Section III is applied to each user on the allocated subcarriers. Specifically, we modify $\rho^*_{k,n}$ for the optimization problem in (7) by letting for each n $\rho^*_{k',n} = 1$ where $k' = \arg\max_k \rho^*_{k,n}$, and $\rho^*_{k,n} = 0$ for $k \neq k'$. Then, we apply the single-user bit allocation algorithm on each user using the assigned subcarriers. We denote the total transmit power (in energy/symbol) obtained using this MAO scheme by P_T. It is easy to see that $\underline{P}_T \leq P^*_T \leq P_T$, where P^*_T is the minimum power in the original problem, and $\underline{P}_T$ is the minimum power for the modified problem with the relaxed constraints. More specifically, the difference between P_T and the minimum $\underline{P}_T$ gives an upper bound to how far away our MAO scheme is from the solution of our original optimization problem.

V. Performance Comparison

In this section, we obtain and compare the performance of the MAO scheme with other static subcarrier allocation schemes. We consider a system that employs M-ary quadrature amplitude modulation (MQAM) with $\mathbf{D} = \{0, 2, 4, 6\}$. Square signal constellations (4-QAM, 16-QAM, and 64-QAM) are used to carry two, four, or six bits/symbol. The bit-error probability is upper bounded by the symbol error probability, which is tightly approximated by $4Q[\sqrt{d^2/(2N_0)}]$ [12, p. 281], where d is the minimum distance between the points in the signal constellation. Since the average energy of a M-QAM symbol is equal to $(M-1)d^2/6$, it follows that the required power for supporting c bits/symbol at a given BER P_e is

$$f(c) = \frac{N_0}{3}\left[Q^{-1}\left(\frac{P_e}{4}\right)\right]^2 (2^c - 1)$$

where we recall that

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-t^2/2}\, dt.$$

It is easy to see that $f(c)$ is convex and increasing in c and that $f(0) = 0$.

To evaluate the performance of our scheme, we have simulated 1000 sets of five-path frequency selective Rayleigh fading channels with an exponential power delay profile. Each set of channels consists of K independent channels, one for each user. We use an OFDM system with 128 subcarriers over a 5 MHz band along with a total (over all users) transmission rate equal to 512 bits/symbol (or equivalently, an average of four bits/subcarrier). Recall that the single-sided power spectral density level N_0 is equal to unity, and we assume that the average subcarrier channel gain $E|\alpha_{k,n}|^2$ is equal to unity for all k and n.

For comparison purposes, we have also considered three other static multiuser subcarrier allocation methods. Two of them are based on the multiple access methods described in [7]. The methods are presented as follows.

- OFDM-TDMA: each user is assigned a predetermined TDMA time slot and can use all the subcarriers within that time slot exclusively.
- OFDM-FDMA: each user is assigned a predetermined band of subcarriers and can only use those subcarriers exclusively in every OFDM symbol.

  In a frequency selective fading channel, there is a high correlation between the channel gains of adjacent subcarriers. In order to avoid the situation where all subcarriers of a user are in deep fade, we propose an enhanced version of OFDM-FDMA, which we shall refer to as OFDM Interleaved-FDMA.
- OFDM Interleaved-FDMA: this is the same as OFDM-FDMA except that subcarriers assigned to a user are interlaced with other users' subcarriers in the frequency domain.

The time and subcarrier assignment of these three multiuser OFDM schemes are illustrated in Fig. 2. Note that these static schemes have predetermined subcarrier allocations which are independent of the channel gains of the users. The main difference between the proposed MAO scheme and these static schemes is that MAO assigns subcarriers adaptively based on the instantaneous channel gains. To ensure a fair comparison, we use the optimal single-user bit allocation (OBA) for each user on the assigned subcarriers. For comparison purposes, we also show the results when equal bit allocation (EBA) is employed on the assigned subcarriers for these three OFDM schemes. Notice that when using EBA, all three schemes will have the same performance in an uncoded system. This is because the average bit signal-to-noise ration (SNR) needed is a function of only the marginal probability density function of each subcarrier gain.

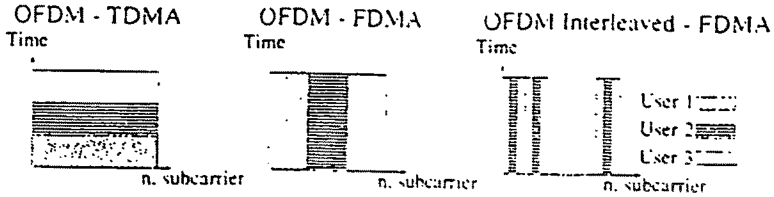

Fig. 2. Subcarrier and time-slot allocations of OFDM-TDMA, OFDM-FDMA, and OFDM interleaved-FDMA schemes.

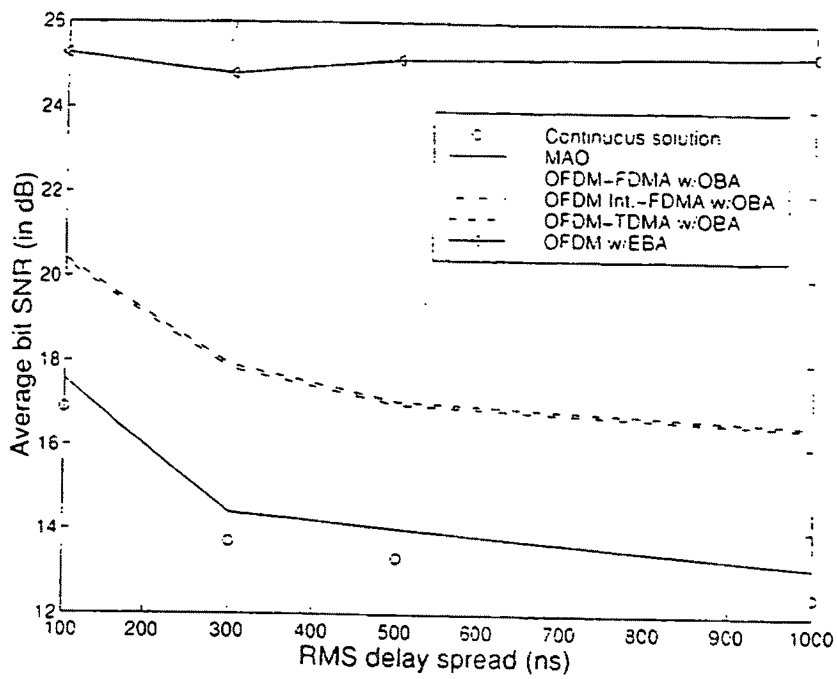

Fig. 3. Average bit signal-to-noise ration (SNR) required by different schemes in various root mean square (RMS) delay spreads in a five-user system with $P_e = 10^{-4}$.

Fig. 3 shows the average bit SNR needed to achieve a BER at $P_e = 10^{-4}$ for a five-user system versus the root mean square (RMS) delay spread (for definition, see for example [18, p. 160]) for different multiuser OFDM schemes. The average required transmit power (in energy per bit) is defined as the ratio of the overall transmit energy per OFDM symbol (including all subcarriers and all users) to the total number of bits transmitted per OFDM symbol. Moreover, we define the average bit SNR as the ratio of the average transmit power to the noise PSD level N_0. As we assume that the data rate is fixed and that N_0 is just a constant, the overall transmit power is proportional to the average bit SNR. For ease of comparison, we have used the average bit SNR for comparison. We find in Fig. 3 that the MAO scheme is never more than 0.6 dB from the lower bound. Since the bit SNR of the optimal combined subcarrier, bit, and power allocation algorithm must lie between the bit SNR's achieved by the lower bound and the MAO scheme, we find that the MAO scheme is never more than 0.6 dB away from the optimal solution. On the other hand, we observe that our proposed MAO scheme is 3–5 dB better than the static subcarrier allocation schemes with OBA, which are in turn 5–10 dB better than that with EBA. We also find that when OBA is used, the OFDM interleaved-FDMA scheme and the OFDM-TDMA scheme have very similar performance, and both of them outperform the OFDM-FDMA scheme.[2] A closer observation of Fig. 3 also indicates that the gains achieved by optimal bit allocation and optimal multiuser subcarrier allocation increase with the RMS delay spread. This is mainly because the larger the RMS delay spread, the more the fading variation and hence higher gains can be obtained when the allocation is performed adaptively.

Fig. 4 shows the average bit SNR (in dB) needed to achieve the same BER versus the number of users when the RMS delay spread is 100 ns. We find that the savings in the required bit SNR achieved by MAO when compared to other schemes are roughly the same, independent of the number of users in the system.

While these two figures show the improvement in the required bit SNR, the results can perhaps be more easily understood using the more familiar BER versus bit SNR curves. For each BER requirement, we compute $f(c)$ for all $c \in D$ and then use our algorithm to calculate the subcarrier

[2] OFDM-FDMA refers only to the specific FDMA scheme that assigns to each user a contiguous band of subcarriers as shown in Fig. 2, but not the general FDMA schemes. In fact, both OFDM interleaved-FDMA and MAO can be considered as different forms of FDMA and they are not outperformed by the OFDM-TDMA scheme.

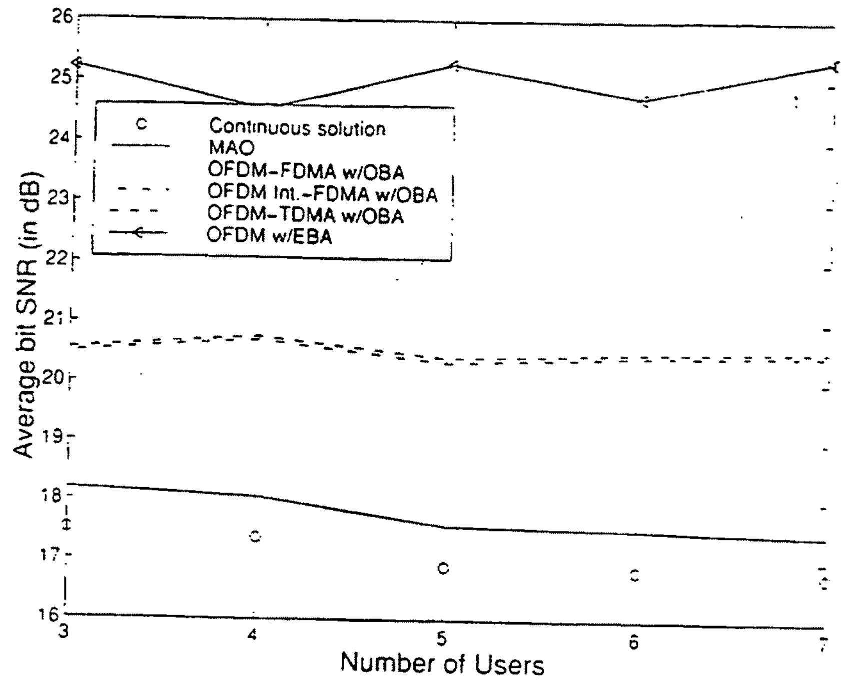

Fig. 4. Average bit SNR required by different schemes versus the number of users in a multiuser OFDM system with 100 ns RMS delay spread, and $P_e = 10^{-4}$.

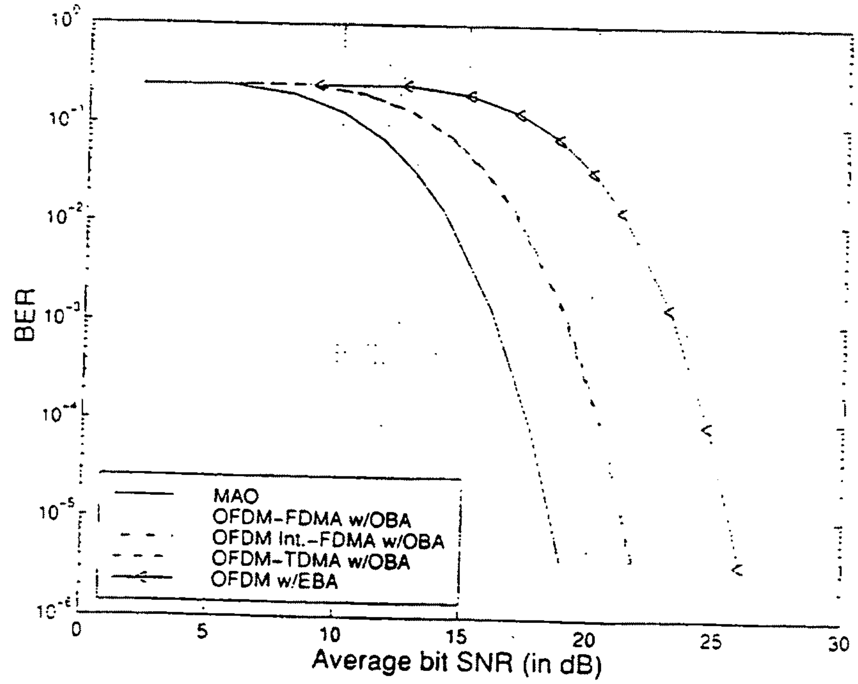

Fig. 5. BER versus average bit SNR for various subcarrier allocation schemes.

allocation for the MAO case. For all other static subcarrier allocation schemes, the allocations are independent of the BER. Once the subcarrier allocation is fixed, we apply the optimal bit and power allocation algorithm to every user. The final average power per bit divided by the noise power spectral density level gives the average bit SNR. We repeat this procedure for different BER values, and the results are plotted in Fig. 5 for a five-user system with an RMS delay spread equal to 100 ns. We find that our proposed MAO has at least 3–4 dB advantage over all other schemes.

Another way to illustrate the impact of the bit and subcarrier allocation is to consider the area of coverage for a given outage probability, assuming that the BS has a maximum transmit power. We consider a circular cell with five users, indepen-

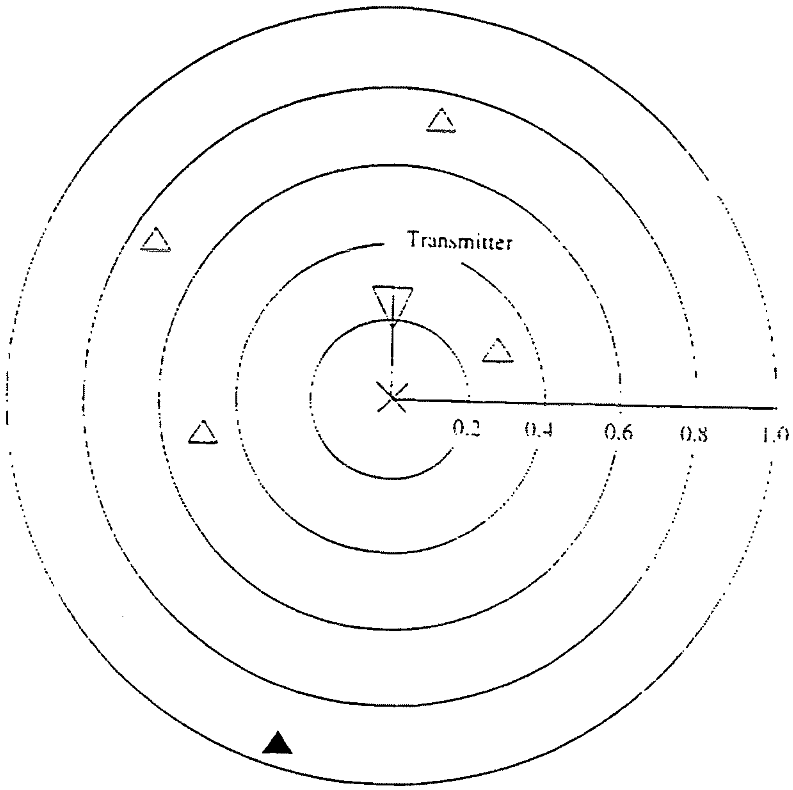

Fig. 6 Cell for analyzing the outage probability.

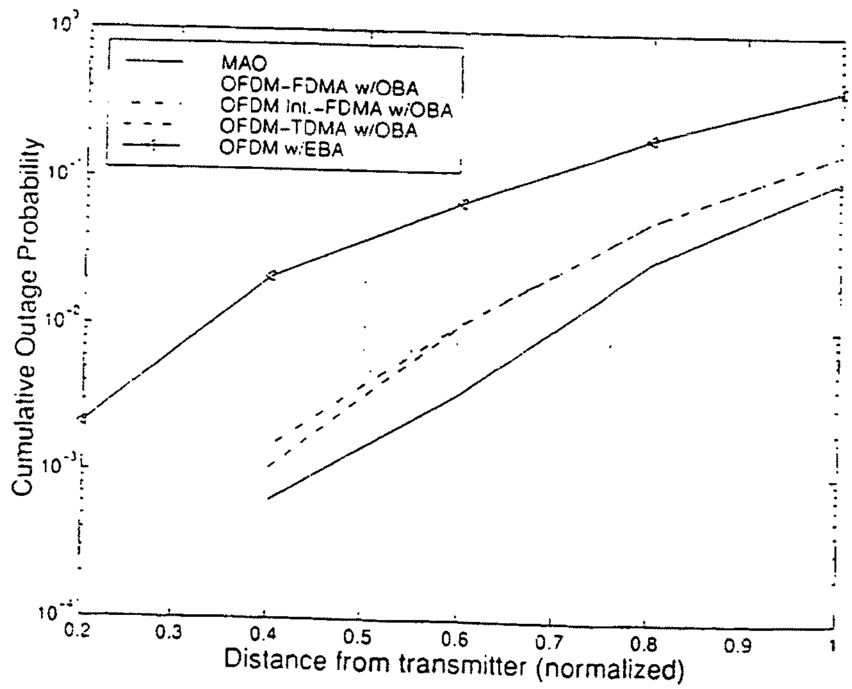

Fig. 7 Outage probability at 17 dB fading margin.

dently and uniformly distributed within the cell. A typical scenario is shown in Fig. 6, where the triangles represent the five users. In addition to frequency selective fading, path loss and log-normal shadowing are also included in simulating the actual channel gains seen by the users. Using these channel gains, subcarriers and bits assigned to each user are determined by the various multiple access schemes and the total required transmit power is calculated. If the total power for all five users

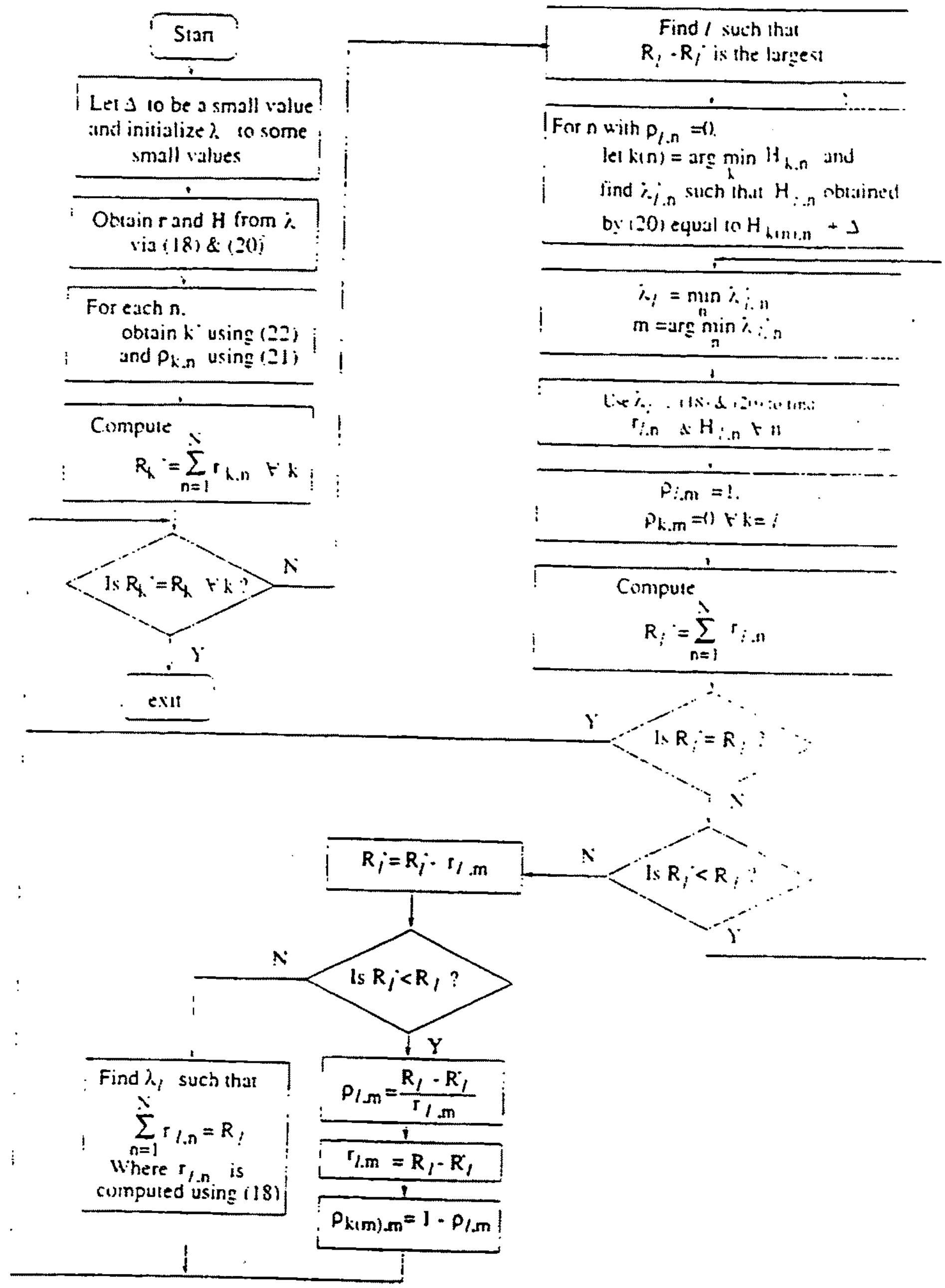

Fig. 8. Flow chart of the multiuser subcarrier allocation algorithm.

exceeds the maximum power of the BS, the user requiring the largest transmit power (in this case, the black one) is dropped and counted as one outage event occurring at a distance equal to the distance between the BS and the dropped user. This process continues until the transmit power is smaller than the maximum power of the BS. In this example, the maximum transmit power is set to the transmit power required for all five users assuming that they are all located at the boundary of the cell, taking into account the path loss effect and a 17 dB fading margin for shadowing.

The cumulative outage probabilities at various normalized distances, normalized to the cell radius, are plotted in Fig. 7. A cumulative outage probability of 5% at a normalized distance of 0.8 means that there is a 5% chance of outage for a mobile located more than $0.8R$ away from the BS where R is the radius of the cell. We observe that MAO outperforms others with a large reduction in the outage probability at all distances. Alternatively, if the same outage probability is maintained, say at 1%, the coverage are provided by MAO is 36% larger than the best of all other schemes.

VI. Conclusion

In this paper, we considered OFDM transmission in a multiuser environment and formulated the problem of minimizing the overall transmit power by adaptively assigning subcarriers to the users along with the number of bits and power level to each subcarrier. In particular, we derived a multiuser adaptive subcarrier and bit allocation algorithm. Given the instantaneous channel information, the algorithm obtains a suboptimal subcarrier allocation, and then single-user bit allocation is applied on the allocated subcarriers. Using this scheme, the overall required transmit power can be reduced by about 5–10 dB from the conventional OFDM without adaptive modulation. Likewise, the transmit power can be reduced by about 3–5 dB from the conventional OFDM with adaptive modulation and adaptive bit allocation, but without adaptive subcarrier allocation. The reduction in transmit power can also be translated to a significant reduction in the required bit SNR for a given BER. Moreover, the same improvement can also be translated to a reduction in the outage probability or to an increase in the area of coverage.

The results in this paper assume perfect channel estimation, and we have not considered issues related to imperfect implementation, such as imperfect synchronization. As channel estimation in wireless fading channels is in general not very accurate, the effect of nonideal channel information on the performance of our proposed MAO scheme is a very important issue. We have started looking at this issue, and our preliminary results have indicated that the MAO scheme is not very sensitive to channel estimation errors. Nevertheless, detailed sensitivity studies will be needed before the algorithm can be applied to practical systems.

APPENDIX

A flow chart providing the detailed description of the multiuser subcarrier allocation algorithm is shown in Fig. 8.

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(Translation)

Issuance Date: April 28, 2006
Submission Due Date: June 28, 2006

THE KOREAN INTELLECTUAL PROPERTY OFFICE
NOTICE OF GROUNDS FOR REJECTION

Applicant : ADAPTIX, INC.

Agency : Koreana Patent Firm

Application No. : Korean Patent Application No. 2003-7007962

Title of Invention: MULTI-CARRIER COMMUNICATIONS WITH GROUP-BASED SUBCARRIER ALLOCATION

This application shall be rejected on the following grounds pursuant to Article 63 of the Korean Patent Law. If you have any objection, please submit an Argument or Amendment to the KIPO by **June 28, 2006**. (The term can be extended ,by one month each, however, a separate Acknowledgement of Extension of Time will not be issued.)

GROUNDS FOR REJECTION

1. The present application does not satisfy the requirement of Article 45 of the Korean Patent Law as shown below and thus cannot be patented.

[below]

Claims 1-24 of the present application relates to a method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA) comprising:
Partitioning subcarriers into a plurality of groups of at least one cluster of subcarriers; and
Allocating at least one cluster in the one or more groups of clusters selected by the subcarrier.

Claims 25-31 of the present application relate to a cellular network, comprising allocating the channels of each base station in each of the plurality of cells or allocating groups of clusters.

The present invention consists of such two different invention groups as above, and thus it does not satisfy the one invention one patent application rule under Article 45 of the Korean Patent Law (The present application can be filed as divisional application under Article 52 of the Korean Patent Law).

2. The inventions of claims 1-24 of the present application can be easily invented from prior art by a skilled person in the art and thus cannot be patented under Article 29(2) of the Korean Patent Law.

[Below]

Claims 1-24 of the present invention relate to a multicarrier OFDM system with group-based subcarrier allocation.

However, the present invention can be easily invented by a skilled person in the art from a technical combination of cited inventions 1 and 2 or cited inventions 1 and 3 as shown below:

A. Constitution

(1) Claims 1-13, 15-21 and 23-24

Claims 1-24 of the present application relate to a method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA), characterized by comprising partioning subcarriers into a plurality of groups of at least one cluster of subcarriers and allocating at least one cluster in the one or more groups of clusters selected by the scubcarrier.

However, this constitution can be easily derived by a skilled person in the art from a combination of cited invention 1 disclosing a constitution of selecting subcarriers for the OFDM system which partitions subcarriers into a plurality of groups of clusters and allocates said clusters, and cited invention 2 relating to a method for selecting subcarriers, characterized in that a feedback information on each cluster group comprises SINR information on each cluster.

(2) Claims 14 and 22

Claims 14 and 22 of the present application relates to a constitution of a method for selecting subcarriers further comprising a step wherein, in the system employing OFDMA, feedback information on at least one or more cluster groups of subcarriers is received from the subscriber.

However, this constitution can be easily derived by a skilled person in the art from a combination of the constitution of cited invention 1 above, and the constitution of cited invention 3 wherein a group idenfier of the feedback information comprises a group index.

B. Object and Effect

The object and effect of the present invention are in the OFDMA system that can adaptively allocate subcarriers to subscribers; however, a technique derived from the combination of cited inventions 1 and 2 or 1 and 3 can achieve the same object and effect based on the similar constitution.

C. Conclusion

Thus, claims 1-24 of the present invention can be easily invented by a skilled person in the art from prior art as shown above.

[Attachment]
Attached 1 A copy of US Patent No. 05726978 (March 10, 1998)
Attached 2 A copy of EP 00999658
Attached 3 A copy of US Patent No. 05280630 (January 18, 1994). END.

Dated April 28, 2006

Electric & Electronic Examination Bureau
of Korean Intellectual Property Office

Examiner(s)-in-charge Hwan-Cheol YOO

KOREANA PATENT FIRM SINCE 1970
Patent Attorneys & Counselors at Law

(Translation)

Issuance Date: April 29, 2006
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THE KOREAN INTELLECTUAL PROPERTY OFFICE
NOTICE OF GROUNDS FOR REJECTION

Applicant : ADAPTIX, INC.

Agent : Koreana Patent Firm

Application No. : Korean Patent Application No. 2003-7007963

Title of Invention: MULTI-CARRIER COMMUNICATIONS WITH ADAPTIVE CLUSTER CONFIGURATION AND SWITCHING

This application shall be rejected on the following grounds pursuant to Article 63 of the Korean Patent Law. If you have any objection, please submit an Argument or Amendment to the KIPO by **June 29, 2006**. (The term can be extended by one month each, however, a separate Acknowledgement of Extension of Time will not be issued.)

GROUNDS FOR REJECTION

1. The claims of the present application do not satisfy the description requirement as follows, and thus cannot be patented under Article 42(4)(ii) of the Korean Patent Law.

A. In "the method defined in Claim 1 wherein using one diversity cluster" recited in claim 5, the constitutional element "using one diversity cluster" is a term not recited in claim 1, and thus it is required to be consistent with the term of claim 1. Accordingly, said claim does not clearly describe the invention (Article 42(4)(ii) of the Korean Patent Law).

B. In "the method defined in Claim 11 wherein using one diversity cluster" recited in claim 20, the constitutional element "using one diversity cluster" is a term not recited in claim 11, and thus it is required to be consistent with the term of claim 11. Accordingly, said claim does not clearly describe the invention (Article 42(4)(ii) of the Korean Patent Law).

2. The invention recited in Claims 1~10 & 26~33 of the present application can be easily invented by a person having ordinary skill in the art to which the present invention pertains prior to its filing as indicated below. Accordingly, this application cannot be patented pursuant to Article 29(2) of the Korean Patent Law.

Claims 1~10 & 26~33 of the present invention relate to a method and apparatus for use in allotting subcarriers in an OFDMA system.

However, this can be easily invented by a person having ordinary skill in the art to which the invention pertains from the combination of cited reference 1 (WANG C. Y. ET AL: 'MULTIUSER OFDM WITH ADAPTIVE SUBCARRIER, BIT, AND POWER ALLOCATION,' IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE

INC. NEW YORK, VOL. 17, 10. OCTOBER 1999) and cited reference 2 (Ye Li ET AL; 'Clustered OFDM with channel estimation for high rate wireless data' Mobile Multimedia Communications, 1999. (MoMuC '99) 1999 IEEE International Workshop on, 15-17 Nov. 1999 Page(s): 43-50).

A more detailed review in this regard is as follows:

A. Constitution

(1) Claims 1~10

Claims 1~10 of the present application relate to a method for use in allocating subcarriers in an OFDMA system comprising allocating at least one diversity cluster of subcarriers to a first subscriber, and allocating at least one coherence cluster to a second subscriber. This can be easily anticipated by a person having ordinary skill in the art from the combination of cited reference 1 which has a constitution wherein subcarrier clusters are allocated to subscribers so as to be adapted to a plurality of subscribers, and cited reference 2 which has a constitution relating to an OFDM system capable of channel estimation and cluster allocation.

(2) Claims 26~33

Claims 26~33 of the present application relate to a subscriber allocation apparatus of an OFDMA system allocating at least one diversity cluster of subcarriers to a first subscriber, and allocating at least one coherence cluster to a second subscriber. This can be easily anticipated by a person having ordinary skill in the art from the combination of the above stated cited references 1 & 2.

B. Object and effect

The object and effect of the present invention is to provide a method and apparatus for efficiently allocating subcarriers to a plurality of subscribers in an OFDMA system. The combination of the technologies of cited references 1 & 2 can realize the same object and effect.

C. Conclusion

Therefore, claims 1~10, 26~33 of the present application can be easily invented by a person having ordinary skill in the art as stated above.

[Attachment]
Attached 1. Cited Reference 1
Attached 2. Cited Reference 2

Dated April 29, 2006

Electric & Electronic Examination Bureau
of Korean Intellectual Property Office

Examiner(s)-in-charge Hwan-Chul Yu

Clustered OFDM with Channel Estimation for High Rate Wireless Data

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Abstract: *Clustered OFDM can provide in-band diversity gain for wideband wireless channels. It is a promising technique for high-rate wireless packet data access, such as mobile multimedia communications. Due to smaller size of each cluster for clustered OFDM than for classical (non-clustered) OFDM, edge effects can be very large. In this paper, we present new transforms for channel estimators in clustered OFDM systems. The new transforms are independent of the channel delay profiles and can effectively mitigate the edge effects. Computer simulation shows that the performance of clustered OFDM with the estimator using the new transforms is very close to the performance with the optimum estimator that depends on the channel delay profile. For the typical-urban or hilly-terrain delay profiles, clustered OFDM using the new transform based estimator is almost as good as classical OFDM with transmitter diversity.*

I. Introduction

Orthogonal frequency division multiplexing (OFDM) has been shown to be an effective technique to combat multipath fading [1-4]. Hence, it is a promising technique for wideband wireless packet data. Recently, clustered OFDM [5-8] has been proposed to provide in-band diversity gain with wideband dispersive fading channels, and therefore, to improve system performance.

For clustered OFDM in high-rate wireless data systems, each user accesses several OFDM clusters located at different frequencies. Then, an error correction code, such as a Reed-Solomon code, or a convolutional code, is used to obtain frequency diversity. As indicated in [9], without channel information, differential demodulation has to be used instead of coherent demodulation at the expense of a 3-4 dB loss in signal-to-noise ratio (SNR) performance. Hence, channel estimation is also desired for clustered OFDM to gain high performance.

For classical OFDM systems, either pilot-symbol-aided [10] or decision-directed [9,11-12] channel estimators can be used to obtain channel information. Furthermore, similar parameter estimators can be used to estimate the coefficients for the minimum-mean-square error diversity combiner (MMSE-DC) for OFDM systems with antenna arrays to suppress co-channel interference [13-14], or to estimate channel information required by the decoder of space-time code based transmitter diversity [15-16].

Earlier work has shown in [9-11] that the optimum transforms for channel estimation is the eigen matrix of the channel frequency-domain correlation matrix. Obviously, the optimum transforms depend on the channel delay profiles that vary with environments. However, since there may be over a hundred contiguous tones for classical OFDM systems, with negligible edge effects [9,11,13-16], the discrete Fourier transform (DFT) can be used instead of the optimum transforms. But, for clustered OFDM, each cluster contains much fewer tones than for classical OFDM and those tones that are on edge are a large portion of the total number of tones in each cluster. Hence, edge effects will be very large if a DFT is used for the estimator in clustered OFDM. In this paper, we present new transforms for the channel estimator in clustered OFDM systems, which have small edge effects and robust to a broad range of channel delay profiles.

This paper is organized as follows. In Section 2, we briefly describe clustered OFDM for high-rate wireless data access and summarize some statistical properties of the wideband mobile wireless channel. Then, in Section 3, we investigate *robust* transforms for channel estimators in clustered OFDM systems. Next, in Section 4, we presents computer simulation results to demonstrate the effectiveness of robust transform based channel estimation for clustered OFDM systems in wideband dispersive fading channels.

II. Clustered OFDM for Wideband Mobile Wireless Systems

In this section, we first briefly describe clustered OFDM for high-rate data access, and then introduce some statistical characteristics of wideband mobile wireless channel that are useful for designing channel estimators.

A. Clustered OFDM for High Rate Data Access

The concept of clustered OFDM for wideband channels can be shown as in Fig. 1. A wideband OFDM signal is divided into many non-overlapped clusters of tones in frequency, and each user accesses several clusters of tones. For example, the OFDM signal in Fig. 1 is divided into 16 clusters. User 1 utilizes the 1st, 5th, 9th, and 13th clusters and Users 2, 3, and 4 use other clusters.

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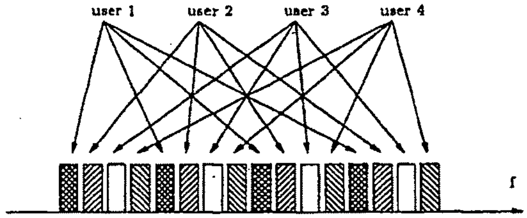

Fig. 1. Concept of clustered OFDM.

The implementation of clustered OFDM is more complicated than classical OFDM. Recently, several receiver structures for clustered OFDM [8] that can be readily implemented have been considered.

The clustered OFDM has some advantages over classical OFDM besides many good common properties, such as combating multipath fading. As indicated in [8], it provides a high degree of flexibility in supportable bit rates and Quality-of-Service (QoS) since clustered OFDM can allocate bandwidth by tone clusters. If 4 users share a wideband wireless channel, the peak rate of each user can be as large as 4 times the average bit rate per user since a single user can access all clusters in the channel if they are not in use by others.

For systems with clustered OFDM, each user utilizes several clusters at different locations of a wideband channel. Hence, frequency diversity gain can be obtained for dispersive fading channels if an error correction code is used across these clusters. The greater the number of clusters, the greater the diversity gain that results in. As shown by the simulation results in Section 4, for a clustered OFDM system with 8 or 4 clusters uniformly located in a 4.096 MHz typical urban (TU) or hilly terrain (HT) channel, the performance is as good as a classical OFDM with delayed transmitter diversity [15-16] if coherent detection is used in both systems.

However, coherent detection requires the channel information. If the DFT based estimator [9] is used here, there will be severe edge effects for channel parameter estimation for the clustered OFDM receiver since the size of each cluster is much smaller than for classical OFDM.

B. Channel Statistics

The complex baseband representation of a wireless channel impulse response can be described by

$$h(t,\tau) = \sum_k \gamma_k(t)\delta(\tau - \tau_k), \qquad (1)$$

where τ_k is the delay of the k-th path, and $\gamma_k(t)$ is the corresponding complex amplitude. Due to the motion of the vehicle, $\gamma_k(t)$'s are wide-sense stationary (WSS) and narrow-band complex Gaussian processes with average power σ_k^2's, which are independent for different paths.

TABLE I
THE AVERAGE POWER AND DELAY OF EACH PATH FOR THE TU AND HT CHANNELS

path number	TU channel		HT channel	
	delay in μsec.	average power	delay in μsec.	average power
1	0.0	0.1897	0.0	0.3933
2	0.2	0.3785	0.2	0.2481
3	0.5	0.2388	0.4	0.1566
4	1.6	0.0951	0.6	0.0785
5	2.3	0.0600	15.0	0.0988
6	5.0	0.0379	17.2	0.0248

From (1), the frequency response of the time-varying radio channel at time t is

$$\begin{aligned} H(t,f) &\triangleq \int_{-\infty}^{\infty} h(t,\tau)e^{-j2\pi f\tau}d\tau \\ &= \sum_k \gamma_k(t)e^{-j2\pi f\tau_k}. \end{aligned}$$

From the above identity, it has been proved in [9] that the correlation function of the frequency response at different times and frequencies can be expressed as

$$\begin{aligned} r_H(\Delta t,\Delta f) &\triangleq E\{H(t+\Delta t, f+\Delta f)H^*(t,f)\} \\ &= \sigma_h^2 r_t(\Delta t) r_f(\Delta f), \end{aligned}$$

where σ_h^2 is the total average power of the channel impulse response, defined as $\sigma_h^2 = \sum_k \sigma_k^2$, $r_t(\Delta t)$ and $r_f(\Delta f)$ are the *time-* and *frequency-domain correlations* of the channel frequency response, which are defined as

$$r_t(\Delta t) \triangleq \frac{E\{\gamma_k(t+\Delta t)\gamma_k^*(t)\}}{E\{|\gamma_k^*(t)|^2\}}, \qquad (2)$$

and

$$r_f(\Delta f) = \sum_k \frac{\sigma_k^2}{\sigma_h^2} e^{-j2\pi\Delta f \tau_k},$$

respectively.

The time-domain correlation of the channel frequency response can be well represented by Jake's model [17] that is determined by the *Doppler frequency*. The *Doppler frequency* is related to the vehicle speed v and the carrier frequency f_c by

$$f_c = \frac{v f_c}{c},$$

where c is the speed of light. For a system with a 2 GHz carrier frequency, the Doppler frequency is as large as 184 Hz when the user is moving at 60 miles/hour.

The frequency correlation changes with the environment. For the TU and HT profiles, the average power and the delay of each path are shown in Table I.

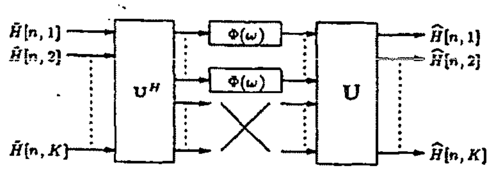

Fig. 2. Structure of the channel estimator.

III. Channel Estimator for Clustered OFDM

After introducing the general structure for channel estimation in this section, we present robust transforms for estimators used in clustered OFDM and give a geometric explanation.

A. General structure

The general structure of the decision-directed channel estimators [9] for OFDM are shown in Fig. 2, which exploits the channel frequency response correlations in both time- and frequency-domain. The unitary transform $\mathbf{U}$ exploits the frequency-domain correlation while the linear filters $\Phi(\omega)$ make full use of the time-domain correlation.

It has been shown in [9,11-12] that for the MMSE or optimum estimator, the transform in the figure is the eigen matrix of the channel frequency-domain correlation matrix $\mathbf{R}_f$, defined as

$$\mathbf{R}_f = (r_f[k_1 - k_2])_{k_1,k_2=1}^{K},$$

i.e.,

$$\mathbf{R}_f \mathbf{U}_{opt} = \mathbf{U}_{opt}\mathbf{D},$$

where $\mathbf{D}$ is a diagonal matrix, and K is the number of tones in classical OFDM or in each cluster of a clustered OFDM system. The channel frequency-domain correlation depends on delay profiles that are different for different environments. Therefore, the optimum transforms or bases for estimators are usually difficult to obtain.

For classical OFDM, it is demonstrated in [9,11-12] that with negligible performance degradation, the unitary transform can be substituted by the DFT, that is,

$$\mathbf{U}_{DFT} = \frac{1}{\sqrt{K}}\left(\exp(\jmath 2\pi \frac{k_1 - k_2}{K})\right)_{k_1,k_2=1}^{K}.$$

However, for clustered OFDM with small clusters, the tones that are on edge are a large portion of the tones per cluster. Therefore, edge effects will cause a significant performance degradation for clustered OFDM if the DFT is used in the estimator.

The Hadamard transform may be a candidate for the transform for the channel estimator, which is defined as

$$\mathbf{U}_{HT} = \frac{1}{\sqrt{K}}\mathbf{H}_n,$$

with $K = 2^n$, and

$$\mathbf{H}_n = \begin{pmatrix} \mathbf{H}_{n-1} & \mathbf{H}_{n-1} \\ \mathbf{H}_{n-1} & -\mathbf{H}_{n-1} \end{pmatrix},$$

and

$$\mathbf{H}_1 = \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}.$$

Note that the Hadamard transform contains only additions and subtractions; it is, therefore, implementable with very low computational complexity.

B. Robust transforms for clustered OFDM channel estimation

As indicated in Section 3.1, the optimum bases, or transforms for estimation are determined by the channel delay profiles. However, delay profiles are usually unknown except some parameters, such as delay spread or maximum delay span. Hence, we can at best *create* some delay profiles such that the transforms based on these delay profiles perform well, not necessarily best, for *all* delay profiles.

The simplest delay profile is a rectangular profile, which can be expressed as

$$\sigma_{rec}(\tau) = \begin{cases} \frac{1}{2\tau_{max}}, & \text{if } |\tau| \le \tau_{max}, \\ 0, & \text{otherwise,} \end{cases}$$

where τ_{max} is a half of the maximum delay span. The delay spread of the rectangular delay profile is $\bar{\tau} = \tau_{max}/\sqrt{3}$. The frequency-domain correlation function can be obtained by

$$\begin{aligned} r_{rec}(\Delta f) &= \int_{-\tau_{max}}^{\tau_{max}} \sigma_{rec}(t) e^{-\jmath 2\pi \Delta f \tau} d\tau \\ &= \frac{\sin(2\pi\Delta f \tau_{max})}{2\pi\Delta f \tau_{max}}. \end{aligned}$$

Based on $r_{rec}(\Delta f)$, the optimum transform for the rectangular profile, $\mathbf{U}_{rec}$, can be obtained by means of eigen-decomposition.

Another profile is exponential, which is defined as

$$\sigma_{exp}(\tau) = \begin{cases} \frac{1}{\bar{\tau}} e^{-\frac{\tau+\bar{\tau}}{\bar{\tau}}}, & \text{if } \tau \ge -\bar{\tau}, \\ 0, & \text{otherwise,} \end{cases}$$

where $\bar{\tau}$ is the delay spread. Then the frequency-domain correlation function is

$$\begin{aligned} r_{exp}(\Delta f) &= \int_{-\tau_{max}}^{\tau_{max}} \sigma_{exp}(t) e^{-\jmath 2\pi \Delta f \tau} d\tau \\ &= \frac{e^{\jmath 2\pi \Delta f \bar{\tau}}}{\jmath 2\pi \Delta f \bar{\tau} + 1}. \end{aligned}$$

Based on it, $\mathbf{U}_{exp}$ can be calculated accordingly.

It can be demonstrated that $\mathbf{U}_{rec}$ and $\mathbf{U}_{exp}$, which we call the *rectangular* and *exponential transforms* or *bases*, respectively, are robust to other channel delay profiles.

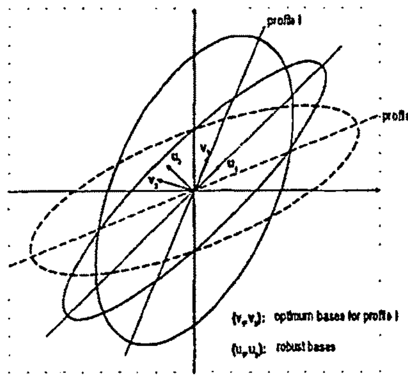

Fig. 3. Explanation of the optimum and robust transforms for clustered OFDM channel estimator.

C. *Geometric Explanation*

The robustness of the new transforms, $\mathbf{U}_{rec}$ and $\mathbf{U}_{exp}$, to a broad range of delay profiles can be explained by Fig. 3. Since each delay profile is specified by the average power of each path and delay, the average power in different directions for a delay profile can be represented by an ellipse. As indicated before, the optimum transform for a specific delay profile is the eigen matrix of the channel frequency-domain correlation matrix since it can catch the most power with the fewest taps. For example, in Fig 3, the average power on each direction for delay profile I can be shown by the solid ellipse with eigenvectors $\mathbf{v}_1$, $\mathbf{v}_2$. For each outcome of delay profile I, the channel parameters can be represented by $\alpha_1\mathbf{v}_1 + \alpha_2\mathbf{v}_2$, where α_1 and α_2 are time-varying for a time-varying channel. However, for delay profile I, $E|\alpha_1|^2$ is much larger than $E|\alpha_2|^2$. Hence, $\alpha_1\mathbf{v}_1$ alone is a good approximation of the channel information. Note that $\mathbf{v}_1$ and $\mathbf{v}_2$ can still be used to decompose other delay profiles, such as profile II. But, the error will be very large if $\alpha_1\mathbf{v}_1$ alone is used for the approximation. Hence, the optimum decomposition transform for one delay profile is not necessarily optimum for another delay profile. Therefore, it is desired to have a decomposition transform that has good, not necessarily the best, performance for all expected delay profiles with certain constrains. The $(\mathbf{u}_1, \mathbf{u}_2)$ transform in the figure is such a *robust* transform, just like $\mathbf{U}_{rec}$ or $\mathbf{U}_{exp}$ derived in Section 3.2.

IV. Performance Evaluation

In this section, we address the performance evaluation of clustered OFDM with the new transform based channel estimation through computer simulation. Before presenting the simulation results, we briefly describe the system parameters.

TABLE II
Parameter sets of clustered OFDM

set number	No. of clusters	inf. tones	guard tones
1	8	2nd - 16th	1st
2	4	2nd - 31st	1st & 32nd
3	2	3rd - 62nd	1st-2nd & 63rd-64th
4	1	5th - 124th	1st-4th & 125th-128th

A. *System Parameters*

In the simulated clustered OFDM system, one transmitter and two receiver antennas are used, unless otherwise specified. The channels corresponding to different receivers have the same statistics with independent fading.

To construct a clustered OFDM signal, assume the entire channel bandwidth, 4.096 MHz, is divided into 512 subchannels, which results in the subchannel space, Δf=8 kHz. To make the tones orthogonal to each other, the symbol duration, $T_s = 1/\Delta f$=125 μsec. An additional 31.25 μsec guard interval is used to provide protection from intersymbol interference due to channel multipath delay spread. This results in a total block length T_f = 156.25 μsec and a subchannel symbol rate $r_b = 1/T_f$ = 6.4 kbaud.

Four users transmit data through the channel at the same time and each uses 120 tones to transmit data and 8 tones as guard tones. The locations of guard tones for clustered OFDM systems with different cluster sizes are shown in Table II. With the estimator for clustered OFDM providing channel information, QPSK modulation with coherent demodulation can be used. As in [9] and [18], a (40,20) R-S code, with each code symbol consisting of 3 QPSK symbols grouped in frequency, is used in the system. Hence, each user forms a R-S codeword for each OFDM block. The R-S decoder erases 10 symbols based on signal strength, and corrects 5 additional random errors.

Each time slot contains 10 (clustered) OFDM blocks. The first block is used as synchronization and initial channel estimation and one of the rest of the blocks is used as a guard block. Consequently, each user can transmit data at 1.23 Mbits/sec before decoding, or 0.614 Mbits/sec after decoding. Or the peak rate for each user is 4.92 Mbits/sec before decoding, or 2.46 Mbits/sec after decoding.

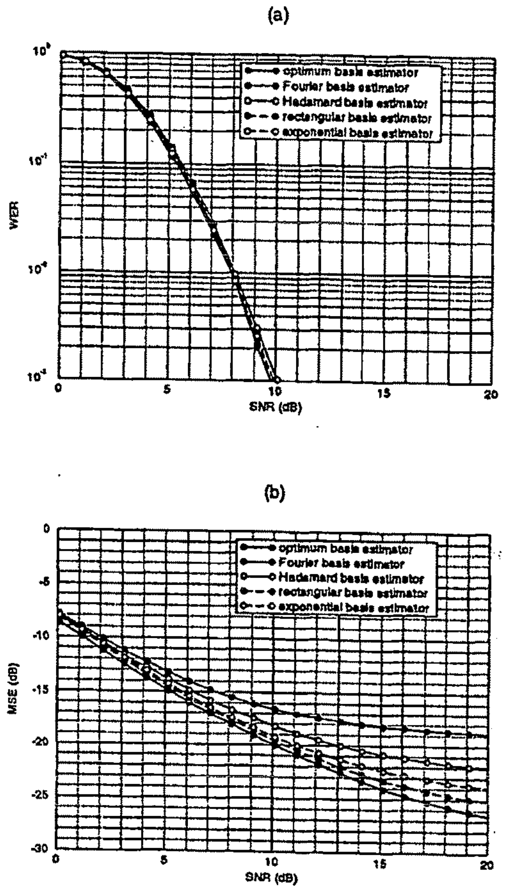

Fig. 4. (a) WER and (b) MSE versus SNR for 8-cluster-15-tone OFDM with different transform based estimators for the TU channel with $f_d = 40$ Hz.

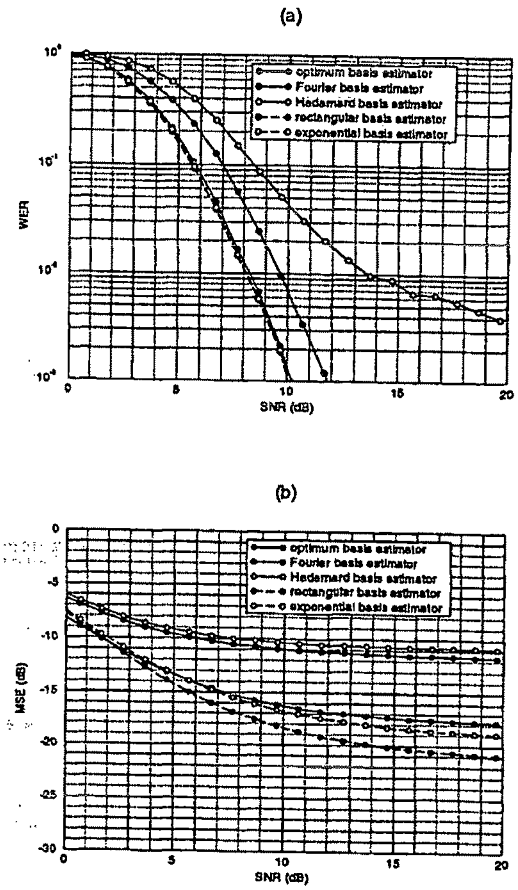

Fig. 5. (a) WER and (b) MSE versus SNR for 8-cluster-15-tone OFDM with different transform based estimators for the HT channel with $f_d = 40$ Hz.

B. Simulation Results

Here we present the simulated results of clustered OFDM under various environments. Our results are based on the average over 10,000 OFDM blocks, or 1,000 time slots.

B.1 Performance of estimator with different transforms

Figures 4 and 5 show the WER's and MSE's of 8-cluster-15-tone OFDM with the estimators using the optimum, Fourier, Hadamard, rectangular, or exponential transforms for the TU and HT channels, respectively. From Fig. 4, for the TU channel with SNR< 10 dB, the MSE's of the estimator with different transforms are much less than the channel noise; therefore, the WER's are almost same for the estimator with different bases. However, as shown in Figure 5 for the HT channel, due to the edge effects of the estimators with the Fourier and Hadamard transforms, the MSE's of the estimators with either of the two transforms are much larger than the estimator with the optimum transform; consequently, compared with the optimum basis, the required SNR's for a 10% WER show about 1.5 dB and 3.0 dB degradations, respectively. But, the WER's for the rectangular and exponential transforms are almost the same as for the optimum transform. Hence, both the rectangular and exponential

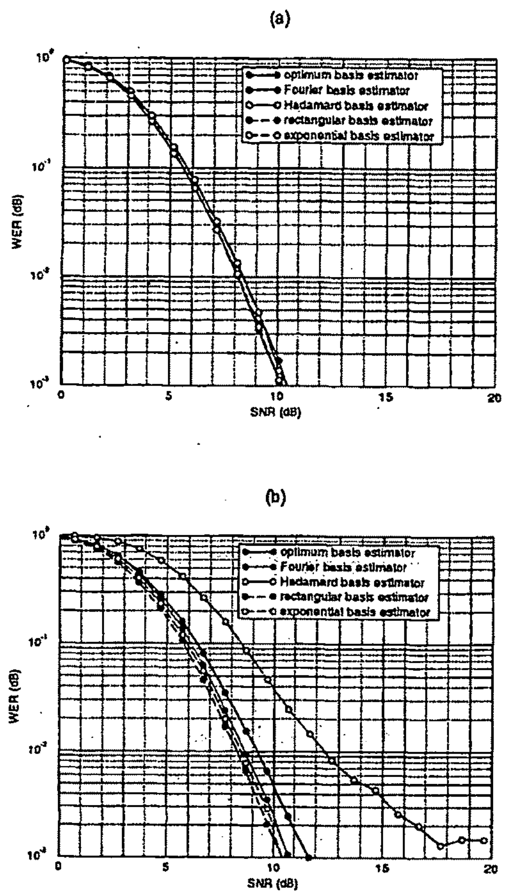

Fig. 6. WER versus SNR for 4-cluster-30-tone OFDM with different transform based estimators for (a) the TU and (b) the HT channel with $f_d = 40$ Hz.

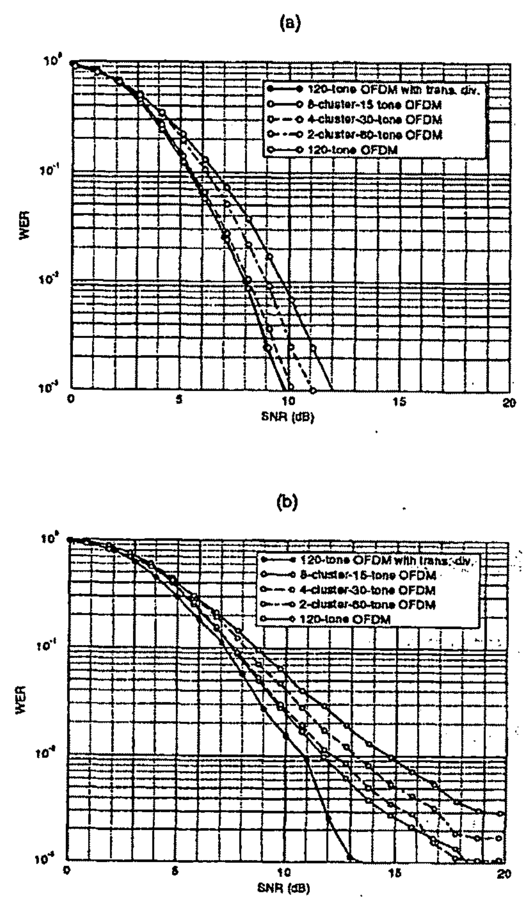

Fig. 7. WER versus SNR for OFDM with different cluster sizes for the TU channel with (a) $f_d = 40$ Hz and (b) $f_d = 200$ Hz, respectively.

transforms are robust to the channel delay profiles.

As indicated before, with an increase in the cluster size, the edge effects of the estimator with the Fourier transform will be reduced. Consequently, the degradation of the Fourier transform disappears when the cluster size is increased to 30 tones, as demonstrated by Fig. 6. Hence, for clustered OFDM with cluster size less than 30 tones, the rectangular or exponential transforms should be used for better channel parameter estimation; however, for clustered OFDM with a larger cluster size, performance degradation due to the edge effects of the Fourier transform is negligible, therefore, it should be used since the fast Fourier transform (FFT) can be utilized for low complexity computation.

B.2 OFDM with different cluster sizes

Figures 7 and 8 demonstrate the WER's of clustered OFDM systems with different numbers of clusters and environments, and compare them with a classical OFDM system with delayed transmitter diversity [4]. From the figures, the performance of the clustered OFDM systems improves with an increasing number of clusters. From Fig. 7, for the TU channel with $f_d = 40$ Hz, the WER's of clustered OFDM with 8 and 4 clusters are the same as the WER of classical OFDM with the delayed transmission diversity. In particular, compared with classical

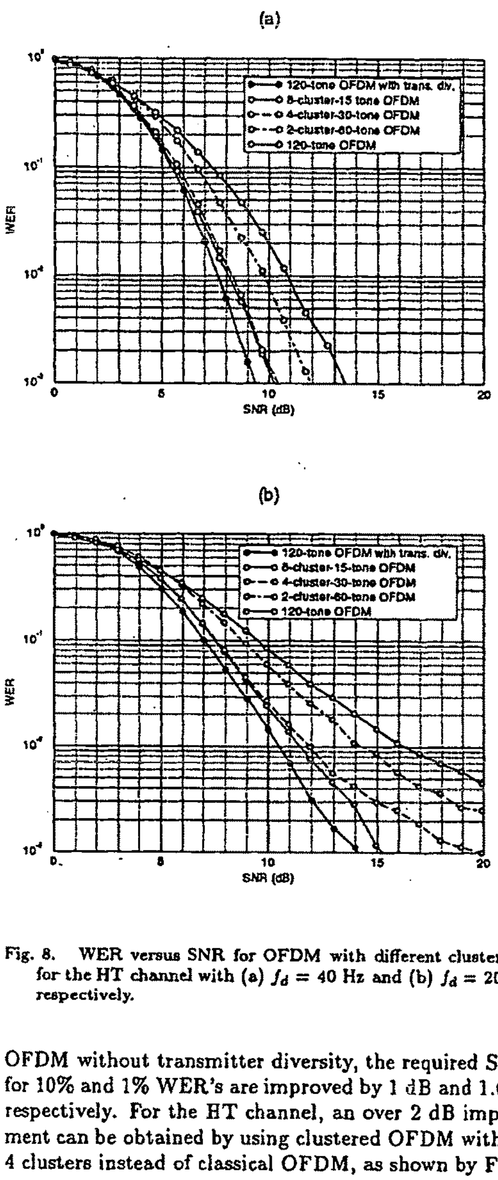

Fig. 8. WER versus SNR for OFDM with different cluster sizes for the HT channel with (a) f_d = 40 Hz and (b) f_d = 200 Hz, respectively.

OFDM without transmitter diversity, the required SNR's for 10% and 1% WER's are improved by 1 dB and 1.6 dB, respectively. For the HT channel, an over 2 dB improvement can be obtained by using clustered OFDM with 8 or 4 clusters instead of classical OFDM, as shown by Fig. 8.

V. Conclusions

In this paper, we have presented new transforms for channel estimation used in clustered OFDM to mitigate edge effects of the discrete Fourier transform in classical OFDM. Computer simulation shows that clustered OFDM with the new transform based estimator can be used for high-rate data access over wideband mobile wireless channels. The performance of clustered OFDM without transmitter diversity is as good as classical OFDM with delayed transmitter diversity. The required SNR for a 10% WER is about 5.5 dB for the TU or HT channel with low Doppler frequency, and 7.5 dB for the TU or HT channel with Doppler frequency as large as 200 Hz.

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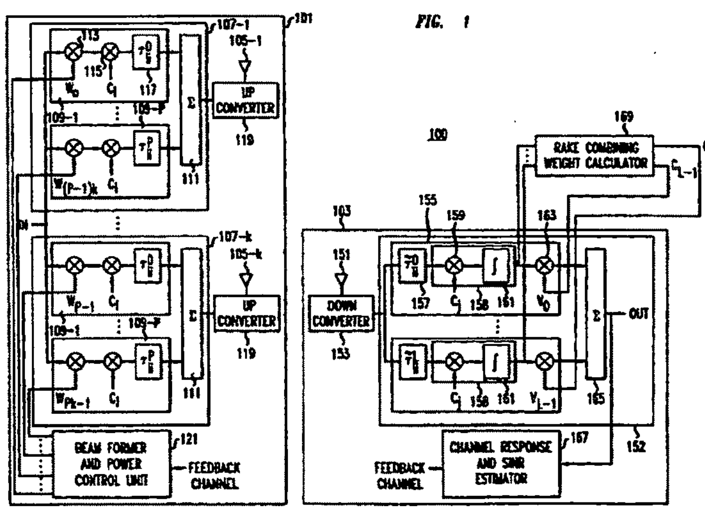
(54) **Space-time diversity for wireless systems**

(57) The signal to interference and noise ratio (SINR) of wireless systems can be improved, if not optimized, by determining operating parameters used by the base station to substantially simultaneously control the transmit beam patterns that are each formed to establish a communication channel between a base station and a respective one of the wireless terminals as a function of received channel information from at least two of the wireless terminals. In an exemplary embodiment of the invention, the weight vectors and the power allocation employed by a base station are determined by the base station using information supplied by at least each of the wireless terminals served by the base station, and potentially from wireless terminals served by other base stations, e.g., in neighboring cells to the cell served by the base station, the information from the other cells being supplied via the neighboring cell base stations using inter-base-station communication, e.g., a wire line connection.

FIG. 1



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Description

Technical Field

[0001] This invention relates to the art of wireless communication, and more particularly, to employing space-time diversity to increase the capacity of wireless systems.

Background of the Invention

[0002] Prior art wireless communication systems, such as time division multiple access (TDMA) or code division multiple access (CDMA) wireless communications systems, are used for communicating between base stations and wireless terminals. When setting various parameters for the communication such prior art systems only consider the strength of the desired signal at the wireless terminal and fail to also take into account the interference caused by communication between the base station and others of the wireless terminals. Also, prior art wireless communication systems that employ so-called "power control," e.g., CDMA systems, perform the power control independent of any weight vectors that are used for beam forming at the base station. Additionally, power control at the base station in such prior art wireless communication systems is performed typically based only on either the pilot signal strength at the wireless terminal or the bit error rate (BER) at the wireless terminal. These design factors of prior art wireless systems cause their signal to interference and noise ratio (SINR) to be less than optimal, resulting in reduced system capacity, i.e., the system cannot serve as many active wireless terminals as it could with a higher SINR.

Summary of the Invention

[0003] We have recognized that the signal to interference and noise ratio (SINR) of wireless systems can be improved, if not optimized, by determining operating parameters used by the base station to substantially simultaneously control the transmit beam patterns that are each formed to establish a communication channel between a base station and a respective one of the wireless terminals as a function of received channel information from at least two of the wireless terminals. In an exemplary embodiment of the invention, the weight vectors and the power allocation employed by a base station are determined by the base station using information supplied by at least each of the wireless terminals served by the base station, and potentially from wireless terminals served by other base stations, e.g., in neighboring cells to the cell served by the base station, the information from the other cells being supplied via the neighboring cell base stations using inter-base-station communication, e.g., a wire line connection.

Brief Description of the Drawing

[0004] In the drawing:

FIG. 1 shows a portion of an exemplary code division multiple access (CDMA) wireless communication system arranged in accordance with the principles of the invention;

FIG. 2 shows an exemplary over-all process for the optimization of transmit beam forming weight vectors, transmit power allocation, and rake receiver combining vectors, in accordance with the principles of the invention;

FIG. 3 shows, in flow chart form, an exemplary process for calculating the transmit beamforming vectors by the base station using the received channel information, in accordance with an aspect of the invention; and

FIG. 4 shows an exemplary process for maximizing the minimum signal to interference ratio (SIR) of a virtual uplink network that is used to represent the downlink of a CDMA system, in accordance with an aspect of the invention.

Detailed Description

[0005] The following merely illustrates the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements which, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples and conditional language recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventors to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure.

[0006] Thus, for example, it will be appreciated by those skilled in the art that the block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudocode, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0007] The functions of the various elements shown in the FIGs., including functional blocks labeled as "processors" may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, read-only memory (ROM) for storing software, random access memory (RAM), and non-volatile storage. Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the FIGS. are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementor as more specifically understood from the context.

[0008] In the claims hereof any element expressed as a means for performing a specified function is intended to encompass any way of performing that function including, for example, a) a combination of circuit elements which performs that function or b) software in any form, including, therefore, firmware, microcode or the like, combined with appropriate circuitry for executing that software to perform the function. The invention as defined by such claims resides in the fact that the functionalities provided by the various recited means are combined and brought together in the manner which the claims call for. Applicant thus regards any means which can provide those functionalities as equivalent as those shown herein.

[0009] FIG. 1 shows a portion of an exemplary code division multiple access (CDMA) wireless communication system 100. CDMA system 100 includes wireless transmitter 101 for one user which is used in a base station and wireless receiver 103 which is used in a wireless terminal. Both wireless transmitter 101 and wireless receiver 103 are arranged in accordance with the principles of the invention.

[0010] Wireless transmitter 101 includes antennas 105, including antennas 105-1 through 105-K. The value of K is selected by the system implementor as a function of the desired price, performance, and capacity of wireless communication system 100. Each of antennas 105 is fed by a signal supplied from a respective associated one of transmit modules 107. Each of transmit modules 107 includes a) P diversity modules 109, b) a combiner 111 and c) upconverter 119. The value of P is typically determined as a function of the desired channel performance. Typically the desired channel performance is selected by a standard setting committee.

[0011] Each of diversity modules 109 includes a beam former multiplier 113, a spreader multiplier 115, and delay element 117. Beam former multiplier 113 multiplies the signal to be transmitted by a beam forming coefficient. Each of the beam forming coefficients supplied to the various beam former multipliers 113 are said to be part of a space-time diversity weight vector W. The beam forming coefficients are generated by beam forming and power control unit 121 in accordance with the principles of the invention, as will be further elaborated on hereinbelow.

[0012] The output from each beam former multiplier 113 is supplied as an input to its respective associated multiplier 115, which multiplies its input from beam former 113 by a spreading code for the user being served by wireless transmitter 101. Should one desire to implement the invention in a time division multiple access (TDMA) system rather than a CDMA system, it is necessary to omit multiplier 115. Because the spreading code is made up of multiple chips for each bit of signal being transmitted, multiplier 115, which must multiply each bit by the chips of its spreading code, operates at a much greater rate of speed than does multiplier 113.

[0013] The output from each multiplier 115 is supplied as an input to its respective associated delay element 117. Each delay element 117 delays the signal supplied to it in a manner such that each delayed signal generated within a one of diversity modules 109 is delayed from any other signal generated within that one of diversity modules 109 by at least a delay of 1 chip. In other words, there is a phase difference of at least one chip between each signal generated within each of diversity modules 109. The particular delays may be specified by the system designer in response to system requirements, e.g., as specified by standard setting organizations, or the delays may be adaptively adjusted as a function of system performance.

[0014] Each diversity module 109 supplies its delayed and spread signal to its associated combiner 111. Each combiner 111 adds the delayed and spread signals which are supplied by each diversity module 109 within the same one of transit modules 107 as itself, and supplies the combined result to an associated upconverter 119. Each upconverter uses the result supplied by its associated combiner 111 to modulate a carrier signal. The modulated carrier signal is then supplied to antenna 105 for broadcast.

[0015] Note that for each wireless terminal served by the base station there are similar K transmit modules 107. However, each upconverter 119 is shared by the various transmit modules 107 of the different wireless terminals, i.e., each upconverter 119 upconverts a signal which is combined from each of the transmit modules 107, and the combined signal is supplied to one of the antennas 105 coupled to that upconverter. In other words, each base station has K times the maximum number of wireless terminals it can serve transmit modules 107, but only K upconverters 119 and only K antennas 105.

[0016] Receiver 103 is a so-called "rake" receiver. Receiver 103 includes a) antenna 151, b) down convener 153, c) receive module 152, and d) channel response and SINR estimator 167, and e) rake combining weight calculator 169. Other than channel response and SINR estimator 167, those portions of receiver 103 shown in FIG. 1 are conventional and will only be briefly described.

[0017] Antenna 151 receives wireless signals that impinge upon it. Down converter 153 downconverts to baseband the wireless signals received by antenna 151. The baseband signal is then supplied to receiver module 152, which includes L rake receiver fingers 155 all of which is coupled to combiner 165. More specifically, the signal from down converter 153 is supplied to each rake receiver finger 155. Each rake receiver finger 155 includes delay element 157, despreader 158, and rake combining multiplier 163. Despreader 158 includes chip multiplier 159 coupled to integrator 161. Thus, the signal received at antenna 151 is downconverted, delayed, despread, and combined to form a decision statistic signal from which the particular bits received are determined.

[0018] Note that FIG. 1 shows the most common form of CDMA rake receiver. However, other embodiments of the invention may employ conventional two-dimesnional rakes or an inventive rake receiver such as disclosed in our concurrently filed, commonly assigned copending United States Patent Application Serial No. (Case Rashid-Farrokhi—Valenzuela 2-12), which is incorporated herein by reference. Using either of the alternative rake receivers does not change the process. Only rake combining vector v is longer, to accommodate the additional dimension.

[0019] FIG. 2 shows an exemplary over-all process for the optimization of 1) transmit beam forming weight vectors, 2) transmit power allocation, and 3) rake receiver combining vectors, in accordance with the principles of the invention. The process is entered in step 201 when a new user, e.g., one served by a wireless terminal (not shown) including wireless receiver 103 (FIG. 1) is to be served by the base station (not shown) incorporating wireless transmitter 101. The base station may already be operating prior to the entering into the process shown in FIG. 2. Alternatively, the process of FIG. 2 may be entered in step 201 periodically, e.g., with a time period approximating the amount of time for the channel between the base station and the wireless terminal to change by an amount that would necessitate a weight vector update. Note that changes in the channel may be caused by various factors, including: changes in atmospheric conditions; changes in the location of the wireless terminal; and changes in other objects along the path or in the environment, between the base station and the wireless terminal.

[0020] In step 203 the base station collects information about the channels between itself and the various wireless terminals. Such channel information may include the channel response and the SINR of the channel. A portion of the information may be provided directly by each of the wireless terminals that the base station is currently actively serving, e.g. by incorporating the information into the uplink communication, i.e., the link from wireless terminal to base station, which may be arranged using a frame structure, so that collectively the base station has information about all the wireless terminals it is serving. Additionally, it is possible that the base station receives channel information for wireless terminals served by other base stations, e.g., in cells neighboring the cell served by the base station, the channel information from the other cells being supplied via the neighboring cell base stations using inter-base-station communication, e.g., a wire line connection.

[0021] Next, in step 205, the base station uses the received channel information to calculate the transmit beamforming vectors, in accordance with an aspect of the invention. Additional details regarding the calculation of the transmit beamforming vectors in accordance with the invention are provided hereinbelow. Thereafter, in step 207, the base station performs base station transmit power control, and more specifically, the base station updates the power to be used for each wireless terminal that it is serving.

[0022] Conditional branch point 209 tests to determine if the sequence of transmit weight vectors which have been previously used within a specified time window has converged, i.e., the error vector norm, which is the square of vector elements of the difference between the current transmit weight vector and the previously employed weight vector, is below a specified threshold. If the test result in step 209 is YES, indicating that the transmit weight vectors have converged, the process exits in step 211. Alternatively, control may be passed back to step 203, e.g., if no further use can be made of the processing power that becomes available by not performing steps 203 through 209.

[0023] If the test result of step 209 is NO, indicating that the transmit weight vectors have not converged yet, control passes to step 213, in which each wireless terminal calculates its optimum rake receiver combining vector, e.g., the weights to be supplied to rake combining multiplier 163 of receiver 103 (FIG. 1), in accordance with an aspect of the invention. The calculation is performed by rake combining weight calculator 169, as described in further detail hereinbelow.

[0024] In step 215, each wireless terminal estimates the channel information, i.e., the channel response, which is the impulse response of the channel, using conventional techniques. Additionally, in step 215, each wireless terminal determines the signal to interference and noise ratio (SINR) using conventional techniques. Thereafter, in step 217, each wireless terminal transmits the estimated channel response and SINR to the base station. This information is incorporated into the wireless terminal's uplink, and it is received by the base station in step 203. Control then panes back to step 203 and the process continues as described above.

[0025] FIG. 3 shows, in flow chart form, an exemplary process for calculating the transmit beamforming vectors by the base station using the received channel information as recited in step 205 of FIG. 2, in accordance with an aspect of the invention. The process of FIG. 3 is entered, in step 301, whenever control passes to step 205 of FIG. 2. Next, in step 303, signal and interference correlation matrices Φ_i^S , Φ_i^I are calculated in accordance with an aspect of the invention. More specifically, in accordance with an aspect of the invention, the signal and interference correlation matrices are developed in the base station for a virtual uplink network which is the mathematical equivalent of the actual downlink set of channels extending from the base station to the wireless terminals.

[0026] To develop the virtual uplink network it is assumed that the transmitter, i.e., the base station, is the receiver, and that the receiver, i.e., the wireless terminal, is the transmitter. Additionally, it is assumed that the channel response for the virtual uplink network is the same as that for the collected set of downlink channels. Once the virtual uplink network is known, the signal and interference correlation matrices are developed therefor in the conventional manner.

[0027] Thereafter, in step 305, the weight vector W for each wireless terminal i at iteration n of step 205 is calculated to maximize the SINR, Γ, using the signal and interference correlation matrices, Φ_i^S , Φ_i^I respectively, of the virtual uplink network. This is achieved by computing:

$$\begin{aligned} W_i^n &= \arg\max_{w_i} \Gamma_i(W_i, P^n, V^{n-1}) \\ &= \arg\max_{w_i} \frac{w_i^H \Phi_i^s w_i}{w_i^H \Phi_i^I w_i} \\ &= \arg\max_{|W_i|=1} \frac{P_i^{n-1} |W_i^H F_{ii}^s v_i|^2}{\sum_j P_j^{n-1} |W_i^H F_{ji}^I v_i|^2 + N_i |v_i|^2} \end{aligned}$$

where:

F_{ji}^I is the channel response from the j^{th} wireless terminal to the base station receiver associated with the i^{th} wireless terminal, which may belong to the same base station or may belong to another base station;

F_{ii}^S is the channel response from the i^{th} wireless terminal to the base station receiver associated with the i^{th} wireless terminal;

N_i is the additive noise power of the i^{th} wireless terminal;

P is a power vector each element of which is the power of a virtual transmitter;

V is a set of rake combining vectors v_i for each wireless terminal; and

H means Hermitian, which is the complex conjugate transpose of a vector or a matrix.

[0028] Note that each individual component of each vector v_i, which corresponds to a particular wireless terminal, is supplied to a respective one of rake combining multipliers 163 of wireless receiver 103 of that particular wireless terminal. Also note that since this step requires the power allocations from the previous iteration of the process of FIG. 2 that the first time the process is executed an arbitrary power allocation may be employed. Once the process is operating the power allocation will eventually move in the direction of the desired solution, regardless of the initial values.

[0029] Further note that each wireless terminal is associated with corresponding circuitry in the base station that is presently serving it, the corresponding circuitry including, using the example shown in FIG. 1, diversity modules 109, combiner 111, and beamformer and power control unit 121. Each wireless terminal and its corresponding base station circuitry are identified by a common identifier. For purpose of simplicity of matrix operation, the identifier is typically a number ranging from 1 to M, where M is the total number of users being served by the entire wireless system, which may be a network of multiple base stations. However, other identifiers may be used at the discretion of the implementor, e.g., the telephone number corresponding to the wireless terminal. Furthermore, various identifiers representing a wireless terminal may be associated together, and the one appropriate for each function to be performed is selected when needed.

[0030] Additionally, in step 305, the virtual uplink power vector is calculated by computing

$$P_i^n = \frac{\gamma_i P_i^{n-1}}{\Gamma_i(W_i^n, P^{n-1}, V^{n-1})}$$

where P_i^n is the virtual uplink transmit power used by the i^{th} wireless terminal to transmit to the base station at the n^{th} iteration of computing the virtual uplink power vector; γ_i is the target SINR for the i^{th} base station—which is a specification of the link quality and may be selected by the user—; and Γ_i is the SINR of the i^{th} base station.

[0031] The process then exits in step 307. Note that upon exiting control passes to step 207 of FIG. 2.

[0032] As described above in connection with step 207 of FIG. 2, the base station performs base station transmit power control, and more specifically, the base station updates the power to be used for each wireless terminal that it is serving. The updated power to be used by the base station for each wireless terminal that it is serving may be computed by

$$\tilde{P}_i^n = \frac{\gamma_i \tilde{P}_i^{n-1}}{\tilde{\Gamma}_i(W^n, v_i^{n-1}, \tilde{P}^{n-1})},$$

where $\tilde{P}_i^n$ is the actual transmit power used by the base station to transmit to the i^{th} wireless terminal; $\tilde{P}^{n-1}$ is the downlink transmit power vector from the previous execution of step 213; v_i^{n-1} is the rake combining vectors v for the i^{th} wireless terminal from the previous power control iteration; γ_i is the target SINR for the i^{th} wireless terminal—which is a specification of the link quality and may be selected by the user—; $\tilde{\Gamma}_i$ is the SINR at the i^{th} wireless terminal; and W^n is the set of transmit weight vectors.

[0033] As described above in connection with step 213 of FIG. 2, each wireless terminal calculates its optimum rake receiver combining vector, e.g., the weights to be supplied to rake combining multiplier 163 of receiver 103 (FIG. 1), in accordance with an aspect of the invention. The optimum rake receiver combining vectors may be determined by computing

$$\mathbf{v}_i^n = \arg\max_{|\mathbf{v}_i|=1} \Gamma_i(W^n, \mathbf{v}_i, \tilde{\mathbf{P}}^{n-1})$$
$$= \arg\max_{\mathbf{w}_i} \frac{\mathbf{v}_i^H \tilde{\Phi}_i^s \mathbf{v}_i}{\mathbf{v}_i^H \tilde{\Phi}_i^I \mathbf{v}_i}$$
$$= \arg\max_{|\mathbf{v}_i|=1} \frac{\tilde{P}_i^n |\mathbf{W}_i^{n^H} \mathbf{F}_{ii} \mathbf{v}_i|^2}{\sum_j \tilde{P}_j^n |\mathbf{W}_j^{n^H} \mathbf{F}_{ij}^I \mathbf{v}_i|^2 + N_i |\mathbf{v}_i|^2}$$

where $\tilde{\Phi}_i^s$ is the correlation matrix of the desired signal at the i^{th} wireless; $\tilde{\Phi}_i^I$ is the interference correlation matrix at the i^{th} wireless.

[0034] The foregoing techniques, when used in combination, result in optimal power allocation and beam forming vectors, resulting in maximum system performance, which can be translated into maximum system capacity per a given SINR or a maximum SINR for a given number of wireless terminals, e.g., users. However, it is recognized that not all of the foregoing techniques need be applied together in one system. Instead, applying only same of the techniques will result in improved, albeit not optimal, system performance. Similarly, there are suboptimal techniques that may be employed, individually or collectively, in lieu of the foregoing techniques, that will result in improved, although not optimal, system performance.

[0035] For example, instead of developing the weight vector W for each wireless terminal i at iteration n of step 205 to maximize the SINR, Γ, using the signal correlation matrix, Φ_i^s, of the virtual uplink network, as described above in connection with step 305, the weight vector W for each wireless i at iteration n of step 205 is computed to only maximize the gain for the desired user i as follows:

$$\mathbf{W}_i^n = \arg\max_{\mathbf{w}_i} \mathbf{w}_i^H \Phi_i^s \mathbf{w}_i$$
$$= \arg\max_{|\mathbf{W}_i|=1} |\mathbf{W}_i^H \mathbf{F}_{ii}^s \mathbf{v}_i|^2,$$

where all the variables have already been described hereinabove. A further alternative to the method for developing the weight vector W for each wireless terminal i at iteration n of step 205 by maximizing the SINR, Γ, is to maximize the gain from the base station to the desired wireless terminal but with a constraint that the totally transmitted interference to other wireless terminals is limited by solving the following constrained gain maximization:

$$\mathbf{W}_i^n = \arg\max_{\mathbf{w}_i} \mathbf{w}_i^H \Phi_i^s \mathbf{w}_i$$
$$\text{subject to} \sum_i \mathbf{w}_i^H \Phi_i^I \mathbf{w}_i < c$$
$$= \arg\max_{\mathbf{w}_i} |\mathbf{W}_i^H \mathbf{F}_{ii}^s \mathbf{v}_i|^2$$
$$\text{subject to} \sum_j |\mathbf{W}_j^H \mathbf{F}_{ji}^I \mathbf{v}_i|^2 < c$$

where c is an arbitrary constant that is eventually canceled out when the base station transmit power control is performed in step 207. Thus no specific value of c need be selected.

[0036] FIG. 4 shows an exemplary process for maximizing the minimum signal to interference ration (SIR) of the virtual uplink network that is used to represent the downlink of the system, in accordance with an aspect of the invention. SIR is similar to SINR but the additive noise is not taken into account In general, maximizing the minimum SIR is achieved by setting all of the SIRs of the virtual uplink network to a common value and then attempting to maximize this common value. This can be expressed mathematically as the need to solve

$$\hat{W}_i = \arg\max_{W} SIR_i(W_i, P, V).$$

The process would be performed as an alternative to steps 205 and 207 of FIG. 2.

[0037] Thus, more specifically, the process shown in FIG. 4 is entered in step 401 at the conclusion of execution of step 203. Next, in step 403, the SIR is maximized for the virtual uplink network to yield beamforming weight vectors, which are calculated by:

$$W_i^n = \arg\max_{w_i} SIR_i(W_i, P^n, V^{n-1})$$
$$= \arg\max_{w_i} \frac{\mathbf{w}_i^H \Phi_i^s \mathbf{w}_i}{\mathbf{w}_i^H \Phi_i^I \mathbf{w}_i}$$
$$= \arg\max_{|W_i|=1} \frac{P_i^{n-1} |\mathbf{W}_i^H \mathbf{F}_{ii}^s \mathbf{v}_i|^2}{\sum_j P_j^{n-1} |\mathbf{W}_i^H \mathbf{F}_{ji}^I \mathbf{v}_i|^2}$$

where all the variables are as defined hereinabove. Note that since this step requires the power allocations from the previous iteration of the process of FIG. 4 the first time the process is executed an arbitrary power allocation may be employed. Once the process is executing the power allocation will eventually move in the direction of the desired solution, regardless of the original values.

[0038] Next, in step 405, power control is performed for the virtual uplink network. In other words, each channel of the virtual uplink network is allocated a transmit power, albeit a virtual one. This is achieved by first constructing two gain matrices, D and F. D is the desired link gain and F is the gain for the interference on the desired link whose weight vector is *w*. Then the spectral radius, i.e, the maximum eigenvalue, of the product of D and F is determined. Thereafter, the optimal power allocation for the virtual uplink is determined by finding the eigenvector corresponding to the spectral radius of the product of D and F. Mathematically, the forgoing is represented as follows:

$$[D_w]_{ii} = 1/|W_i^H F_{ii}^s v_i|^2$$
$$[F_w]_{ji} = |W_j^H F_{ji}^I v_i|^2$$
$$\gamma_{max} = \rho(D_w F_w)$$
$$P^{n+1} = \gamma_{max} D_w F_w P^n$$

where ρ is the spectral radius and γ_{max} is the maximum achievable SIR.

Claims

1. A method for use in a wireless base station, comprising the steps of:

   receiving at said base station channel information from a plurality of wireless terminals; and
   determining operating parameters used by said base station to substantially simultaneously control each respective transmit beam pattern which is formed to establish a communication channel between said base station and each respective one said wireless terminals as a function of said received channel information.

2. The invention as defined in claim 1 wherein said operating parameters include weight vectors.

3. The invention as defined in claim 1 wherein said operating parameters include a transmit power level for use by the base station for each of said wireless terminals.

4. The invention as defined in claim 1 wherein said received channel information is used to develop signal and interference correlation matrices in the base station for a virtual uplink network, said virtual uplink network being mathematically equivalent to an actual downlink set of channels extending from said base station to said wireless terminals.

5. The invention as defined in claim 4 wherein channel information received at said base station from said plurality of wireless terminals is employed as said actual downlink set of channels extending from said base station to said wireless terminals.

6. The invention as defined in claim 1 wherein said received channel information is used to develop signal and interference correlation matrices, Φ_i^s, Φ_i^I respectively, in said base station for a virtual uplink network, said virtual uplink network being mathematically equivalent to an actual downlink set of channels extending from said base station to said wireless terminals, and wherein said operating parameters include weight vectors, and wherein a weight vector W for each wireless *i* at iteration *n* of weight vector calculation is calculated to maximize a signal to interference and noise ratio (SINR), Γ, by computing:

$$\mathbf{W}_i^n = \arg\max_{w_i} \Gamma_i(\mathbf{W}_i, \mathbf{P}^n, \mathbf{V}^{n-1})$$
$$= \arg\max_{w_i} \frac{\mathbf{w}_i^H \Phi_i^s \mathbf{w}_i}{\mathbf{w}_i^H \Phi_i^I \mathbf{w}_i}$$
$$= \arg\max_{|W_i|=1} \frac{P_i^{n-1} |\mathbf{W}_i^H \mathbf{F}_{ii}^s \mathbf{v}_i|^2}{\sum_j P_j^{n-1} |\mathbf{W}_i^H \mathbf{F}_{ji}^I \mathbf{v}_i|^2 + N_i |\mathbf{v}_i|^2}$$

where:

F_{ji}^I is a channel response from j^{th} wireless terminal of said wireless terminals to a base station receiver associated with an i^{th} wireless terminal of said wireless terminals, which may be associated with said base station or another base station;

F_{ii}^S is a channel response from an i^{th} wireless terminal of said wireless terminals to a base station receiver associated with an i^{th} wireless terminal of said wireless terminals;

N_i is additive noise power of said i^{th} wireless terminal;

P is a power vector; and

V is a set of rake combining vectors v_i for wireless terminal of said wireless terminals.

7. The invention as defined in claim 1 wherein said received channel information is used to develop signal correlation matrix, Φ_i^S in said base station for a downlink from said base station to an i^{th} one of said wireless terminals, and wherein said operating parameters include weight vectors, and wherein a weight vector W for each wireless i at iteration n of weight vector calculation is calculated to maximize the gain by computing;

$$\begin{aligned} W_i^n &= \arg\max_{w_i} w_i^H \Phi_i^s w_i \\ &= \arg\max_{|W_i|=1} |W_i^H F_{ii}^s v_i|^2 \end{aligned}$$

where:

F_{ii}^S is a channel response from an i^{th} wireless terminal of said wireless terminals to a base station receiver associated with an i^{th} wireless terminal of said wireless terminals; and

v_i is a rake combining vector for an i^{th} wireless terminal of said wireless terminals.

8. The invention as defined in claim 1 wherein said received channel information is used to develop signal and interference correlation matrices, Φ_i^S, Φ_i^I respectively, in said base station for a virtual uplink network, said virtual uplink network being mathematically equivalent to an actual downlink set of channels extending from said base station to said wireless terminals, and wherein said operating parameters include weight vectors, and wherein a weight vector W for each wireless i at iteration n of weight vector calculation is calculated to maximize a signal to interference ratio (SIR), by computing:

$$\begin{aligned} W_i^n &= \arg\max_{w_i} SIR_i(W_i, P^n, V^{n-1}) \\ &= \arg\max_{w_i} \frac{w_i^H \Phi_i^s w_i}{w_i^H \Phi_i^I w_i} \\ &= \arg\max_{|W_i|=1} \frac{P_i^{n-1}|W_i^H F_{ii}^s v_i|^2}{\sum_j P_j^{n-1}|W_i^H F_{ji}^I v_i|^2} \end{aligned}$$

where:

F_{ji}^I is a channel response from a j^{th} wireless terminal of said wireless terminals to a base station receiver associated with an i^{th} wireless terminal of said wireless terminals, which may be associated with said base station or another base station;

F_{ii}^S is a channel response from an i^{th} wireless terminal of said wireless terminals to a base station receiver associated with an i^{th} wireless terminal of said wireless terminals;

N_i is additive noise power of said i^{th} wireless terminal;

P is a power vector, and

V is a set of rake combining vectors vi for wireless terminal of said wireless terminals.

9. The invention as defined in claim 8 wherein power control is performed for the virtual uplink network by performing the steps of:

constructing two gain matrices, D and F, where D is a desired link gain and F is a gain for interference on the desired link whose weight vector is w;

determining a spectral radius for a product of D and F; and

and finding an eigenvector corresponding to the spectral radius of the product of D and F.

10. The invention as defined in claim 8 wherein power control is performed for the virtual uplink network by solving:

$$[D_w]_{ii} = 1/|W_i^H F_{ii}^s v_i|^2$$

$$[F_w]_{ji} = |W_j^H F_{ji}^I v_i|^2$$

$$\gamma_{max} = \rho(D_w F_w)$$

$$P^{n+1} = \gamma_{max} D_w F_w P^n$$

where

D and F are gain matrices, D being a desired link gain and F being a gain for interference on the desired link whose weight vector is w;

P is a power vector;

v_i is a rake combining vector for an i^{th} wireless terminal of said wireless terminals;

ρ is the spectral radius; and

γ_{max} is the maximum achievable signal to interference ratio (SIR).

11. Apparatus for use in a wireless base station, comprising:

a multichannel receiver that receives channel information from a plurality of wireless terminals served by said wireless base; and

a processor that controls each respective transmit beam pattern which is formed to establish a communication channel between said base station and each respective one said wireless terminals as a function of said received channel information.

12. A method for use in a wireless base station, comprising the steps of:

receiving channel information from at least a plurality of wireless terminals served by said base station; and

determining weight vectors used by said base station as a function of all of said received channel information.

13. The invention as defined in 12 further comprising the step of determining a transmit power level for use by said base station for each of said wireless terminals as a function of all of said received channel information.

14. A method for use in a wireless base station which receives channel information from a plurality of wireless terminals, the method comprising the step of:

determining operating parameters used by said base station to substantially simultaneously control each respective transmit beam pattern which is formed to establish a communication channel between said base station and each respective one said wireless terminals as a function of said received channel information, said operating parameters being determined using signal and interference correlation matrices in the base station for a virtual uplink network, said virtual uplink network being mathematically equivalent to an actual downlink set of channels extending from said base station to said wireless terminals, said received channel information being used to develop interference correlation matrices.

15. The invention as defined in claim 14 wherein channel information regarding said wireless terminals is received directly by said wireless base station from wterminal

16. Apparatus for use in a wireless base station, comprising:

means for receiving at said base station channel information from a plurality of wireless terminals; and

means for determining operating parameters used by said base station to substantially simultaneously control each respective transmit beam pattern which is formed to establish a communication channel between said base station and each respective one said wireless terminals as a function of said received channel information.

17. A method comprising the steps of:

assigning power allocations to a virtual uplink network; and

determining weight vectors for a real world set of downlinks corresponding to said virtual uplink network as a function of said power allocations.

18. Apparatus for use in a wireless base station, comprising:

a multichannel receiver that receives channel information regarding a plurality of wireless terminals; and

a processor that controls each respective transmit beam pattern which is formed to establish a communication channel between said base station and respective ones of said wireless terminals served by said wireless base station as a function of said received channel information.

19. The invention as defined in claim 18 wherein said plurality of wireless terminals includes at least one wireless terminal served by said wireless base station and at least one wireless terminal served by another wireless base station.

FIG. 1

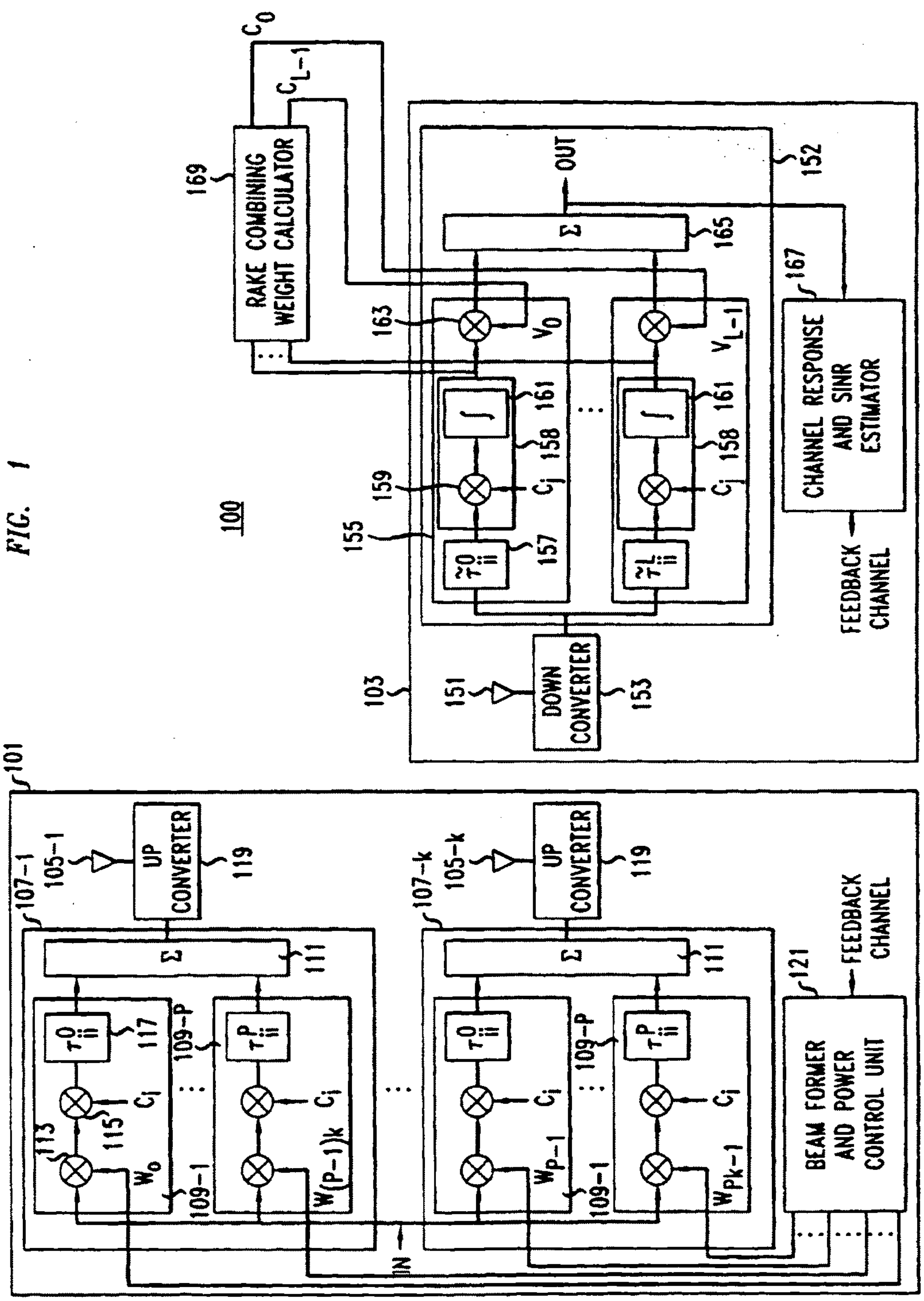

100
101
103
RAKE COMBINING WEIGHT CALCULATOR
169
CHANNEL RESPONSE AND SINR ESTIMATOR
167
DOWN CONVERTER
153
151
155
157
158
159
161
163
165
152
OUT
FEEDBACK CHANNEL
UP CONVERTER
119
105-1
105-k
107-1
107-k
109-1
109-P
111
113
115
117
BEAM FORMER AND POWER CONTROL UNIT
121
FEEDBACK CHANNEL
IN

FIG. 2

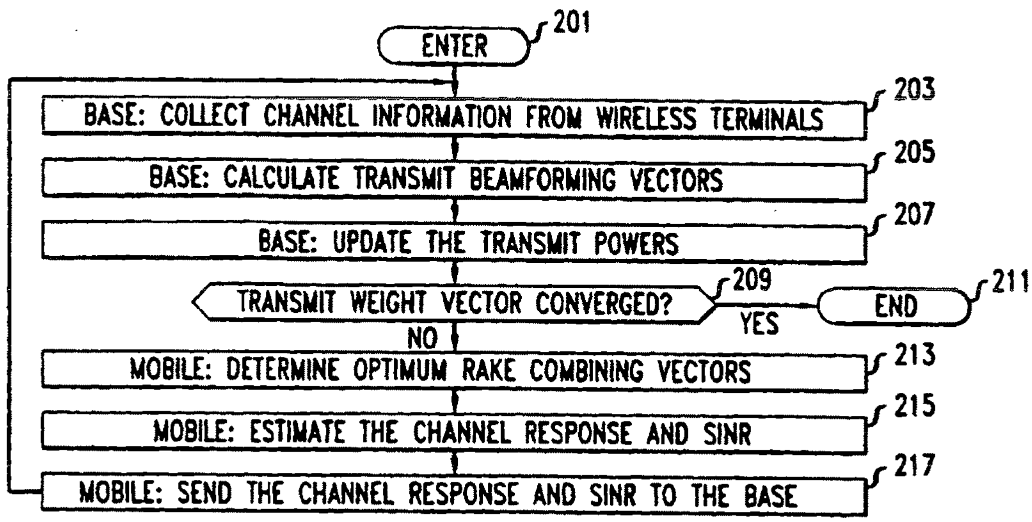


FIG. 3

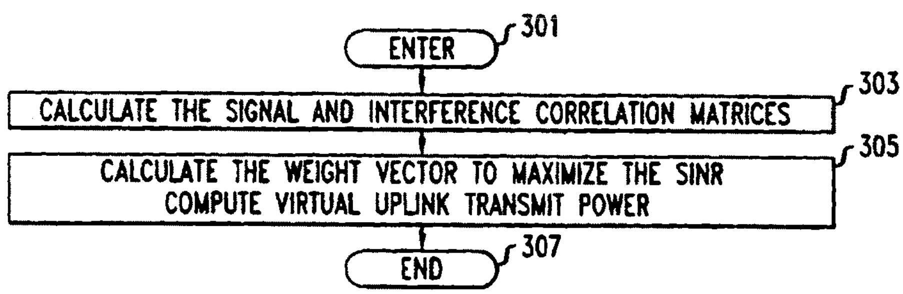
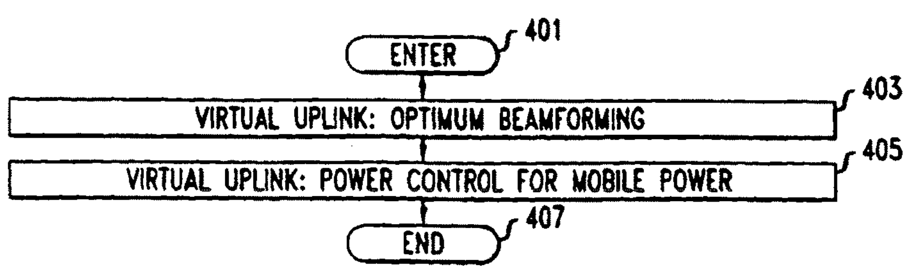


FIG. 4



05-18-06

 IFW

Docket No.:
68144/P014C1/10503148
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Xiaodong Li et al.

Application No.: 11/199,586 | Confirmation No.: 1128

Filed: August 8, 2005 | Art Unit: 2661

For: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING | Examiner: Not Yet Assigned

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT (IDS)

MS Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In accordance with 37 CFR 1.97, Applicant(s) hereby make of record the following additional documents. A PTO Form SB/08 and a full copy of each of the documents required under 37 CFR 1.98(a)(2) accompany this statement.

Applicant(s) have become aware of three documents, cited in a Korean Office Action issued April 28, 2006, during the prosecution of Korean application no. 2003-7007962, which corresponds to US patent no. 6,904,283 which is related to the above referenced application, and in accordance with 37 CFR 1.97(b)(3), hereby submit(s) these documents for the Examiner's consideration. These documents are cited on the enclosed PTO Form SB/08, and a copy of the Korean Office Action and of each document required under 37 CFR 1.98(a)(2) cited thereon are enclosed as well.

In addition, applicant(s) have become aware of one document, cited in a Korean Office Action issued April 29, 2006, during the prosecution of Korean application no. 2003-7007963, which corresponds to US application no. 09/837,701 which is related to the above referenced application, and in accordance with 37 CFR 1.97(b)(3), hereby submit(s) this document for the Examiner's consideration. This document is cited on the enclosed PTO Form SB/08, and a copy of the Korean Office Action and of each document required under 37 CFR 1.98(a)(2) cited thereon are enclosed as well.

This statement is not to be interpreted as a representation that the cited documents are material, that an exhaustive search has been conducted, or that no other relevant information exists. Nor shall the citation of any document herein be construed *per se* as a representation that such document is prior art. Moreover, Applicant(s) understand(s) the Examiner will make an independent evaluation of the cited documents.

This Information Disclosure Statement is filed before the mailing date of a first Office Action on the merits as far as is known to the undersigned (37 CFR 1.97(b)(3)).

Furthermore, in accordance with 37 CFR 1.704(d), Applicant(s) note(s) that to our knowledge this communication was not received by any individual designated in 1.56(c) more than thirty days prior to the filing of this statement.

Applicant believes no fee is due. However, if a fee is due, the Director is hereby authorized to charge any deficiency in the fees filed, asserted to be filed or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our Deposit Account No. 06-2380, under Order No. 68144/P014C1/10503148.

Dated: May 17, 2006

Respectfully submitted,

By ______________________

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PTO/SB/08A (10-01)
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Substitute for form 1449A/PTO				*Complete if Known*	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				**Application Number**	11/199,586
(use as many sheets as necessary)				**Filing Date**	August 8, 2005
				First Named Inventor	Xiaodong Li
				Art Unit	2661
				Examiner Name	Not Yet Assigned
Sheet	1	of	1	Attorney Docket Number	68144/P014C1/10503148

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number — Number-Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US 5,726,978	March 10, 1998	Frodigh et al.	
		US 5,280,630	Jan. 18, 1994	Wang	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document — Country Code[3]-Number[4]-Kind Code[5] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
	BA	EP 0 999 658	May 10, 2000	Lucent Technologies, Inc.		

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

[1]Applicant's unique citation designation number (optional). [2]See attached Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4]For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the application number of the patent document. [5]Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6]Applicant is to place a check mark here if English language Translation is attached.

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	CA	Ye Li et al.; "Clustered OFDM with Channel Estimation for High Rate Wireless Data"; Mobile Multimedia Communications, 1999. (MoMuC'99) 1999 IEEE International Workshop on Nov. 15-17, 1999; pages 43-50.	
	CB	Korean Office Action issued for 2003-7007962 dated April 28, 2006.	
	CC	Korean Office Action issued for 2003-7007963 dated April 29, 2006.	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached.

25657177 .1		Date Considered	

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Transmittal (1 page)
Supplemental Information Disclosure Statement (2 pages)
PTO Form SB-08 (1 page)
4 out of 6 Cited References
1 Return Postcard

PTO/SB/21 (09-04)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

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Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	2661
Examiner Name	Not Yet Assigned
Attorney Docket Number	68144/P014C1/10503148
Total Number of Pages in This Submission	05

ENCLOSURES (*Check all that apply*)

- [ ] Fee Transmittal Form
  - [ ] Fee Attached
- [ ] Amendment/Reply
  - [ ] After Final
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Clustered OFDM with Channel Estimation for High Rate Wireless Data

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Abstract: *Clustered OFDM can provide in-band diversity gain for wideband wireless channels. It is a promising technique for high-rate wireless packet data access, such as mobile multimedia communications. Due to smaller size of each cluster for clustered OFDM than for classical (non-clustered) OFDM, edge effects can be very large. In this paper, we present new transforms for channel estimators in clustered OFDM systems. The new transforms are independent of the channel delay profiles and can effectively mitigate the edge effects. Computer simulation shows that the performance of clustered OFDM with the estimator using the new transforms is very close to the performance with the optimum estimator that depends on the channel delay profile. For the typical-urban or hilly-terrain delay profiles, clustered OFDM using the new transform based estimator is almost as good as classical OFDM with transmitter diversity.*

I. Introduction

Orthogonal frequency division multiplexing (OFDM) has been shown to be an effective technique to combat multipath fading [1-4]. Hence, it is a promising technique for wideband wireless packet data. Recently, clustered OFDM [5-8] has been proposed to provide in-band diversity gain with wideband dispersive fading channels, and therefore, to improve system performance.

For clustered OFDM in high-rate wireless data systems, each user accesses several OFDM clusters located at different frequencies. Then, an error correction code, such as a Reed-Solomon code, or a convolutional code, is used to obtain frequency diversity. As indicated in [9], without channel information, differential demodulation has to be used instead of coherent demodulation at the expense of a 3-4 dB loss in signal-to-noise ratio (SNR) performance. Hence, channel estimation is also desired for clustered OFDM to gain high performance.

For classical OFDM systems, either pilot-symbol-aided [10] or decision-directed [9,11-12] channel estimators can be used to obtain channel information. Furthermore, similar parameter estimators can be used to estimate the coefficients for the minimum-mean-square error diversity combiner (MMSE-DC) for OFDM systems with antenna arrays to suppress co-channel interference [13-14], or to estimate channel information required by the decoder of space-time code based transmitter diversity [15-16].

Earlier work has shown in [9-11] that the optimum transforms for channel estimation is the eigen matrix of the channel frequency-domain correlation matrix. Obviously, the optimum transforms depend on the channel delay profiles that vary with environments. However, since there may be over a hundred contiguous tones for classical OFDM systems, with negligible edge effects [9,11,13-16], the discrete Fourier transform (DFT) can be used instead of the optimum transforms. But, for clustered OFDM, each cluster contains much fewer tones than for classical OFDM and those tones that are on edge are a large portion of the total number of tones in each cluster. Hence, edge effects will be very large if a DFT is used for the estimator in clustered OFDM. In this paper, we present new transforms for the channel estimator in clustered OFDM systems, which have small edge effects and robust to a broad range of channel delay profiles.

This paper is organized as follows. In Section 2, we briefly describe clustered OFDM for high-rate wireless data access and summarize some statistical properties of the wideband mobile wireless channel. Then, in Section 3, we investigate *robust* transforms for channel estimators in clustered OFDM systems. Next, in Section 4, we presents computer simulation results to demonstrate the effectiveness of robust transform based channel estimation for clustered OFDM systems in wideband dispersive fading channels.

II. Clustered OFDM for Wideband Mobile Wireless Systems

In this section, we first briefly describe clustered OFDM for high-rate data access, and then introduce some statistical characteristics of wideband mobile wireless channel that are useful for designing channel estimators.

A. Clustered OFDM for High Rate Data Access

The concept of clustered OFDM for wideband channels can be shown as in Fig. 1. A wideband OFDM signal is divided into many non-overlapped clusters of tones in frequency, and each user accesses several clusters of tones. For example, the OFDM signal in Fig. 1 is divided into 16 clusters. User 1 utilizes the 1st, 5th, 9th, and 13th clusters and Users 2, 3, and 4 use other clusters.

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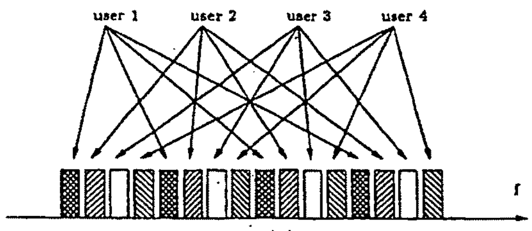

Fig. 1. Concept of clustered OFDM.

The implementation of clustered OFDM is more complicated than classical OFDM. Recently, several receiver structures for clustered OFDM [8] that can be readily implemented have been considered.

The clustered OFDM has some advantages over classical OFDM besides many good common properties, such as combating multipath fading. As indicated in [8], it provides a high degree of flexibility in supportable bit rates and Quality-of-Service (QoS) since clustered OFDM can allocate bandwidth by tone clusters. If 4 users share a wideband wireless channel, the peak rate of each user can be as large as 4 times the average bit rate per user since a single user can access all clusters in the channel if they are not in use by others.

For systems with clustered OFDM, each user utilizes several clusters at different locations of a wideband channel. Hence, frequency diversity gain can be obtained for dispersive fading channels if an error correction code is used across these clusters. The greater the number of clusters, the greater the diversity gain that results in. As shown by the simulation results in Section 4, for a clustered OFDM system with 8 or 4 clusters uniformly located in a 4.096 MHz typical urban (TU) or hilly terrain (HT) channel, the performance is as good as a classical OFDM with delayed transmitter diversity [15-16] if coherent detection is used in both systems.

However, coherent detection requires the channel information. If the DFT based estimator [9] is used here, there will be severe edge effects for channel parameter estimation for the clustered OFDM receiver since the size of each cluster is much smaller than for classical OFDM.

B. Channel Statistics

The complex baseband representation of a wireless channel impulse response can be described by

$$h(t,\tau) = \sum_k \gamma_k(t)\delta(\tau - \tau_k), \qquad (1)$$

where τ_k is the delay of the k-th path, and $\gamma_k(t)$ is the corresponding complex amplitude. Due to the motion of the vehicle, $\gamma_k(t)$'s are wide-sense stationary (WSS) and narrow-band complex Gaussian processes with average power σ_k^2's, which are independent for different paths.

TABLE I

THE AVERAGE POWER AND DELAY OF EACH PATH FOR THE TU AND HT CHANNELS

path number	TU channel		HT channel	
	delay in μsec.	average power	delay in μsec.	average power
1	0.0	0.1897	0.0	0.3933
2	0.2	0.3785	0.2	0.2481
3	0.5	0.2388	0.4	0.1566
4	1.6	0.0951	0.6	0.0785
5	2.3	0.0600	15.0	0.0988
6	5.0	0.0379	17.2	0.0248

From (1), the frequency response of the time-varying radio channel at time t is

$$\begin{aligned} H(t,f) &\triangleq \int_{-\infty}^{\infty} h(t,\tau)e^{-j2\pi f\tau}d\tau \\ &= \sum_k \gamma_k(t)e^{-j2\pi f\tau_k}. \end{aligned}$$

From the above identity, it has been proved in [9] that the correlation function of the frequency response at different times and frequencies can be expressed as

$$\begin{aligned} r_H(\Delta t,\Delta f) &\triangleq E\{H(t+\Delta t, f+\Delta f)H^*(t,f)\} \\ &= \sigma_h^2 r_t(\Delta t) r_f(\Delta f), \end{aligned}$$

where σ_h^2 is the total average power of the channel impulse response, defined as $\sigma_h^2 = \sum_k \sigma_k^2$, $r_t(\Delta t)$ and $r_f(\Delta f)$ are the *time- and frequency-domain correlations* of the channel frequency response, which are defined as

$$r_t(\Delta t) \triangleq \frac{E\{\gamma_k(t+\Delta t)\gamma_k^*(t)\}}{E\{|\gamma_k^*(t)|^2\}}, \qquad (2)$$

and

$$r_f(\Delta f) = \sum_k \frac{\sigma_k^2}{\sigma_h^2} e^{-j2\pi\Delta f \tau_k},$$

respectively.

The time-domain correlation of the channel frequency response can be well represented by Jake's model [17] that is determined by the *Doppler frequency*. The *Doppler frequency* is related to the vehicle speed v and the carrier frequency f_c by

$$f_c = \frac{v f_c}{c},$$

where c is the speed of light. For a system with a 2 GHz carrier frequency, the Doppler frequency is as large as 184 Hz when the user is moving at 60 miles/hour.

The frequency correlation changes with the environment. For the TU and HT profiles, the average power and the delay of each path are shown in Table I.

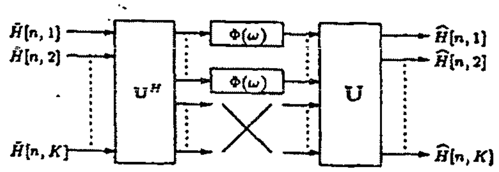

Fig. 2. Structure of the channel estimator.

III. Channel Estimator for Clustered OFDM

After introducing the general structure for channel estimation in this section, we present robust transforms for estimators used in clustered OFDM and give a geometric explanation.

A. General structure

The general structure of the decision-directed channel estimators [9] for OFDM are shown in Fig. 2, which exploits the channel frequency response correlations in both time- and frequency-domain. The unitary transform $\mathbf{U}$ exploits the frequency-domain correlation while the linear filters $\Phi(\omega)$ make full use of the time-domain correlation.

It has been shown in [9,11-12] that for the MMSE or optimum estimator, the transform in the figure is the eigen matrix of the channel frequency-domain correlation matrix $\mathbf{R}_f$, defined as

$$\mathbf{R}_f = (r_f[k_1 - k_2])_{k_1,k_2=1}^{K},$$

i.e.,

$$\mathbf{R}_f \mathbf{U}_{opt} = \mathbf{U}_{opt}\mathbf{D},$$

where $\mathbf{D}$ is a diagonal matrix, and K is the number of tones in classical OFDM or in each cluster of a clustered OFDM system. The channel frequency-domain correlation depends on delay profiles that are different for different environments. Therefore, the optimum transforms or bases for estimators are usually difficult to obtain.

For classical OFDM, it is demonstrated in [9,11-12] that with negligible performance degradation, the unitary transform can be substituted by the DFT, that is,

$$\mathbf{U}_{DFT} = \frac{1}{\sqrt{K}}\left(\exp(\jmath 2\pi \frac{k_1 - k_2}{K})\right)_{k_1,k_2=1}^{K}.$$

However, for clustered OFDM with small clusters, the tones that are on edge are a large portion of the tones per cluster. Therefore, edge effects will cause a significant performance degradation for clustered OFDM if the DFT is used in the estimator.

The Hadamard transform may be a candidate for the transform for the channel estimator, which is defined as

$$\mathbf{U}_{HT} = \frac{1}{\sqrt{K}}\mathbf{H}_n,$$

with $K = 2^n$, and

$$\mathbf{H}_n = \begin{pmatrix} \mathbf{H}_{n-1} & \mathbf{H}_{n-1} \\ \mathbf{H}_{n-1} & -\mathbf{H}_{n-1} \end{pmatrix},$$

and

$$\mathbf{H}_1 = \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}.$$

Note that the Hadamard transform contains only additions and subtractions; it is, therefore, implementable with very low computational complexity.

B. Robust transforms for clustered OFDM channel estimation

As indicated in Section 3.1, the optimum bases, or transforms for estimation are determined by the channel delay profiles. However, delay profiles are usually unknown except some parameters, such as delay spread or maximum delay span. Hence, we can at best *create* some delay profiles such that the transforms based on these delay profiles perform well, not necessarily best, for *all* delay profiles.

The simplest delay profile is a rectangular profile, which can be expressed as

$$\sigma_{rec}(\tau) = \begin{cases} \frac{1}{2\tau_{max}}, & \text{if } |\tau| \le \tau_{max}, \\ 0, & \text{otherwise}, \end{cases}$$

where τ_{max} is a half of the maximum delay span. The delay spread of the rectangular delay profile is $\bar{\tau} = \tau_{max}/\sqrt{3}$. The frequency-domain correlation function can be obtained by

$$r_{rec}(\Delta f) = \int_{-\tau_{max}}^{\tau_{max}} \sigma_{rec}(t) e^{-\jmath 2\pi \Delta f \tau} d\tau = \frac{\sin(2\pi \Delta f \tau_{max})}{2\pi \Delta f \tau_{max}}.$$

Based on $r_{rec}(\Delta f)$, the optimum transform for the rectangular profile, $\mathbf{U}_{rec}$, can be obtained by means of eigen-decomposition.

Another profile is exponential, which is defined as

$$\sigma_{exp}(\tau) = \begin{cases} \frac{1}{\bar{\tau}} e^{-\frac{\tau+\bar{\tau}}{\bar{\tau}}}, & \text{if } \tau \ge -\bar{\tau}, \\ 0, & \text{otherwise}, \end{cases}$$

where $\bar{\tau}$ is the delay spread. Then the frequency-domain correlation function is

$$r_{exp}(\Delta f) = \int_{-\tau_{max}}^{\tau_{max}} \sigma_{exp}(t) e^{-\jmath 2\pi \Delta f \tau} d\tau = \frac{e^{\jmath 2\pi \Delta f \bar{\tau}}}{\jmath 2\pi \Delta f \bar{\tau} + 1}.$$

Based on it, $\mathbf{U}_{exp}$ can be calculated accordingly.

It can be demonstrated that $\mathbf{U}_{rec}$ and $\mathbf{U}_{exp}$, which we call the *rectangular* and *exponential transforms* or *bases*, respectively, are robust to other channel delay profiles.

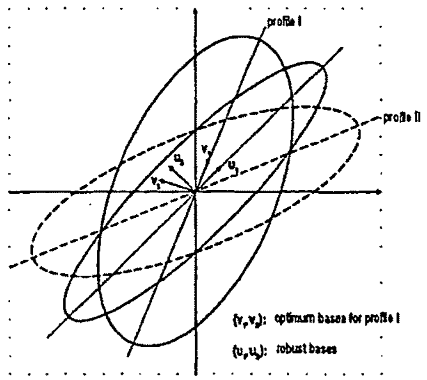

Fig. 3. Explanation of the optimum and robust transforms for clustered OFDM channel estimator.

C. Geometric Explanation

The robustness of the new transforms, $\mathbf{U}_{rec}$ and $\mathbf{U}_{exp}$, to a broad range of delay profiles can be explained by Fig. 3. Since each delay profile is specified by the average power of each path and delay, the average power in different directions for a delay profile can be represented by an ellipse. As indicated before, the optimum transform for a specific delay profile is the eigen matrix of the channel frequency-domain correlation matrix since it can catch the most power with the fewest taps. For example, in Fig 3, the average power on each direction for delay profile I can be shown by the solid ellipse with eigenvectors $\mathbf{v}_1$, $\mathbf{v}_2$. For each outcome of delay profile I, the channel parameters can be represented by $\alpha_1\mathbf{v}_1 + \alpha_2\mathbf{v}_2$, where α_1 and α_2 are time-varying for a time-varying channel. However, for delay profile I, $E|\alpha_1|^2$ is much larger than $E|\alpha_2|^2$. Hence, $\alpha_1\mathbf{v}_1$ alone is a good approximation of the channel information. Note that $\mathbf{v}_1$ and $\mathbf{v}_2$ can still be used to decompose other delay profiles, such as profile II. But, the error will be very large if $\alpha_1\mathbf{v}_1$ alone is used for the approximation. Hence, the optimum decomposition transform for one delay profile is not necessarily optimum for another delay profile. Therefore, it is desired to have a decomposition transform that has good, not necessarily the best, performance for all expected delay profiles with certain constrains. The $(\mathbf{u}_1, \mathbf{u}_2)$ transform in the figure is such a *robust* transform, just like $\mathbf{U}_{rec}$ or $\mathbf{U}_{exp}$ derived in Section 3.2.

IV. Performance Evaluation

In this section, we address the performance evaluation of clustered OFDM with the new transform based channel estimation through computer simulation. Before presenting the simulation results, we briefly describe the system parameters.

TABLE II
PARAMETER SETS OF CLUSTERED OFDM

set number	No. of clusters	inf. tones	guard tones
1	8	2nd - 16th	1st
2	4	2nd - 31st	1st & 32nd
3	2	3rd - 62nd	1st-2nd & 63rd-64th
4	1	5th - 124th	1st-4th & 125th-128th

A. System Parameters

In the simulated clustered OFDM system, one transmitter and two receiver antennas are used, unless otherwise specified. The channels corresponding to different receivers have the same statistics with independent fading.

To construct a clustered OFDM signal, assume the entire channel bandwidth, 4.096 MHz, is divided into 512 subchannels, which results in the subchannel space, Δf=8 kHz. To make the tones orthogonal to each other, the symbol duration, $T_s = 1/\Delta f$=125 μsec. An additional 31.25 μsec guard interval is used to provide protection from intersymbol interference due to channel multipath delay spread. This results in a total block length T_f = 156.25 μsec and a subchannel symbol rate $r_b = 1/T_f$ = 6.4 kbaud.

Four users transmit data through the channel at the same time and each uses 120 tones to transmit data and 8 tones as guard tones. The locations of guard tones for clustered OFDM systems with different cluster sizes are shown in Table II. With the estimator for clustered OFDM providing channel information, QPSK modulation with coherent demodulation can be used. As in [9] and [18], a (40,20) R-S code, with each code symbol consisting of 3 QPSK symbols grouped in frequency, is used in the system. Hence, each user forms a R-S codeword for each OFDM block. The R-S decoder erases 10 symbols based on signal strength, and corrects 5 additional random errors.

Each time slot contains 10 (clustered) OFDM blocks. The first block is used as synchronization and initial channel estimation and one of the rest of the blocks is used as a guard block. Consequently, each user can transmit data at 1.23 Mbits/sec before decoding, or 0.614 Mbits/sec after decoding. Or the peak rate for each user is 4.92 Mbits/sec before decoding, or 2.46 Mbits/sec after decoding.

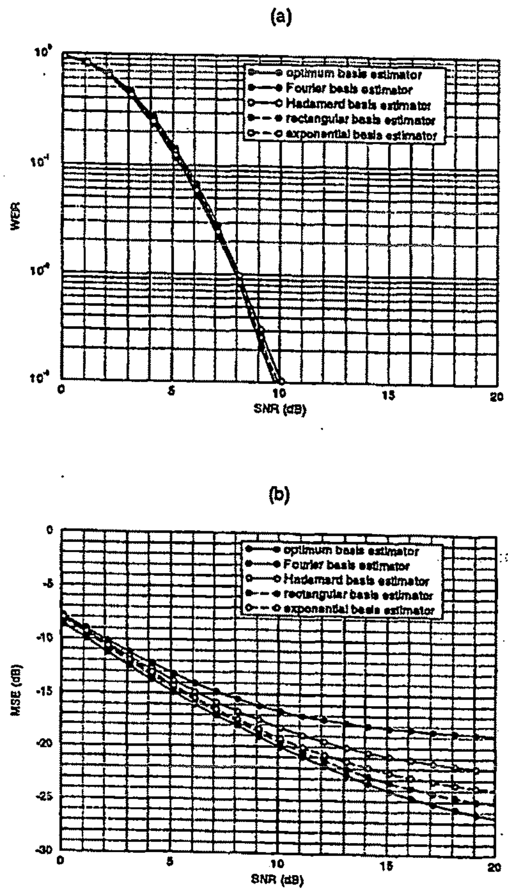

Fig. 4. (a) WER and (b) MSE versus SNR for 8-cluster-15-tone OFDM with different transform based estimators for the TU channel with $f_d = 40$ Hz.

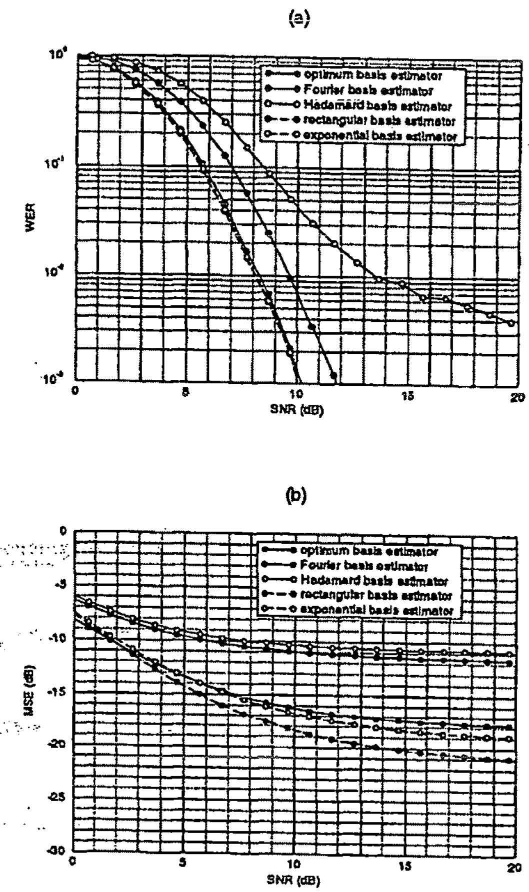

Fig. 5. (a) WER and (b) MSE versus SNR for 8-cluster-15-tone OFDM with different transform based estimators for the HT channel with $f_d = 40$ Hz.

B. Simulation Results

Here we present the simulated results of clustered OFDM under various environments. Our results are based on the average over 10,000 OFDM blocks, or 1,000 time slots.

B.1 Performance of estimator with different transforms

Figures 4 and 5 show the WER's and MSE's of 8-cluster-15-tone OFDM with the estimators using the optimum, Fourier, Hadamard, rectangular, or exponential transforms for the TU and HT channels, respectively. From Fig. 4, for the TU channel with SNR< 10 dB, the MSE's of the estimator with different transforms are much less than the channel noise; therefore, the WER's are almost same for the estimator with different bases. However, as shown in Figure 5 for the HT channel, due to the edge effects of the estimators with the Fourier and Hadamard transforms, the MSE's of the estimators with either of the two transforms are much larger than the estimator with the optimum transform; consequently, compared with the optimum basis, the required SNR's for a 10% WER show about 1.5 dB and 3.0 dB degradations, respectively. But, the WER's for the rectangular and exponential transforms are almost the same as for the optimum transform. Hence, both the rectangular and exponential

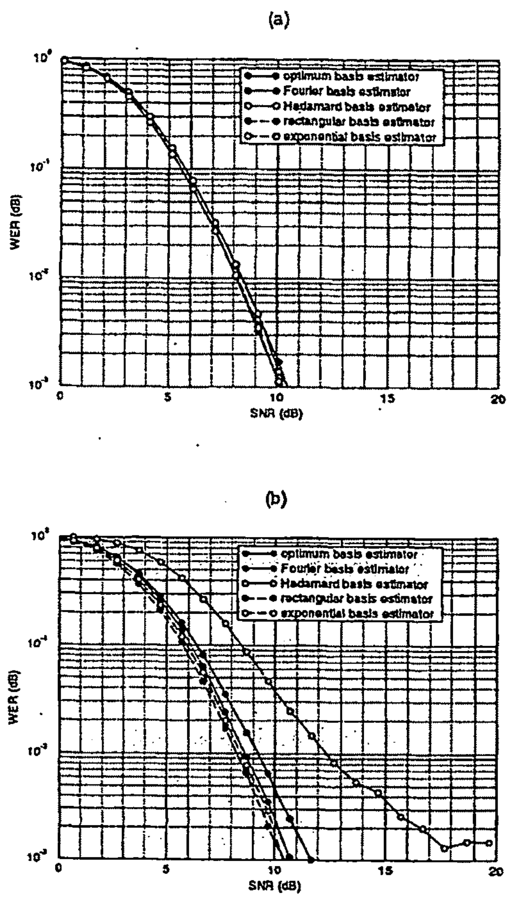

Fig. 6. WER versus SNR for 4-cluster-30-tone OFDM with different transform based estimators for (a) the TU and (b) the HT channel with $f_d = 40$ Hz.

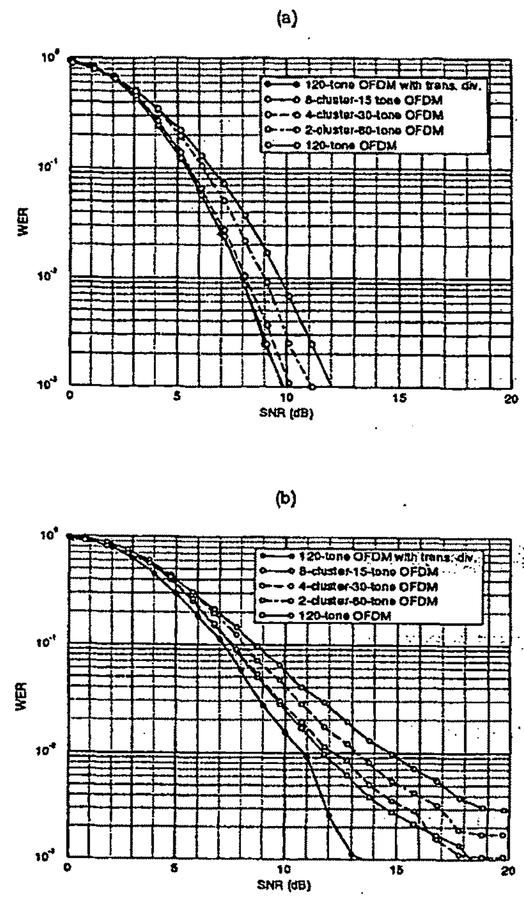

Fig. 7. WER versus SNR for OFDM with different cluster sizes for the TU channel with (a) $f_d = 40$ Hz and (b) $f_d = 200$ Hz, respectively.

transforms are robust to the channel delay profiles.

As indicated before, with an increase in the cluster size, the edge effects of the estimator with the Fourier transform will be reduced. Consequently, the degradation of the Fourier transform disappears when the cluster size is increased to 30 tones, as demonstrated by Fig. 6. Hence, for clustered OFDM with cluster size less than 30 tones, the rectangular or exponential transforms should be used for better channel parameter estimation; however, for clustered OFDM with a larger cluster size, performance degradation due to the edge effects of the Fourier transform is negligible, therefore, it should be used since the fast Fourier transform (FFT) can be utilized for low complexity computation.

B.2 OFDM with different cluster sizes

Figures 7 and 8 demonstrate the WER's of clustered OFDM systems with different numbers of clusters and environments, and compare them with a classical OFDM system with delayed transmitter diversity [4]. From the figures, the performance of the clustered OFDM systems improves with an increasing number of clusters. From Fig. 7, for the TU channel with $f_d = 40$ Hz, the WER's of clustered OFDM with 8 and 4 clusters are the same as the WER of classical OFDM with the delayed transmission diversity. In particular, compared with classical

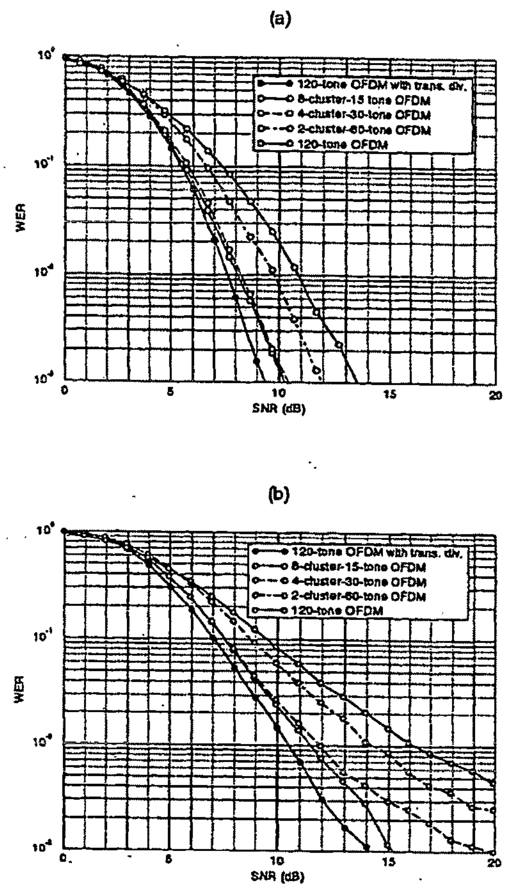

Fig. 8. WER versus SNR for OFDM with different cluster sizes for the HT channel with (a) $f_d = 40$ Hz and (b) $f_d = 200$ Hz, respectively.

OFDM without transmitter diversity, the required SNR's for 10% and 1% WER's are improved by 1 dB and 1.6 dB, respectively. For the HT channel, an over 2 dB improvement can be obtained by using clustered OFDM with 8 or 4 clusters instead of classical OFDM, as shown by Fig. 8.

V. Conclusions

In this paper, we have presented new transforms for channel estimation used in clustered OFDM to mitigate edge effects of the discrete Fourier transform in classical OFDM. Computer simulation shows that clustered OFDM with the new transform based estimator can be used for high-rate data access over wideband mobile wireless channels. The performance of clustered OFDM without transmitter diversity is as good as classical OFDM with delayed transmitter diversity. The required SNR for a 10% WER is about 5.5 dB for the TU or HT channel with low Doppler frequency, and 7.5 dB for the TU or HT channel with Doppler frequency as large as 200 Hz.

Acknowledgement

We would like to thank L. Cimini and J. Chuang for their comments.

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(Translation)

Issuance Date: April 28, 2006
Submission Due Date: June 28, 2006

THE KOREAN INTELLECTUAL PROPERTY OFFICE
NOTICE OF GROUNDS FOR REJECTION

Applicant	:	ADAPTIX, INC.
Agency	:	Koreana Patent Firm
Application No.	:	Korean Patent Application No. 2003-7007962
Title of Invention:		MULTI-CARRIER COMMUNICATIONS WITH GROUP-BASED SUBCARRIER ALLOCATION

This application shall be rejected on the following grounds pursuant to Article 63 of the Korean Patent Law. If you have any objection, please submit an Argument or Amendment to the KIPO by **June 28, 2006**. (The term can be extended by one month each, however, a separate Acknowledgement of Extension of Time will not be issued.)

GROUNDS FOR REJECTION

1. The present application does not satisfy the requirement of Article 45 of the Korean Patent Law as shown below and thus cannot be patented.

[below]

Claims 1-24 of the present application relates to a method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA) comprising:
Partitioning subcarriers into a plurality of groups of at least one cluster of subcarriers; and
Allocating at least one cluster in the one or more groups of clusters selected by the subcarrier.

Claims 25-31 of the present application relate to a cellular network, comprising allocating the channels of each base station in each of the plurality of cells or allocating groups of clusters.

The present invention consists of such two different invention groups as above, and thus it does not satisfy the one invention one patent application rule under Article 45 of the Korean Patent Law (The present application can be filed as divisional application under Article 52 of the Korean Patent Law).

2. The inventions of claims 1-24 of the present application can be easily invented from prior art by a skilled person in the art and thus cannot be patented under Article 29(2) of the Korean Patent Law.

[Below]

Claims 1-24 of the present invention relate to a multicarrier OFDM system with group-based subcarrier allocation.

However, the present invention can be easily invented by a skilled person in the art from a technical combination of cited inventions 1 and 2 or cited inventions 1 and 3 as shown below:

A. Constitution

(1) Claims 1-13, 15-21 and 23-24

Claims 1-24 of the present application relate to a method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA), characterized by comprising partioning subcarriers into a plurality of groups of at least one cluster of subcarriers and allocating at least one cluster in the one or more groups of clusters selected by the scubcarrier.

However, this constitution can be easily derived by a skilled person in the art from a combination of cited invention 1 disclosing a constitution of selecting subcarriers for the OFDM system which partitions subcarriers into a plurality of groups of clusters and allocates said clusters, and cited invention 2 relating to a method for selecting subcarriers, characterized in that a feedback information on each cluster group comprises SINR information on each cluster.

(2) Claims 14 and 22

Claims 14 and 22 of the present application relates to a constitution of a method for selecting subcarriers further comprising a step wherein, in the system employing OFDMA, feedback information on at least one or more cluster groups of subcarriers is received from the subscriber.

However, this constitution can be easily derived by a skilled person in the art from a combination of the constitution of cited invention 1 above, and the constitution of cited invention 3 wherein a group idenfier of the feedback information comprises a group index.

B. Object and Effect

The object and effect of the present invention are in the OFDMA system that can adaptively allocate subcarriers to subscribers; however, a technique derived from the combination of cited inventions 1 and 2 or 1 and 3 can achieve the same object and effect based on the similar constitution.

C. Conclusion

Thus, claims 1-24 of the present invention can be easily invented by a skilled person in the art from prior art as shown above.

[Attachment]
Attached 1 A copy of US Patent No. 05726978 (March 10, 1998)
Attached 2 A copy of EP 00999658
Attached 3 A copy of US Patent No. 05280630 (January 18, 1994). END.

Dated April 28, 2006

Electric & Electronic Examination Bureau
of Korean Intellectual Property Office

Examiner(s)-in-charge Hwan-Cheol YOO

PTO/SB/21 (09-04)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	11/199,586-Conf. #1128
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	2661
Examiner Name	Not Yet Assigned
Attorney Docket Number	68144/P014C1/10503148

Total Number of Pages in This Submission: 7

ENCLOSURES (*Check all that apply*)

- [ ] Fee Transmittal Form
  - [ ] Fee Attached
- [ ] Amendment/Reply
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
- [ ] Express Abandonment Request
- [x] Information Disclosure Statement
- [ ] Certified Copy of Priority Document(s)
- [ ] Reply to Missing Parts/ Incomplete Application
  - [ ] Reply to Missing Parts under 37 CFR 1.52 or 1.53
- [ ] Drawing(s)
- [ ] Licensing-related Papers
- [ ] Petition
- [ ] Petition to Convert to a Provisional Application
- [ ] Power of Attorney, Revocation Change of Correspondence Address
- [ ] Terminal Disclaimer
- [ ] Request for Refund
- [ ] CD, Number of CD(s) ______
  - [ ] Landscape Table on CD
- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC (**Appeal Notice, Brief, Reply Brief**)
- [ ] Proprietary Information
- [ ] Status Letter
- [x] Other Enclosure(s) (please Identify below):

SB-08 (4 pages)
Return Postcard (1)
6 out of 21 references cited

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	FULBRIGHT & JAWORSKI L.L.P.		
Signature	R. R. Vi		
Printed name	R. Ross Viguet		
Date	July 26, 2006	Reg. No.	42,203

Information Disclosure Statement Transmittal

I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being deposited with the U.S. Postal Service as First Class Mail, on the date shown below in an envelope addressed to:
MS Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Dated: July 26, 2006 Signature: ______________________ (Phyllis Ewing)

IFW

Docket No.:
68144/P014C1/10503148
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Xiaodong Li et al.

Application No.: 11/199,586

Confirmation No.: 1128

Filed: August 8, 2005

Art Unit: 2661

For: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

Examiner: Not Yet Assigned

INFORMATION DISCLOSURE STATEMENT (IDS)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Pursuant to 37 CFR 1.56, 1.97 and 1.98, the attention of the Patent and Trademark Office is hereby directed to the references listed on the attached PTO/SB/08. It is respectfully requested that the information be expressly considered during the prosecution of this application, and that the references be made of record therein and appear among the "References Cited" on any patent to issue therefrom.

This Information Disclosure Statement is filed before the mailing date of a first Office Action on the merits as far as is known to the undersigned (37CFR 1.97(b)(3)).

Copies of the references on the PTO/SB/08 are not provided.

Those documents which are marked with a double asterisk (**) next to the Cite No. in the attached form PTO/SB/08 are not supplied because they were previously cited by or submitted to the Office in prior application numbers 09/738,086, filed December 15, 2000, 09/837,701, filed April 17, 2001, and 09/837,337, filed April 17, 2001 and relied upon in this application for an earlier filing date under 35 U.S.C. 120.

In accordance with 37 CFR 1.97(g), the filing of this Information Disclosure Statement shall not be construed to mean that a search has been made or that no other material information as defined in 37 CFR 1.56(a) exists. In accordance with 37 CFR 1.97(h), the filing of this Information Disclosure statement shall not be construed to be an admission that any patent, publication or other information referred to therein is "prior art" for this invention unless specifically designated as such.

It is submitted that the Information Disclosure Statement is in compliance with 37 CFR 1.98 and the Examiner is respectfully requested to consider the listed references.

Applicant believes no fee is due with this response. However, if a fee is due, the Director is hereby authorized to charge any deficiency in the fees filed, asserted to be filed or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our Deposit Account No. 06-2380, under Order No. 68144/P014C1/10503148.

Dated: July 26, 2006

Respectfully submitted,

By [signature]

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Substitute for form 1449A/PTO	Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	11/199,586
	Filing Date	August 8, 2005
	First Named Inventor	Xiaodong Li
(use as many sheets as necessary)	Art Unit	2661
	Examiner Name	Not Yet Assigned
Sheet 1 of 4	Attorney Docket Number	68144/P014C1/10503148

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(use as many sheets as necessary)

Sheet	2	of	4

Complete if Known	
Application Number	11/199,586
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	2661
Examiner Name	Not Yet Assigned
Attorney Docket Number	68144/P014C1/10503148

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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

[1] Applicant's unique citation designation number (optional). [2] See attached Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the application number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

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Examiner Signature		Date Considered	

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Sheet 3 of 4

Complete if Known	
Application Number	11/199,586
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	2661
Examiner Name	Not Yet Assigned
Attorney Docket Number	68144/P014C1/10503148

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Examiner Signature		Date Considered	

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U. S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Substitute for form 1449A/PTO				Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Application Number	11/199,586
				Filing Date	August 8, 2005
				First Named Inventor	Xiaodong Li
				Art Unit	2661
(use as many sheets as necessary)				Examiner Name	Not Yet Assigned
Sheet	4	of	4	Attorney Docket Number	68144/P014C1/10503148

	CS	Ye Li et al.; "Clustered OFDM with Channel Estimation for High Rate Wireless Data"; Mobile Multimedia Communications, 1999. (MoMuC'99) 1999 IEEE International Workshop on Nov. 15-17, 1999; pages 43-50.	
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached.

Examiner Signature		Date Considered	

25678792.1

1144 IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 44, NO. 9, SEPTEMBER 1996

CD3-OFDM: A Novel Demodulation Scheme for Fixed and Mobile Receivers

Vittoria Mignone and Alberto Morello

Abstract— This paper describes a novel channel estimation scheme identified as coded decision directed demodulation (CD3) for coherent demodulation of orthogonal frequency division multiplex (OFDM) signals making use of any constellation format [e.g., quaternary phase shift keying (QPSK), 16-quadrature amplitude modulation (QAM), 64-QAM]. The structure of the CD3-OFDM demodulator is described, based on a new channel estimation loop exploiting the error correction capability of a forward error correction (FEC) decoder and frequency and time domain filtering to mitigate the effects of noise and residual errors. In contrast to the conventional coherent OFDM demodulation schemes, CD3-OFDM does not require the transmission of a comb of pilot tones for channel estimation and equalization, therefore yielding a significant improvement in spectrum efficiency (typically between 5–15%). The performance of the system with QPSK modulation is analyzed by computer simulations, on additive white Gaussian noise (AWGN) and frequency selective channels, under static and mobile reception conditions. For convolutional coding rate 1/2, the results indicate that CD3-OFDM allows to achieve a very fast adaptation to the channel characteristics in a mobile environment (maximum tolerable Doppler shift of about 80 Hz for an OFDM symbol duration of 1 ms, as differential demodulation) and an E_b/N_o performance similar to coherent demodulation (e.g., $E_b/N_o = 4.3$ dB at bit-error rate (BER) $= 2 \cdot 10^{-4}$ on the AWGN channel). Therefore, CD3-OFDM can be suitable for digital sound and television broadcasting services over selective radio channels, addressed to fixed and vehicular receivers.

I. Introduction

Digital sound and television broadcasting over the terrestrial VHF and UHF radio channels require to adopt a single transmission format suitable to serve both fixed and mobile receivers in a multipath propagation environment, affected by frequency selective fading and Doppler effects. Coded orthogonal frequency division multiplex (C-OFDM) modulation schemes [1]–[5], making use of a guard interval to separate adjacent symbols, are often proposed for video and sound broadcasting applications because of their excellent performance under multipath propagation. These modulation schemes are based on the transmission of thousands of modulated carriers, frequency multiplexed with the minimum frequency spacing to achieve orthogonality. Since the total bitstream is split in many parallel low-rate channels, C-OFDM is characterized by long symbol duration (typically from some hundred microseconds to few milliseconds, depending on the application), and therefore the channel estimation and tracking in a mobile environment must be carried out within few (possibly one) symbols.

Paper approved by J. Chuang, the Editor for Wireless Networks of the IEEE Communications Society. Manuscript received July 10, 1995; revised December 11, 1995.

The authors are with RAI, Radiotelevisione Italiana, Research Centre, Torino, I-10135, Italy.

Publisher Item Identifier S 0090-6778(96)07077-8.

Section II describes the conventional demodulation systems adopted with C-OFDM, namely coherent demodulation based on pilot tones and differential demodulation.

Coherent demodulation allows optimum detection of C-OFDM signals using M-quadrature amplitude modulation (M-QAM) constellations, on additive white gaussian noise (AWGN) and on frequency selective channels. The transmitted C-OFDM frame usually contains, in addition to some time and frequency synchronization symbols, a comb of unmodulated pilot tones, which are interpolated and filtered by the receiver to estimate the channel frequency response across the signal bandwidth, and to recover, by means of a single stage equalizer, the amplitude and phase rotation of each single constellation of the OFDM signal. The insertion of these pilot tones leads to a significant loss in transmission capacity. Conversely, differential demodulation of C-OFDM signals based on differentially-encoded phase shift keying constellations (DCPSK) does not require the transmission of pilot tones, and allows good tracking capability of the channel characteristics and demodulator simplicity, but at the expense of the sensitivity to noise [6].

In Europe, differential demodulation of C-OFDM DC-quaternary phase shift keying (QPSK) has been standardized in DAB [7], the digital sound broadcasting system for fixed and vehicular reception, while coherent demodulation of C-OFDM QPSK/16QAM/64QAM, based on the insertion of pilot tones, has been proposed for the future digital terrestrial television broadcasting Standard [8].

Section III describes the novel CD3-OFDM channel estimation scheme applicable for coherent demodulation of any constellation format (e.g., QPSK, 16QAM, 64QAM). This feedback channel estimation loop exploits the error correction capability of a forward error correction (FEC) decoder and frequency and time domain filtering, without requiring the transmission of a comb of pilot tones. In [9] and [10], decision feedback channel estimation and equalization techniques are evaluated for single carrier systems, but without the exploitation of FEC correction and noise filtering.

Section IV reports computer simulation results on a QPSK CD3-OFDM system, making use of convolutional coding (rates 1/2, 3/4, and 7/8) and soft-decision Viterbi decoding. These results, covering AWGN and frequency selective multipath channels, show that CD3-OFDM allows a very fast

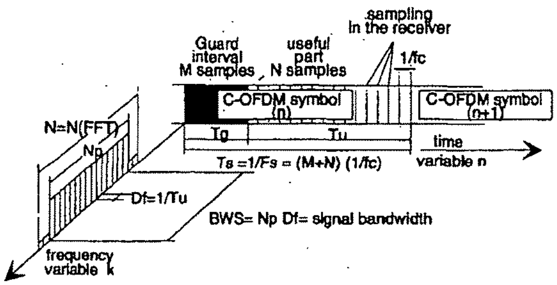

Fig. 1. Time and frequency domain representation of a C-OFDM symbol.

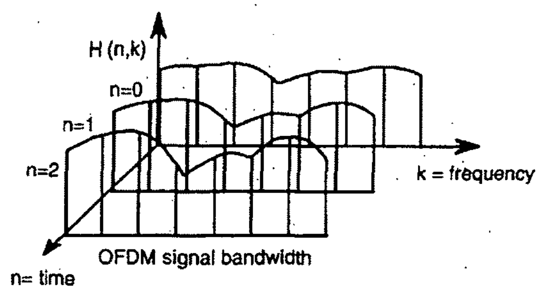

Fig. 2. Frequency and time domain representation of $H(n, k)$.

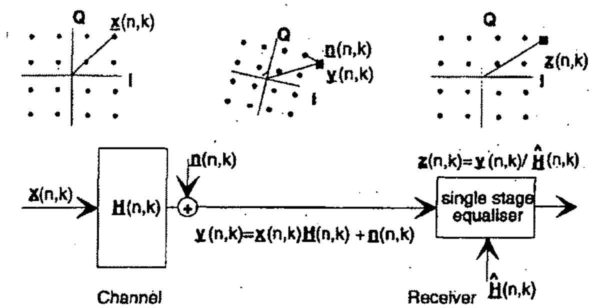

Fig. 3. Channel effect on a single OFDM carrier and equalization in the receiver.

adaptation to the channel characteristics in a mobile environment (within one OFDM symbol, as differential demodulation) and a C/N performance similar to ideal coherent demodulation with pilot tones. In addition, the simulations show the stability of the feedback loop also in the presence of high residual BER levels.

II. Principles of Conventional Coherent and Differential Demodulation for OFDM

C-OFDM systems [1]–[3] (see the Appendix for a symbol list and for relevant formulas) split the total information stream into N_p narrow-band, low bit-rate, digital signals, regularly multiplexed in the frequency domain (Fig. 1). Mutual orthogonality is guaranteed for carrier spacing equal to the useful symbol rate $1/T_u$.

This modulation system is inherently robust against frequency selective fading produced by the terrestrial multipath radio channel, since the narrow-band subcarriers occupy small portions of the spectrum, where the channel frequency response is "locally flat" and nondistorting. The ruggedness of C-OFDM systems against echoes is also based on the presence of a time guard interval (with duration T_g) separating adjacent OFDM symbols. From the $M + N$ complex samples corresponding to a symbol, the receiver discards the M samples of the guard interval, so that echoes reaching the receiver with a delay τ shorter than T_g do not produce intersymbol interference (ISI). In addition to the guard interval, C-OFDM systems make use of powerful error correction schemes, allowing to reconstruct the information transported by those carriers which are destroyed by frequency selective fading.

The elementary transmitted signal, over the OFDM symbol n (time domain index) and the individual carrier k (frequency domain index), can be written as

$$\boldsymbol{x}(n,k) = x(n,k)e^{j\Phi}(n,k)$$

(complex envelope representation)

where Φ (n,k) represents the phase information and $x(n,k)$ the amplitude information.

The channel frequency response

$$\boldsymbol{H}(n,k) = H(n,k)e^{j\Theta}(n,k)$$

although approximately constant in the bandwidth of each C-OFDM carrier, can be variable throughout the total signal bandwidth (index k), and also in time (index n), depending on the moving obstacles around the receiver and on the receiver motion (see Fig. 2). In the following, it is assumed that $\boldsymbol{H}$ is quasistationary during the C-OFDM symbol period and that it is slowly changing over several periods.

The elementary complex received signal $\boldsymbol{y}(n,k)$ [after C-OFDM demodulation by fast Fourier transform (FFT)] is a replica of the transmitted signal $\boldsymbol{x}(n,k)$ multiplied by the channel frequency response, plus a complex narrow band Gaussian noise component $\boldsymbol{n}(n,k)$ (see Fig. 3)

$$\begin{aligned}\boldsymbol{y}(n,k) &= \boldsymbol{x}(n,k)\cdot \boldsymbol{H}(n,k) + \boldsymbol{n}(n,k)\\ &= x(n,k)\cdot H(n,k)\cdot e^{j[\Phi(n,k)+\Theta(n,k)]} + \boldsymbol{n}(n,k). \quad (1)\end{aligned}$$

Coherent demodulation requires the estimation (indicated with ^) of the channel frequency response $\boldsymbol{H}(n,k)$, so that the signal can be equalised as follows:

$$\begin{aligned}\boldsymbol{z}(n,k) &= \boldsymbol{y}(n,k)/\hat{\boldsymbol{H}}(n,k)\\ &\approx x(n,k)\cdot e^{j[\Phi(n,k)]} + \boldsymbol{\nu}(n,k) \quad (2)\end{aligned}$$

where $\boldsymbol{\nu}(n,k) = \boldsymbol{n}(n,k)/\hat{\boldsymbol{H}}(n,k)$.

A. The "Pilot Tones" Solution

The estimation of $\boldsymbol{H}(n,k)$ can be achieved [8] by introducing a number of pilot tones in the C-OFDM symbol. Under typical operation conditions, the duration of the channel impulse response $\boldsymbol{h}(t)$ should be limited to the guard interval T_g ($T_g = M/f_c, f_c$ = sampling frequency in the time domain = N/T_u). Therefore, the channel frequency response can be sampled in

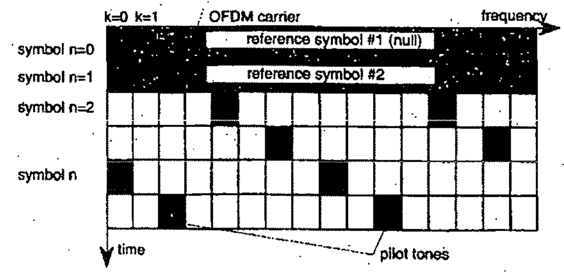

Fig. 4. Example of C-OFDM frame with $Dk = 1/2$ and $Dn = 1/4$.

the frequency domain with "minimum sampling frequency" $T_g = M/f_c$ (Sampling theorem applied to the frequency domain) or with sample spacing $1/T_g = f_c/M$. Since the carrier spacing in C-OFDM is $1/T_u = f_c/N$, a theoretical subsampling factor N/M can be applied in the frequency domain (reducing the number of pilot carriers accordingly), while keeping the possibility to reconstruct $H(n,k)$ for any k (sample spacing $1/T_u$) by ideal interpolation

$$H(n,k) = H_s(n,k) * (M/N)\,\mathrm{sinc}(k\pi M/N)e^{-jk\pi M/N} \quad (3)$$

where $\mathrm{sinc}(x) = \sin(x)/x$ and H_s is the subsampled frequency response.

In practical cases, the density of the pilot carriers in the frequency domain Dk is higher than M/N (e.g., $Dk = 2M/N$), to allow aliasing-free interpolation through a nonideal digital low-pass filter. If the time variations of $H(n,k)$ are sufficiently slow, also a time domain subsampling can be introduced, by spreading the required pilots over several OFDM symbols. Indicating with Dn the pilot density in the time domain, the system efficiency relevant to the pilot tones is

$$\eta_p = 1 - (Dk \cdot Dn).$$

To improve the channel estimation performance, the pilot tones can be boosted over the data carrier average power density. Since the power transmitted on the pilot tones is subtracted from the useful data, an E_b/N_o loss (indicated as ε) is expected at a given residual BER

$$\varepsilon = 10\log\left[\frac{\eta_p(1-\beta)+\beta}{\eta_p}\right] \quad (4)$$

where β is the amplification factor of the pilot tones over the data carriers (e.g., $\beta = 1$ for nonboosted pilots, $\beta = 2$ for 3 dB boosted pilots).

Fig. 4 shows an example of C-OFDM frame with two reference symbols (for timing and frequency synchronization) and a comb of pilot tones with $\eta_p = 7/8$.

A first method to recover the channel response in the receiver is to store the pilots over $1/Dn$ OFDM symbols, and to apply frequency domain interpolation, but more sophisticated techniques can be adopted to improve the receiver tracking speed, based on time and frequency domain interpolation.

B. The Differential Demodulation Solution

In DC-PSK, the transmitted information is not associated to the absolute phase of a transmitted sample, but to the phase difference between two samples transmitted at the same frequency position in two adjacent OFDM symbols: $\Delta\Phi(n,k) = \Phi(n,k) - \Phi(n-1,k)$.

The differential demodulation rule is the following (with $x(n) = 1 \forall n$):

$$z(n,k) = \frac{y(n,k)}{y(n-1,k)} \approx e^{j[\Delta\Phi(n,k)]} + \eta(n,k) \quad (5)$$

where η is a "noise" component. The last equality holds if the channel response $H(n,k)$ is quasistationary during two OFDM symbols, and if the noise component $n(n,k)$ is sufficiently small.

Compared to coherent demodulation with pilot tones, differential demodulation allows a significant simplification of the demodulator and an increase of the spectrum efficiency (assuming the same modulation and channel coding scheme) due to the absence of pilot tones for channel estimation. In addition, fast tracking of the channel characteristics is achieved, but at the expense of an E_b/N_o performance loss, due to the noisy demodulation reference. A further limitation of this demodulation method is that rotational symmetry is required in the constellation (points placed over one or more circles), such as in M-PSK or DAPSK [11].

III. CD3 Demodulation Principles

A. Demodulation with a Known Reference Sequence

In the case where the transmitted OFDM symbol at time $n-1$ was known "*a priori*" by the receiver (reference sequence), the channel frequency response could be obtained by dividing the received signal $y(n-1,k)$ in (1) by the transmitted signal $x(n-1,k)$

$$\begin{aligned}\hat{H}(n-1,k) &= y(n-1,k)/x(n-1,k)\\ &= H(n-1,k) + \varepsilon(n-1,k)\end{aligned} \quad (6)$$

where $\varepsilon(n-1,k) = n(n-1,k)/x(n-1,k)$ is a Gaussian noise component, depending also on the amplitude of the transmitted signal $x(n-1,k)$. Therefore, in the case of nonconstant envelope constellations (i.e., 16QAM and 64QAM) the noise level associated to the channel estimation changes from sample to sample.

Once $\hat{H}(n-1,k)$ is derived, the equalization of the successive symbol can be easily obtained by (2), assuming that the channel frequency response is quasistationary over the two symbols $n-1$ and n

$$z(n,k) = y(n,k)/\hat{H}(n-1,k) \approx x(n,k) + \nu(n,k). \quad (7)$$

As already explained, in OFDM systems $H(n,k)$ is oversampled in the frequency domain by a factor of N/M, while the noise components $\varepsilon(n,k)$ are statistically independent

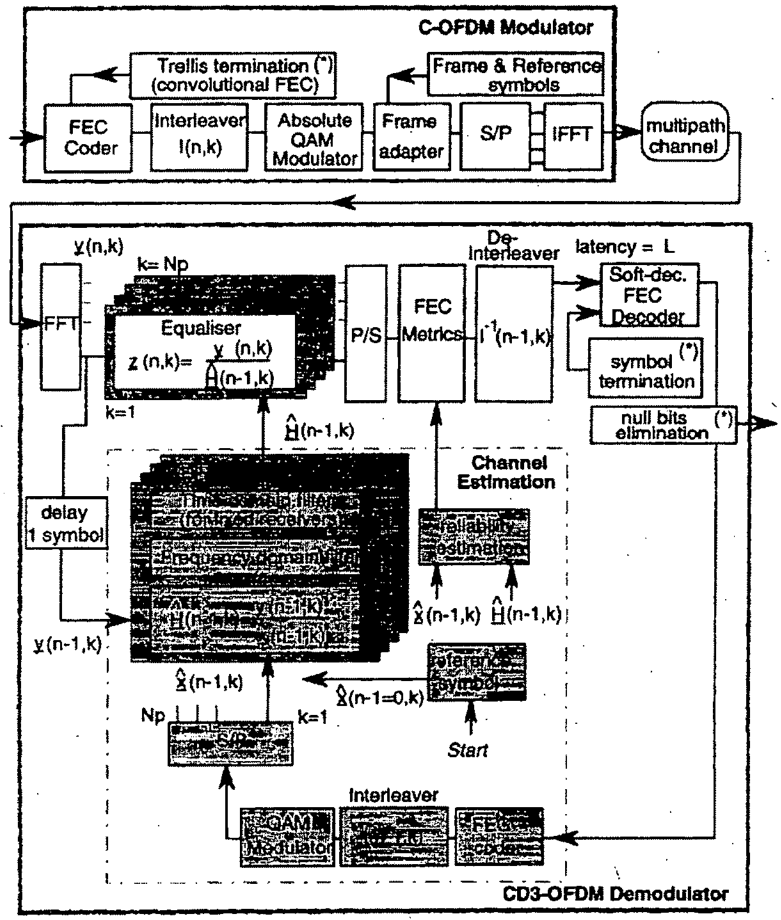

Fig. 5. Basic scheme of a CD3-OFDM modem.

throughout k. Therefore, the channel frequency response can be "low-pass filtered" in the frequency domain to average the noise component, $\varepsilon(n, k)$, with a filter which should be "flat" in the time domain over an interval equal to T_g. For example, the ideal window filter as in (3) can be used, giving a C/N improvement on $\hat{H}(n, k)$ of $10 \log(N/M)$ dB.

If $\hat{H}(n, k)$ is filtered neither in the frequency domain nor in the time domain, the same E_b/N_o versus BER performance as differential demodulation is achieved, since the channel estimation sample $\hat{H}(n-1, k)$ is as noisy as the signal $y(n, k)$ to be demodulated. In the case of frequency-domain filtering, assuming $N/M = 4$ and QPSK modulation, the C/N improvement on $\hat{H}(n, k)$ is of 6 dB. With additional time-domain filtering (according to the channel variation speed) the E_b/N_o versus BER performance of ideal coherent demodulation can be approached.

In conclusion, the demodulation method based on (6) and (7) could offer good performance over noisy channels, but to achieve high channel tracking speed it would require the transmission of a large percentage of reference OFDM symbols.

B. "Coded Decision-Directed" Reconstruction of the Transmitted Sequences

To overcome the need for transmission of reference sequences as described in Section III-A, other kinds of reliable estimation of $x(n-1, k)$ must be devised.

The basic block diagram of the proposed coded decision-directed demodulation (CD3) scheme is given in Fig. 5.

The CD3-OFDM process can be described by the following steps.

Step 0) Start the decoding process from a reference sequence $x(n = 0, k)$.

Step 1) Perform the channel estimation according to (6)

$$\hat{H}(n-1, k) = y(n-1, k)/x(n-1, k).$$

Step 2) Filter the channel estimation $\hat{H}(n-1, k)$ in the frequency domain (and, if required, in the time domain) to reduce the noise components.

Step 3) Equalize the successive C-OFDM symbol through (7)

$$z(n, k) = y(n, k)/\hat{H}(n-1, k).$$

Step 4) Reliable estimation of the transmitted sequence is achieved by exploiting the error correction capability of the FEC code over $z(n,k)$; this error correction process is anyhow present in C-OFDM systems to protect data, and does not increase the receiver complexity. The bit-stream after FEC correction is not only delivered to the user, but it is re-encoded and re-modulated to generate $\hat{x}(n,k)$.

Step 5) The estimated sequence $\hat{x}(n,k)$ after error correction is used in a "feedback loop" to perform the channel estimation relevant to the symbol n, according to Step 1), so that the process can continue symbol-by-symbol.

The core of the CD3-OFDM process is in Steps 4) and 1), allowing to up-date the channel estimation symbol-by-symbol and to exploit the error correcting capability of the FEC.

Using this process, the need to transmit pilot carriers, as well as additional training sequences, is in principle abolished.

C. CD3-OFDM Implementation Remarks

The CD3-OFDM demodulator could become unstable for high residual BER after FEC decoding, since the errors are reinjected into the equaliser through the feedback loop. When the number of reinjected errors becomes comparable to the number of channel-induced errors before FEC decoding, a rapid system breakdown can take place, until the reception of the next reference OFDM symbols. In reality, this instability effect does not take place at the levels of BER (after FEC decoding) of interest for many applications, provided that powerful error correcting schemes are adopted in combination with frequency domain filtering of $\hat{H}(n,k)$, allowing to attenuate the "spikes" produced by the residual errors in the feedback loop. Computer simulation tests, over AWGN and frequency selective channels (see Section IV), have indicated that punctured convolutional codes (64 states) with rates up to 7/8 and soft decision Viterbi decoding can assure full stability[1] for FEC-decoded BER's as high as $10^{-2} \div 10^{-3}$. These results have been achieved with QPSK constellation, about 7000 C-OFDM active carriers, frequency domain filtering (using the filter of (3), with $N/M = 4$), and no time domain filtering.

If the adopted FEC is a convolutional code, the L-samples latency introduced by the Viterbi decoder (typically $L \approx 100$ samples) would preclude a symbol-by-symbol decoding in a mobile environment. To solve this problem the following method can be used.

1) Transmitting side: the convolutional code is driven to the "0 state" at the end of each OFDM symbol ("the trellis is terminated"), by appending a stream of P null bits to the useful information to be encoded (P corresponding to the code memory). This process affects only marginally the transmission efficiency.
2) Receiving side: the samples belonging to an OFDM symbol are fed to the Viterbi decoder. At the end of the symbol, a number of additional samples (corresponding to the state zero of the encoder) are fed to the Viterbi decoder, which delivers the last decoded bits stored in its memory.

[1] The output BER remains stable over thousands of OFDM symbols without the need of periodical reset by reference sequences.

Since the trellis is terminated at the transmitting side, this process does not affect the error correction performance.

An alternative method to avoid the trellis termination replaces those samples $\hat{x}(n-1,k)$ which are still missing at the output of the Viterbi decoder with the uncorrected samples $z(n-1,k)$. Being these missing samples in a limited number compared to the total number of samples in an OFDM symbol, the total performance degradation is negligible.

To achieve good performance over frequency selective channels, the metrics computation for soft-decision FEC decoding should take into account the reliability of each C-OFDM carrier, which show different C/N levels depending on the selective attenuation. This is usually achieved by multiplying the samples (after equalization and de-mapping for high order modulations) by $|\hat{H}(n,k)|^2$, before applying Viterbi decoding.

The C-OFDM schemes usually make use of a "frequency interleaver" (see $I(n,k)$ in Fig. 5), to reduce the correlation between adjacent carriers in frequency selective channels. If the interleaving rule $I(n,k)$ is kept constant in adjacent OFDM symbols, an error burst after Viterbi decoding would be spread, in the CD3 loop, over distant OFDM carriers by the interleaver $I(n,k)$ and then remerged in a single burst by the de-interleaver $I^{-1}(n,k)$. The presence of these bursts would affect the Viterbi correction at the next symbol. Therefore, to achieve an efficient error spreading in the CD3 loop, it is advisable to adopt two (or more) different interleaving/de-interleaving rules, namely $I(1,k)$ for odd C-OFDM symbols and $I(2,k)$ for even symbols. It should be noted that the interleaver is very important also to improve the effectiveness of the frequency domain filter against the residual errors on $\hat{H}(n,k)$. In fact, the interleaver spreads the errors over distant C-OFDM carriers, and allows an efficient "correction" of the erroneous samples by means of the adjacent correct samples.

In sophisticated receivers, the time domain filter could be adaptive, to automatically choose between high channel tracking speed (short time averaging time) and effective noise filtering (long averaging time). This could be implemented by measuring the average variation V of $\hat{H}(n,k)$ over two adjacent symbols $n-1$ and $n-2$

$$V = \frac{1}{N_p} \sum_{k=1}^{N_p} |\hat{H}(n-2,k) - \hat{H}(n-1,k)|$$

and by choosing different time domain filter bandwidths as a function of V. Furthermore the measurement of V could allow to avoid loop instability effects in the presence of impulsive noise. When a symbol is destroyed by impulsive noise, V shows a sudden variation, and the receiver could perform equalization with an old version of $\hat{H}$ instead of the corrupted one. Similarly, the frequency domain filter bandwidth could be modified adaptively, according to the channel impulse response duration (maximum echo delay). In some OFDM receivers this function can be simply implemented, since the computation of $\hat{h}(t) = \Im^{-1}\{\hat{H}(n,k)\}$ is already performed for timing synchronization purposes.

The CD3 demodulation principles, with suitable modifications, are also applicable to implement differential demodulation of QPSK signals with absolute mapping, or coherent demodulation of differentially coded signals.

IV. Simulation Results on a CD3-OFDM System

A CD3-OFDM system has been simulated, assuming a signal bandwidth BWS = 7.5 MHz, a sampling frequency $f_c = 9.14$ MHz, 6875 useful carriers, no pilot tones, a guard interval with a duration of 224 μs (with $M/N = 1/4$), QPSK modulation, punctured convolutional coding (mother code with rate 1/2, 64 states) and soft-decision Viterbi decoding (3-bit samples quantization). To achieve good performance on frequency selective channels, metrics weighting has been performed by multiplying the samples after equalization by $|\hat{H}(n-1,k)|^2$. The very long guard interval adopted is suitable to handle natural echoes as well as "active" echoes generated by other synchronized transmitters (single frequency network configuration). The frequency domain filter is a sinc filter [see (3)] with "time domain bandwidth" of $1.2 \cdot T_g = 0.3 \cdot T_u$, implemented by means of a FIR filter with 199 taps. No time domain filtering is applied, and the channel estimation is performed symbol-by-symbol, to achieve a channel tracking speed comparable with differential demodulation. The C-OFDM frame is composed of 98 symbols, including a null symbol and a reference symbol. This choice was based on considerations of receiver lock-in time and not to avoid CD3 loop instabilities, which do not occur at the BER levels of interest (BER after Viterbi decoding lower than 10^{-3}). Pseudo-random frequency interleaving is adopted, with two different interleaving rules for odd and even OFDM symbols.

To allow a fair comparison with other demodulation schemes, ideal coherent demodulation without pilot tones and differential demodulation have also been simulated on the same channels. In the case of ideal coherent demodulation and stationary channel, the channel frequency response has been evaluated on a *noise-free* reference symbol.

In addition to the AWGN channel, three simple frequency selective channels have been implemented to compare the systems, namely channel "F," channel "P," and channel "M," representing elementary examples of "fixed" reception with directive antenna, "portable," and "mobile" reception with omnidirectional antenna, respectively. The three channels consist of a main path plus a single echo with a delay of 222 μs (inside the guard interval), with a power level below the main signal of 10 dB (channel "F"), 4 dB (channel "P"), and 0 dB (channel "M"). Since the echo delay is very long, a large number of periodic notches (more than 1600) is present in the signal bandwidth, so that the individual OFDM carriers experience different phase rotations and amplitude attenuations, corresponding to variable signal to noise ratios before Viterbi decoding. For the "F" and "P" channels, the echo phase is fixed (0 rad with respect to the main path), while for the "M" channel a Doppler frequency shift is included on the 0 dB echo, producing a rapid shift of the notches in the frequency domain, while the total received power remains constant [12]. Therefore, the static and the dynamic performance of the channel estimation algorithms is deeply tested by these simple channel models.

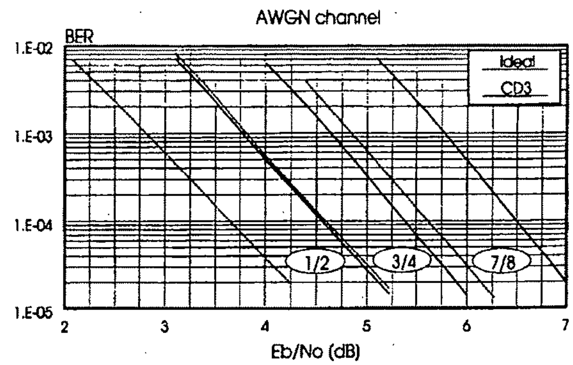

Fig. 6. CD3-OFDM performance over the Gaussian channel.

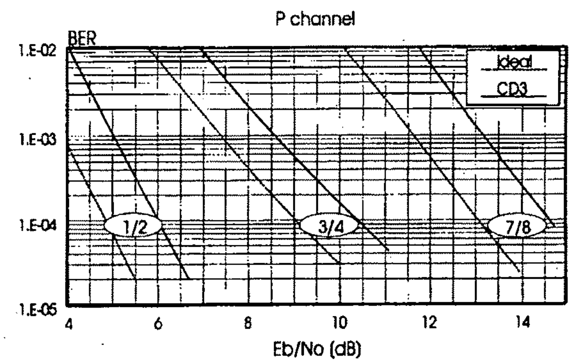

Fig. 7. CD3-OFDM performance over the "P" stationary channel.

Figs. 6 (AWGN channel) and 7 (channel "P") show the simulation results for stationary channels. The signal energy per bit at the receiver input, E_b, refers to the combination of the main path and the echo (for generality reasons, the figures do not include the losses due to guard interval, reference sequences and outer codes). The CD3-OFDM system (without time domain filtering) shows a degradation of the order of 1 dB compared with ideal coherent demodulation (without pilot carriers), due to the residual noise on $\hat{H}(n,k)$ (rather than to the errors in the feedback loop). This degradation can be recovered by time domain filtering. The figures clearly show the good performance and stability of the CD3-OFDM algorithm also at high residual BER's.

Table I summarizes the required E_{bu}/N_o [dB] (see (A-4) of the Appendix) over the stationary AWGN, F and P channels, for a residual BER of $2 \cdot 10^{-4}$ after Viterbi decoding.[2] The performance of the coherent system using pilot tones is derived from the simulation results of the ideal coherent

[2]This is a typical BER target after Viterbi decoding for digital television systems making use of a concatenated Reed-Solomon RS(255 239) outer code in addition to the convolutional inner code.

TABLE I
REQUIRED E_{bu}/N_o AT BER $= 2 \cdot 10^{-4}$ OF CD3 DEMODULATION FOR STATIONARY RECEPTION

inner code rate	channel type	CD3-OFDM (*) E_{bu}/N_o [dB]	Ideal coherent + pilots E_{bu}/N_o [dB]	differential DC-QPSK E_{bu}/N_o [dB]
1/2	AWGN	5.7	5.9	7.7
	F	6.2	6.3	8.1
	P	7.1	7.1	9.7
3/4	AWGN	6.6	6.8	8.3
	F	7.6	7.8	9.3
	P	11.2	11.0	12.6
7/8	AWGN	7.7	7.9	9.5
	F	9.5	9.7	11.2
	P	15.6	15.2	16.8

system (perfect channel estimation on a noise-free reference symbol), and include an additional E_b/N_o loss of $\varepsilon \cong 1.1$ dB [see (4) with $\eta_p = 7/8$ and $\beta = 2$, corresponding to 3 dB boosted pilot tones]. For real coherent systems this degradation is optimistic, since also in this case the channel estimation is affected by noise, and a further E_b/N_o loss is to be expected.

These results confirm the excellent performance of CD3-OFDM, comparable with ideal coherent demodulation with pilot carriers in all the analyzed configurations, even without time domain filtering.

It should be noted that a guard interval duration of $T_u/4$ is a limit situation, while for $T_g < T_u/4$ the performance of CD3 and of the coherent system with pilot tones can be improved. In fact, in this case CD3 can use a lower bandwidth in the frequency domain filter, to achieve a better E_b/N_o performance, while the coherent system can use a reduced pilot density, to obtain a better spectrum efficiency and a lower E_b/N_o loss ε [see (4)].

Additional simulations have been carried out to check the CD3-OFDM system performance (rate 1/2 code, no time domain filtering and symbol-by-symbol channel estimation) under mobile reception conditions on the "M" channel. Fig. 8 compares the E_b/N_o performance of CD3-OFDM with differential demodulation, at a residual BER $= 2\cdot 10^{-4}$, for different Doppler frequency shifts. In these conditions, CD3 shows an E_b/N_o gain over differential demodulation of about 2 dB and similar channel tracking speed.

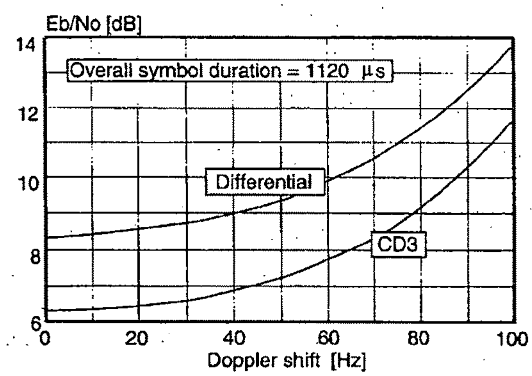

Fig. 8. CD3 and D-QPSK OFDM performance over the mobile "M" channel.

The additional complexity of CD3-OFDM is small compared with conventional coherent C-OFDM demodulation, since only the channel estimation is modified. To achieve the maximum channel tracking speed in mobile receivers, channel estimation should be repeated every OFDM symbol, but this requires also an increase of computation speed within the CD3 feedback loop. When the channel time-variations are slower (fixed receivers), the channel estimation loop could accept longer delays, so that the receiver processing speed can be similar to that of a conventional C-OFDM receiver.

V. CONCLUSION

C3-OFDM is a new channel estimation concept for C-OFDM systems, applicable to any constellation shape (e.g., QPSK, 16QAM, 64QAM). It is based on an efficient symbol-by-symbol channel estimation loop including the error correction capability of FEC codes. The system offers fast tracking of the channel characteristics in mobile receivers (similar to differential demodulation), and excellent C/N performance in fixed and mobile receivers (comparable with coherent demodulation). As it exploits the decoded data stream for channel estimation, CD3-OFDM does not require the transmission of pilot carriers for coherent demodulation, with a significant increase of the spectrum efficiency (typically between 5–15%).

APPENDIX
C-OFDM NOTATION AND FORMULAS

With reference to Fig. 1, the following notation is adopted.

- f_c Complex sampling frequency at transmitter and receiver.
- T_u Useful OFDM symbol duration.
- T_g Guard interval duration.
- Ts $T_u + T_g =$ total OFDM symbol duration.
- F_s $1/T_s =$ OFDM symbol rate.
- Df Carrier frequency spacing $= 1/T_u$.
- N $N(\text{FFT}) =$ total FFT points = number of complex samples in T_u.
- M Number of samples in T_g.
- N_p Number of active carriers (useful + pilot tones) in an OFDM symbol.
- K Number of useful data carriers in an OFDM symbol.

R_u Useful bit-rate.
BWS Transmitted signal bandwidth.
η_g $T_u/T_s = (T_s - T_g)/T_s = N/(N + M)$ = guard interval efficiency.
η_m Modulation spectral efficiency (bit/s/Hz).
η_c $\eta_{\text{outer}} \cdot \eta_{\text{inner}}$ = coding rate (efficiency) (inner and outer codes).
α Reference symbols efficiency = useful symbols per frame/total number of symbols per frame (including reference symbols).
η_p Pilot tones efficiency $= K/N_p$.
β Amplification factor of the pilots (e.g., $\beta = 2$ for 3 dB boosted pilots).

Useful Formulas:

$$R_u = \alpha \eta_p \eta_m \eta_c \eta_g \text{ BWS.} \quad \text{(A-1)}$$

The required E_{bu}/N_o [E_{bu} = energy per useful bit; $N_o/2$ = two-sided power spectral density (PSD) of AWGN noise] to achieve a target BER (e.g., BER $= 2 \cdot 10^{-4}$) after the inner decoder is given by

$$E_{bu}/N_o) = [E_b/N_o] + 10\log(1/\alpha\eta_g\eta_p\eta_{\text{outer}}) + 10\log[\eta_p(1-\beta)+\beta] \quad \text{(A-2)}$$

where E_b/N_o refers to the modulation and inner code only, the second term takes into account the spectrum efficiency losses due to reference symbols, guard interval, pilot tones, and outer code, and the last term refers to the boosting of the pilot tones [see (4)].

The required C/N (in a bandwidth B) is

$$\text{C/N} = [E_{bu}/N_o] + 10\log(R_u/B). \quad \text{(A-3)}$$

Taking B = BWS (receiver noise bandwidth)

$$C/N_{\text{BWS}} = [E_b/N_o] + 10\log(\eta_m\eta_{\text{inner}}) + 10\log[\eta_p(1-\beta)+\beta] \quad \text{(A-4)}$$

(the losses due to $\eta_{\text{outer}}, \alpha, \eta_p, \eta_g$ are included in the relevant bandwidth expansion).

Acknowledgment

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Multiuser OFDM with Adaptive Subcarrier, Bit, and Power Allocation

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***Abstract*—Multiuser orthogonal frequency division multiplexing (OFDM) with adaptive multiuser subcarrier allocation and adaptive modulation is considered. Assuming knowledge of the instantaneous channel gains for all users, we propose a multiuser OFDM subcarrier, bit, and power allocation algorithm to minimize the total transmit power. This is done by assigning each user a set of subcarriers and by determining the number of bits and the transmit power level for each subcarrier. We obtain the performance of our proposed algorithm in a multiuser frequency selective fading environment for various time delay spread values and various numbers of users. The results show that our proposed algorithm outperforms multiuser OFDM systems with static time-division multiple access (TDMA) or frequency-division multiple access (FDMA) techniques which employ fixed and predetermined time-slot or subcarrier allocation schemes. We have also quantified the improvement in terms of the overall required transmit power, the bit-error rate (BER), or the area of coverage for a given outage probability.**

***Index Terms*—Adaptive modulation, frequency selective fading channel, multiaccess communication, multiuser channel, orthogonal frequency division multiplexing (OFDM), resource management.**

I. Introduction

RECENTLY, intense interest has focused on modulation techniques which can provide broadband transmission over wireless channels for applications including wireless multimedia, wireless Internet access, and future-generation mobile communication systems. One of the main requirements on the modulation technique is the ability to combat intersymbol interference (ISI), a major problem in wideband transmission over multipath fading channels. There are many methods proposed to combat the ISI, e.g., [1]–[3]. Multicarrier modulation techniques, including orthogonal frequency division multiplex (OFDM), (e.g., [4]) are among the more promising solutions to this problem.

Assuming that the transmitter knows the instantaneous channel transfer functions of all users, many papers [5]–[7] have demonstrated that significant performance improvement can be achieved if adaptive modulation is used with OFDM. In particular, subcarriers with large channel gains employ higher order modulation to carry more bits/OFDM symbol, while subcarriers in deep fade carry one or even zero bits/symbol. Integrated design of forward error correcting code and adaptive modulation has also been studied using BCH code and trellis coded modulation (TCM) in [8] and [9], respectively. Although both references considered only time-varying flat fading channels, the same coded adaptive modulation design can be easily applied to OFDM systems. As different subcarriers experience different fades and transmit different numbers of bits, the transmit power levels must be changed accordingly. The problem of optimal power allocation has also been studied in [10].

In this paper, we consider extending OFDM with adaptive modulation to multiuser frequency selective fading environments. When OFDM with adaptive modulation is applied in a frequency selective fading channel, a significant portion of the subcarriers may not be used. These are typically subcarriers which experience deep fade and are not power efficient to carry any information bit. In multiuser systems using static time-division multiple access (TDMA) or frequency-division multiple access (FDMA) as multiaccess schemes, each user is allocated a predetermined time slot or frequency band to apply OFDM with adaptive modulation. Consequently, these unused subcarriers (as a result of adaptive modulation) within the allocated time slot or frequency band of a user are wasted and are not used by other users. However, the subcarriers which appear in deep fade to one user may not be in deep fade for other users. In fact, it is quite unlikely that a subcarrier will be in deep fade for all users, as the fading parameters for different users are mutually independent. This motivates us to consider an adaptive multiuser subcarrier allocation scheme where the subcarriers are assigned to the users based on instantaneous channel information. This approach will allow all the subcarriers to be used more effectively because a subcarrier will be left unused only if it appears to be in deep fade to all users.

We consider a multiuser subcarrier, bit, and power allocation scheme where all users transmit in all the time slots. Our objective is to minimize the overall transmit power by allocating the subcarriers to the users and by determining the number of bits and the power level transmitted on each subcarrier based on the instantaneous fading characteristics of *all* users. In this paper, we formulate the multiuser subcarrier, bit, and power allocation problem and propose an iterative algorithm to perform the multiuser subcarrier allocation. Once

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the subcarrier allocation is determined, the bit and power allocation algorithm can be applied to each user on its allocated subcarriers. We also compare the performance of our proposed solution to various other static subcarrier allocation schemes.

The results of the work can be applied, for instance, to the downlink transmission in a time division duplex (TDD) wireless communication system to improve the downlink capacity. In such a system, the base station (BS) can estimate the instantaneous channel characteristics of all the BS-to-mobile links based on the received uplink transmissions. The multiuser subcarrier, bit, and power allocation can then be used. It is clear that there is a certain amount of transmission overhead as the BS has to inform the mobiles about their allocated subcarriers and the number of bits assigned to each subcarrier.[1] However, this overhead can be relatively small, especially if the channels vary slowly (e.g., in an indoor low mobility environment), and the assignment is done once every many OFDM symbols. To further reduce the overhead, we can assign a contiguous band of subcarriers with similar fading characteristics as a group, instead of assigning each individual subcarrier. In this paper, we will not focus on how the subcarrier allocation information is transmitted. Instead, we will focus on how— and by how much—this new strategy can reduce the required transmit power; or how and by how much this new scheme can improve the bit-error rate (BER) for a fixed transmit power. Alternately, we also consider how and by how much this new scheme can increase the area of coverage for a given transmit power and target BER.

While the bit allocation algorithm can be viewed as a practical implementation of the water-pouring interpretation for achieving the Shannon capacity of an ISI channel [13], the multiuser subcarrier and bit allocation algorithm presented in this paper is the counterpart of the multiuser water-pouring solution given in [14]. In information theoretic studies, the usual approach is to maximize the capacity (or information rate) under the power constraint. In this study, we focus on deriving practical algorithms that can support real-time multimedia data whose bit rates are generally fixed by the compression algorithms. Hence, we assume a given set of user data rates and attempt to minimize the total transmit power under a fixed performance requirement.

The organization of this paper is as follows. In Section II, we will first give the system model and formulate the minimum overall transmit power problem. The optimization problem seeks to minimize the overall transmit power using combined subcarrier, bit, and power allocation schemes for multiuser OFDM systems. The bit and power allocation algorithm for a single-user system is studied in Section III. In Section IV, we derive a lower bound to the minimum overall transmit power by relaxing some of the constraints in the original problem. We also derive a suboptimal subcarrier allocation algorithm. In Section V, we compare the performance between our proposed method and other static approaches via Monte Carlo simulations. Finally, we conclude in Section VI.

[1] Note that the power level used does not need to be transmitted to the receiver in such a TDD system. As the subcarrier gain is known to the transmitter, it can adjust the transmit power level to achieve a predetermined receiver power level based on the number of bits allocated to that subcarrier. However, in FDD systems, the transmit power levels determined by the receiver have to be sent back to the transmitter. In such systems, the additional performance gain achieved by power allocation may not justify the cost of sending the transmit power level information to the transmitter.

II. System Model

The configuration of our multiuser adaptive OFDM system is shown in Fig. 1. We assume that the system has K users and the kth user has a data rate equal to R_k bit per OFDM symbol. In the transmitter, the serial data from the K users are fed into the subcarrier and bit allocation block which allocates bits from different users to different subcarriers. We assume that each subcarrier has a bandwidth that is much smaller than the coherence bandwidth of the channel and that the instantaneous channel gains on all the subcarriers of all the users are known to the transmitter. Using the channel information, the transmitter applies the combined subcarrier, bit, and power allocation algorithm to assign different subcarriers to different users and the number of bits/OFDM symbol to be transmitted on each subcarrier. Depending on the number of bits assigned to a subcarrier, the adaptive modulator will use a corresponding modulation scheme, and the transmit power level will be adjusted according to the combined subcarrier, bit, and power allocation algorithm. We define $c_{k,n}$ to be the number of bits of the kth user that are assigned to the nth subcarrier. As we do not allow more than one user to share a subcarrier, it follows that for each n, if $c_{k',n} \neq 0$, $c_{k,n} = 0$ for all $k \neq k'$. We also assume that the adaptive modulator allows $c_{k,n}$ to take values in the set $\mathrm{D} = \{0, 1, 2, \ldots, M\}$ where M is the maximum number of information bits/OFDM symbol that can be transmitted by each subcarrier.

The complex symbols at the output of the modulators are transformed into the time domain samples by inverse fast Fourier transform (IFFT). Cyclic extension of the time domain samples, known as the guard interval, is then added to ensure orthogonality between the subcarriers, provided that the maximum time dispersion is less than the guard interval. The transmit signal is then passed through different frequency selective fading channels to different users.

We assume that the subcarrier and bit allocation information is sent to the receivers via a separate control channel. At the receiver, the guard interval is removed to eliminate the ISI, and the time samples of the kth user are transformed by the FFT block into modulated symbols. The bit allocation information is used to configure the demodulators while the subcarrier allocation information is used to extract the demodulated bits from the subcarriers assigned to the kth user.

In the frequency selective fading channel, different subcarriers will experience different channel gains. We denote by $\alpha_{k,n}$ the magnitude of the channel gain (assuming coherent reception) of the nth subcarrier as seen by the kth user. We assume that the single-sided noise power spectral density (PSD) level N_0 is equal to unity (i.e., $N_0 = 1$), for all

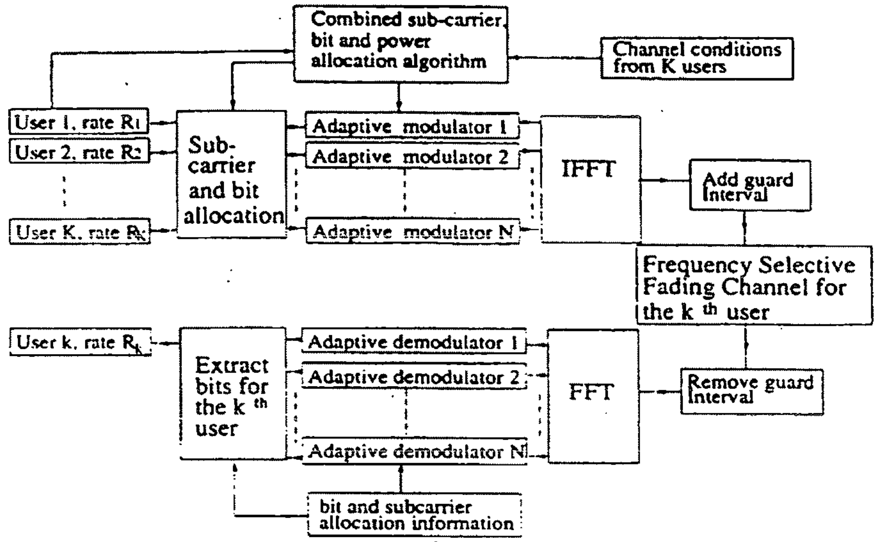

Fig. 1. Block diagram of a multiuser OFDM system with subcarrier, bit, and power allocation.

subcarriers and is the same for all users. Furthermore, we denote by $f_k(c)$ the required received power (in energy per symbol) in a subcarrier for reliable reception of c information bits/symbol when the channel gain is equal to unity. Note that the function $f_k(c)$ depends on k, and this allows different users to have different quality-of-service (QoS) requirements and/or different coding and modulation schemes. In order to maintain the required QoS at the receiver, the transmit power, allocated to the nth subcarrier by the kth user must equal

$$P_{k,n} = \frac{f_k(c_{k,n})}{\alpha_{k,n}^2}. \tag{1}$$

Using these transmit power levels, the receiver can demodulate the modulated symbols at the output of the FFT processor and achieve the desired QoS's of all users.

The goal of the combined subcarrier, bit, and power allocation algorithm is then to find the best assignment of $c_{k,n}$ so that the overall transmit power, the sum of $P_{k,n}$ over all subcarriers and all users, is minimized for given transmission rates of the users and given QoS requirements specified through $f_k()$, $k = 1, \dots, K$. In order to make the problem tractable, we further require that $f_k(c)$ is a convex and increasing function with $f_k(0) = 0$. This condition essentially means that no power is needed when no bit is transmitted and that the required additional power to transmit an additional bit increases with c [i.e., $f_k(c+1) - f_k(c)$ is increasing in c]. Almost all popular coding and modulation schemes satisfy this condition.

It is important to note that even though the problem is formulated to minimize the overall transmit power for given QoS requirements, the same solution can be applied to improve the QoS's of the users for a given overall transmit power. The latter can simply be achieved by increasing the power proportionally for all the subcarriers, while using the same set of $c_{k,n}$.

Mathematically, we can formulate the problem as

$$P_T^* = \min_{c_{k,n} \in D} \sum_{n=1}^{N} \sum_{k=1}^{K} \frac{1}{\alpha_{k,n}^2} f_k(c_{k,n}) \tag{2}$$

and the minimization is subjected to the constraints

$$\text{C1: For all } k \in \{1, \dots, K\},\ R_k = \sum_{n=1}^{N} c_{k,n} \tag{3}$$

and

$$\begin{aligned}&\text{C2: For all } n \in \{1, \dots, N\},\\ &\quad \text{if there exists } k' \text{ with } c_{k',n} \neq 0, \text{ then } c_{k,n} = 0,\\ &\quad \forall k \neq k'.\end{aligned} \tag{4}$$

Note that constraint (3) is the data rate requirement and constraint (4) ensures that each subcarrier can only be used by one user. Moreover, $D = \{0, 1, 2, \dots, M\}$ is the set of all possible values for $c_{k,n}$, and $c_{k,n} = 0$ means that the kth user does not use the nth subcarrier to transmit any information.

III. Bit Allocation Algorithm for Single User Channel

Before we try to solve the multiuser allocation problem, we will first derive the bit allocation algorithm for the single-user environment. The single-user problem not only gives better understanding of the issues involved, but also provides a bit allocation algorithm that we will use in our multiuser solution.

We can rewrite the optimization problem in (2) for the single-user case as

$$P_T^* = \min_{c_n \in D} \sum_{n=1}^{N} \frac{1}{\alpha_n^2} f(c_n) \tag{5}$$

and the minimization is under the constraint

$$R = \sum_{n=1}^{N} c_n. \tag{6}$$

Note that we have dropped the subscript k, which denotes the user in all notations.

As the power needed to transmit a certain number of bits in a subcarrier is independent of the numbers of bits allocated to other subcarriers, it turns out that a greedy approach is optimal. A greedy algorithm assigns bits to the subcarriers one bit at a time, and in each assignment, the subcarrier that requires the least additional power is selected. The bit allocation process will be completed when all R bits are assigned. Several papers (e.g., [15] and [16]) have provided various algorithms for this problem, and the basic structure of most algorithms are similar and can be described as follows:

Initialization:

For all n, let $c_n = 0$ and $\Delta P_n = [f(1) - f(0)]/\alpha_n^2$;

Bit Assignment Iterations:

Repeat the following R times:

$\hat{n} = \arg\min_n \Delta P_n$;

$c_{\hat{n}} = c_{\hat{n}} + 1$;

$\Delta P_{\hat{n}} = [f(c_{\hat{n}} + 1) - f(c_{\hat{n}})]/\alpha_{\hat{n}}^2$;

End;

Finish:

$\{c_n\}_{n=1}^{N}$ is the final bit allocation solution.

The initialization stage computes, for each subcarrier, the additional power needed to transmit an additional bit. For each bit assignment iteration, the subcarrier that needs the minimum additional power is assigned one more bit, and the new additional power for that subcarrier is updated. After R iterations, the final bit assignment gives the optimal bit allocation for each subcarrier. It is important to note that the bit allocation is optimal only for the given function $f(c)$, which depends on the selected modulation scheme. Different modulation schemes will lead to different $f(c)$, different bit allocation, and possibly lower transmit power P_T^*.

The concept of this algorithm is fairly simple, and many similar algorithms based on the same principle have been obtained before. In particular, there exist faster and less complex algorithms which can speed up the bit allocation process significantly (e.g., [15] and [16]). In our simulations, we use the algorithm given in [16].

IV. Multiuser Subcarrier and Bit Allocation

We have observed that, in the single-user case, a greedy approach which assigns one bit at a time to the subcarrier that requires the least additional power gives the optimal allocation in the sense of minimizing the overall transmit power. Unfortunately, the problem becomes more difficult in the multiuser environment. As users cannot share the same subcarrier, allocating bits to a subcarrier essentially prevents other users from using that subcarrier. This dependency makes any greedy algorithm a nonoptimal solution. It turns out that the optimal solution may not assign any of a user's bits to the best subcarrier seen by that user. This may happen when the best subcarrier of a user is also the best subcarrier of another user who happens to have no other good subcarriers. Hence, the multiuser subcarrier and bit allocation problem is much more complicated to solve than that of the single-user case.

It turns out that the optimization problem in (2) is a combinatorial optimization problem. To make the problem tractable, we consider a different but similar optimization problem. We relax the requirement $c_{k,n} \in \mathbf{D}$ to allow $c_{k,n}$ to be a real number within the interval $[0, M]$. Moreover, in order to deal with constraint (4), K variables, $\rho_{k,n}$, $k = 1, \ldots, K$ with values within the interval $[0, 1]$, are introduced to the cost function as sharing factors of the nth subcarrier. The new optimization problem becomes

$$\underline{P}_T = \min_{\substack{c_{k,n} \in [0, M] \\ \rho_{k,n} \in [0, 1]}} \sum_{n=1}^{N} \sum_{k=1}^{K} \frac{\rho_{k,n}}{\alpha_{k,n}^2} f_k(c_{k,n}) \tag{7}$$

where $c_{k,n}$ and $\rho_{k,n}$ have to satisfy

$$R_k = \sum_{n=1}^{N} \rho_{k,n} c_{k,n}, \qquad \text{for all } k \in \{1, \ldots, K\} \tag{8}$$

and

$$1 = \sum_{k=1}^{K} \rho_{k,n}, \qquad \text{for all } n \in \{1, \ldots, N\}. \tag{9}$$

For any valid set of $c_{k,n} \in \mathbf{D}$ satisfying the constraints (3) and (4) in the original optimization problem, we can let

$$\rho_{k,n} = \begin{cases} 1, & \text{if } c_{k,n} \neq 0, \\ 0, & \text{if } c_{k,n} = 0. \end{cases} \tag{10}$$

Then, it is easy to show that the same set of $c_{k,n}$ and the corresponding $\rho_{k,n}$ defined in (10) satisfy the constraints (8) and (9) in the new optimization problem. Moreover, with $\rho_{k,n}$ defined in (10), the new cost function in (7) is equal to the cost function in (2). Hence, the minimization problem in (7) is the same as the original optimization problem, except that the minimization is done over a larger set. Consequently, the minimum power obtained in (7) $\underline{P}_T$ is a lower bound to the minimum power obtained in (2), P_T^*.

Another way to interpret the optimization in (7) is to consider $\rho_{k,n}$ as the time-sharing factor for the kth user of the nth subcarrier. For example, in every L OFDM symbol (L being a very large number), user k uses the nth subcarrier in $L\rho_{k,n}$ symbols. Clearly, the average (over L symbols) information data rate and the average transmit power has to be scaled by the same factor $\rho_{k,n}$. Hence, we can consider (7) as the optimization problem when the users are allowed to time-share each subcarrier over a large number of OFDM symbols. However, most wireless communication channels are time varying, and the channels may not stay unchanged long enough for timesharing to be feasible. Hence, in this paper, we will continue to consider the original problem in (2) and use the optimization problem in (7) as a lower bound, even though it has its own physical interpretation.

The modified optimization problem in (7) is more tractable. However, even though the function $f_k(c)$ is convex in c, the terms in the cost function have the form $\rho f_k(c)$, and as a function of (ρ, c), $\rho f_k(c)$ is not convex in (ρ, c). To proceed further, we let $r_{k,n} = c_{k,n}\rho_{k,n}$ and rewrite the cost function in terms of $r_{k,n}$ and $\rho_{k,n}$. The constraint on $r_{k,n}$

becomes $r_{k,n} \in [0, M\rho_{k,n}]$, and it can be easily shown that $\rho f_k(c) = \rho f_k(r/\rho)$ is convex in (ρ, r) within the triangular region specified by $\rho \in [0, 1]$ and $r \in [0, M\rho]$. In particular, the Hessian evaluated at any point within this region is a positive semidefinite matrix. Hence, we can reformulate the optimization problem in (7) as a convex minimization problem over a convex set. That is

$$\underline{P}_T = \min_{\substack{r_{k,n} \in [0, M\rho_{k,n}] \\ \rho_{k,n} \in [0,1]}} \sum_{n=1}^{N} \sum_{k=1}^{K} \frac{\rho_{k,n}}{\alpha_{k,n}^2} f_k\left(\frac{r_{k,n}}{\rho_{k,n}}\right) \tag{11}$$

where $r_{k,n}$ and $\rho_{k,n}$ have to satisfy

$$R_k = \sum_{n=1}^{N} r_{k,n}, \qquad \text{for all } k \in \{1, \ldots, K\} \tag{12}$$

and

$$1 = \sum_{k=1}^{K} \rho_{k,n}, \qquad \text{for all } n \in \{1, \ldots, N\}. \tag{13}$$

Using standard optimization techniques in [17], we obtain the Lagrangian

$$L = \sum_{n=1}^{N} \sum_{k=1}^{K} \frac{\rho_{k,n}}{\alpha_{k,n}^2} f_k\left(\frac{r_{k,n}}{\rho_{k,n}}\right) - \sum_{k=1}^{K} \lambda_k \left(\sum_{n=1}^{N} r_{k,n} - R_k\right) - \sum_{n=1}^{N} \beta_n \left(\sum_{k=1}^{K} \rho_{k,n} - 1\right) \tag{14}$$

where λ_k and β_n are the Lagrangian multipliers for the constraints (12) and (13), respectively.

After differentiating L with respect to $r_{k,n}$ and $\rho_{k,n}$, respectively, we obtain the necessary conditions for the optimal solution, $r_{k,n}^*$ and $\rho_{k,n}^*$. Specifically, if $\rho_{k,n}^* \neq 0$, we have

$$\left.\frac{\partial L}{\partial r_{k,n}}\right|_{(r_{k,n}, \rho_{k,n}) = (r_{k,n}^*, \rho_{k,n}^*)} = \frac{1}{\alpha_{k,n}^2} f_k'\left(\frac{r_{k,n}^*}{\rho_{k,n}^*}\right) - \lambda_k \begin{cases} > 0, & \text{if } r_{k,n}^* = 0 \\ = 0, & \text{if } r_{k,n}^* \in (0, M\rho_{k,n}^*) \\ < 0, & \text{if } r_{k,n}^* = M\rho_{k,n}^* \end{cases} \tag{15}$$

and

$$\left.\frac{\partial L}{\partial \rho_{k,n}}\right|_{(r_{k,n}, \rho_{k,n}) = (r_{k,n}^*, \rho_{k,n}^*)} = \frac{1}{\alpha_{k,n}^2}\left[f_k\left(\frac{r_{k,n}^*}{\rho_{k,n}^*}\right) - f_k'\left(\frac{r_{k,n}^*}{\rho_{k,n}^*}\right)\frac{r_{k,n}^*}{\rho_{k,n}^*}\right] - \beta_n \begin{cases} = 0, & \text{if } \rho_{k,n}^* \in (0, 1) \\ < 0, & \text{if } \rho_{k,n}^* = 1. \end{cases} \tag{16}$$

On the other hand, if $\rho_{k,n}^* = 0$, then $r_{k,n}^* = 0$, and we have

$$r_{k,n} \frac{\partial L}{\partial r_{k,n}} + \rho_{k,n} \frac{\partial L}{\partial \rho_{k,n}} \geq 0, \quad \text{for all } \rho_{k,n} \in (0, 1] \text{ and } r_{k,n} \in (0, M\rho_{k,n}]. \tag{17}$$

These necessary conditions can be interpreted by the fact that if the minimum occurs within the constrained region [(0, 1) for $\rho_{k,n}$ and $(0, M\rho_{k,n})$ for $r_{k,n}$], then the derivative evaluated at the minimum point must be zero. On the other hand, if the optimal solution occurs at a boundary point, then the derivative must be positive along all directions pointing toward the interior of the constraint set. Then, (17) follows from considering the boundary point at $(r_{k,n}^*, \rho_{k,n}^*) = (0, 0)$.

From (15) and (17), we can conclude that

$$r_{k,n}^* = \rho_{k,n}^* f_k'^{-1}(\lambda_{q,k}\alpha_{k,n}^2) \tag{18}$$

where

$$\lambda_{q,k} = \begin{cases} f_k'(0)/\alpha_{k,n}^2, & \text{if } f_k'^{-1}(\lambda_k\alpha_{k,n}^2) < 0; \\ \lambda_k, & \text{if } 0 \leq f_k'^{-1}(\lambda_k\alpha_{k,n}^2) \leq M; \\ f_k'(M)/\alpha_{k,n}^2, & \text{if } f_k'^{-1}(\lambda_k\alpha_{k,n}^2) > M. \end{cases}$$

Moreover, from (16) and (17), it follows that

$$\rho_{k,n}^* = \begin{cases} 0, & \text{if } \beta_n < H_{k,n}(\lambda_{q,k}) \\ 1, & \text{if } \beta_n > H_{k,n}(\lambda_{q,k}) \end{cases} \tag{19}$$

where

$$H_{k,n}(\lambda) = \frac{1}{\alpha_{k,n}^2}\left[f_k(f_k'^{-1}(\lambda\alpha_{k,n}^2)) - \lambda\alpha_{k,n}^2 f_k'^{-1}(\lambda\alpha_{k,n}^2)\right]. \tag{20}$$

Since constraint (13) must be satisfied, we find from (19) that for each n, if $H_{k,n}(\lambda_{q,k})$ for $k = 1, \ldots, K$ are all different, then only the user with the smallest $H_{k,n}(\lambda_{q,k})$ can use that subcarrier. In other words, for the nth subcarrier, if $H_{k,n}(\lambda_{q,k})$ are different for all k, then

$$\rho_{k',n}^* = 1, \ \rho_{k,n}^* = 0, \qquad \text{for all } k \neq k' \tag{21}$$

where

$$k' = \arg\min_k H_{k,n}(\lambda_{q,k}). \tag{22}$$

Hence, it follows that for a fixed set of Lagrange multipliers λ_k, $k = 1, \ldots, K$, we can use them to determine k' for each n using (22). The $r_{k,n}^*$ and $\rho_{k,n}^*$ obtained will then form an optimal solution for the optimization problem; however, the individual rate constraint (12) may not be satisfied.

In order to find the set of λ_k such that the individual rate constraints are satisfied, we have obtained an iterative searching algorithm. Starting with some small values for all λ_k, this iterative procedure increases one of the λ_k until the data rate constraint (12) for user k is satisfied. Then, we switch to another user and go through the users one at a time. This process repeats for all users until the data rate constraint for all users are satisfied. This algorithm converges because for a given k, as λ_k increases, $H_{k,n}(\lambda_{q,k})$ for all n decreases, and more $\rho_{k,n}^*$ in (19) become one while $r_{k,n}^*$ in (18) increases for those n where $\rho_{k,n}^* > 0$. Hence, $\sum_{n=1}^{N} r_{k,n}^*$ increases. During this process, some of the other $\rho_{k',n}^*$ may change from one to zero and consequently decrease the total data rate for other users. However, as all the λ_k increase, $r_{k,n}^*$ increases accordingly. As long as the total data rate is less than MN bits/symbol, which is the total number of bits possibly transmitted within an OFDM symbol, the algorithm will converge to a solution that satisfies all the constraints. Since the optimization problem is a convex optimization problem over a convex set, the set of necessary conditions is also sufficient, and the solution that satisfies all the necessary conditions is the unique optimal solution.

In the process of adjusting λ_k for $k = 1, \ldots, K$, the situation where, for a fixed n, more than one $H_{k,n}(\lambda_{q,k})$ has the same values cannot be ignored. In that case, $\rho^*_{k,n}$ has to take values within the interval (0, 1). This solution suggests that the subcarrier should be shared by multiple users. In practice, this can be done by having these users with $\rho^*_{k,n} > 0$ time share the nth subcarrier, and the ratio of the symbols used by different users are set proportionally to $\rho^*_{k,n}$. The detailed flow chart of the algorithm is given in the Appendix.

Now, we have an algorithm to obtain the optimal values of $\rho^*_{k,n}$ and

$$c^*_{k,n} = \begin{cases} \tau^*_{k,n}/\rho^*_{k,n}, & \text{if } \rho^*_{k,n} \neq 0 \\ 0, & \text{otherwise.} \end{cases} \quad (23)$$

This solution, when substituted in (7), gives a lower bound to the minimum overall transmit power. However, we cannot use these results immediately in (2). One problem is that $c^*_{k,n}$ may not be in D, and the other is that some $\rho^*_{k,n}$ may be within (0, 1), indicating a time-sharing solution. Furthermore, simply quantizing $c^*_{k,n}$ and $\rho^*_{k,n}$ will not satisfy the individual rate constraints in (3).

To solve this problem, we propose a multiuser adaptive OFDM (MAO) scheme where the subcarrier allocation follows essentially the solution to the lower bound in (7), and then the single-user bit allocation algorithm given in Section III is applied to each user on the allocated subcarriers. Specifically, we modify $\rho^*_{k,n}$ for the optimization problem in (7) by letting for each n $\rho^*_{k',n} = 1$ where $k' = \arg\max_k \rho^*_{k,n}$, and $\rho^*_{k,n} = 0$ for $k \neq k'$. Then, we apply the single-user bit allocation algorithm on each user using the assigned subcarriers. We denote the total transmit power (in energy/symbol) obtained using this MAO scheme by P_T. It is easy to see that $\underline{P}_T \leq P^*_T \leq P_T$, where P^*_T is the minimum power in the original problem, and $\underline{P}_T$ is the minimum power for the modified problem with the relaxed constraints. More specifically, the difference between P_T and the minimum $\underline{P}_T$ gives an upper bound to how far away our MAO scheme is from the solution of our original optimization problem.

V. Performance Comparison

In this section, we obtain and compare the performance of the MAO scheme with other static subcarrier allocation schemes. We consider a system that employs M-ary quadrature amplitude modulation (MQAM) with $D = \{0, 2, 4, 6\}$. Square signal constellations (4-QAM, 16-QAM, and 64-QAM) are used to carry two, four, or six bits/symbol. The bit-error probability is upper bounded by the symbol error probability, which is tightly approximated by $4Q[\sqrt{d^2/(2N_0)}]$ [12, p. 281], where d is the minimum distance between the points in the signal constellation. Since the average energy of a M-QAM symbol is equal to $(M-1)d^2/6$, it follows that the required power for supporting c bits/symbol at a given BER P_e is

$$f(c) = \frac{N_0}{3}\left[Q^{-1}\left(\frac{P_e}{4}\right)\right]^2 (2^c - 1)$$

where we recall that

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-t^2/2}\, dt.$$

It is easy to see that $f(c)$ is convex and increasing in c and that $f(0) = 0$.

To evaluate the performance of our scheme, we have simulated 1000 sets of five-path frequency selective Rayleigh fading channels with an exponential power delay profile. Each set of channels consists of K independent channels, one for each user. We use an OFDM system with 128 subcarriers over a 5 MHz band along with a total (over all users) transmission rate equal to 512 bits/symbol (or equivalently, an average of four bits/subcarrier). Recall that the single-sided power spectral density level N_0 is equal to unity, and we assume that the average subcarrier channel gain $E|\alpha_{k,n}|^2$ is equal to unity for all k and n.

For comparison purposes, we have also considered three other static multiuser subcarrier allocation methods. Two of them are based on the multiple access methods described in [7]. The methods are presented as follows.

- OFDM-TDMA: each user is assigned a predetermined TDMA time slot and can use all the subcarriers within that time slot exclusively.
- OFDM-FDMA: each user is assigned a predetermined band of subcarriers and can only use those subcarriers exclusively in every OFDM symbol.

  In a frequency selective fading channel, there is a high correlation between the channel gains of adjacent subcarriers. In order to avoid the situation where all subcarriers of a user are in deep fade, we propose an enhanced version of OFDM-FDMA, which we shall refer to as OFDM Interleaved-FDMA.
- OFDM Interleaved-FDMA: this is the same as OFDM-FDMA except that subcarriers assigned to a user are interlaced with other users' subcarriers in the frequency domain.

The time and subcarrier assignment of these three multiuser OFDM schemes are illustrated in Fig. 2. Note that these static schemes have predetermined subcarrier allocations which are independent of the channel gains of the users. The main difference between the proposed MAO scheme and these static schemes is that MAO assigns subcarriers adaptively based on the instantaneous channel gains. To ensure a fair comparison, we use the optimal single-user bit allocation (OBA) for each user on the assigned subcarriers. For comparison purposes, we also show the results when equal bit allocation (EBA) is employed on the assigned subcarriers for these three OFDM schemes. Notice that when using EBA, all three schemes will have the same performance in an uncoded system. This is because the average bit signal-to-noise ration (SNR) needed is a function of only the marginal probability density function of each subcarrier gain.

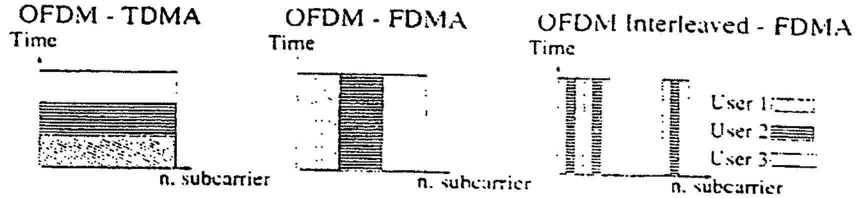

Fig. 2. Subcarrier and time-slot allocations of OFDM-TDMA, OFDM-FDMA, and OFDM interleaved-FDMA schemes.

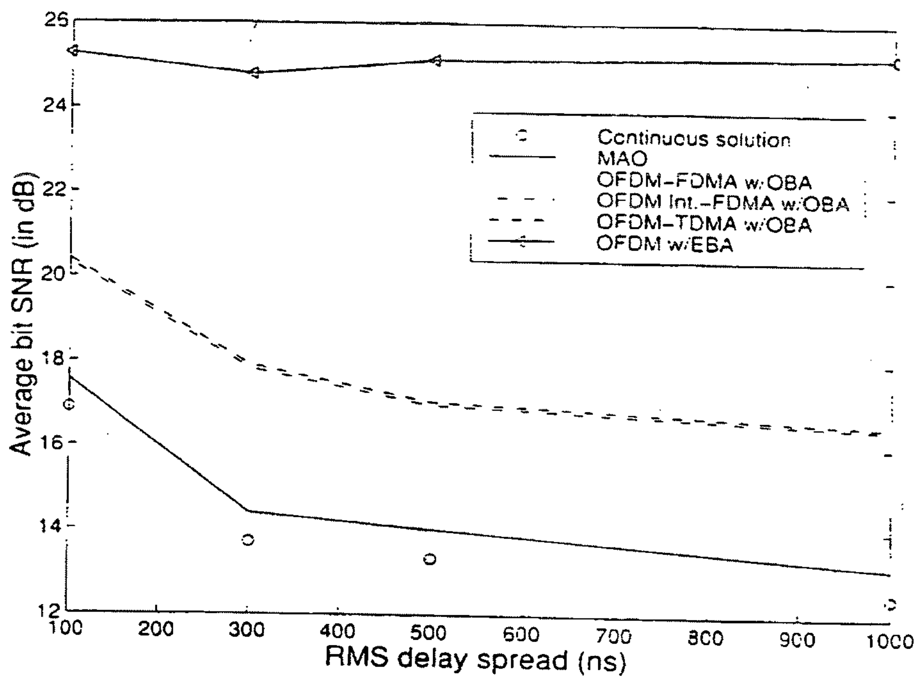

Fig. 3. Average bit signal-to-noise ration (SNR) required by different schemes in various root mean square (RMS) delay spreads in a five-user system with $P_e = 10^{-4}$.

Fig. 3 shows the average bit SNR needed to achieve a BER at $P_e = 10^{-4}$ for a five-user system versus the root mean square (RMS) delay spread (for definition, see for example [18, p. 160]) for different multiuser OFDM schemes. The average required transmit power (in energy per bit) is defined as the ratio of the overall transmit energy per OFDM symbol (including all subcarriers and all users) to the total number of bits transmitted per OFDM symbol. Moreover, we define the average bit SNR as the ratio of the average transmit power to the noise PSD level N_0. As we assume that the data rate is fixed and that N_0 is just a constant, the overall transmit power is proportional to the average bit SNR. For ease of comparison, we have used the average bit SNR for comparison. We find in Fig. 3 that the MAO scheme is never more than 0.6 dB from the lower bound. Since the bit SNR of the optimal combined subcarrier, bit, and power allocation algorithm must lie between the bit SNR's achieved by the lower bound and the MAO scheme, we find that the MAO scheme is never more than 0.6 dB away from the optimal solution. On the other hand, we observe that our proposed MAO scheme is 3–5 dB better than the static subcarrier allocation schemes with OBA, which are in turn 5–10 dB better than that with EBA. We also find that when OBA is used, the OFDM interleaved-FDMA scheme and the OFDM-TDMA scheme have very similar performance, and both of them outperform the OFDM-FDMA scheme.[2] A closer observation of Fig. 3 also indicates that the gains achieved by optimal bit allocation and optimal multiuser subcarrier allocation increase with the RMS delay spread. This is mainly because the larger the RMS delay spread, the more the fading variation and hence higher gains can be obtained when the allocation is performed adaptively.

Fig. 4 shows the average bit SNR (in dB) needed to achieve the same BER versus the number of users when the RMS delay spread is 100 ns. We find that the savings in the required bit SNR achieved by MAO when compared to other schemes are roughly the same, independent of the number of users in the system.

While these two figures show the improvement in the required bit SNR, the results can perhaps be more easily understood using the more familiar BER versus bit SNR curves. For each BER requirement, we compute $f(c)$ for all $c \in D$ and then use our algorithm to calculate the subcarrier

[2] OFDM-FDMA refers only to the specific FDMA scheme that assigns to each user a contiguous band of subcarriers as shown in Fig. 2, but not the general FDMA schemes. In fact, both OFDM interleaved-FDMA and MAO can be considered as different forms of FDMA and they are not outperformed by the OFDM-TDMA scheme.

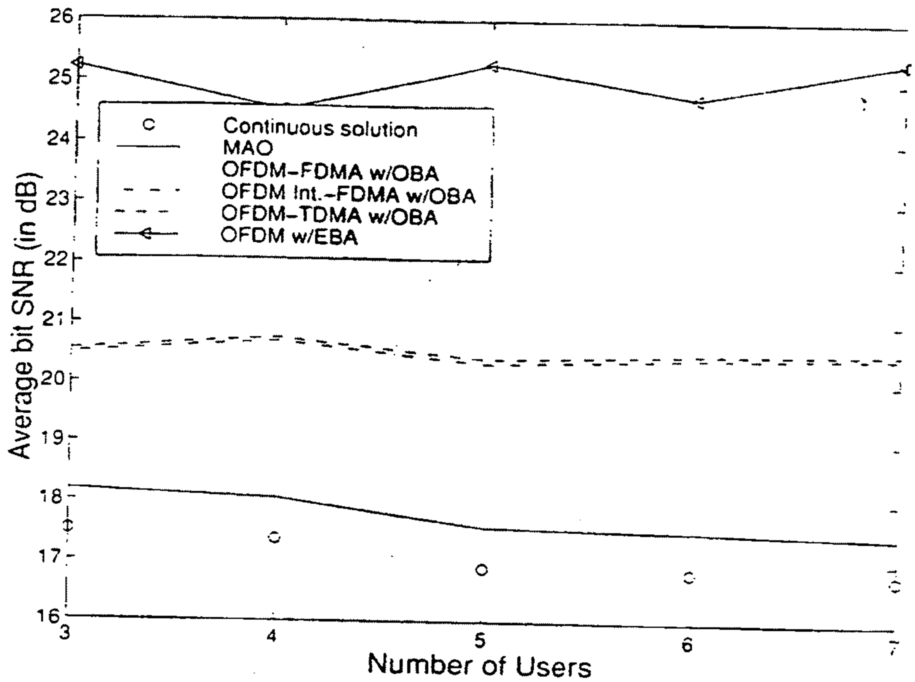

Fig. 4. Average bit SNR required by different schemes versus the number of users in a multiuser OFDM system with 100 ns RMS delay spread, and $P_e = 10^{-4}$.

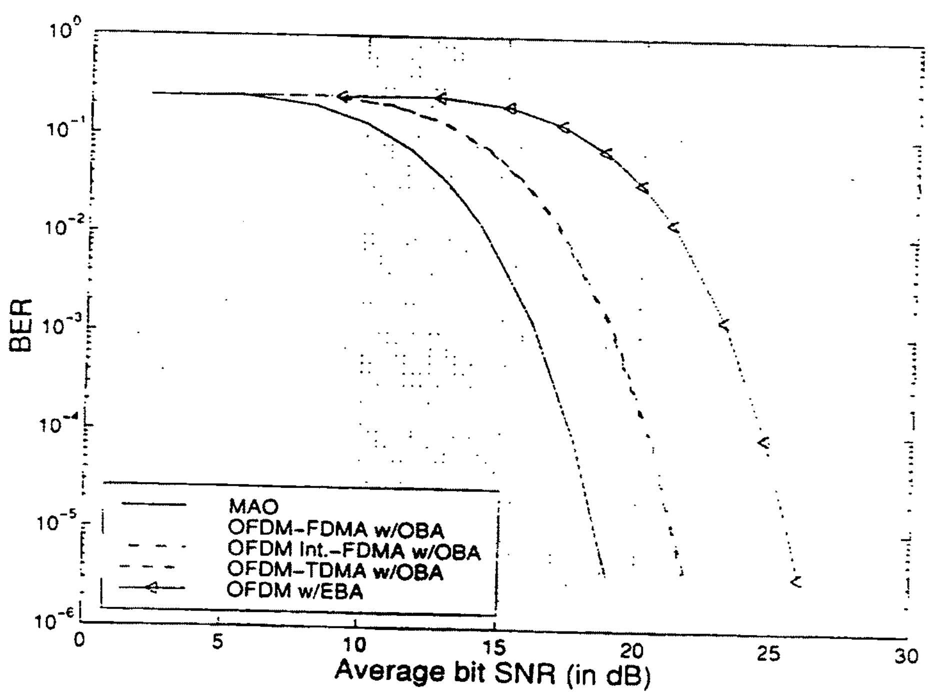

Fig. 5. BER versus average bit SNR for various subcarrier allocation schemes.

allocation for the MAO case. For all other static subcarrier allocation schemes, the allocations are independent of the BER. Once the subcarrier allocation is fixed, we apply the optimal bit and power allocation algorithm to every user. The final average power per bit divided by the noise power spectral density level gives the average bit SNR. We repeat this procedure for different BER values, and the results are plotted in Fig. 5 for a five-user system with an RMS delay spread equal to 100 ns. We find that our proposed MAO has at least 3–4 dB advantage over all other schemes.

Another way to illustrate the impact of the bit and subcarrier allocation is to consider the area of coverage for a given outage probability, assuming that the BS has a maximum transmit power. We consider a circular cell with five users, indepen-

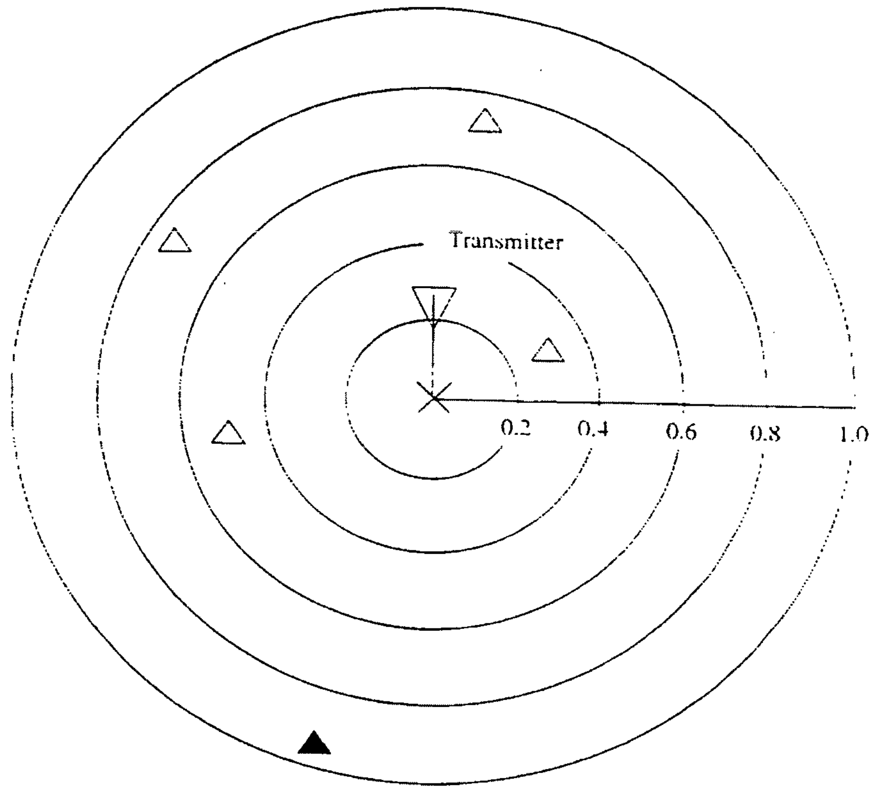

Fig. 6. Cell for analyzing the outage probability.

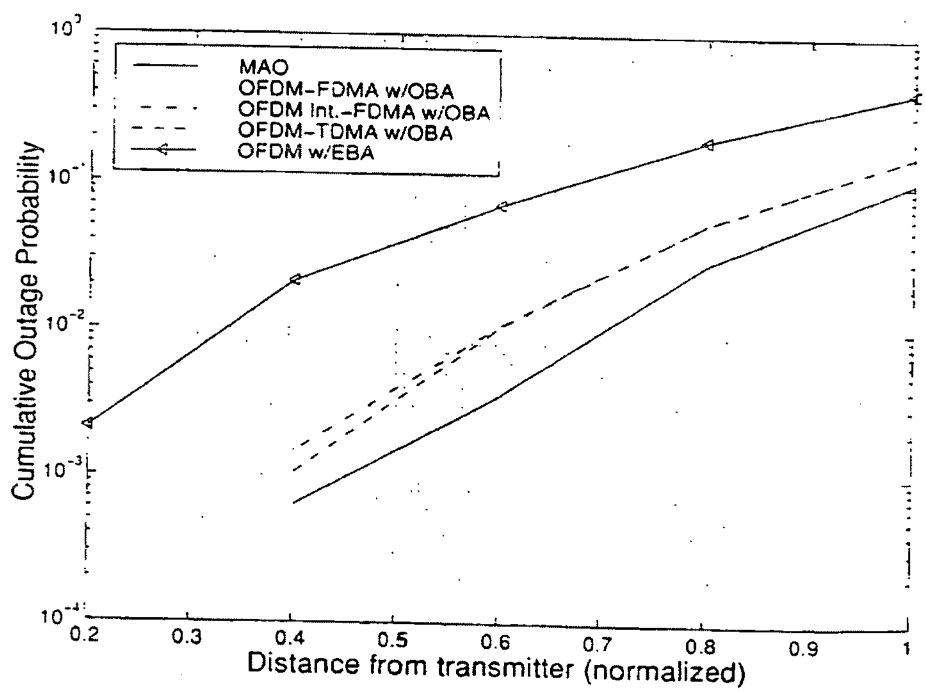

Fig. 7. Outage probability at 17 dB fading margin.

dently and uniformly distributed within the cell. A typical scenario is shown in Fig. 6, where the triangles represent the five users. In addition to frequency selective fading, path loss and log-normal shadowing are also included in simulating the actual channel gains seen by the users. Using these channel gains, subcarriers and bits assigned to each user are determined by the various multiple access schemes and the total required transmit power is calculated. If the total power for all five users

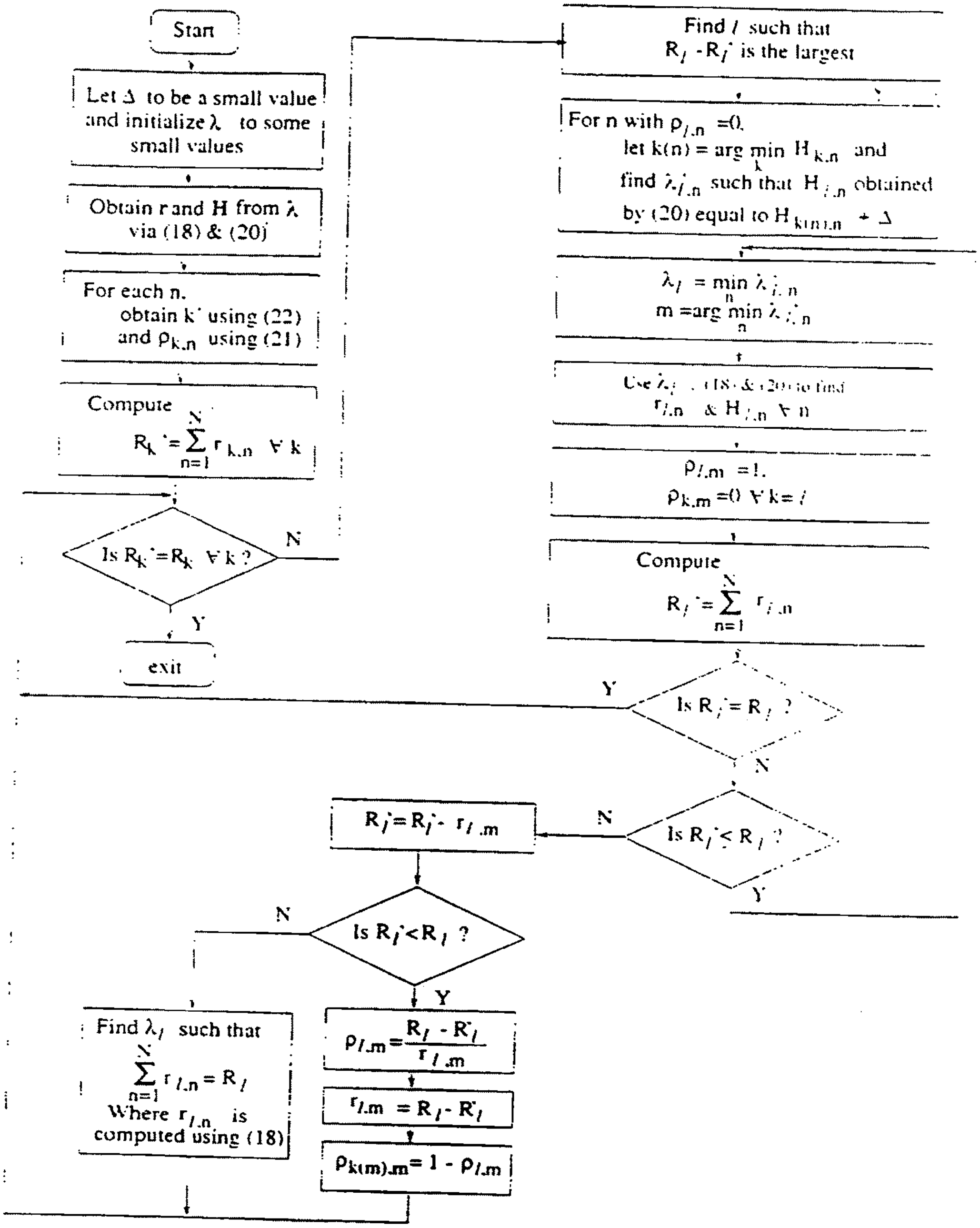

Fig. 8. Flow chart of the multiuser subcarrier allocation algorithm.

exceeds the maximum power of the BS, the user requiring the largest transmit power (in this case, the black one) is dropped and counted as one outage event occurring at a distance equal to the distance between the BS and the dropped user. This process continues until the transmit power is smaller than the maximum power of the BS. In this example, the maximum transmit power is set to the transmit power required for all five users assuming that they are all located at the boundary of the cell, taking into account the path loss effect and a 17 dB fading margin for shadowing.

The cumulative outage probabilities at various normalized distances, normalized to the cell radius, are plotted in Fig. 7. A cumulative outage probability of 5% at a normalized distance of 0.8 means that there is a 5% chance of outage for a mobile located more than $0.8R$ away from the BS where R is the radius of the cell. We observe that MAO outperforms others with a large reduction in the outage probability at all distances. Alternatively, if the same outage probability is maintained, say at 1%, the coverage are provided by MAO is 36% larger than the best of all other schemes.

VI. Conclusion

In this paper, we considered OFDM transmission in a multiuser environment and formulated the problem of minimizing the overall transmit power by adaptively assigning subcarriers to the users along with the number of bits and power level to each subcarrier. In particular, we derived a multiuser adaptive subcarrier and bit allocation algorithm. Given the instantaneous channel information, the algorithm obtains a suboptimal subcarrier allocation, and then single-user bit allocation is applied on the allocated subcarriers. Using this scheme, the overall required transmit power can be reduced by about 5–10 dB from the conventional OFDM without adaptive modulation. Likewise, the transmit power can be reduced by about 3–5 dB from the conventional OFDM with adaptive modulation and adaptive bit allocation, but without adaptive subcarrier allocation. The reduction in transmit power can also be translated to a significant reduction in the required bit SNR for a given BER. Moreover, the same improvement can also be translated to a reduction in the outage probability or to an increase in the area of coverage.

The results in this paper assume perfect channel estimation, and we have not considered issues related to imperfect implementation, such as imperfect synchronization. As channel estimation in wireless fading channels is in general not very accurate, the effect of nonideal channel information on the performance of our proposed MAO scheme is a very important issue. We have started looking at this issue, and our preliminary results have indicated that the MAO scheme is not very sensitive to channel estimation errors. Nevertheless, detailed sensitivity studies will be needed before the algorithm can be applied to practical systems.

Appendix

A flow chart providing the detailed description of the multiuser subcarrier allocation algorithm is shown in Fig. 8.

Acknowledgment

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Instituto Mexicano de la Propiedad Industrial

"2006, Año del Bicentenario del natalicio del Benemérito de las Américas, Don Benito Juárez García"

DIRECCION DIVISIONAL DE PATENTES
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Expediente PA/a/2003/005311 de Patente PCT.

Asunto: Se comunica el resultado del examen de fondo.

1er. requisito

México, D.F., a 31 de marzo de 2006

MA. ANGELICA PARDAVELL JUAREZ
Apoderado de
ADAPTIX INC.
San Francisco 310
Col. Del Valle
03100, , Distrito Federal

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ANTONIA H. RAMIREZ C.
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REF: Su solicitud No. PA/a/2003/005311 de Patente PCT presentada el 13 de Diciembre de 2001.

Como resultado del examen de fondo, realizado con fundamento en los artículos 53 de la Ley de la Propiedad Industrial (LPI) y 42 del Reglamento de la Ley de la Propiedad Industrial (RLPI); se le comunica lo siguiente:

El examen fue realizado en base a los siguientes documentos de la solicitud:

Descripción: No. 1 al 59, como originalmente fueron presentadas.

Reivindicaciones: No. 1 al 47, como originalmente fueron presentadas.

Figuras: No. 1 al 13, como originalmente fueron presentadas.

1) Durante el proceso de búsqueda practicado a su solicitud de patente se encontraron documentos que contienen características técnicas esenciales que coinciden con lo que se pretende proteger, en las prioridades E.U.A. 09/738,086 de fecha 15 de Diciembre de 2000, E.U.A. 09/837,701 de fecha 17 de Abril de 2001 y que corresponde con la publicación No. **WO0249385 A3** de fecha del 20 de Junio del 2002.

- DE 198 00 953 (SIEMENS AG), del 29 de July de 1999 (1999-07-29).
- WONG C.Y. ET AL: "MULTIUSER OFDM WITH ADAPTIVE SUBCARRIER, BIT, AND POWER ALLOCATION", IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE INC. NEW YORK, US, VOL. 17, NR. 10, PAGE(S) 1747-1758 XP000854075 ISSN: 0733-8716.

En cumplimiento en lo dispuesto en los artículos 55 y 179 de la LPI y 43 del RLPI, deberá presentar los documentos señalado anteriormente con su respectiva traducción al español, para valorar la patentabilidad de la invención.

Las aclaraciones o modificaciones realizadas ya sea en la descripción, en los dibujos y/o en las reivindicaciones, no deberán contener materia adicional con mayor alcance que la materia presentada originalmente en la solicitud y/o elementos que den soporte a reivindicaciones adicionales, de tal manera que se cumpla con lo establecido en el artículo 55 BIS LPI.

Asimismo deberá efectuar el pago que establece la tarifa vigente y exhibir el comprobante correspondiente.

PA/2006/23433

Instituto Mexicano de la Propiedad Industrial

Para que satisfaga estos requisitos, se le concede un plazo de dos meses contados a partir del día siguiente a la fecha en que se le notifique el presente oficio, apercibido que de no cumplir este requerimiento en el plazo señalado se considerará abandonada su solicitud de Patente de conformidad con lo dispuesto por los arts. 55 y 58 de la Ley de la Propiedad Industrial.

El suscrito firma el presente oficio con fundamento en los artículos 6° fracciones III y XI y 7° bis 2 de la Ley de la Propiedad Industrial; artículos 1°, 3°, 4°, 7° fracciones III, V, IX, XV y XVI, 8° fracciones I, II, III, IV y V, 11° y 12° fracciones I, II, III, IV y VI del Reglamento del Instituto Mexicano de la Propiedad Industrial (D.O.F. 14 de diciembre de 1999); artículos 5°, 11° fracciones III, V, IX y XVI, 12° fracción II, 15° y 18° fracciones I, II, III, IV y VI del Estatuto Orgánico del Instituto Mexicano de la Propiedad Industrial (D.O.F. 27 de diciembre de 1999); artículos 1°, 2° y 5° incisos e), l) y párrafos antepenúltimo y penúltimo de este artículo, del Acuerdo por el que se delegan facultades en los Directores Generales Adjuntos, Coordinador, Directores Divisionales, Titulares de las Oficinas Regionales, Subdirectores Divisionales, Coordinadores Departamentales y otros Subalternos del Instituto Mexicano de la Propiedad Industrial (D.O.F. 15 de diciembre de 1999); y artículo tercero transitorio del Decreto por el que se reforma el Reglamento Interior de la Secretaría de Comercio y Fomento Industrial publicado en el Diario Oficial de la Federación el 14 de septiembre de 1994.

A T E N T A M E N T E
EL COORDINADOR DEPARTAMENTAL

ING. PEDRO DAVID FRAGOSO LOPEZ

JMH/DDP.6.2006.2

(Translation)

Issuance Date: April 29, 2006
Submission Due Date: June 29, 2006

THE KOREAN INTELLECTUAL PROPERTY OFFICE
NOTICE OF GROUNDS FOR REJECTION

Applicant : ADAPTIX, INC.

Agent : Koreana Patent Firm

Application No. : Korean Patent Application No. 2003-7007963

Title of Invention: MULTI-CARRIER COMMUNICATIONS WITH ADAPTIVE CLUSTER CONFIGURATION AND SWITCHING

This application shall be rejected on the following grounds pursuant to Article 63 of the Korean Patent Law. If you have any objection, please submit an Argument or Amendment to the KIPO by **June 29, 2006**. (The term can be extended by one month each, however, a separate Acknowledgement of Extension of Time will not be issued.)

GROUNDS FOR REJECTION

1. The claims of the present application do not satisfy the description requirement as follows, and thus cannot be patented under Article 42(4)(ii) of the Korean Patent Law.

A. In "the method defined in Claim 1 wherein using one diversity cluster" recited in claim 5, the constitutional element "using one diversity cluster" is a term not recited in claim 1, and thus it is required to be consistent with the term of claim 1. Accordingly, said claim does not clearly describe the invention (Article 42(4)(ii) of the Korean Patent Law).

B. In "the method defined in Claim 11 wherein using one diversity cluster" recited in claim 20, the constitutional element "using one diversity cluster" is a term not recited in claim 11, and thus it is required to be consistent with the term of claim 11. Accordingly, said claim does not clearly describe the invention (Article 42(4)(ii) of the Korean Patent Law).

2. The invention recited in Claims 1~10 & 26~33 of the present application can be easily invented by a person having ordinary skill in the art to which the present invention pertains prior to its filing as indicated below. Accordingly, this application cannot be patented pursuant to Article 29(2) of the Korean Patent Law.

Claims 1~10 & 26~33 of the present invention relate to a method and apparatus for use in allotting subcarriers in an OFDMA system.

However, this can be easily invented by a person having ordinary skill in the art to which the invention pertains from the combination of cited reference 1 (WANG C. Y. ET AL: 'MULTIUSER OFDM WITH ADAPTIVE SUBCARRIER, BIT, AND POWER ALLOCATION,' IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE

INC. NEW YORK, VOL. 17, 10. OCTOBER 1999) and cited reference 2 (Ye Li ET AL; 'Clustered OFDM with channel estimation for high rate wireless data' Mobile Multimedia Communications, 1999. (MoMuC '99) 1999 IEEE International Workshop on, 15-17 Nov. 1999 Page(s): 43-50).

A more detailed review in this regard is as follows:

A. Constitution

(1) Claims 1~10

Claims 1~10 of the present application relate to a method for use in allocating subcarriers in an OFDMA system comprising allocating at least one diversity cluster of subcarriers to a first subscriber, and allocating at least one coherence cluster to a second subscriber. This can be easily anticipated by a person having ordinary skill in the art from the combination of cited reference 1 which has a constitution wherein subcarrier clusters are allocated to subscribers so as to be adapted to a plurality of subscribers, and cited reference 2 which has a constitution relating to an OFDM system capable of channel estimation and cluster allocation.

(2) Claims 26~33

Claims 26~33 of the present application relate to a subscriber allocation apparatus of an OFDMA system allocating at least one diversity cluster of subcarriers to a first subscriber, and allocating at least one coherence cluster to a second subscriber. This can be easily anticipated by a person having ordinary skill in the art from the combination of the above stated cited references 1 & 2.

B. Object and effect

The object and effect of the present invention is to provide a method and apparatus for efficiently allocating subcarriers to a plurality of subscribers in an OFDMA system. The combination of the technologies of cited references 1 & 2 can realize the same object and effect.

C. Conclusion

Therefore, claims 1~10, 26~33 of the present application can be easily invented by a person having ordinary skill in the art as stated above.

[Attachment]
Attached 1. Cited Reference 1
Attached 2. Cited Reference 2

Dated April 29, 2006

Electric & Electronic Examination Bureau
of Korean Intellectual Property Office

Examiner(s)-in-charge Hwan-Chul Yu

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	220147	"455"/("60", "41.2-41.3", 62-45, "63.1-63.2", 423-425, "455", 443-453, "456.5-456.6", 463-464, "509", 512-513, 524-526, "550.1", "553", "168.1", "176.1", "179.1", "188.1", "422.1", 516-517, "67.11", "561", "562.1", 132-135,).ccls.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:21
L2	288791	"370"/(203-206, "208", "210", "311", "329", "347", "480").ccls.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:22
L3	101	375/311.ccls.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:23
L4	461935	l1 or l2 or l3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:23
L5	4	(subcarrier near9 (plural$3 or multiple)) same (interference with (pilot near7 symbol))	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:26
L6	78	l4 and OFDMA	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:26
L7	63	l6 and interference	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:27
L8	30	l7 and feedback	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:27

EAST Search History

L9	2	l8 and (balanc$3 near7 load)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:28
L10	6	l8 and (subcarrier near7 (set$1 or group$1 or cluster$4))	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:29
L11	1076	ratio with SINR	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:33
L12	1004	l11 same interference	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:34
L13	95	l12 and OFDMA	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:34
L14	53	l13 and feedback	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:34
L15	17	l14 and (subcarrier near7 (cluster or group or set))	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2006/08/07 20:35

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/199,586	08/08/2005	Xiaodong Li	68144/P014C1/10503148	1128

29053 7590 08/24/2006

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EXAMINER	
ZEWDU, MELESS NMN	
ART UNIT	**PAPER NUMBER**
2617	

DATE MAILED: 08/24/2006

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	**Application No.** 11/199,586	**Applicant(s)** LI ET AL.	
	Examiner Meless N. Zewdu	**Art Unit** 2617	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-62* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-4,7,8,12-20,23,26-33,37,43-49,52 and 55-62* is/are rejected.

7)☒ Claim(s) *5,6,9-11,21,22,24,25,34,35,38-42,50,51,53 and 54* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *08 August 2005* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date *4/25/06 & 5/17/06*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

DETAILED ACTION

1. This action is the first on the merit of the instant application.

2. Claims 1-62 are pending in this action.

Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory obviousness-type double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement.

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

Claims 1-62 are rejected on the ground of nonstatutory double patenting over claims 1-119 of U. S. Patent No. 6,904,283 B2 since the claims, if allowed, would improperly extend the "right to exclude" already granted in the patent.

The subject matter claimed in the instant application is fully disclosed in the patent and is covered by the patent since the patent and the application are claiming common subject matter, as follows: the difference between the claims in the instant application and the claims in the patent is that the claims in the instant application are more broader than the claims in the patent.

Furthermore, there is no apparent reason why applicant was prevented from presenting claims corresponding to those of the instant application during prosecution of the application which matured into a patent. See *In re Schneller*, 397 F.2d 350, 158 USPQ 210 (CCPA 1968). See also MPEP § 804.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

Claims 1, 12, 14, 17-18, 30, 43 and 46-47 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter (DE 19800953 C1) in view of Larsson et al. (Larsson) (US 5,956,642).

As per claim 1: a method for sub-carrier selection for a system employing orthogonal frequency division multiple access (OPDMA) comprising:

the subscriber selecting a set of candidate sub-carriers reads on '953 (see abstract). Each mobile station, determining the quality of a preferred segment, suitable for its own connection, is same as selecting a set of desirable sub-carriers.

the subscriber providing feedback information on the set of candidate sub-carriers to the base station reads on '953 (see abstract).

the subscriber receiving an indication of sub-carriers of the set of sub-carriers selected by the base station for use by the subscriber reads on '953 (see abstract). Since a segment includes a plurality of sub-carriers, it can be considered as a set of sub-carriers. Furthermore, Ritter discloses that a mobile measures channel/segment quality based on received data symbols transmitted by a base station. But, Ritter does not explicitly teach about a subscriber measuring channel and interference information for a plurality of sub-carriers, as claimed by applicant. However, in the same field of endeavor, Larsson teaches that a mobile can measure a signal quality level (C/I) of the channels within the subset of M channels, and the interference level (I) of all the N available channels (see col. 5, lines 6-21). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify the teaching of Ritter with that of Larsson for the advantage of enabling Ritter's communication system to allocate resources adaptively (see col. 16-19). Note: when the references are combined as shown above, the measurement or the parameters in question will be based on pilot symbols/data received from a base station.

As per claim 30: the features of claim 30 are similar to the features of claim 1, except claim 30 is directed to an apparatus intended to perform the steps of method claim 1. Hence, since the method steps of claim 1 are taught and the apparatus of claim 30 is required to perform the steps of claim 1, claim 30 has been rejected on the same ground and motivation as claim 1.

As per claim 12: the method, wherein the pilot symbols occupy an entire OFDM frequency bandwidth reads on '953 (see abstract). In the prior, the pilot symbols occupy the entire OFDM frequency bandwidth.

As per claim 14: Larsson teaches a method, further comprising a base station selecting sub-carriers from a set of candidate sub-carriers (see col. 7, lines 43-54). When the references are combined, the selection would be based on information available to the base station, as a feedback from the mobile station, as provided in Ritter. Furthermore, the recited, **additional** information reads on Ritter's channel quality of measurement on different channels/segments.

As per claim 17: the method wherein the indication of sub-carriers is received via a downlink control channel reads on '953 (see abstract).

As per claim 18: the method wherein the plurality of sub-carriers comprises all sub-carriers allocable by a base station reads on '953 (see abstract). In the prior, the pilot symbols occupy the entire OFDM frequency bandwidth.

As per claim 43: the feature of claim 43 is similar to the feature of claim 14. Hence, claim 43 is rejected on the same ground and motivation as claim 14.

As per claim 46: the apparatus wherein the indication of sub-carriers is received via a downlink control channel between the base station and the at least one subscriber reads on '953 (see abstract).

As per claim 47: the apparatus wherein the plurality of sub-carriers comprises all sub-carriers allocable by a base station reads on '953 (see abstract). In the prior, the pilot symbols occupy the entire OFDM frequency bandwidth.

Claims 2-4, 8, 13, 31-33 and 37 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter as applied to the claims above, and further in view of Wong (US 6,330,460 B1).

As per claim 2: Ritter teaches a method, further comprising:

the subscriber continuously monitoring reception of the pilot symbols known to the base station reads on '953 (see abstract). The subscriber/s must continuously monitor for the pilot symbols transmitted by a base station in order to acquire a communication channel. But, Ritter does not explicitly teach about a subscriber measuring signal-plus-interference-to-noise ratio (SINR) of each cluster of sub-carriers, as claimed by applicant. However, in the same field of endeavor, Wong teaches that a subscriber station/mobile station is capable of measuring signal-plus-interference-to-noise ratio (SINR) (see col. 8, lines 11-26). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify Ritter's reference with the teaching of Wong for the advantage enabling Ritter's base station determine the highest acceptable traffic data rate for a particular mobile station.

As per claim 3: the method, further comprising the subscriber measuring inter-cell interference, wherein the subscriber selects candidate sub-carriers based on the inter-cell interference reads on '460 (see col. 8, lines 11-26). In Ritter, the mobile station selects suitable segment/sub-carrier. When the references are combined as shown in the rejection of claim 2, the selection will be based on the inter-cell interference as measured by the mobile station/subscriber, according to the teaching of Wong.

As per claim 4: the method further comprising the base station selecting sub-carriers for the subscriber based on inter-cell interference avoidance reads on '460 (see col. 8, lines 11-26).

As per claim 8: the method further comprising the subscriber using information from pilot symbol periods and data periods to measure channel and interference information reads on '460 (see col. 8, lines 11-26). In Ritter, the subscriber receives pilot symbols which it can use to measure channel and interference, as taught by Wong.

As per claim 13: the method wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other reads on '460 (see col. 8, lines 11-26). The combined prior art teaches measuring interference based on information extracted (in Ritter) from pilot symbols transmitted by a base station. Interference, in the context of the prior art, is measured so as to avoid, by being aware of it, communication loss if it occurs to the extent of undesired degree. It is obvious that if two pilot symbols from neighboring cells sites are allowed to collide, they will. But, what will be the benefit? Hence, colliding two signals, as claimed, does not carry patentable weight.

As per claim 31: the apparatus wherein each of the plurality of subscribers continuously monitors reception of the pilot symbols known to the base station reads on '953 (see abstract). The subscriber/s must continuously monitor for the pilot symbols transmitted by a base station in order to acquire a communication channel. But, Ritter does not explicitly teach about a subscriber measuring signal-plus-interference-to-noise ratio (SINR) of each cluster of sub-carriers, as claimed by applicant. However, in a related field of endeavor, Wong teaches that a subscriber station/mobile station is capable of measuring signal-plus-interference-to-noise ratio (SINR) (see col. 8, lines 11-26). Since the features of claim 31 are similar to the features of claim 2, claim 31 is rejected on the same ground and motivation as claim 2.

As per claim 32: the apparatus wherein each of the plurality of subscribers measures inter-cell interference, wherein the at least one subscriber selects candidate sub-carriers based on the inter-cell interference reads on '460 (see col. 8, lines 11-26). In Ritter, the mobile station selects suitable segment/sub-carrier. When the references are combined as shown in the rejection of claims 2 and 31, the selection will be based on the inter-cell interference as measured by the mobile station/subscriber, according to the teaching of Wong.

As per claim 33: the apparatus defined in Claim 32 wherein the base station selects sub-carriers for the one subscriber based on inter-cell interference 3 avoidance reads on '460 (see col. 8, lines 11-26).

As per claim 37: the apparatus defined in Claim 30 wherein the at least one subscriber uses information from pilot symbol periods and data periods to measure channel and interference information reads on '460 (see col. 8, lines 11-26). In Ritter, the subscriber receives pilot symbols which it can use to measure channel and interference, as taught by Wong.

Claims 15, 16, 44 and 45 are rejected under 35 U.S.C. 103(a) as being unpatentable over the references applied to the claims above, and further in view of Westroos et al. (Westroos) (US 6,327,472).

As per claim 15: but, the above mentioned references do not explicitly teach about a base station having additional information that comprises traffic load information on each cluster of sub-carriers, as claimed by applicant. However, in a related field of endeavor, Westroos teaches about the use of a load monitoring device that collects and holds traffic information on neighboring cells (see col. 2, line 44-col. 3, line 10; col.5, lines 19-65). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to further modify the above references with the teaching of Westroos for the advantage of making load dependent channel allocation. Note: although Westroos' traffic load information collector/holder is residing in the MSC, it is by choice of design. It could have been placed in, for example, the BSC or BS, as well.

As per claim 16: the method wherein the traffic load information is provided by a data buffer in the base station reads on .472 (see col. 5, lines 45-65). Also, see the explanation above.

As per claim 44: but, the above mentioned references do not explicitly teach about a base station having additional information that comprises traffic load information on each cluster of sub-carriers, as claimed by applicant. However, in a related field of endeavor, Westroos teaches about the use of load monitoring device that collects and holds traffic information on neighboring cells (see col. 2, line 44-col. 3, line 10; col.5, lines 19-65). Motivation is same as provided in the rejection of claim 15 above.

As per claim 45: the apparatus wherein the traffic load information is provided by a data buffer in the base station reads on .472 (see col. 5, lines 45-65). Also, see the explanation above.

Claims 19, 20, 23, 48, 49 and 52 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter as applied to claim 1 above, and further in view of Bodin et al. (Bodin) (US 5,507,034).

As per claim 19: Ritter discloses about a subscriber sending feedback information to a base station in an OFDMA communication system using segmented spectrum channels, which is same as sub-carriers (see abstract). But, Ritter does not explicitly teach about arbitrarily ordering the set of candidates of sub-carriers as cluster of sub-carriers, as claimed by applicant. However, in a related field of endeavor, Bodin teaches that frequencies can be sequentially ordered and assigned priorities (see col. 3, lines 44-64). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify Ritter's reference with the teaching of Bodin for the advantage of selecting a bandwidth/channel for a pending communication.

As per claim 20: the method wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first reads on '034 (see col. 3, lines 44-64).

As per claim 23: the method wherein providing feedback information comprises sequentially ordering candidate clusters reads on '034 (see col. 3, lines 44-64).

As per claim 48: Ritter discloses about a subscriber/subscribers sending feedback information to a base station in an OFDMA communication system using segmented spectrum channels, which is same as sub-carriers (see abstract). But, Ritter does not explicitly teach about arbitrarily ordering the set of candidates of sub-carriers as cluster of sub-carriers, as claimed by applicant. However, in a related field of endeavor, Bodin teaches that frequencies can be sequentially ordered and assigned priorities (see col. 3, lines 44-64). Motivation is same as provided in the rejection of claim 19 above.

As per claim 49: the apparatus wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first reads on '034 (see col. 3, lines 44-64).

As **per claim 52**: the apparatus wherein providing feedback information comprises sequentially ordering candidate clusters reads on '034 (see col. 3, lines 44-64).

Claims 29 and 62 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter In view of Feuerstein et al. (Feuerstein) (US 6,141,565).

As per claim 29: an apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of sub-carriers desired for use by the plurality of subscribers reads on '953 (see abstract). The mobile station of the prior art is in a cell. Furthermore, since, there is not a second cell mentioned, the prior art cell can be considered as a first cell.

a first base station in the first cell, the first base station performing sub-carrier allocation for OFDMA to allocate OFDMA sub-carriers in clusters to the plurality of subscribers reads on '953 (see abstract). Segments of the frequency spectrum in the prior art are sub-carriers/clusters. Since there is no mention of a second base station, 'a first base station' is read as a base station; hence, a base station in a cell.

But Ritter does not explicitly teach about inter-cell interference avoidance and intra-cell traffic load balancing, as claimed by applicant. However, in a related field of endeavor, Feuerstein teaches about network optimization based on measured local interference and/or local traffic load conditions (see col. 2, lines 27-37). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify Ritter's reference with the teaching of Feuerstein's for the advantage of optimizing network parameters based on dynamic communication and network conditions such as traffic load and balancing conditions and/or changing interference conditions (see col. 1, lines 20-26).

As per claim 62: the features of claim 62 are similar to the features of claim 29. Hence, claim 62 is rejected on the same ground and motivation as claim 29.

Claims 7, 26, 36, 55, 58, 60 and 61 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter in view of Frodigh et al. (Frodigh) (US 5,726,978). For examination purpose, claim 58 is considered first.

As per claim 58: a method comprising:

the base station allocating sub-carriers to establish a data link between the base station and the subscriber reads on '953 (see abstract). But, Ritter does not explicitly teach about a base station allocating a first portion of the sub-carriers and allocating a second portion of the sub-carriers to the subscriber to increase communication bandwidth, as claimed by applicant. However, in a related field of endeavor, Frodigh advantageously teaches about a method of adaptively allocating selected sub-carriers to subscribers (see col. 4, lines 32-49). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify Ritter's reference with the teaching of Frodigh for the advantage of lessening co-channel interference between cells of the system (see col. 4, lines 25-31). Note: adaptive allocation of sub-carriers can increase or decrease a communication bandwidth.

As per claim 60: a base station comprising:

means for allocating sub-carriers to establish a data link between the base station and the subscriber reads on '953 (see abstract). But, Ritter does not explicitly teach about a means for allocating a first portion and a second portion of the sub-carriers to a subscriber to increase communication bandwidth, as claimed by applicant. However, in a related field of endeavor, Frodigh teaches that in an OFDMA system subcarriers can be selected and adaptively allocated based on set allocation criteria (see col. 4, lines 32-49). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify the teaching of Ritter with that of Frodigh for the advantage of lessening co-channel interference between cells of the system (see col. 4, lines 25-31). Note: adaptive allocation of sub-carriers can increase or decrease a communication bandwidth.

As per claim 61: the apparatus defined in Claim 60 wherein the base station allocates the second portion after allocating each subscriber in the cell sub-carriers to establish a data link between the base station and said each subscriber reads on '979 (see col. 4, lines 32-49). When the references are combined as shown above, bandwidth will be allocated adaptively.

As per claim 7: the method further comprising the subscriber submitting new feedback information after being allocated the set of subscribers to be allocated a new set of sub-carriers and thereafter the subscriber receiving another indication of the new set of sub-carriers reads on '979 (see col. 4, lines 32-49). When the references are combined as shown above, bandwidth will be allocated adaptively—which can include allocating a first and a second portion as needed.

As per claim 26: the features of claim 26 are similar to the features of claim 58. Hence, claim 26 is rejected on the same ground and motivation as claim 58.

As per claim 27: the method wherein the base station allocates the second portion after allocating each subscriber in the cell sub-carriers to establish a data link between the base station and said each subscriber reads on '978 (see col. 4, lines 32-49). Adaptive allocation includes/considers the needs of subscribers operating under the adaptively allocating base station.

As per claim 28: the method wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell sub-carriers to establish their data link to the base station reads on '978 (see col. 4, lines 32-49)..

As per claim 36: the apparatus wherein the subscriber submits new feedback information after being allocated the set of subscribers to receive a new set of sub-carriers and thereafter receives another indication of the new set of sub-carriers reads on '979 (see col. 4, lines 32-49). When the references are combined as shown above, bandwidth will be allocated adaptively—which can include allocating a first and a second portion as needed.

As per claim 55: the apparatus wherein the base station allocates the sub-carriers to establish a data link between the base station and the subscriber reads on '953 (see abstract). But, Ritter does not explicitly teach about a base station allocating a second portion, after a first portion has been allocated, of the sub-carriers to the subscriber to increase communication bandwidth However, in a related field of endeavor, Frodigh teaches that in an OFDMA system sub-carriers can be selected and adaptively allocated based on set allocation criteria (see col. 4, lines 32-49). The motivation is as provided in the rejection of claim 58.

As per claim 56: the apparatus wherein the base station allocates the second portion after allocating each subscriber in the cell sub-carriers to establish a data link between the base station and said each subscriber reads on '978 (see col. 4, lines 32-49). Adaptive allocation can allow the base station to perform this feature priority.

As per claim 57: the apparatus wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell sub-carriers to establish their data link to the base station reads on '978 (see col. 4, lines 32-49). Adaptive allocation can allow the base station to perform allocation priority.

As per claim 59: the method wherein the base station allocates the second portion after allocating each subscriber in the cell sub-carriers to establish a data link between the base station and said each subscriber reads on '978 (see col. 4, lines 32-49). Adaptive allocation can allow the base station to perform this feature priority.

Allowable Subject Matter

Claims 5-6, 9-11, 21-22, 24-25, 34-35, 38-42, 50-51 and 53-54 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. Note: claims 4-6, 22, 25, 33-35, 39-42, 51and 54 are objected because of their dependency on claims 5, 9, 21, 24, 34, 38, 50 and 53, respectively.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Meless N. Zewdu whose telephone number is (571) 272-7873. The examiner can normally be reached on 8:30 am to 5:00 pm..

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Corsaro Nick can be reached on (571) 272-7876. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Any inquiry of a general nature relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is (571) 272-2600.

Meless zewdu

Examiner

08 August 2006.

UNITED STATES PATENT AND TRADEMARK OFFICE

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United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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Bib Data Sheet

CONFIRMATION NO. 1128

SERIAL NUMBER	FILING OR 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
11/199,586	08/08/2005 RULE	455	2617	68144/P014C1/10503148

APPLICANTS

Xiaodong Li, Bellevue, WA;
Hui Lui, Sammamish, WA;
Kemin Li, Bellevue, WA;
Wenzhong Zhang, Bellevue, WA;

** **CONTINUING DATA** ************************* yes M.Z.

This application is a CON of 09/738,086 12/15/2000 PAT 6,947,748

** **FOREIGN APPLICATIONS** ******************** None M.Z.

IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** SMALL ENTITY **
** 09/12/2005

Foreign Priority claimed / 35 USC 119 (a-d) conditions met / Verified and Acknowledged	STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ☐ yes ☒ no 35 USC 119 (a-d) conditions met ☐ yes ☒ no ☐ Met after Allowance Verified and Acknowledged [signature] Examiner's Signature M.Z. Initials	WA	7	40	6

ADDRESS
000029053

TITLE
OFDMA with adaptive subcarrier-cluster configuration and selective loading

FILING FEE RECEIVED		
1365	FEES: Authority has been given in Paper No. _________ to charge/credit DEPOSIT ACCOUNT No. _________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ____________ ☐ Credit

Index of Claims

Application/Control No.	Applicant(s)/Patent Under Reexamination
11/199,586	LI ET AL.
Examiner	**Art Unit**
Meless N. Zewdu	2617

Symbol	Meaning	Symbol	Meaning	Symbol	Meaning	Symbol	Meaning
√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

Claim Final	Claim Original	Date 8/8/06
	1	√
	2	√
	3	√
	4	√
	5	O
	6	O
	7	√
	8	√
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	10	O
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	50	O

Claim Final	Claim Original	Date 8/8/06
	51	O
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Claim Final	Claim Original	Date
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Search Notes	Application/Control No. 11/199,586	Applicant(s)/Patent under Reexamination LI ET AL.
	Examiner Meless N. Zewdu	Art Unit 2617

SEARCHED

Class	Subclass	Date	Examiner
455	179.1	8/8/2006	M.Z.
455	188.1	8/8/2006	M.Z.
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455	67.11	8/8/2006	M.Z.
455	561	8/8/2006	M.Z.
455	562.1	8/8/2006	M.Z.
455	132-135	8/8/2006	M.Z.
370	203-206	8/8/2006	M.Z.
370	208, 210	8/8/2006	M.Z.
370	311, 329	8/8/2006	M.Z.
370	347, 480	8/8/2006	M.Z.
375	311	8/8/2006	M.Z.

INTERFERENCE SEARCHED

Class	Subclass	Date	Examiner

SEARCH NOTES (INCLUDING SEARCH STRATEGY)

	DATE	EXMR
Searched: EAST (US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM-TDB).	8/8/2008	M.Z.
Search strategies: (subcarrier near9 (plural$3 or multiple)) same (interfernce with (pilot near7 symbol)) and OFDMA	8/8/2008	M.Z.
(interference and feedback) and (balance$3 near7 load)	8/8/2008	M.Z.
(subcarrier near7 (cluster or group or set))) and OFDMA	8/8/2006	M.Z.

U.S. Patent and Trademark Office — Part of Paper No. 20060807

Search Notes (continued)

Application/Control No.	Applicant(s)/Patent under Reexamination
11/199,586	
Examiner	**Art Unit**
Meless N. Zewdu	2617

SEARCHED			
Class	Subclass	Date	Examiner
455	456.5-456.6	8/8/2006	M.Z.
455	60, 455	8/8/2006	M.Z.
455	423-425	8/8/2006	M.Z.
455	63.1-63.2	8/8/2006	M.Z.
455	62-45	8/8/2006	M.Z.
455	41.2-41.3	8/8/2006	M.Z.
455	443-453	8/8/2006	M.Z.
455	463-464	8/8/2006	M.Z.
455	509, 553	8/8/2006	M.Z.
455	512-513	8/8/2006	M.Z.
455	524-526	8/8/2006	M.Z.
455	550.1	8/8/2006	M.Z.
455	168.1	8/8/2006	M.Z.
455	176.1	8/8/2006	M.Z.

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR

Substitute for form 1449A/PTO	Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	11/199,586
	Filing Date	August 8, 2005
	First Named Inventor	Xiaodong Li
(use as many sheets as necessary)	Art Unit	2617
	Examiner Name	M. N. Zewdu
Sheet 1 of 1	Attorney Docket Number	68144/P014C1/10503148

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number: Number-Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

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Examiner Initials*	Cite No.[1]	Foreign Patent Document: Country Code[3]-Number[4]-Kind Code[5] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
MZ	BA	DE 198 00 953	July 29, 1999	Siemens AG		

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] Applicant's unique citation designation number (optional). [2] See attached Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the application number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
MZ	CA	Wong et al. "Multiuser OFDM with Adaptive Subcarrier, Bit, and Power Allocation", IEEE Journal on Selected Areas in Communications. IEEE. New York, US, 1999, Vol. 17. NR. 10, pp. 1747-1758	
MZ	CB	Mexican Office Action issued for PA/a/2003/005311 dated March 31, 2006.	

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25649312.1	/Meless Zewdu/	Date Considered	08/18/2006

PTO/SB/08A (10-01)
Approved for use through 10/31/2002.OMB 0651-0031
U. S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Substitute for form 1449A/PTO				*Complete if Known*	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Application Number	11/199,586
				Filing Date	August 8, 2005
				First Named Inventor	Xiaodong Li
				Art Unit	2661
(use as many sheets as necessary)				Examiner Name	Not Yet Assigned
Sheet	1	of	1	Attorney Docket Number	68144/P014C1/10503148

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number: Number-Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
MZ		US 5,726,978	March 10, 1998	Frodigh et al.	
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Examiner Initials*	Cite No.[1]	Foreign Patent Document: Country Code[3]-Number[4]-Kind Code[5] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
MZ	BA	EP 0 999 658	May 10, 2000	Lucent Technologies, Inc.		

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NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
MZ	CA	Ye Li et al.; "Clustered OFDM with Channel Estimation for High Rate Wireless Data"; Mobile Multimedia Communications, 1999. (MoMuC'99) 1999 IEEE International Workshop on Nov. 15-17, 1999; pages 43-50.	
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25657177 .1	/Meless Zewdu/	Date Considered	08/18/2006

Substitute for form 1449A/PTO		Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT		Application Number	11/199,586
(use as many sheets as necessary)		Filing Date	August 8, 2005
		First Named Inventor	Xiaodong Li
		Art Unit	2661
		Examiner Name	Not Yet Assigned
Sheet 1	of 4	Attorney Docket Number	68144/P014C1/10503148

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Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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MZ	AS1	US-5,280,630**	01-18-1994	Wang	

Examiner Signature	/Meless Zewdu/	Date Considered	08/18/2006

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Approved for use through 10/31/2002.OMB 0651-0031
U. S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Substitute for form 1449A/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(use as many sheets as necessary)

Sheet 2 of 4

Complete If Known	
Application Number	11/199,586
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	2661
Examiner Name	Not Yet Assigned
Attorney Docket Number	68144/P014C1/10503148

MZ	AT1	US-6,377,636 B1**	04-23-2002	Paulraj et al.	
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

[1]Applicant's unique citation designation number (optional). [2]See attached Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3]Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4]For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the application number of the patent document. [5]Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6]Applicant is to place a check mark here if English language Translation is attached.

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
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Examiner Signature	/Meless Zewdu/	Date Considered	08/18/2006

25678792.1

Substitute for form 1449A/PTO				Complete If Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Application Number	11/199,586
				Filing Date	August 8, 2005
				First Named Inventor	Xiaodong Li
				Art Unit	2661
(use as many sheets as necessary)				Examiner Name	Not Yet Assigned
Sheet	3	of	4	Attorney Docket Number	68144/P014C1/10503148

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Examiner Signature	/Meless Zewdu/	Date Considered	08/18/2006

Substitute for form 1449A/PTO				Complete If Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Application Number	11/199,586
				Filing Date	August 8, 2005
				First Named Inventor	Xiaodong Li
				Art Unit	2661
(use as many sheets as necessary)				Examiner Name	Not Yet Assigned
Sheet	4	of	4	Attorney Docket Number	68144/P014C1/10503148

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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached.

Examiner Signature	/Meless Zewdu/	Date Considered	08/18/2006

25678792.1

Notice of References Cited	Application/Control No. 11/199,586	Applicant(s)/Patent Under Reexamination LI ET AL.	
	Examiner Meless N. Zewdu	Art Unit 2617	Page 1 of 1

Page 241

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*	C	US-6,330,460 B1	12-2001	Wong et al.	455/562
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*	E	US-5,507,034	04-1996	Bodin et al.	455/34.1
*	F	US-6,141,565	10-2000	Feuerstein et al.	455/560
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	I	US-			
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*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N	DE 019800953C1	07-1999	DE	Ritter	H04B 7/005
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	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
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*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

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L1: Entry 2 of 3   File: EPAB   Jul 29, 1999

PUB-NO: DE019800953C1
DOCUMENT-IDENTIFIER: DE 19800953 C1
TITLE: Resource allocation in radio interface of radio communications system

PUBN-DATE: July 29, 1999

INVENTOR-INFORMATION:

NAME	COUNTRY
RITTER, GERHARD	DE

ASSIGNEE-INFORMATION:

NAME	COUNTRY
SIEMENS AG	DE

APPL-NO: DE19800953
APPL-DATE: January 13, 1998

PRIORITY-DATA: DE19800953A (January 13, 1998)

INT-CL (IPC): H04 B 7/005; H04 B 7/204; H04 B 7/26; H04 J 13/02; H04 Q 7/38; H04 L 27/00
EUR-CL (EPC): H04Q007/38 ; H04B017/00

ABSTRACT:

CHG DATE=19991102 STATUS=N>The method involves transmitting data symbols (d) in time slots (ts) over the radio interface between a base station (BS) and several mobile stations (MS) handled by the base station. An OFDMA multi-carrier method is used for the transmission of the data symbols, which assigns respectively several sub-carriers (oc) and a segment (S...) of a frequency spectrum to the mobile stations, to form a connection between base station and mobile station. The quality of different segments of the frequency spectrum is measured through each mobile station. At least one preferred segment, suitable for its own connection, is determined through each mobile station, and a corresponding information is transmitted to the base station. The information received from the mobile stations is evaluated through the base station, and a segment for the respective connection is assigned to each mobile station, dependent on the evaluation. An information about the assigned segment is transmitted to each mobile station through the base station.

Previous Doc   Next Doc   Go to Doc#

Electronic Acknowledgement Receipt

EFS ID:	1332068
Application Number:	11199586
International Application Number:	
Confirmation Number:	1128
Title of Invention:	OFDMA with adaptive subcarrier-cluster configuration and selective loading
First Named Inventor/Applicant Name:	Xiaodong Li
Customer Number:	29053
Filer:	David H. Tannenbaum/Lorraine Davidoff
Filer Authorized By:	David H. Tannenbaum
Attorney Docket Number:	68144/P014C1/10503148
Receipt Date:	22-NOV-2006
Filing Date:	08-AUG-2005
Time Stamp:	17:31:17
Application Type:	Utility

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)	Multi Part /.zip	Pages (if appl.)
1		11199586AdaptixP014C1.pdf	856330	yes	18

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Amendment - After Non-Final Rejection	1	1
	Claims	2	8
	Applicant Arguments/Remarks Made in an Amendment	9	18

Warnings:	
Information:	
Total Files Size (in bytes):	856330

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

Docket No.: 68144/P014C1/10503148
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Xiaodong Li et al.

Application No.: 11/199,586

Confirmation No.: 1128

Filed: August 8, 2005

Art Unit: 2617

For: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

Examiner: M. N. Zewdu

RESPONSE TO NON-FINAL OFFICE ACTION

MS Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

INTRODUCTORY COMMENTS

In response to the Office Action dated August 24, 2006 (hereinafter the "Current Action"), please consider the following remarks:

Amendments to the Claims are reflected in the listing of claims which begins on page 2 of this paper.

Remarks/Arguments begin on page 9 of this paper.

AMENDMENTS TO THE CLAIMS

1. (Currently Amended) A method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA) comprising:

a subscriber unit measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station;

the subscriber unit selecting a set of candidate subcarriers;

the subscriber unit providing feedback information on the set of candidate subcarriers to the base station; and

the subscriber unit receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber unit.

2. (Currently Amended) The method defined in Claim 1 further comprising the subscriber unit sending the indication to [[a]] the base station.

3. (Currently Amended) The method defined in Claim 2 further comprising sending an indication of the group of clusters selected by the base station for use by the subscriber unit.

4. (Currently Amended) The method defined in Claim 3 further comprising the base station selecting subcarriers for the subscriber unit based on inter-cell interference avoidance.

5. (Canceled)

6. (Canceled)

7. (Currently Amended) The method defined in Claim 1 further comprising the subscriber unit submitting new feedback information after being allocated the set of subscriber units to be allocated a new set of subcarriers and thereafter the subscriber unit receiving another indication of the new set of subcarriers.

8. (Currently Amended) The method defined in Claim 1 further comprising the subscriber unit using information from pilot symbol periods and data periods to measure channel and interference information.

9. (Canceled)

10. (Canceled)

11. (Canceled)

12. (Original) The method defined in Claim 1 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

13. (Original) The method defined in Claim 12 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

14. (Original) The method defined in Claim 1 further comprising the base station selecting the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

15. (Original) The method defined in Claim 14 wherein the additional information comprises traffic load information on each cluster of subcarriers.

16. (Original) The method defined in Claim 15 wherein the traffic load information is provided by a data buffer in the base station.

17. (Original) The method defined in Claim 1 wherein the indication of subcarriers is received via a downlink control channel.

18. (Original) The method defined in Claim 1 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

19. (Original) The method defined in Claim 1 wherein providing feedback information comprises arbitrarily ordering the set of candidate of subcarriers as clusters of subcarriers.

20. (Original) The method defined in Claim 19 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

21. (Canceled)

22. (Canceled)

23. (Original) The method defined in Claim 1 wherein providing feedback information comprises sequentially ordering candidate clusters.

24. (Canceled)

25. (Canceled)

26. (Currently Amended) The method defined in Claim 1 further comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber unit; and then

the base station allocating a second portion of the subcarriers to the subscriber unit to increase communication bandwidth.

27. (Currently Amended) The method defined in Claim 26 wherein the base station allocates the second portion after allocating each subscriber unit in the cell subcarriers to establish a data link between the base station and said each subscriber unit.

28. (Canceled)

29. (Currently Amended) An apparatus comprising:

a plurality of subscriber units in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscriber units; and

a first base station in the first cell, the first base station performing subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscriber units based on inter-cell interference avoidance and intra-cell traffic load balancing in response to the feedback information.

30. (Currently Amended) An apparatus comprising:

a plurality of ~~subscribers~~ subscriber units in a first cell operable to generate feedback information indicating clusters of subcarriers desired for use by the plurality of ~~subscribers~~

subscriber units; and

a first base station in the first cell, the first base station operable to allocate OFDMA subcarriers in clusters to the plurality of ~~subscribers~~ subscriber units;

each of [[a]] said plurality of ~~subscribers~~ subscriber units to measure channel and interference information for the plurality of subcarriers based on pilot symbols received from the first base station and at least one of the plurality of ~~subscribers~~ subscriber units to select a set of candidate subcarriers from the plurality of subcarriers, and [[the]] said at least one subscriber unit to provide feedback information on the set of candidate subcarriers to the base station and to receive an indication of subcarriers from the set of subcarriers selected by the first base station for use by the at least one subscriber unit.

31. (Currently Amended) The apparatus defined in Claim 30 wherein each of the plurality of ~~subscribers~~ subscriber units continuously monitors reception of the pilot symbols known to the base station and the plurality of subscriber units and measures signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

32. (Currently Amended) The apparatus defined in Claim 31 wherein each of the plurality of subscriber units measures inter-cell interference, wherein the at least one subscriber unit selects candidate subcarriers based on the inter-cell interference.

33. (Currently Amended) The apparatus defined in Claim 32 wherein the base station selects subcarriers for the one subscriber unit based on inter-cell interference avoidance.

34. (Canceled)

35. (Canceled)

36. (Currently Amended) The apparatus defined in Claim 30 wherein the subscriber unit submits new feedback information after being allocated the set of ~~subscribers~~ subscriber units to receive a new set of subcarriers and thereafter receives another indication of the new set of subcarriers.

37. (Currently Amended) The apparatus defined in Claim 30 wherein the at least one subscriber unit uses information from pilot symbol periods and data periods to measure channel and interference information.

38. – 42. (Canceled)

43. (Original) The apparatus defined in Claim 30 wherein the base station selects the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

44. (Original) The apparatus defined in Claim 43 wherein the additional information comprises traffic load information on each cluster of subcarriers.

45. (Original) The apparatus defined in Claim 44 wherein the traffic load information is provided by a data buffer in the base station.

46. (Currently Amended) The apparatus defined in Claim 30 wherein the indication of subcarriers is received via a downlink control channel between the base station and the at least one subscriber unit.

47. (Original) The apparatus defined in Claim 30 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

48. (Currently Amended) The apparatus defined in Claim 30 wherein the plurality of ~~subscribers~~ subscriber units provide feedback information that comprises an arbitrarily ordered set of candidate subcarriers as clusters of subcarriers.

49. (Original) The apparatus defined in Claim 48 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

50. (Canceled)

51. (Canceled)

52. (Original) The apparatus defined in Claim 30 wherein providing feedback information comprises sequentially ordering candidate clusters.

53. (Canceled)

54. (Canceled)

55. (Currently Amended) The apparatus defined in Claim 30 wherein the base station allocates a first portion of the subcarriers to establish a data link between the base station and the subscriber unit; and then allocates a second portion of the subcarriers to the subscriber unit to increase communication bandwidth.

56. (Currently Amended) The apparatus defined in Claim 55 wherein the base station allocates the second portion after allocating each subscriber unit in the cell subcarriers to establish a data link between the base station and said each subscriber unit.

57. (Canceled)

58. (Currently Amended) A method comprising:

[[the]] a base station allocating a first portion of a plurality of [[the]] subcarriers to establish a data link between the base station and [[the]] a subscriber unit; and [[then]]

the base station allocating a second portion of said plurality of [[the]] subcarriers to the subscriber unit to increase communication bandwidth.

59. (Currently Amended) The method defined in Claim 57 wherein the base station allocates the second portion after allocating each subscriber unit in the cell subcarriers to establish a data link between the base station and said each subscriber unit.

60. (Currently Amended) A base station comprising:

means for allocating a first portion of a plurality of [[the]] subcarriers to establish a data link between the base station and [[the]] a subscriber unit; and

means for allocating a second portion of said plurality of [[the]] subcarriers to the subscriber unit to increase communication bandwidth.

61. (Currently Amended) The apparatus defined in Claim 60 wherein the base station allocates the second portion after allocating each subscriber unit in the cell subcarriers to establish a data link between the base station and said each subscriber unit.

62. (Currently Amended) An apparatus comprising:

a plurality of subscriber units in a cell; and

a base station in the cell, the base station to perform subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscriber units based on inter-cell interference avoidance and intra-cell traffic load balancing.

REMARKS

I. General

Applicant hereby traverses the rejections of record and requests reconsideration and withdrawal of such in view the remarks contained herein. Claims 1-4, 7, 8, 12-20, 23, 26-33, 37, 43-49, 52, 55, 56, and 58-62 are pending in this application. Claims 5, 6, 9-11, 21, 22, 24, 25, 34, 35, 38-42, 50, 51, 53, 54, and 57 have been previously cancelled. Claims 1-4, 7, 8, 26, 27, 29-33, 36, 37, 46, 48, 55, 56, and 58-62 have been amended. Note that the claims have been amended only for the purpose of correcting a minor informality and not in the face of prior art. No new matter has been added.

II. Double Patenting Rejection

In the Current Action, the Examiner bases the non statutory double patenting rejection upon the notion that "the difference between the claims in the instant application and the claims in the [issued] patent is that the claims in the instant application are more broader then the claims in the [issued] patent. *See* Current Action, pg. 3. Applicant submits that the idea that the pending claims may be broader than the issued claims (which form the basis of the rejection) is not, by itself, appropriate rational for a double patenting rejection. Non statutory double patenting requires rejection of an application claim "when the claimed subject matter is not patentably distinct from the subject matter claim in the commonly owned patent." *See* M.P.E.P. 804(B)(1). In the case at hand, the Examiner's assertion that the pending claims are broader than the issued claims is not determinative as to whether or not the pending claims are patentably distinct in view of the issued claims. Applicant respectfully notes that the Examiner's statement is immaterial with respect to double patenting. As the Manual of Patent Examining Procedure correctly explains, "[d]omination and double patenting should not be confused . . . . Domination by itself, i.e., in the absence of statutory or nonstatutory double patenting grounds, cannot support a double patenting rejection." *In re Kaplan*, 789 F.2d 1574, 1577-78 (Fed. Cir. 1986), *cited in* M.P.E.P. § 804(II). As such, the Examiner has not provided a sufficient double patenting rejection. Therefore, Applicant requests withdrawal of the rejection of record.

III. Claim Objections

Claims 5, 6, 9-11, 21, 22, 24, 25, 34, 35, 38-42, 50, 51, 53, and 54 are objected to as being dependent upon a rejected base claim. Please note that these claims were cancelled in a preliminary amendment and are no longer pending this application.

IV. Rejections Under 35 U.S.C. §103

Claims 1, 12, 14, 17-18, 30, 43, and 46-47 are rejected under 35 U.S.C. §103(a) as being unpatentable over German Patent DE 198 009 53 to Ritter (hereinafter "Ritter") in view of U.S. Patent 5,956,642 to Larsson et al. (hereinafter "Larsson"). Claims 2-4, 8, 13, 31-33, and 37 are rejected under 35 U.S.C. §103(a) as being unpatentable over Ritter as applied to the claims above, and further in view of U.S. Patent 6,330,460 to Wong (hereinafter "Wong"). Claims 15, 16, 44, and 45 are rejected under 35 U.S.C. §103(a) as being unpatentable over the references applied to the claims above, and further in view of U.S. Patent 6,327,472 to Westroos (hereinafter "Westroos"). Claims 19, 20, 23, 48, 49, and 52 are rejected under 35 U.S.C. §103(a) as being unpatentable over Ritter as applied to Claim 1 above, and further in view of U.S. Patent 5,507,034 to Bodin et al. (hereinafter "Bodin"). Claims 29 and 62 are rejected under 35 U.S.C. §103(a) as being unpatentable over Ritter in view of U.S. Patent 6,141,565 to Feuerstein et al. (hereinafter "Feuerstein"). Claims 7, 26, 36, 55, 58, 60, and 61 are rejected under 35 U.S.C. §103(a) as being unpatentable over Ritter in view of U.S. Patent 5,726,978 to Frodigh et al. (hereinafter "Frodigh").

To establish a prima facie case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art cited must teach or suggest all the claim limitations. *See* M.P.E.P. §2143. Without conceding that the first or second criteria are satisfied, Applicant respectfully asserts that the Examiner's rejection fails to satisfy the third criteria.

A. Claims 1, 12, 14, 17-18, 30, 43, and 46-47 are rejected under 35 U.S.C. §103(a) as being unpatentable over Ritter in view of Larsson.

Independent claim 1 recites "measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station." Independent claim 30 recites a similar limitation. In the Current Action, the Examiner seems to acknowledge that neither Ritter or Larsson teach or suggest these limitations. Instead, the Examiner simply notes "when the references are combined as shown above, the measurement or the parameters in question will be based on pilot symbols/data received from a base station." *See* Current Action, pg. 4. As an initial matter, Applicant submits that the Examiner's mere conclusion, apparently drawn without support from the references, does not serve as an appropriate basis for a 35 U.S.C. §103 rejection. As discussed above, M.P.E.P. § 2143 requires the prior art cited must teach or suggest all the claim limitations. (emphasis added)

Nevertheless, Applicant points out there is no suggestion in either reference of a subscriber unit measuring channel information based on pilot symbols received from a base station. For instance, Ritter generally describes OFDM communication between a base station and subscriber. However, Ritter does not mention a subscriber unit measuring anything based on pilot symbols received from a base station, much less interference information for a plurality of subcarriers, as set forth in the claim. Also, Larsson is silent as to pilot channels at all, much less those received from a base station. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

Claims 12, 14, 17, and 18 depend from claim 1 and claims 43, 46, and 47 depend from claim 30, respectively, and inherit every limitation of the claim from which they depend. As shown, the Examiner's proposed combination fails to teach or suggest every limitation of claims 1 and 30. As such, claims 12, 14, 17, 18, 43, 46, and 47 set forth limitations not taught or suggested by the Examiner's proposed combination and are patentable at least by virtue of their dependency on claims 1 and 30. In addition, these claims set forth limitations making them patentable in their own right.

For example, claim 12 recites "wherein the pilot symbols occupy an entire OFDM frequency bandwidth." In the Current Action the Examiner points to Ritter, at the Abstract, as satisfying this limitation. *See* Current Action, pg. 5. However, as discussed above, Ritter (and Larsson for that matter) is silent with respect to pilot symbols. It follows that neither Ritter or Larsson teach or suggest pilot symbols occupying an entire OFDM frequency bandwidth, as set forth in the claim. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

Claims 17 and 46 recite "wherein the indication of subcarriers is received via a downlink control channel." In the Current Action the Examiner points to Ritter, at the Abstract, as satisfying this limitation. *See* Current Action, pg. 5. Applicant points out that Ritter does not mention how an indication of subcarriers is received from the base station. There is no mention at all as to the channels (i.e., control, data, etc.) used in Ritter's Abstract. Moreover, Larsson is not relied upon to teach or suggest this limitation, nor does it do so. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

Claims 18 and 47 recite "wherein the plurality of subcarriers comprises all subcarriers allocable by a base station." In the Current Action the Examiner points to Ritter, at the Abstract, as satisfying this limitation. *See* Current Action, pg. 5. Applicant points out that Ritter is wholly silent as to "all subcarriers allocable by a base station," as set forth in the claims. Moreover, Larsson is not relied upon to teach or suggest this limitation, nor does it do so. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

B. Claims 2-4, 8, 13, 31-33, and 37 are rejected under 35 U.S.C. §103(a) as being unpatentable over Ritter as applied to the claims above, and further in view of Wong.

Claims 2-4, 8, and 13 depend from claim 1 and claims 31-33, and 37 depend from claim 30, respectively, and inherit every limitation of the claim from which they depend. As shown above, Ritter does not teach or suggest every limitation of claims 1 and 30. Moreover, Wong is not relied upon to teach or suggest the missing limitations, nor does it do so. As such, claims 2-4, 8, 13, 31-33, and 37 set forth limitations not taught or suggested by the Examiner's proposed combination and are patentable at least by virtue of their dependency from claims 1 and 30. In addition, claims set forth limitation making the patentable in their own right.

For example, claim 2 recites "the subscriber unit sending the indication to the base station." In the Current Action the Examiner argues that Ritter, as modified by Wong, teaches "a subscriber station/mobile station is capable of measuring signal-plus-interference-to-noise ratio (SINR)." *See* Current Action, pg. 6. Applicant respectfully points out that claim 2 does not recite "measuring signal-plus-interference-to-noise ratio (SINR)," as the Examiner apparently understands. Nevertheless, Applicant points out that the proposed combination does not teach or suggest the claim limitation at issue. For instance, Ritter merely discloses that information about the assigned segment (e.g., an "indication") is transmitted to each mobile station. However, Ritter does not mention that the mobile stations send that indication to the base station, as set forth in the claim. Moreover, Wong is silent as to this limitation. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

Claim 3 recites "sending an indication of the group of clusters selected by the base station for use by the subscriber." In the Current Action the Examiner does not point out where, in Ritter or Wong, this limitation is taught or suggested. Instead, the Examiner seems to focus on "the subscriber measuring inter-cell interference, wherein the subscriber selects candidate sub-carriers base on inter cell interference," which is not recited in the claim. Nevertheless, Applicant points out that Ritter and Wong are silent as to sending an indication of a group of clusters selected by the base station for use by the subscriber, as set forth in the claim. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

Claims 4 and 33 recite "the base station select[s] subcarriers for the subscriber unit based on inter-cell interference avoidance." In the Current Action the Examiner relies upon Wong, at col. 8 lines 11-26, as satisfying this limitation. *See* Current Action, pg. 7. However, Wong describes a subscriber determining a maximum rate at which it may receive data based upon, for example, SINR and ambient interfering sources. However, Applicant points out that a subscriber determining a maximum data rate at which is may receive data is not the same as a base station selecting subcarriers for the subscriber unit, as set forth in the claim. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

Claim 32 recites "wherein the at least one subscriber unit selects candidate subcarriers based on the inter-cell interference." In the Current Action the Examiner relies upon Wong, at col. 8 lines 11-26, as satisfying this limitation. *See* Current Action, pg. 7. However, Wong describes a subscriber determining a maximum rate at which it may receive data based upon, for example, SINR and ambient interfering sources. However, Applicant points out that a subscriber determining a maximum data rate at which is may receive data is not the same as a subscriber unit selecting subcarriers, as set forth in the claim. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

C. Claims 15, 16, 44, and 45 are rejected under 35 U.S.C. §103(a) as being unpatentable over the references applied to the claims above, and further in view of Westroos.

Claims 15 and 16 depend from claim 1 and claims 44 and 45 depend from claim 30, respectively, and inherit every limitation of the claim from which they depend. As shown above, Ritter does not teach or suggest every limitation of claims 1 and 30. Moreover, Westroos is not relied upon to teach or suggest the missing limitations, nor does it do so. As such, claims 15, 16, 44, and 45 set forth limitations not taught or suggested by the Examiner's proposed combination and are patentable at least by virtue of their dependency from claims 1 and 30. In addition, claims 15, 16, 44, and 45 set forth limitation making the patentable in their own right.

For example, claims 16 recites "wherein the traffic load information is provided by a data buffer in the base station." Claim 44 recites a similar limitation. In the Current Action the Examiner relies upon Westroos, at col. 5 lines 45-65, as satisfying this limitation. However, Westroos describes assigning a traffic channel to a mobile station when a mobile station attempts to access a particular cell. The assignment may be a "load dependent traffic assignment." But, Westroos does not describe what mechanism is used to make the traffic assignment, or even if the assignment is necessarily made at the base station. It follows that Westroos does not teach or suggest traffic information provided by a data buffer in the bases station, as set forth in the claim.

Moreover, Ritter does not teach or suggest this limitation, nor does it do so. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

D. Claims 19, 20, 23, 48, 49, and 52 are rejected under 35 U.S.C. §103(a) as being unpatentable over Ritter as applied to Claim 1 above, and further in view of Bodin.

Claims 19, 20, and 23 depend from claim 1 and claims 48, 49, and 52 depend from claim 30, respectively, and inherit every limitation of the claim from which they depend. As shown above, Ritter does not teach or suggest every limitation of claims 1 and 30. Moreover, Bodin is not relied upon to teach or suggest the missing limitations, nor does it do so. As such, claims 19, 20, 23, 48, 49, and 52 set forth limitations not taught or suggested by the Examiner's proposed combination and are patentable at least by virtue of their dependency from claims 1 and 30. In addition, these claims set forth limitation making them patentable in their own right.

E. Claims 29 and 62 are rejected under 35 U.S.C. §103(a) as being unpatentable over Ritter in view of Feuerstein.

Independent claims 29 and 62 recite performing subcarrier allocation based on intra-cell traffic load balancing. In the Current Action the Examiner acknowledges that Ritter does not teach or suggest this claim limitation. Instead, the Examiner points to Feuerstein, at col. 2 lines 27-37, as satisfying this limitation. *See* Current Action, pg. 12. However, at the Examiner's citation, Feuerstein describes changing network parameters according to "local interference and/or local traffic conditions" in order to optimize the network parameters. *See* Feuerstein at col. 2 lines 32-33. In discussing "local interference" Feuerstein contemplates traffic density distribution, etc. between cells. *Id.* at col. 2 lines 50-52. For example, according to Feuerstein, a mobile unit may request handoff based on the relative traffic loads between two cells. *Id.* at col. 6 lines 51-57. However, Applicant notes that merely evaluating relative traffic loads between two cells is not the same as allocating subcarriers based on traffic load balancing within a cell. Feuerstein does not contemplate evaluating load balancing within each cell. As such, Feuerstein does not teach or suggest performing subcarrier allocation based on intra-cell traffic load balancing, as set forth in the claim.

F. Claims 7, 26, 36, 55, 58, 60, and 61 are rejected under 35 U.S.C. §103(a) as being unpatentable over Ritter in view of Frodigh.

Independent claim 58 recites "the base station allocating a second portion of said plurality of subcarriers to the subscriber unit to increase communication bandwidth." Independent claim 60 recites a similar limitation. In the Current Action the Examiner acknowledges that Ritter does not teach or suggest this limitation. *See* Current Action, pg. 12. Instead, the Examiner relies upon Frodigh, at col. 4 lines 32-49, as satisfying this limitation. *Id.* at pg. 13. Generally, Frodigh "selectively chooses" a group of subcarriers to be adaptively allocated to avoid requiring that all OFDM subcarriers be adaptively allocated. *See* Frodigh at col. 4 lines 44-49. In doing so, the use of system resources is minimized. *Id.* As such, Frodigh merely describes minimizing the use of resources by adaptively allocating only a portion of (as opposed to all) subcarriers. In any event, Frodigh is silent as to how merely selecting a portion of available subcarriers will be used to affect communication between a base station and subscriber unit. As such, Frodigh falls short of disclosing allocating a second portion of subcarriers to increase communication bandwidth. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

Claims 7 and 26 depend from claim 1 and claims 36 and 55 depend from claim 30, respectively, and inherit every limitation of the claim from which they depend. As an initial matter, Applicant notes that the Examiner relied upon the combination of Ritter and Larsson in rejecting claims 1 and 30. As such, according to the Examiner's own rationale, Larsson is required to satisfy every limitation of claims 1 and 30 (and therefore claims 7, 26, 36, and 55). However, the Examiner does not rely upon Larsson in rejecting claims 7, 26, 36, and 55. Clearly, if Larsson is required to satisfy the limitations of independent claims 1 and 30, Larsson is required to satisfy the limitations of claims depending therefrom. Therefore, according to the Examiner's own rationale, the rejection of claims 7, 26, 36, and 55 is insufficient under 35 U.S.C. §103.

Nevertheless, Applicant endeavors to show that the art of record does not teach or suggest every claim limitation. Ritter does not teach or suggest every limitation of claims 1 and 30. Moreover, Frodigh is not relied upon to teach or suggest the missing limitations, nor does it do so. As such, claims 7, 26, 36, and 55 set forth limitations not taught or suggested by the Examiner's proposed combination and are patentable at least by virtue of their dependency from claims 1 and 30. In addition, claims 15, 16, 44, and 45 set forth limitation making them patentable in their own right.

For example, claims 7 recites "the subscriber unit submitting new feedback information after being allocated the set of subscriber units to be allocated a new set of subcarriers and thereafter the subscriber unit receiving another indication of the new set of subcarriers." Claim 36 recites a similar limitation. In the Current Action the Examiner acknowledges that Ritter does not teach or suggest this limitation. *See* Current Action, pg. 14. Instead, the Examiner relies upon Frodigh, at col. 4 lines 32-49, as satisfying this limitation. *Id.* at pg. 13. Generally, Frodigh "selectively chooses" a group of subcarriers to be adaptively allocated to avoid requiring that all OFDM subcarriers be adaptively allocated. *See* Frodigh at col. 4 lines 44-49. In doing so, the use of system resources is minimized. *Id.* As such, Frodigh merely describes minimizing the use of resources by adaptively allocating only a portion of (as opposed to all) subcarriers. In any event, Frodigh is silent as to the subscriber unit submitting new feedback information for receiving a new set of subcarriers, as set forth in the claims. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

Claim 26 recites "the base station allocating a second portion of the subcarriers to the subscriber unit to increase communication bandwidth." Claim 55 recites a similar limitation. In the Current Action the Examiner acknowledges that Ritter does not teach or suggest this limitation. *See* Current Action, pg. 14. Instead, the Examiner relies upon Frodigh, at col. 4 lines 32-49, as satisfying this limitation. *Id.* at pg. 13. Generally, Frodigh "selectively chooses" a group of subcarriers to be adaptively allocated to avoid requiring that all OFDM subcarriers be adaptively allocated. *See* Frodigh at col. 4 lines 44-49. In doing so, the use of system resources is minimized. *Id.* As such, Frodigh merely describes minimizing the use of resources by adaptively allocating only a portion of (as opposed to all) subcarriers. In any event, Frodigh is silent as to how merely selecting a portion of available subcarriers will be used to affect communication between a base station and subscriber unit. As such, Frodigh falls short of disclosing allocating a second portion of subcarriers to increase communication bandwidth. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Applicant requests withdrawal of the rejection of record.

V. Conclusion

In view of the above remarks, Applicant believes the pending application is in condition for allowance. Applicant believes no fee is due with this response. However, if a fee is due, please charge our Deposit Account No. 06-2380, under Order No. 68144/P014C1/10503148 from which the undersigned is authorized to draw.

Dated: November 22, 2006

Respectfully submitted,

By_______________

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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 11199586

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	150		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	250		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	100		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	40 minus 20 =	* 20	x 25 =	500	OR	x =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	6 minus 3 =	* 3	x 100 =	300		x =	
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			N/A			N/A	
			TOTAL	1300		TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

11/22/06 1, 29, 30, 58, 60, 62

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 40	Minus	** 40	= 0	x =		OR	x =	
Independent (37 CFR 1.16(h))	* 6	Minus	*** 6	= 0	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Electronic Acknowledgement Receipt

EFS ID:	1397555
Application Number:	11199586
International Application Number:	
Confirmation Number:	1128
Title of Invention:	OFDMA with adaptive subcarrier-cluster configuration and selective loading
First Named Inventor/Applicant Name:	Xiaodong Li
Customer Number:	29053
Filer:	David H. Tannenbaum/John Pallivathukal
Filer Authorized By:	David H. Tannenbaum
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Application Type:	Utility

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed	IDS.pdf	125716	no	3
Warnings:					

Information:					
This is not an USPTO supplied IDS fillable form					
2	NPL Documents	OA.pdf	360789	no	7
Warnings:					
Information:					
3	Foreign Reference	KR.pdf	2303750	no	38
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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

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EP 유럽특허 : 오스트리아 벨기에 스위스 리히텐슈타인 독일 덴마크 스페인 프랑스 영국 그리스 이탈리아 룩셈부르크 모나코 네덜란드 포르투칼 오스트리아 스위스 리히텐슈타인 독일 덴마크 스페인 핀랜드 영국
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(74) 대리인 김기종, 권동용, 최재철

심사청구 : 없음

(54) 주파수 분할 다중시스템에서의 적응채널할당

요약

주파수 분할 다중시스템의 적응할당의 방법 및 장치가 제공된다. 이 방법과 시스템에서 M가입자의 부분집합은 링크상에서 통신에 유용한 N가입자의 큰 집합으로부터 선택된다. 통신이 링크상에서 발생할 때, M가입자의 부분집합의 가입자의 신호품질(C/I)과 N가입자의 군의 가입자에 대한 간섭(I)측정(344)은 주기적으로 수행된다. C/I와 I측정은 M가입자의 부분집합을 재구성(422)하여 링크에 대한 공통채널 간섭을 감소하는데 이용된다.

대표도

도2

명세서

기술분야

본 발명은 셀룰러 전기통신시스템에 관한 것이다. 특히, 본 발명은 주파수 분할 다중 셀룰러시스템에 관한 것이다.

배경기술

셀룰러 무선통신시스템에서, 이동국의 이용자는 이 시스템의 지형적인 커버러지 에어리어(coverage area)를 이동하는 동안 무선 인터페이스를 통해 시스템과 통신한다. 이동국과 시스템 사이의 무선 인터페이스는 시스템의 커버러지 에어리어를 통해 분산된 기지국을 제공함으로써 수행되고, 이들 각각은 이 시스템내에서 작동하는 이동국과 무선통신을 할 수 있다. 일반적인 셀룰러 전기통신시스템에서 이 시스템의 각각의 기지국은 셀이라고 하는 지형적 커버리지 에어리어내에서의 통신을 제어하고 특정 셀내에 위치한 이동국은 이 셀을 제어하는 기지국과 통신한다. 이동국이 시스템을 통해 이동함에 따라 시스템과 이동국 사이의 통신제어는 시스템을 통해 이동국의 이동에 따라 셀에서 셀로 이동한다. 기존의 셀룰러 전기통신시스템은 특정 시스템에 작동하도록 된 장비의 호환성을 보장하는 여러 공중 인터페이스 표준에 따라 작

동한다. 각각의 표준은 모든 작동 모우드에서 시스템의 이동국과 기지국사이에서 발생하는 처리의 특정의 디테일(details)을 제공한다. 이러한 작동 모우드는 아이들 상태, 제어채널의 리스캔(rescan), 등록 및 음성 또는 트랙픽 채널의 연결을 포함한다. 셀 시스템기술의 발달은 최근에 급속히 이루어지고 있다. 셀룰러시스템에 의해 제공되는 향상된 서어비스에 대한 요구가 증가함에 따라 셀룰러시스템의 기술이 향상되었다. 이러한 요구를 만족시키기 위해 셀시스템의 기술과 셀시스템의 전체의 수가 전세계적으로 향상됨에 따라 셀룰러시스템이 작동하는 시스템 표준수가 증가하게 된다.

셀룰러 전기통신시스템에서, 대부분의 무선시스템처럼, 사용에 이용가능한 주파수 대역폭이 제한된 자원이다. 이러한 이유때문에, 새로운 셀룰러시스템을 개발할 때, 유효한 주파수 대역폭의 가장 효율적인 이용이 강조된다. 셀룰러시스템내에서의 통신은 흔히 다중통로 전파와 상호채널 간섭과 같은 RF신호왜곡을 받는다. 새로운 표준시스템의 개발은 시스템의 셀내에서 통신에 대한 RF신호왜곡의 영향을 최소화 하기 위해 이러한 필요성이 강조된다.

주파수 분할다중(FDM)은 셀룰러시스템에 이용되는 데이터를 전송하는 방식이다. 직교분할다중(OFDM)은 특히, 셀룰러시스템에 적절한 FDM의 특정방식이다. OFDM신호는 상이한 주파수에 있는 가입자와 함께 다중된 다수의 가입자로 구성되어 있고, 각각은 연속적이 아니라 불연속적으로 변하는 신호에 의해 변조된다. 변조신호의 레벨이 불연속적으로 변하기 때문에, 각각의 가입자의 전력 스펙트럼은 $(\sin x/x)^2$ 분배를 추종한다. 각각의 가입자에 전송된 스펙트럼 모양은 각각의 서브 채널의 스펙트라가 또다른 가입자 주파수에서 제로가 되도록 되어 있고, 가입자 사이에서 간섭이 발생하지 않는다. 일반적으로, N열 데이터 성분은 N가입자 주파수를 변조한 다음 다중 주파수 분할이 된다. 각각의 N열 데이터 성분은 T=1/fs의 기간을 하는 데이터 블록을 포함하고, 여기서 fs는 다수의 1/T에 의해 주파수가 분할된다. 가입자의 주파수 스펙트럼이 중첩될지라도 주파수 공간은 각각의 변조된 캐리어의 전력의 피키가 또 다른 캐리어의 전력 스펙트럼에서의 널에 해당하는 주파수에서 발생하도록 하나의 문자간격에 대해 가입자를 직교로 한다. OFDM의 전체의 스펙트럼은 다수의 OFDM이 OFDM신호에 포함될 때 직각으로 폐쇄된다.

시간주기 T동안 OFDM신호는 N샘플의 블록으로 표현된다. N샘플의 값은 다음과 같다.

$$x(n)=\sum_{k=0}^{N-1} X(k)e^{2jnk/N}$$

N값 X(k)는 OFDM캐리어 $e^{2jnk/N}$을 변조하는 불연속적으로 변하는 신호의 주기 T동안 각각의 데이터를 나타낸다. 위로부터, OFDM신호는 한 세트의 데이터 샘플 X(k)의 역 이산 퓨리어 변환에 해당한다. 데이터 스트림을 OFDM신호로 변환하기 위해 데이터 스트림은 N샘플 X(k)의 블록으로 스플릿되고, 역 이산 퓨리어 변환이 각각의 블록에서 수행된다. 시간에 대해 특정의 샘플에서 나타나는 블록의 열은 주파수 fn으로 어느 가입자를 변조한 불연속적으로 변하는 신호를 구성한다.

OFDM은 셀룰러시스템에서 바람직한 여러 장점을 제공한다. OFDM에서 주파수 스펙트럼에서의 가입자의 직교성은 OFDM신호의 전체의 스펙트럼을 직각으로 폐쇄 한다. 이로 인해 시스템에 유용한 대역폭이 효과적으로 이용될 수 있다. 또한 OFDM은 다중통로 전파효과에 의해 야기된 간섭이 감소하는 장점을 제공한다. 다중 통로 전파는 무선파의 통로에 있는 비딩 및 또다른 구조로부터의 스캐터링하는 무선파에 의해 야기된다. OFDM시스템에서, 다중통로는 주파수 선택 다중통로 페이딩을 야기 한다. 각각의 개별의 데이터 성분의 스펙트럼은 작은 부분의 유용한 대역폭만을 점유한다. 이것은 많은 수에 대해 작은 부분의 다중통로 페이드를 분산하는 효과를 지닌다. 이것은 주파수 선택 다중통로 페이딩에 의해 야기된 버스트 에러를 효과적으로 랜덤화하여 하나, 또는 여러 문자가 완전히 파괴되는 대신 많은 문자가 약간만 파괴된다. 또한, OFDM은 전송채널에 대한 문자 지연 시간과 비교해서 시간주기 T가 매우 크다는 장점이 있다. 이것은 동일한 시간에 상이한 문자의 부분을 소신 함으로써 야기된 상호 문자 간섭을 감소시키는 효과를 지닌다.

셀룰러시스템의 OFDM의 이용은 다음에 제안되어 있다(다음 ; Cimni, 'Analysis and Simulation of a Digital Mobile Channel Using Orthogonal Frequency Division Multiplexing' IEEE Trans. Commun., Vol.33, No.7, pp.665~675(July, 1985). 이동시스템에서의 OFDM의 유사한 응용이 다음에 제안되어 있다(다음 : Casa, 'OFDM for Data Communication Over Mobile Radio FM-Channels-Part I : Analysis and Experimental Results', IEEE Trans. Commun., Vol.39, No.5, pp.783~793(May, 1991). 이들 OFDM셀룰러 시스템에서, 한 세트의 가입자 주파수는 기지국으로부터 이동국(다운링크) 및 이동국으로부터 셀내에서 작동하는 기지국(업링크)으로의 전송을 위해 발생하는 각각의 통신링크에 할당된다. 각각의 통신링크에 할당된 가입자 주파수의 세트는 시스템에 유용한 동일한 가입자 주파수로부터 선택된다. 셀내에서 동일한 가입자 주파수는 하나 이상의 통신링크에 할당될 수 없다. 따라서, 동일한 셀내에서의 가입자 사이의 상호 채널 간섭은 발생하지 않는다. 그러나, 이러한 OFDM시스템에서, 시스템의 셀의 통신링크는 시스템내의 또다른 셀에서 설정된 통신링크에 할당된 하나 이상의 가입자 주파수를 포함하는 한 세트의 가입자 주파가 할당될 수 있다. 각각의 공통으로 할당된 이들 가입자 주파수는 다른 셀에서의 동일한 가입자 주파수를 이용함으로써 야기된 상호채널 간섭을 받을 수도 있다. 이 OFDM시스템에서는 상이한 셀내에서 발생된 통신링크에 대한 가입자 주파수의 할당을 조정하는 방법 또는 시스템이 존재하지 않는다. 이러한 시스템에서, 이웃하는 셀에서 이용되는 가입자에 의해 야기된 통신링크에서의 상호채널 간섭은 매우 클 수 있다.

비 OFDM시스템에서의 셀사이에 채널 주파수를 할당하는 방법은 상호채널 간섭을 감소하거나 최소화하기 위해 개발되었다. 적응채널할당(ACA)은 이러한 방법이다. ACA에서, 셀룰러시스템에 할당된 채널주파수는 어떤 간섭기준이 만족되면 어느 곳에라도 시스템에 이용될 수 있다. 또한, 채널 주파수는 간섭 기준이 만족되는 한 시스템을 통해 자유롭게 이용될 수 있다.

적응채널할당에서, 동적으로 할당된 채널 주파수에 대한 신호특성과 간섭레벨의 여러 측정이 셀내에서 발생될 수 있는, 통신링크에 할당될 수 있는 트랙픽 또는 음성채널의 리스트를 구축하기 위해 셀의 커버러지 에어리어에서 수행된다. 셀의 커버러지 에어리어내에서의 셀과 이동국을 제어하는 기지국은 시스템내에서의 통신을 위해 동적으로 할당되도록 되어 있는, 한 세트의 채널 주파수에 대한 측정을 수행한다. 이론적으로, 양 업링크와 다운링크 측정이 수행된다. 이러한 측정을 기반으로, 새로운 링크가 발생해야할 때, 채널 주파수가 어느 법칙을 기반으로한 링크에 할당된다. 예를 들어, 최소간섭 ACA에서 시스템은 각각의 셀내에서 측정했듯이, 최소간섭(최대량) 채널로부터 최대간섭(최저량)으로 채널의 테이블을 구축한다. 다음, 이 시스템은 이 셀에서의 통신에 대해 할당하기 위해 리스트로부터 어떤수의 최소간섭 채널 주파수를 선택한다. 선택되어 주파수가 상호 변조를 발생하는 채널의 결합을 방지하는 채널 상이의 필요한 주파수 분할과 같은 기준이 고려된다. 이는 다음에 제안되어 있다(다음 : ACA의 예로, H.Eriksson, 'Capacity Improvement by Adaptive Channel Allocation', <u>IEEE Global Telecomm. Conf.</u>, pp.1355~1359, Nov.28~Dec.). 모든 채널이 모든 기지국에 의해 할당된 공통 자원인 셀룰러 무선시스템과 연관된 용량 이득을 예시한다. 위에서 언급된 논문에서, 이동국은 다운링크의 신호의 품질을 측정하고 채널은 간섭비에 대한 최대의 캐리어(C/I레벨)를 지닌 채널을 선택하는 것을 기반으로 할당된다.

각각의 링크에 대한 하나의 캐리어 주파수를 이용하여 비 OFDM셀룰러시스템에서 발생된 기존의 ACA알고리즘은 OFDM을 이용하는 셀룰러시스템에서 효과적으로 이용될 수 없다. 기존의 ACA방식의 하나의 문제는 OFDM시스템에서의 가입자의 수는 각각의 통신링크에 대해 단일의 캐리어를 이용하는 시스템에서의 캐리어의 수에 비에 대단히 많다는 것이다. 이것은 ACA에 필요한 업링크와 다운링크 측정결과를 얻기 위해 시간과 시스템 자원을 낭비하는 확장된 측정 노력을 요구한다. 또한, 처리를 위해 시스템에 이동국에서 이루어진 다운링크 측정의 많은 수의 결과를 전달하기 위해 다수의 신호자원을 이용해야 한다.

다음, OFDM시스템에 이용하기 위해 적응채널 할당의 방법 및 시스템을 갖는 장점을 제공할 수 있다. 이 방법과 장치는 시스템의 셀사이의 상호채널 간섭을 감소하는 OFDM시스템내에 가입자를 할당해야 한다. 또한, 이 방법과 시스템은 채널을 할당할 때 시스템자원을 효과적으로 활용하기 위해 OFDM시스템의 유일한 특성을 고려하여 설계되어야 한다. 본 발명은 이러한 방법과 시스템을 제공하는 것이다.

발명의 상세한 설명

본 발명은 직교주파수 분할다중(OFDM)시스템에서 적응채널할당(ACA)의 방법과 시스템을 제공하는 것이다. 이 방법과 시스템은 시스템의 셀사이의 상호 채널 간섭을 감소하는 OFDM의 링크에 대한 가입자의 할당을 제공한다.

또한, 본 발명은 비 OFDM시스템에서 OFDM으로 이용하도록 된 종래의 ACA방법 및 시스템을 수행하는 어려움과 단점을 극복하는 것이다. 종래의 ACA방식은 RF채널을 하나의 채널이 링크당 이용되는 시스템에 적합하게 할당하도록 되어 있다. OFDM 시스템에 적용되듯이, 이들 종래의 OFDM방식은 사용자에 할당된 OFDM가입자가 적응적으로 할당되는 것이 필요하다. OFDM시스템에서 OFDM가입자를 적응할 수 있게 할당하는 것은 시스템의 수신기와 송신기사이에 채널측정정보 및 할당정보를 전송하기 위해 많은 량의 측정과 신호자원을 필요할 것이다. 적응적으로 할당될 가입자를 선택적으로 선택하고 할당결정의 기준을 설정함으로써, 본 발명의 시스템과 방법은 아직까지 효과적인 ACA를 제공하는 동안 측정과 신호자원의 이용을 최소화한다.

본 발명의 제1태양에 있어서, M가입자의 초기부분집합은 OFDM시스템의 각각의 분리링크에 관한 통신에 유용한 N가입자의 다수군으로부터 선택된다. 수 M은 특정 링크의 데이터비에 의존하고 시스템의 링크사이에서 변할 수 있다. 통신이 발생할 때, M가입자의 부분집합내의 가입자의 신호품질레벨(C/I)과 모든 유효한 N가입자의 간섭레벨(I)은 주기적으로 측정된다. 이들 C/I와 I측정결과는 시스템에 보고된다. 링에 대한 통신중, M의 집합의 가입자보다 링크상에서 더 양호한 신호 수신을 제공할 수 있는 매우 바람직한 이용하지 않는 가입자가 링크가 존재하는 셀내에서 유용한지를 이 시스템은 C/I 및 I로부터 결정한다. 매우 바람직한 이용하지 않는 가입자가 존재한다고 결정되면, 시스템은 이용하지 않는 가입자를 포함하도록 M가입자의 부분집합을 재구성한다.

본 발명의 제2태양에 따라, 링크수신기로서의 이동국은 모든 측정결과가 아니라 간격을 보고하는 것을 선택할 때, 측정결과의 제한된 집합만을 시스템에 전송 한다. 측정결과의 전송된 제한된 집합은 최저 C/I측정결과의 선택수와 최저 I측정결과의 선택수를 포함한다. 결과의 제한된 집합의 전송은 업링크 신호자원의 이용을 감소시킨다.

본 발명의 또다른 실시예에서, 링크수신기로의 이동국은 M가입자의 부분집합내의 가입자의 신호품질레벨(C/I) 및 유용한 N가입자의 간섭레벨(I)을 주기적으로 측정하고, 가입자 요구 메시지를 후보 가입자가 링크의 가입자를 대체하도록 할당하게 요청하는 시스템에 전송한다. 다음, 이동국은 C/I 및 I측정을 기반으로 한 링크에 대한 후보대체 가입자를 결정하고 후보 가입자가 링크의 가입자를 대체하기 위해 할당되는 것을 요청하는 시스템에 가입자 요청 메세지를 전달한다. 시스템은 가입자 허용 또는 가입자 거절 메시지와 함께 요청 메시지에 응답한다. 가입자 허용 메시지가 수신되는 경우, 이동국은 후보 가입자를 포함하도록 M가입자의 부분집합을 재구성한다. 가입자가 거절되면, 이동국은 새로운 후보 가입자를 요구하는 가입자 요청 메시지를 전송한다.

실시예

도 1은 일반적으로 본 발명이 포함하는 형태의 주파수 분할다중(FDM) 셀룰러 전기통신시스템을 도시한다. 도 1에서, 임의의 지형적 영역이 다수의 연속하는 무선 커버러지 에어리어 또는 C1~C10으로 분할될 수 있다. 도 1의 시스템이 10개의 셀만을 포함하는 것으로 도시되어 있을 지라도 주지해야할 것은 실질적으로 셀의 수는 더 많을 수 있다.

각각의 셀(C1~C10)과 함께 관련하여 위치한 기지국이 다수의 기지국(B1~B10)으로 표시되어 있다. 각각의 기지국(B1~B10)은 선행기술에 공지되어 있듯이, 송신기, 수신기 및 기지국 제어기를 포함한다. 도 1

에서 기지국 (B1~B10)은 각각의 셀(C1~C10)의 중앙에 위치되어 있다. 그러나, 셀룰러 무선시스템의 또 다른 구성에서, 기지국(B1~B10)은 그 주변에 위치될 수 있고, 셀(C1~C10)로부터 멀리 떨어져서 위치할 수 있고, 전방향 또는 일방향중 하나로 무선신호로 셀(C1~C10)을 조명할 수 있다. 따라서, 도 1의 셀룰러 무선시스템의 대표도는 단지 예시만을 목적으로 한 것이고, 본 발명이 수행된 셀룰러 무선전기 통신시스템의 가능한 수행의 제한으로 의도하지는 않았다.

도 1을 계속해서 참고를 하면, 다수의 이동국(M1~M10)이 셀(C1~C10)내에서 발견될 수 있다. 다시, 단지 10개의 이동국이, 도 1에서 도시되어 있지만 주지해야 할 것은 이동국의 실제의 수는 이보다 상당이 많고 기지국의 수를 크게 초과하는 반면, 어떠한 이동국(M1~M10)도 셀(C1~C10)내에서 발견되지 않으면 셀(C1~C10)중 특정의 하나에서의 이동국(M1~M10)의 존재 또는 비존재가 셀의 어느 위치로부터 다른 위치, 하나의 셀에서 또다른 셀 심지어 특정의 MSC에 의해 서비스되는 셀룰러 무선시스템으로부터 또다른 이러한 시스템으로 이동하는 이동국(M1~M10)의 사용자의 개별의 요구에 의존한다는 것을 이해해야 할 것이다.

각각의 이동국(M1~M10)은 하나 이상의 이동국(B1~B10) 및 이동교환국(MSC)을 통해 전화호출을 초기화하거나 수신할 수 있다. 이동교환국(MSC)은 통신링크 또는 케이블에 의해 기지국(B1~B10) 및 도시되지 않은 고정 공중교환 전화망 (PSTN) 또는 통합시스템 디지털 망(ISDN)시설을 포함하는 유사한 고정망에 연결되어 있다. 이동국 교환망(MSC)과 기지국(B1~B10)사이 또는 이동국 교환망(MSC)과 PSTN 또는 ISDN사이의 관련된 연결은 도 1에 완전히 도시되어 있지는 않지만 선행기술에 공지되어 있다. 이와 유사하게 셀 무선시스템에서 하나 이상의 이동국 교환국을 포함하고, 각각의 부가적인 이동국 교환망을 기지국의 상이한 그룹 또는 또다른 이동국 교환국에 케이블 또는 무선링크를 경유하여 연결되어 있다는 것이 공지 되어 있다.

각각의 MSC는 시스템에서 각각의 기지국(B1~B10)과 이와 통신하는 이동국 (M1~M10)사이의 통신관리를 제어한다. 이동국이 시스템 주위를 이동함에 따라 이동국은 이동국이 위치한 영역을 제어하는 기지국을 통해 시스템으로 위치를 등록 한다. 이동국 전기통신시스템이 특정의 이동국에 어드레스된 호출을 수신할 때, 이동국이 믿을 수 있는 영역을 제어하는 기지국의 제어채널에 이동국이 전송하는 어드레스된 페이징 메시지가 위치된다. 이에 어드레스된 페이징 메시지를 수신할 때, 이동국은 시스템 액세스 채널을 스캔하고, 이것은 가장 강한 어세스 채널신호를 수신하는 기지국에 대한 페이지 응답을 전달한다. 이러한 과정은 다음 호출연결을 설정하도록 초기화된다. MSC는 이동국에 대한 호출의 수신, 이동국으로부터의 페이지 응답의 수신기지국에 의한 이동국으로의 무선채널의 할당은 물론 통신이 진행되는 동안 셀에서 셀로의 시스템을 통해 이동하는 이동국에 응답사한 기지국에서 또다른 기지국으로의 이동국과의 핸드오프 통신에 응답하여 기지국(B1~B10)에 의해 서어비스되는 지형적인 영역에 있다고 믿을 수 있는 이동국의 페이징을 제어한다.

각각의 셀(C1~C10)은 다수의 FDM가입자 주파수와 하나 이상의 표시된 제어 채널이 할당된다. 제어채널은 이를 유닛으로부터 전송되고 수신된 정보에 의해 이동국의 작동을 제어하거나 감독하는데 이용된다. 이러한 정보는 인입호출신호, 페이지신호, 페이지 응답신호, 위치등록신호 및 음성 및 트랙픽 가입자 할당을 포함할 수 있다.

본 발명은 도 1에 도시되어 있듯이, FDM셀룰러시스템으로 적응채널할당 (ACA)의 방법 및 시스템을 수행하는 것이다. 본 발명의 실시예에서, ACA는 시스템 대역폭이 5MHz이고, 가입자 공간이 5KHz로 작동하는 OFDM시스템으로 수행된다. 이 시스템에 유용한 가입자의 전체의 수는 5MHz/5KHz=1000이다. 가입자는 시스템 RF채널에 대한 전송을 위해 주파수가 2GHz인 시스템 RF캐리어로 변조되고 전송된 신호의 주파수 스팩트라는 RF캐리어 주위로 집중된다. 모든 가입자는 각각의 시스템에서 이용하는 것이 유용하지만 가입자는 셀의 하나 이상의 링크에서 동시에 이용되지는 않는다. 주파수 분할 듀플렉스(FDD)는 업링크와 다운링크의 가입자 주파수를 분할하는데 이용된다. 이 시스템은 핸드오버용 정보, 긴기간 채널할당정보, 긴 기간 전력제어정보 및 메시지 및 측정결과를 전송하기 위해 업링크와 다운링크 모두인 전용 제어채널(DCCH)를 포함한다. 또한, 시스템은 짧은 기간의 채널할당정보, 짧은 기간의 전력제어정보, 측정 메시지 및 측정결과를 전송하기 위해 업링크 및 다운링크인 물리적 제어채널(PCCH)을 포함한다.

본 발명의 ACA에서, 이동국과 기지국사이의 업링크와 다운링크에 대하여 시스템은 다수(N)의 가입자의 집합으로부터 가입자의 부분집합의 수(M)를 선택한다. N가입자의 집합은 각각의 링크에 대해 시스템내에서 유용한 가입자의 집합이다. 여기서 N> M이다. N가입자의 집합은 통신중 변하지 않는다. 또한, N가입자의 집합은 유용한 가입자의 수보다 작지만은 M가입자의 부분집합에서의 캐리어의 수보다 많은 집합이다.

도 2는 OFDM시스템의 본 발명을 따른 가입자의 할당을 도시한다. 기지국(200)은 다운링크(206)와 업링크(208)에 걸쳐 이동국(204)과 통신한다. 기지국(200)은 또한 다운링크(210) 및 업링크(212)를 걸쳐 이동국(204)과 통신한다. 링크 (206, 208, 210, 212)에 대한 전송은 시스템 RF채널에 걸쳐 이루어진다. 각각의 링크에 전송해야 할 음성 및 데이터는 가입자수(M)로 변조된다. M가입자는 다음 시스템 RF채널에 걸쳐 전송하기 위해 시스템 RF캐리로 변조된다. 셀내의 각각의 링크 (206, 208, 210, 212)는 M가입자의 분리부분집합을 이용한다. 가입자는 셀내에서 한번 이용될 수 있다.

도 3A는 본 발명을 따른 시스템의 블록도이다. 이 시스템은 링크전송기 (300), 링크수신기(330), ACA처리유닛(360) 및 RF채널(380)로 구성되어 있다. 특정 링크의 수신기(330)와 송신기(300)는 링크의 대향단에 위치되어 있다. 다운링크에서, 수신기(330)는 이동국에 위치되어 있고 송신기(300)는 기지국에 위치되어 있다. 업링크에서 수신기(330)는 기지국에 위치되어 있고 송신기(300)는 이동국에 위치되어 있다. RF채널은 N유효한 가입자의 집합을 갖는다. 링크수신기(330)와 링크 전송기는 유용한 가입자의 M의 부분집합을 이용하여 RF채널(380)에 대해 통신한다.

도 3B 및 도 3C는 도 3A의 송신기(300)와 수신기(330)를 도시한다. 도 3A와 도 3B에 도시된 기능적인 특징은 기지국과 이동국 수신기 및 송신기에 공통이다.

송신기(300)는 직병렬 변환기(302), 맵핑회로(MAP)(304), 역급속 퓨리에 변환(IFFT)회로(306), 주파수 멀티플렉스(MuX)(308) 및 변조기(310)를 포함한다. 송신작동에서, 직병렬 변환기(302)는 직렬 디지털 데이터 스트림(312)을 M문자(314)의 블록으로 변환시키고 여기서, M은 시스템의 문자의 크기와 데이터비에 의해 결정된다. 다음, M문자는 IFFT회로(306)에 대한 데이터 입력의 블록에서 수행된다. M문자는 다음 MAP

회로(304)에 전달되고 여기서 각각의 M문자는 IFFF회로(306)의 가입자 입력에 맵된다. 역고속 퓨리어 변환(IFFT)이 IFFT회로(306)의 데이터 입력의 블록에서 수행된다. IFFT회로(306)의 N출력에서 발생된 신호(318)는 M멀티플랙스된 가입자를 포함하는 신호(320)를 발생하도록 MuX(308)에서 멀티플랙스된다. 각각의 이들은 M문자(314)의 하나의 문자에 포함된 데이터를 운반한다. 신호(320)는 다음 변조기(310)에서 시스템 RF캐리어(324)로 변조되어 시스템 RF채널(322)에 걸쳐 OFDM신호로 전송된다.

수신기(330)는 복조기(332), 주파수 디멀티플랙서(DEMUX)(338), 고속 퓨리어 변환(FFT)회로(336), 디-맵핑회로(DEMAP)(338), 병직렬 변환기(340), 간섭측정수단(344), 신호품질 측정수단(342) 및 프로세서(346)를 포함한다. 수신기 작동에서, 시스템 RF캐리어는 시스템 RF채널(322)에 수신된 다음 복조기(332)에서 복조되고 멀티플랙스된 가입자를 포함하는 신호의 N샘플(332)을 얻기 위해 DEMUX(334)에서 디멀티플랙스된다. 고속 퓨리어 변환(FFT)이 각각의 가입자에 전송된 어떠한 변조 데이터를 포함하는 데이터 신호(350)를 발생하도록 입력으로 N샘플을 지닌 FFT회로(336)에 의해 수행된다. 보조되어서 FFT를 받은 N가입자는 프로세서(346)로부터의 DEMUX(334) 및 FFT에 대한 파라미터 입력에 의해 결정된다. N샘플로부터 복원된 간섭측정수단(344)은 각각의 N샘플(348)상의 간섭(I)레벨을 측정한다. N수신 데이터신호(350)는 다음 디 맵핑 블록(338)에 입력되고, 여기서 링크 통신에 현재에 할당된 M가입자 주파수에 수신된 M데이터 신호(352)는 N데이터 신호(350)로부터 디맵된다. 디맵핑은 프로세서(346)로부터의 DEMAP블록(338)에 대한 파라미터 입력에 따라 수행된다. M디 맵된 데이터 신호(352)는 다음 병직렬 변환기(340)에 입력되고 직렬 수신 데이터(354)로 변환된다. 신호품질(C/I)은 수신기(330)가 수신하는 링크에 현재할당된 M가입자 주파수에 수신된 디 맵된 데이터 신호(352)에 대한 디 맵핑 블록(338)의 출력에서 측정된다.

각각의 채널에 대한 적응채널할당은 링크수신기에서 수행된 측정의 결과로 작동하는 도 3A의 ACA처리부(360)에 의해 수행된다. 도시된 실시예에서 프로세서 (346)는 간섭측정수단(344)으로부터 간섭측정을 그리고 신호품질 측정수단(342)으로부터 신호품질 측정결과를 수신한다. 프로세서(346)는 시스템의 ACA처리부(360)에 대한 입력에 대한 데이터를 발생하기 위해 측정결과를 연산한다. 프로세서 (346)에 의해 발생된 데이터는 다음 인터페이스(362)를 걸쳐 ACA처리부(360)에 전송된다. 도시된 실시예에서, ACA처리부(360)는 시스템의 기지국내에 교번하여 위치된다. 이동국, 기지국 및 MSC사이에 분배된 ACA처리부에 의해 수행되는 기능을 고려할 수 있다. 필요한 데이터를 기록하기 위해 메모리를 구성하는 방법 및 이러한 형태의 기능을 수행하기 위해 마이크로 프로세서 및 소프트웨어를 구성하는 방법이 선행기술에 공지되어 있다.

이동국이 링크수신기로 기능을 할 때, 프로세서(346)는 적절한 제어채널상의 업링크를 포함하는 인터페이스(362)에 걸쳐 시스템에 전송하기 위해 ACA데이터를 이동국 송신기에 전송한다. 링크수신기로 기지국에서, 프로세서(346)는 랜드라인 (landline) 및 또 다른 연결을 포함하는 인터페이스(362)에 걸쳐 ACA데이터를 MSC에 전달한다. ACA처리부(360)는 데이터를 작동한 다음 기지국이 링크수신기일 때 랜드라인 또는 기타연결을 포함하는 인터페이스(364)에 걸쳐 적절한 가입자 할당 명령을 링크수신기(330)에 리턴시키고 이동국이 링크수신기일 때 적절한 제어채널상의 다운링크에 리턴시킨다.

링크수신기(330)의 프로세서(346)는 명령을 수신한 다음 링크에 대한 수정 가입가가 수신되도록 수신기에 대하여 수정 입력 파라미터를 발생시킨다. 또한, ACA처리부(360)는 인터페이스(336)를 걸쳐 링크송신기(300)와 연결된 MAP회로(304)에 명령을 전달한다. MAP회로(304)는 M가입자의 보정부분집합이 전송되도록 MAP회로(304)의 적절한 출력에 대한 M문자를 맵한다.

필요한 데이터가 이동국사이에 전송되고, 이 시스템의 MSC 및 기지국이 공지된 방법에 의해 성취된다. 설명된 실시예에서, DCCH와 PCCH는 이동국과 시스템사이에 측정결과 또는 가입자 할당 메시지를 전송하기 위해 업링크와 다운링크 모두에서 이용될 수 있다. 이러한 정보를 운반하기 위한 제어채널의 이용은 선행기술에 공지되어 있다.

도 4A는 ACA처리중 링크수신기(330)에 의해 수행되는 단계를 예시한 흐름도 이다. 다운링크에서 수신하는 이동국에 의해 수행된 단계 및 업링크에서 수신하는 기지국에 의해 수행된 단계는 근본적으로 동일하고, 도 4A는 양 경우에 링크수신기(330)에 의해 수행된 단계를 설명하는데 이용된다. 이동국과 기지국에서 수행되는 처리단계사이의 차이는 도 4A의 단계(428)와 관련이 있다. 도 4B는 ACA측정처리의 단계(428)동안 이동국에 의해 수행되는 부가적인 단계를 예시하는 흐름도이다. 이들 부가적인 단계가 도 4A의 처리에서 설명되어 있듯이, 도 4B를 참고로 설명될 것이다.

업링크와 다운링크중 하나에서 이동국과 기지국사이에서 통신링크를 발생해야할 때, ACA처리가 개시된다. 다시 도 4A를 참조하면, 단계(402)에서, 링크수신기는 링크에 유용한 N가입자의 각각의 군에 대한 간섭(I)을 측정하기 위해 시스템으로부터 측정순서 메시지를 수신한다. N가입자는 시스템내에서 유용한 모든 가입자일 수 있고, 시스템내에서 유용한 모든 가입자로부터 선택된 가입자의 작은 군일 수 있다. 다음, 단계(404)에서 I측정이 수행된다. 이후, 단계(404)로부터 처리가 단계(406)에 이동하는데 이 단계에서 I측정결과가 이 시스템에 전달된다. 이동국이 링크수신기일 때, I측정결과가 DCCH 및 PCCH에 걸쳐 기지국에 전달된 다음 MSC에 전달된다. 기지국이 링크수신기일 때, I측정결과가 적절한 오버랜드수단을 경유해 MSC에 전달된다. I측정결과를 전달한 후, 이 처리는 단계(408)에 이동하고 이 단계에서, 링크수신기가 시스템으로부터 응답을 대기한다. 링크수신기 단계(408)에서 대기상태에 있을 때 발생하는 처리단계는 도 5을 참고로 하면서 설명할 것이다.

도 5는 ACA처리중 시스템의 ACA처리부분에서 수행되는 처리단계를 도시한다. 단계(502)에서 링크수신기에서 N가입자에서 수행되는 I측정의 결과는 ACA프로세서에 의해 수신된다. 다음, 단계(504)에서 ACA프로세서는 N가입자에서 이루어진 I측정의 결과로부터 M방해된 이용하지 않는 가입자FMF 결정한다. 단계(504)로부터, 처리가 단계(506)에 이동하고 이곳에서 링크에 대해 방해된 M가입자의 부분집합를 할당하는 가입자 할당 메시지가 양 링크수신기와 링크송신기에 전송된다. ACA프로세서는 지금 단계(508)에 이동하고 링크 수신기로부터 또다른 입력을 대기한다. 처리 흐름은 도 4의 단계(408)에 리턴한다. 가입자 할당 메시지에 대한 M가입자를 결정하는 또다른 방법은 단계(506)와 대체하여 이용될 수 있다. 예를 들어, 가입자가 이들의 이용이 인접셀에서의 전송에 미치는 방법을 기반으로 할당된다. 하나 이상의 간섭된 M가입자가 이웃하는 셀에 이용되면 가입자가 이용되지 않을 수 있다. 이 경우에 M가입자는 최근에 간섭된 M가입자일 수

없다.

다시 도 4A를 참조하면, 408에서 대기상태로 있는 링크수신기는 단계(410)에 이동하고 링크에 M가입자에 채널할당 메시지를 할당하는 채널할당 메시지를 수신 한다. 다음 처리는 링크수신기가 M가입자의 할당된 부분집합을 이용하여 링크에 수신하기 시작할 때 단계(412)에 이동한다. 단계(412)로부터 처리는 단계(414)에 이동하고 또다른 입력을 대기한다. 단계(416)에서 입력이 수신된다. 링크수신기는 M가입자의 할당된 부분집합을 이용하여 수신하는 동안 3개형태의 입력을 수신할 수 있다. 결정단계(418)에서 호출단 신호가 수신되었는 지를 링크수신기가 결정한다. 호출단 신호는 시스템에 의해 링크수신기에 전달되고 링크수신기 자체에서 초기화 된다. 호출단 신호는 링크상의 통신이 종단된 처리를 표시한다. 호출단 신호가 수신되지 않으면 처리가 단계(420)에 이동하고 링크수신기는 측정 타이머 메시지가 수신되었는 지를 결정한다. 측정 타이머는 링크수신기에 관련된 프로세서에 포함 되어 있다. 측정 타이머는 측정을 하기 위해 링크수신기에 알리는 주기적인 간격으로 측정 메시지를 발생한다. 각각의 측정 타이머 신호는 측정간격을 한정한다. 측정 타이머 메시지가 수신되면 이 처리는 단계(424)로 이동한다. 단계(424)에서 링크수신기는 N가입자의 집합의 I을 측정한다. I측정은 정확도를 얻기 위해 각 가입자에 대한 전의 다수의 I측정결과와 평균될 수 있다. 단계(424)를 통해 측정이 단계(404)에서 얻어진 결과와 평균된다. I측정은 단계(404)에서 얻어진 결과와 평균된다. 단계(424)를 통과한 후, 측정결과가 최종 n전의 측정과 평균된다. 여기서 n은 시스템내의 가입자의 간섭레벨을 정확히 추종하는 값이다. 단계(424)로부터 처리가 단계(426)에 이동하고 링크수신기는 단계(426)에 이동하고 링크수신기는 M캐리어의 각각의 부분집합에 대한 C/I을 측정한다. C/I측정은 최종 n전의 C/I측정과 평균된다. 다음 단계(428)에서 링크수신기는 I 및 C/I측정결과를 시스템의 ACA처리부에 전달한다. 링크수신기가 기지국 또는 이동국인가에 따라서 단계(428)는 상이한 방식으로 수행될 수 있다. 링크수신기가 기지국이면 평균된 측정결과가 직접 ACA프로세서에 전달될 수 있다. 링크수신기가 다운링크의 이동국이면 도 4B에 도시된 부분집합은 결과가 기지국을 경유하여 업링크에 걸쳐 시스템이 전송됨에 따라 신호 트랙픽을 감소하는데 이용될 수 있다.

도 4B는 도 4A의 단계(428)를 수행하는 이동국에 의해 수행되는 처리부분집합을 도시한 흐름도이다. 업링크상의 신호 트랙픽은 상이한 시간 간격을 걸쳐 측정결과의 상이한 집합을 시스템에 전달함으로써 감소된다. 긴 보고 간격에 걸쳐 모든 I측정 및 C/I측정결과는 시스템에 전달된다. 매우 짧은 보고 간격에 대해 I측정 및 C/I측정결과의 감소한 집합이 전달된다. 길고 짧은 주기는 긴주기가 n번째 짧은 주기 또는 n번째 측정주기마다 발생하도록 규정되어 있다. 여기서 n은 수가 25이다. 단계(428a)에서, 측정주기가 측정결과를 보고하기 위해 짧은 시간간격과 관련되었는 지를 결정한다. 측정기간이 측정결과를 보고하기 위한 짧은 시간간격과 관련되면 이 처리는 단계(428b)에 이동하고, 이 단계에서 이동국은 M가입자의 부분집합의 최악의 품질 Y에 대해 C/I측정을 전달하고, 여기서 Y < M이고, 그리고 N가입자의 간섭된 Z에 대해 I측정을 전달한다. 여기서 Z < N이다. Y 및 Z의 값은 신호 트랙픽을 최소로 하는 동안 효과적인 ACA에 대한 적절한 정보를 허락하도록 선택된다. Y는 1에 설정되고, Z는 동일한 셀내에서 이용되지 않는 하나 이상의 가입자의 I측정결과를 평균적으로 포함하기 위해 산출된 수에 설정될 수 있다. 다음 처리가 단계 (414)에 이동하고 이곳에서 이동국은 또다른 입력을 대기한다. 그러나, 단계 (428a)에서, 측정주기가 측정결과를 보고하기 위한 짧은 시간 간격과 관련되지 않는 다고 결정되면 이 처리는 단계(428c)에 이동한다. 단계(428c)에서, 이동국은 M가입자의 전체 부분집합에 대해 C/I를 그리고 모든 N가입자에 대한 I측정을 시스템에 전달한다. 다음 이 처리는 단계(414)에서 이동국은 또다른 입력을 대기한다. 이 처리는 ACA프로세서가 링크수신기로부터 측정결과를 수신할 때 도 5로 이동한다.

다시 도 5을 참조하면, 단계(508)에서 대기상태에 있는 ACA프로세서는 링크수신기로부터 입력을 수신한다. ACA프로세서는 단계(510)에서 측정결과 또는 호출단 신호를 수신한다. 입력이 수신될 때, 처리는 단계(512)에 이동하고 이곳에서 입력형태가 어느 것이 수신되었는 지를 결정한다. 호출단 신호가 수신되면 처리는 종료된다. 이예에서, 처리가 단계(514)에 이동하도록 수신된 메시지가 측정결과이다. 단계(514)에서 ACA프로세서는 최저 C/I측정값으로 가입자에게 이용되는 M의 부분집합의 가입자를 결정한다. 다음, 단계(516)에서 M가입자의 부분집합의 C/I측정값의 C/I가 ACA C/I트리거 임계치이하로 되는 지가 결정된다. 단계(516)에서 최저 C/I측정값이 ACA C/I트리거 임계치이하로 떨어지지 않으면 처리가 단계(508)에 이동하여 이곳에서 ACA가 또 다른 입력을 대기한다. 그러나, 만일 단계(516)에서 최저 C/I측정값이 ACA C/I트리거 임계치이하이면 처리가 단계(518)로 이동한다. 단계(518)에서 ACA프로세서는 최저 C/I측정값을 지닌 M의 부분집합의 가입자의 I측정값 이하의 I측정값이 존재하는 지를 N가입자의 집합의 이용하지 않는 가입자에 의해 결정된다. 단계(518)에서 이용되지 않는 가입자가 최저 I측정값으로 존재된다고 결정되면 프로세서 처리는 단계(508)에 이동하고 이곳에서, ACA프로세서가 또다른 입력을 대기한다. 그러나, 단계(518)에서 사용하지 않는 가입자가 낮은 I측정값으로 존재하지 않으면 매우 바람직한 가입자가 존재하고 처리가 단계(520)에 진행한다. 단계(520)에서 ACA프로세서는 방해된 이용되지 않는 가입자를 M가입자의 부분집합에 끼우고 이 부분집합으로부터 최저 C/I측정값을 지닌 M의 부분집합의 가입자를 제거한다. 히스테리시스 효과를 방지하기 위해 가입자의 변경이 단계(518)동안 최근 간섭된 이용하지 않는 가입자의 C/I을 산출하고 산출된 C/I가 제거될 가입자의 C/I이상의 최소량이라는 것을 결정한 후 수행된다. 간섭된 이용하지 않는 가입자의 C/I가 제거될 가입자의 C/I이상의 최소량이 아니면 이용되지 않는 가입자가 대체로 허용될 수 없는 것으로 간주된다. 단계(520)로부터 처리가 단계(522)에 진행하고 있어서 시스템은 링크에 할당된 M가입자의 부분집합를 재구성하여 프로세서에 의해 이루어진 변경을 추종하도록 링크수신기를 명령하는 링크수신기 재구성 부분집합 메시지를 전달한다. 다음, ACA프로세서는 단계(508)에 진행하고 링크수신기로부터 또다른 입력을 대기한다. 단계(514~520)에 의해 주어진 절차는 덜 간섭된 이용되지 않는다. 수의 가입자를 결정하고 C/I임계치이하의 간섭레벨을 지닌 다수의 덜 간섭을 받은 이용하지 않는 가입자를 결정하고, 이들을 C/I임계치 이하의 간섭레벨을 지닌 다수의 이용되는 가입자와 교환함으로써 교번하여 수행된다. 이 부분집합은 또다른 기준에 따라 재구성된다. 예를 들면, M의 부분집합은 이웃하는 셀에서 발생하는 통신에 관해서 링크 셀에서의 부분집합을 이용하는 효과를 기반으로 하여 재구성될 수 있다. 셀에서 이용되는 M가입자가 이웃하는 셀에 이용되지 않으면, 이들은 셀에서 이용되지 않는 가입자와 대체할 수 있고, 이웃하는 셀에서는 이용되지 않는다. 이용하지 않는 가입자가 C/I이하로 되지 않거나 사용하지 않는 가입자가 대체된 가입자보다 높은 간섭레벨을 할지라도 재구성이 발생할 수 있다.

호출이 되고 링크에 대한 통신이 지속되는 한 이 처리가 지속된다. 링크수신기는 입력을 수신할 때, 단계(408)에서 대기상태로부터 이동되고, 도 4A 및 도 4B 및 도 5에 도시된 처리는 호출단과 호출단 신호가

시스템의 링크송신기, 링크수신기 및 ACA처리부분에 의해 수신될 때까지 반복된다.

본 발명의 또다른 실시예에서, 링크수신기로서의 이동국은 M가입자의 부분집합을 요구하고 링크에서 이용
될 M가입자에 대한 대체를 요청하는 요청 메시지를 전송한다. 신호측정결과는 이동국으로부터 시스템에
전달될 필요가 없다. 다음 시스템은 부분집합 허여 또는 가입자 허여 메시지를 이동국에 전달한다. 다운
링크 ACA처리는 이동국의 수신기의 프로세서(346)에서 주로 발생한다. 또다른 실시예 단계(504, 514,
516, 518, 520)는 도 5에 도시되어 제1실시예의 시스템에 의해 수행되는데 이는 이동국의 프로세서(346)
에 의해 수행된다. 업링크 측정에 대한 기지국 ACA처리흐름은 도 4A, 도 4B 및 도 5에서 처럼 유지된다.

도 6A는 본 발명의 또다른 실시예의 ACA처리동안 링크수신기로 이동국에 의해 수행되는 단계를 예시한 흐
름도를 도시한다. 단계(602)에서 이동국이 측정순서 메시지를 수신할 때 ACA처리가 개시된다. 다음, 단계
(604)에서 링크에 유효한 N가입자의 군에 대한 간섭(I)이 이동국에서 측정된다. 다음, 처리는 단계(606)
에 진행하고 이곳에서 간섭된 M가입자가 결정된다. 단계(606)로부터 처리가 단계(608)에 진행되고 부분집
합 요청 메시지가 이동국에 의해 시스템에 전달된다. 부분집합 요청 메세지는 이동국이 요청된 부분집합
각각의 가입자에 이용을 요청하는 시스템에 표시된다. 지금, 처리가 단계(610)로 진행하고 이동국이 시스
템으로부터의 대답을 대기한다. 처리가 단계(610)에서 대기상태에 있을 때, 발생하는 처리 단계는 도 7에
설명되어 있다.

도 7은 이동국이 ACA처리에 관련이 있을 때, 본 발명의 또다른 실시예를 따른 시스템의 ACA처리부내에서
수행되는 처리 단계를 도시한다. 단계(702)에서 ACA처리부는 부분집합 요청 메시지를 수신한다. 다음, 단
계(704)에서 이동국이 요청되는 부분집합의 M가입자의 모두를 이용하게 하는 지를 시스템이 결정한다. 어
느 가입자가 셀에 이용하는데 유용하지 않을 수 있다. 예를 들면, 이들이 또다른 이동국에 의해 이용되거
나 이들이 특정 이용을 위한 시스템내에서 예약되는 경우이다. M 가입자의 이용가능성은 이들의 이용이
이웃하는 셀내의 이송에 어떻게 영향을 미치는 가가 결정된다. ACA는 이들을 결정할 때, 시스템 오퍼레이
터에 대한 유연성을 허락하도록 되어 있다. 이동국이 요청된 부분집합에서 모든 M가입자를 이용하도록 허
용되는 것이 결정될 때, 시스템은 부분집합 허여 메시지를 링크수신기에 전달한다. 그러나, 단계(704)에
서 요청된 부분집합의 가입자가 이동국에 의해 이용되지 않는 다는 것이 결정될 때, 처리는 단계(720)에
진행하고 시스템은 M가입자의 부분집합의 부분으로 유효하지 않은 가입자를 거절하는 가입자 거절 메시지
를 전송한다. 처리흐름은 이동국으로부터의 응답을 대기한다.

도 6A를 참고하면, 이동국은 부분집합 허여 메시지 또는 가입자 거절 메시지를 시스템으로부터 수신한다.
집합 허여 메시지가 수신되면, 처리가 단계(620)에 이동하고 이곳에서, 링크수신기는 할당된 부분집합을
이용하여 수신하기를 시작한다. 그러나 단계(614)에서 가입자 거절 메시지가 수신되면 처리가 단계(616)
로 이동한다. 단계(616)에서 링크수신기는 거절된 요청 가입자를 대치하기 위해 다음 후보를 결정한다.
이들 후보는 M의 요청된 집합에 있지 않은, N유효 가입자의 집합의 다음 간섭된 가입자일 수 있다.

단계(616)에서 처리가 단계(618)에 이동하고 이곳에서 다음 후보 가입자를 요청하는 가입자 요청 메시지
가 시스템에 전달된다. 다음, 처리는 링크수신기가 대답을 대기함에 따라 단계(610)에 이동한다. 이 처리
는 M가입자의 전체의 집합이 받아들여 질 때 까지 단계(610, 612, 614, 616, 618, 706, 708)를 통해 지속
된다. 다음, 처리가 단계(620)에 진행하고 이곳에서 이동국은 허여된 부분집합을 이용하여 링크에 수신되
기 시작한다. 처리는 지금 단계(622)의 대기상태로 이동한다. 단계(622)의 대기상태에서, 처리가 호출단
이나 측정 타이머 메시지중 하나를 수신할 수도 있다. 호출단과 측정 타이머 메시지는 본 발명의 전의 실
시예에 대해 위에서 설명한 호출단과 측정 메시지에 해당한다. 링크수신기는 단계(624)에서 호출단 또는
측정타이머 메시지를 수신하고 단계(626)에 이동하고 이곳에서, 호출단이 수신되는 지를 결정한다. 그러
나, 측정 타이머 메시지가 수신되면, 처리가 단계(628)에 이동한다. 단계(628)에서 이동국은 N이용가능한
가입자에 대한 I를 측정하고 각각의 가입자에 대한 결과를 평균한다. 다음 단계(630)에서 링크수신기는 M
가입자의 부분집합의 C/I를 측정하는 각 가입자에 대한 결과를 평균한다. 지금 처리는 도 6B의 단계(63
2)에 이동한다.

단계(632)에서 링크수신기는 최저 C/I를 지닌 M의 부분집합의 가입자를 결정한다. 다음, 단계(634)에서
최저 C/I가 임계치 이하이면 처리가 단계(622)에 리턴하고 이곳에서 링크수신기가 또다른 호출단 또는 측
정 타이머 메시지를 대기한다. 그러나, 최저 C/I가 임계치 C/I이하고 결정되면 처리가 단계(636)에 진행
한다. 단계(636)에서 M의 부분집합에 있지 않은, N의 집합의 덜 간섭된 가입자가 존재하는 지를
결정한다. 그러나 덜 간섭된 가입자가 존재하지 않으면 처리가 단계(622)에 리턴한다. 그러나 덜 간섭된
가입자가 존재하면 매우 바람직한 가입자가 존재하고 처리가 단계(638)에 진행한다. 단계(638)에서 이동
국이 최저 C/I와 가입자의 대체로 M가입자의 부분집합에 존재하지 않는 간섭된 가입자를 요청하는 시스템
에 가입자 요청 메시지를 전송한다. 이동국에서의 처리는 단계(640)의 대기상태로 이동하고 처리흐름이
도 7의 단계(708)에 이동한다. 시스템의 ACA처리부는 단계(710)에서 요청된 가입자 메시지를 수신한다.
단계(632~638)절차의 대략은 부분집합의 최저 C/I을 지닌 이용된 다수의 가입자를 결정한 다음 요청된
대체로 덜 간섭받은 다수의 가입자를 결정함으로써 대안적으로 수행된다. 가입자 요청 메시지를 수신한
후 단계(716)에서 요청된 가입자가 셀내에서 이용되면 시스템은 단계(718)에 이동하고, 요청된 가입자 거
절 메시지를 이동국에 전달하고, 처리가 단계(708)에 리턴 한다. 그러나 요청된 대체가 셀내에서 이용되
지 않으면 시스템은 요청된 가입자 허용 메시지를 이동국에 전달하고 처리가 단계(708)에 리턴한다. 요청
된 가입자가 셀과 이용되는 것을 결정하듯이 또다른 기준이 이용가능성을 결정하는데 이용된다. 예를 들
어, 요청된 가입자가 이웃하는 셀에 이동되면, 시스템은 가입자 요청을 거절할 수 있다. 처리는 다음 이
동국이 허여 또는 거절 메시지를 수신할 때 단계 (640)의 대기상태로부터 단계(642)로 이동한다. 다음,
단계(644)에서 요청된 가입자가 허용되는 지를 결정한다. 요청된 가입자가 허용되면 처리가 단계(646)에
이동 하고 이동국이 요청 가입자를 포함하도록 수신하고 최저 C/I를 지닌 가입자를 삭제하는 M가입자의
부분집합을 재구성한다. 다음, 처리가 단계(622)의 대기상태에 이동한다. 그러나 요청된 가입자가 허용되
지 않으면, 처리가 단계(648)에 이동한다. 단계(648)에서 이 측정 간격내에서 요청된 가입자로 이미 거절
되지 않은 최저 C/I를 지닌 M가입자보다 간섭을 덜 받은 새로운 후보 가입자가 존재하는 지를 이동국이
결정한다. 새로운 가입자가 존재하지 않으면, 프로세서는 단계(622)의 대기상태에 다시 이동한다. 새로운
가입자가 존재하지 않으면 프로세스는 단계(638)에 진행하고 이곳에서 이동국이 가입자 요청 메시지를 시
스템에 전달한다. 이 메시지는 새로운 대체 가입자로 단계(648)에서 발견된 새로운 후보 가입자를 요청한

다. 다음 처리는 단계(640)에 이동하고 시스템으로부터의 응답을 대기한다. 요청된 가입자가 허용되거나 새로운 후보가 존재하지 않을 때까지 처리가 단계(642, 644, 648, 650, 638, 710, 712, 714, 716, 718)에 의해 형성된 루우프를 통해 지속된다. 처리가 다음 단계(622)의 대기상태로 이동한다. ACA처리는 호출을 통해 지속되고 측정 타이머 메시지가 수신될 때마다 야기된다. 호출이 종료될 때, 처리는 단계(624, 626)를 통해 종료된다.

위의 설명에서 알 수 있듯이, 본 발명은 OFDM시스템의 적응채널할당의 방법 및 시스템을 제공하는 것이다. 본 발명의 이용은 수행되는 OFDM의 수행을 향상 시킨다. 적응채널할당은 링크가 아직 적응채널할당의 장점을 제동하는 시스템의 측정결과를 수행하는데 필요한 신호 자원을 최소로 하도록 되어 있다. 이 결과는 각각의 양호한 품질특성과 덜 강하된 호출 및 양호한 스팩트럼 효율을 지닌 시스템이다.

본 발명은 청구범위내에서 벗어나지 않는다면 여러수정과 변경이 가능하다.

도면의 간단한 설명

도 1은 본 발명이 실행될 수 있는 셀룰러 전기통신망의 도면.

도 2A는 직교주파수 분할다중시스템에서의 본 발명을 따른 가입자의 할당을 도시한 도면.

도 3A는 본 발명의 실시예를 따른 시스템의 블럭도.

도 3B 및 도 3C는 본 발명의 실시예를 따른 링크 송신기와 링크수신기의 블록도.

도 4A 및 도 4B는 수신기에 의해 수행된 본 발명의 실시예를 따른 처리 단계의 흐름도.

도 5는 셀룰러 전기통신망내에서 수행된 본 발명의 실시예를 따른 처리 단계의 흐름도.

도 6A 및 도 6B는 링크수신기에 의해 수행된 본 발명의 또다른 실시예를 따른 처리 단계의 흐름도.

도 7은 셀룰러 전기통신시스템내에서 수행된 본 발명을 따른 처리 단계의 흐름도.

(57) 청구의 범위

청구항 1

링크 송신기로부터 링크수신기로의 통신이 링크에 유용한 다수의 가입자의 집합의 부분집합에 걸쳐 수신된 전기통신시스템에서 상기 링크와 통신하는 가입자를 할당하는 방법은,

상기 부분집합을 제공하기 위해 상기 집합으로부터 다수의 가입자를 할당하는 단계 ;

상기 집합의 각각 가입자에 대한 수신된 신호를 측정하는 단계 ;

하나 이상의 이용하지 않는 가입자가 상기 부분집합의 가입자보다 상기 링크에 허용되는데 더 바람직한 상기 집합에 존재하는 지를 결정하는 단계 ;

확인 결정에 응답하여 상기 부분집합을 재구성하는 단계를 구비한 방법.

청구항 2

청구항 1에 있어서, 상기 집합의 각각의 가입자에 대한 간섭레벨(I)를 측정하는 단계 ;

상기 집합의 다수의 간섭된 이용하지 않는 가입자를 포함하는 부분집합을 결정하는 단계를 구비한 방법.

청구항 3

청구항 2에 있어서, 간섭레벨(I)을 측정하는 상기 단계는 상기 링크수신기로부터 시스템에 상기 간섭레벨(I)측정의 다수의 결과를 전송하는 단계를 더 포함하고 전송된 상기 다수의 결과의 수는 상기 집합의 가입자의 수보다 적은 방법.

청구항 4

청구항 1에 있어서, 측정하는 상기 단계는 상기 집합의 각각의 가입자의 간섭레벨(I)을 측정하는 단계를 더 구비하는 방법.

청구항 5

청구항 1에 있어서, 상기 부분집합의 각각의 가입자의 신호품질(C/I)을 측정하는 단계를 포함하는 방법.

청구항 6

청구항 1에 있어서, 상기 집합의 각각의 가입자의 간섭레벨(I)을 측정하는 단계 ;

상기 부분집합의 각각의 가입자의 신호품질레벨(I)을 측정하는 단계를 구비하고,

결정하는 상기 단계는 최저 신호품질레벨(C/I)을 지닌 부분집합의 가입자를 결정하는 단계 ;

상기 집합의 이용하지 않는 가입자가 상기 신호품질레벨(C/I)을 지닌 상기 부분집합의 상기 가입자의 간섭레벨(I)보다 낮은 간섭레벨(I)을 갖는 것이 존재하는 지를 결정하는 단계를 구비한 방법.

청구항 7

청구항 6에 있어서, 재구성하는 상기 단계는 확정 결정에 응답하여 상기 부분집합으로부터 상기 최저 신

호품질(C/I)을 지닌 상기 가입자를 제거하는 단계 ;

상기 이용되지 않는 가입자를 상기 부분집합에 끼우는 단계를 구비한 방법.

청구항 8

청구항 6에 있어서, 상기 링크로부터 상기 시스템으로 상기 간섭레벨(I)측정의 다수의 측정결과를 전송하는 단계 ; 를 구비하고, 전송된 상기 결과의 수는 상기 집합의 가입자의 수보다 적고 ; 신호품질(C/I)을 측정하는 상기 단계는 상기 링크수신기로부터 상기 시스템으로 상기 신호품질(C/I) 다수의 결과를 전송하는 단계를 포함하도록 전송된 상기 결과의 수는 상기 부분집합의 가입자의 수보다 적은 방법.

청구항 9

청구항 1에 있어서, 할당단계는

상기 집합의 각각의 가입자의 간섭레벨(I)을 측정하는 단계 ;

상기 집합의 다수의 간섭된 가입자를 포함하는 후보 부분집합을 결정하는 단계 ;

링크수신기로부터 상기 시스템에 부분집합 요청을 전송하는 단계 ;

상기 수신기에서 상기 시스템으로부터 응답 메시지를 수신하는 단계 ;

상기 후보 부분집합이 상기 응답메세지로부터 상기 링크에 대해 허용되는 지를 결정하는 단계를 구비한 방법.

청구항 10

청구항 9에 있어서, 응답 메시지를 수신하는 상기 집합은 부분집합 허며 메시지를 수신하는 단계를 포함하는 방법.

청구항 11

청구항 9에 있어서, 응답메세지를 수신하는 상기 단계는 하나 이상의 가입자 거절 메시지를 수신하는 단계를 포함하고, 상기 후보 부분집합이 허용가능한 지를 결정하는 상기 단계는 상기 부분집합에 대한 하나 이상의 다음 후보 가입자를 결정하는 단계 ;

상기 링크수신기로부터 상기 시스템으로 하나 이상의 가입자 요청 메시지를 전송하는 단계 ;

하나 이상의 다음 후보 가입자를 결정하는 상기 단계를 되풀이 하고, 완전한 부분집합이 허용가능할 때까지, 하나 이상의 가입자 요청 메시지를 상기 시스템에 전달하는 단계를 구비한 방법.

청구항 12

청구항 1에 있어서, 이용되지 않는 가입자가 존재하는 지를 결정하는 상기 단계는,

상기 집합의 후보 가입자가 상기 부분집합의 가입자보다 상기 링크에 이용하기에 더 바람직한 것이 존재하는 지를 결정하는 단계 ;

상기 링크수신기에서의 상기 시스템으로부터 응답을 수신하는 단계 ;

상기 후보 가입자가 이용되지 않는 지를 상기 응답으로부터 결정하는 단계 ;

부분의 결정에 응답하여 상기 집합의 가입자가 더 바람직한 것이 존재하는 지를 결정하는 단계를 되풀이하고 확인 결정의 상기 응답 결과로부터 결정하는 상기 단계까지 상이한 후보 가입자를 상기 응답에 따라 결정하는 단계를 구비한 방법.

청구항 13

청구항 12에 있어서, 상기 부분집합의 각각의 가입자에 대해 수신된 신호를 측정하는 상기 단계는,

상기 집합의 간섭레벨(I)을 측정하는 단계 ;

상기 부분집합의 각각의 가입자의 신호품질레벨(C/I)을 측정하는 단계를 구비하고,

후보 가입자가 상기 부분집합의 가입자보다 상기 링크에 이용하기 더 바람직한 것이 있는 지를 결정하는 상기 단계는 최저 신호품질레벨(C/I)을 지닌 상기 부분집합의 가입자를 결정하는 단계 ;

상기 최저 신호품질레벨(C/I)을 지닌 상기 부분집합의 상기 가입자의 간섭레벨(I)보다 낮은 간섭레벨(I)을 지닌 상기 집합의 후보 가입자를 결정하는 단계를 구비한 방법.

청구항 14

링크 송신기로부터 링크수신기로의 통신이 링크에 유용한 다수의 가입자의 집합의 부분집합에 걸쳐 수신된 전기통신시스템에서 상기 링크와 통신하는 가입자를 할당하는 시스템은,

상기 부분집합을 제공하기 위해 상기 집합으로부터 다수의 가입자를 할당하는 수단 ;

상기 집합의 각각의 가입자에 대한 수신된 신호를 측정하는 수단 ;

하나 이상의 이용하지 않는 가입자가 상기 부분집합의 가입자보다 상기 링크에 허용되는데 더 바람직한 상기 집합에 존재하는 지를 결정하는 수단 ;

확인결정에 응답하여 상기 부분집합을 재구성하는 수단을 구비한 시스템.

청구항 15

청구항 14에 있어서, 상기 집합의 각각의 가입자에 대한 간섭레벨(I)을 측정하는 수단단계 ;

상기 집합의 다수의 간섭된 이용하지 않는 가입자를 포함하는 부분집합을 결정하는 수단을 구비한 시스템.

청구항 16

청구항 15에 있어서, 간섭레벨(I)을 측정하는 상기 수단은 상기 링크수신기로부터 시스템에 상기 간섭레벨(I)측정의 다수의 결과를 전송하는 수단을 더 포함하고 전송된 상기 다수의 결과의 수는 상기 집합의 가입자의 수보다 적은 시스템.

청구항 17

청구항 14에 있어서, 측정하는 상기 수단은 상기 집합의 각각의 가입자의 간섭레벨(I)을 측정하는 수단을 더 구비하는 시스템.

청구항 18

청구항 14에 있어서, 측정수단은 상기 부분집합의 각각의 가입자의 신호품질 (C/I)을 측정하는 수단을 포함하는 시스템.

청구항 19

청구항 14에 있어서, 상기 집합의 각각의 가입자의 간섭레벨(I)을 측정하는 수단 ;

상기 부분집합의 각각의 가입자의 신호품질레벨(I)을 측정하는 수단을 구비하고,

결정하는 상기 수단은 최저 신호품질레벨(C/I)을 지닌 부분집합의 가입자를 결정하는 수단 ;

상기 집합의 이용하지 않는 가입자가 상기 신호품질레벨(C/I)을 지닌 상기 부분집합의 상기 가입자의 간섭레벨(I)보다 낮은 간섭레벨(I)을 갖는 것이 존재하는 지를 결정하는 수단을 구비한 시스템.

청구항 20

청구항 19에 있어서, 재구성하는 상기 수단은 확정결정에 응답하여 상기 부분집합으로부터 상기 최저 신호품질(C/I)을 지닌 상기 가입자를 제거하는 수단 ;

상기 이용되지 않는 가입자를 상기 부분집합에 끼우는 수단을 구비한 시스템.

청구항 21

청구항 19에 있어서, 상기 링크로부터 상기 시스템으로 상기 간섭레벨(I)측정의 다수의 측정결과를 전송하는 수단 ; 을 구비하고, 전송된 상기 결과의 수는 상기 집합의 가입자의 수보다 적고 ; 신호품질(C/I)을 측정하는 상기 수단은 상기 링크수신기로부터 상기 시스템으로 상기 신호품질(C/I) 다수의 결과를 전송하는 수단을 포함하도록 전송된 상기 결과의 수는 상기 부분집합의 가입자의 수보다 적은 시스템.

청구항 22

청구항 14에 있어서, 할당수단은

상기 집합의 각각의 가입자의 간섭레벨(I)을 측정하는 수단 ;

상기 집합의 다수의 간섭된 가입자를 포함하는 후보부분집합을 결정하는 수단 ;

링크수신기로부터 상기 시스템에 부분집합 요청을 전송하는 수단 ;

상기 수신기에서 상기 시스템으로부터 응답 메시지를 수신하는 수단 ;

상기 후보부분집합이 상기 응답메세지로부터 상기 링크에 대해 허용되는 지를 결정하는 수단을 구비한 시스템.

청구항 23

청구항 22에 있어서, 응답 메시지를 수신하는 상기 수단은 부분집합 허여 메시지를 수신하는 수단을 포함하는 시스템.

청구항 24

청구항 22에 있어서, 응답메세지를 수신하는 상기 수단은 하나 이상의 가입자 거절 메시지를 수신하는 수단을 포함하고 상기 후보부분집합이 허용가능한 지를 결정하는 상기 수단은 상기 부분집합에 대한 하나 이상의 다음 후보 가입자를 결정하는 수단 ;

상기 링크수신기로부터 상기 시스템으로 하나 이상의 가입자 요청 메시지를 전송하는 수단 ;

하나 이상의 다음 후보 가입자를 결정하는 상기 단계를 되풀이 하고 완전한 부분집합이 허용가능할 때까지 하나 이상의 가입자 요청 메시지를 상기 시스템에 전달하는 수단을 구비한 시스템.

청구항 25

청구항 14에 있어서, 이용되지 않는 가입자가 존재하는 지를 결정하는 상기 수단은,

상기 집합의 후보 가입자가 상기 부분집합의 가입자보다 상기 링크에 이용하기에 더 바람직한 것이 존재하는 지를 결정하는 수단 ;

가입자 요청 메시지를 상기 링크수신기로부터 상기 시스템에 전달하는 수단 ;

상기 링크수신기에서의 상기 시스템으로부터 응답을 수신하는 수단 ;

상기 후보 가입자가 이용되지 않는 지를 상기 응답으로부터 결정하는 수단 ;

을 구비한 시스템.

청구항 26

청구항 25에 있어서, 상기 부분집합의 각각의 가입자에 대해 수신된 신호를 측정하는 상기 수단은,

상기 집합의 간섭레벨(I)을 측정하는 수단 ;

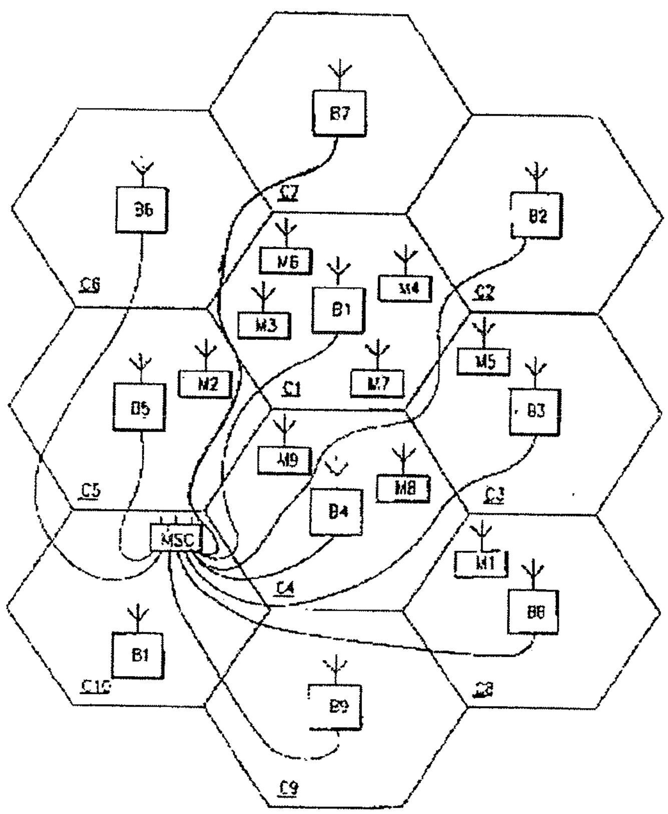
상기 부분집합의 각각의 가입자의 신호품질레벨(C/I)을 측정하는 수단을 구비하고,

후보 가입자가 상기 부분집합의 가입자 보다 상기 링크에 이용하기 더 바람직한 것이 있는 지를 결정하는 상기 단계는 최저 신호품질레벨(C/I)을 지닌 상기 부분집합의 가입자를 결정하는 수단 ;

상기 최저 신호품질레벨(C/I)을 지닌 상기 부분집합의 상기 가입자의 간섭레벨(I)보다 낮은 간섭레벨(I)을 지닌 상기 집합의 후보 가입자를 결정하는 수단을 구비한 시스템.

도면

도면1



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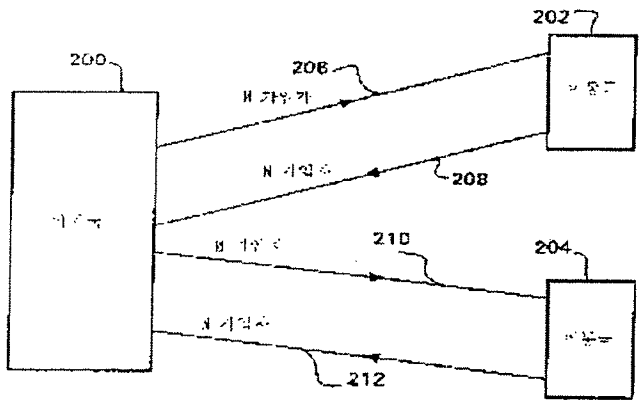

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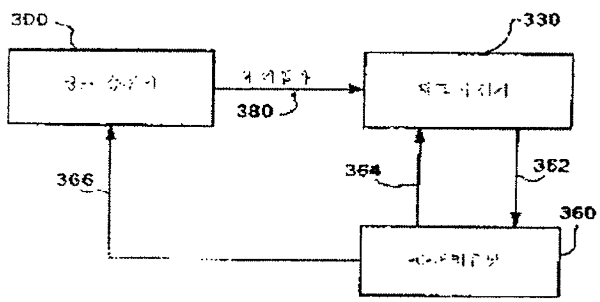

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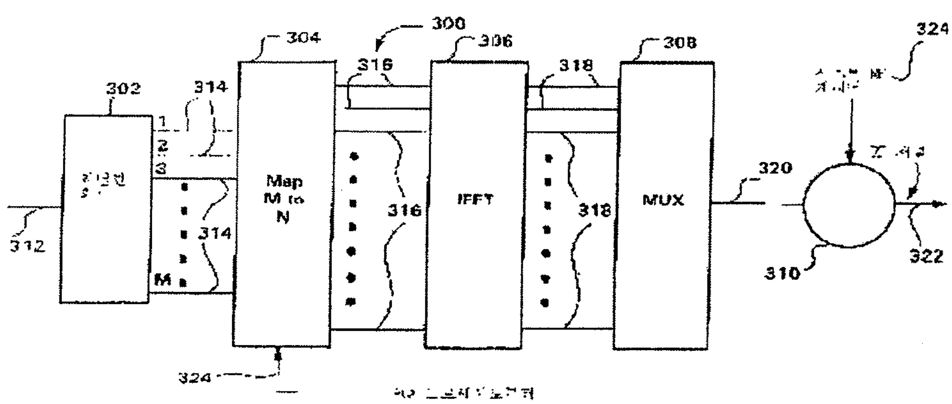

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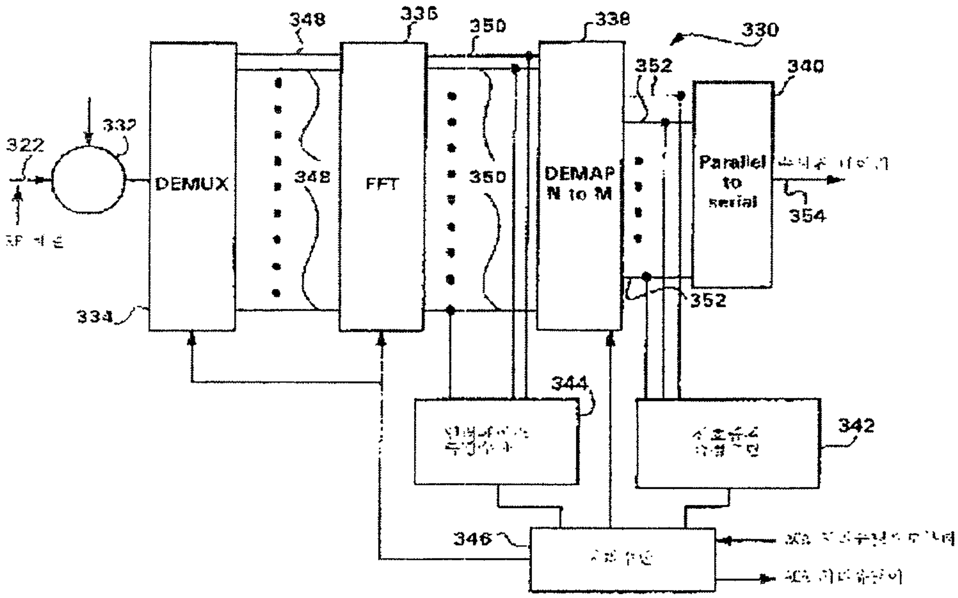
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FFT
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Parallel to serial
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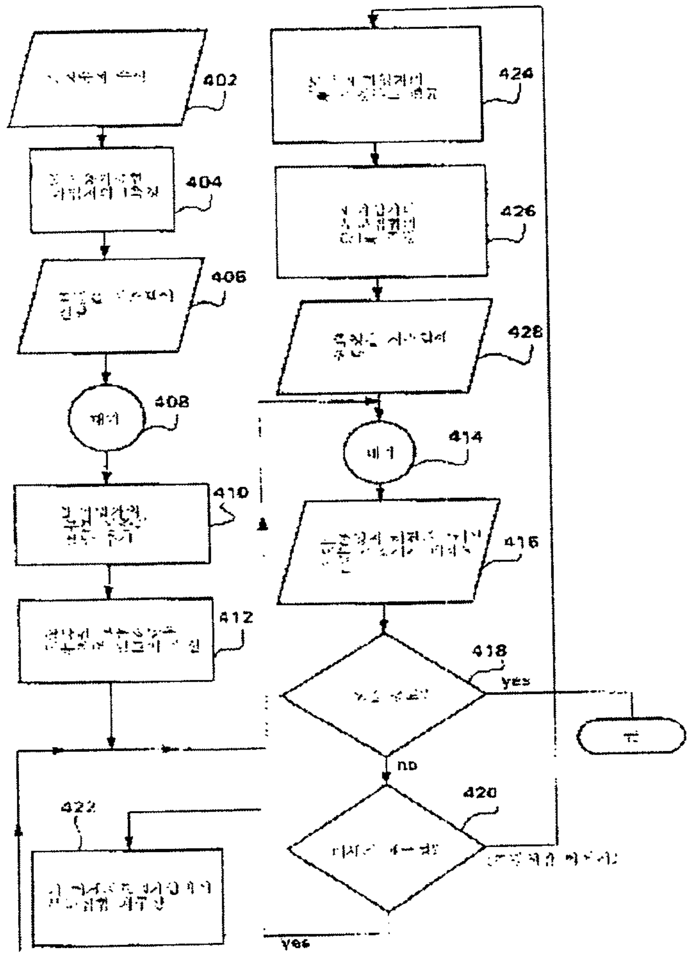
도면4A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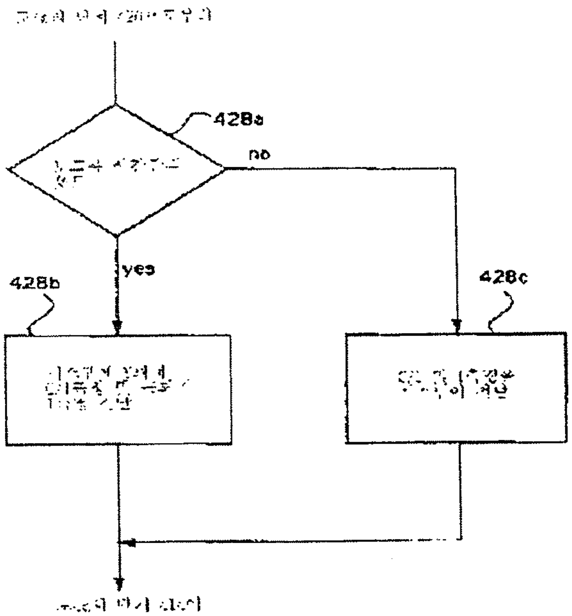
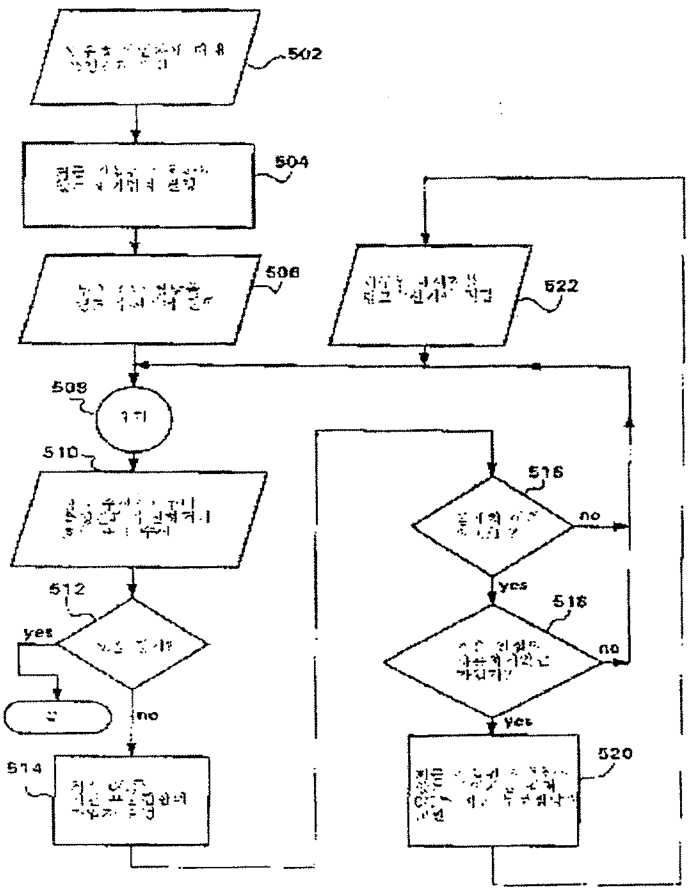


도면5



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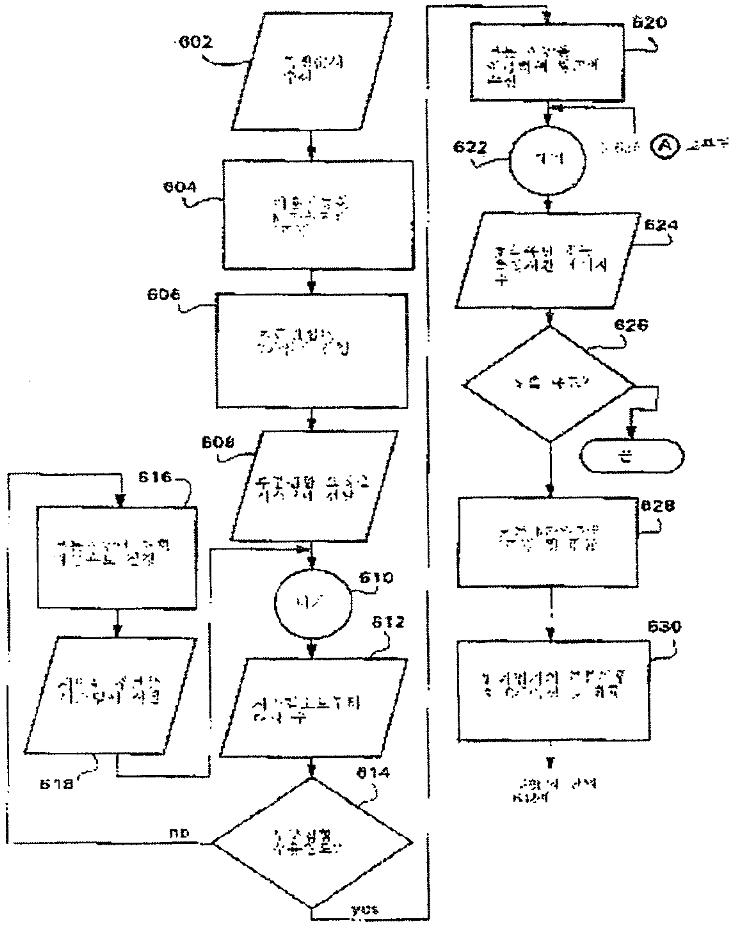
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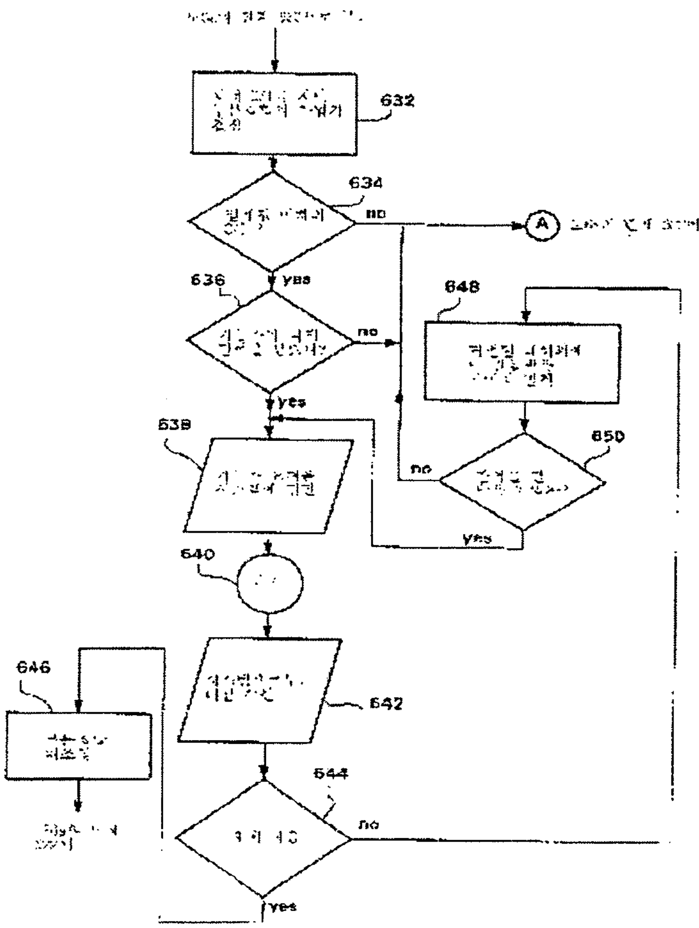
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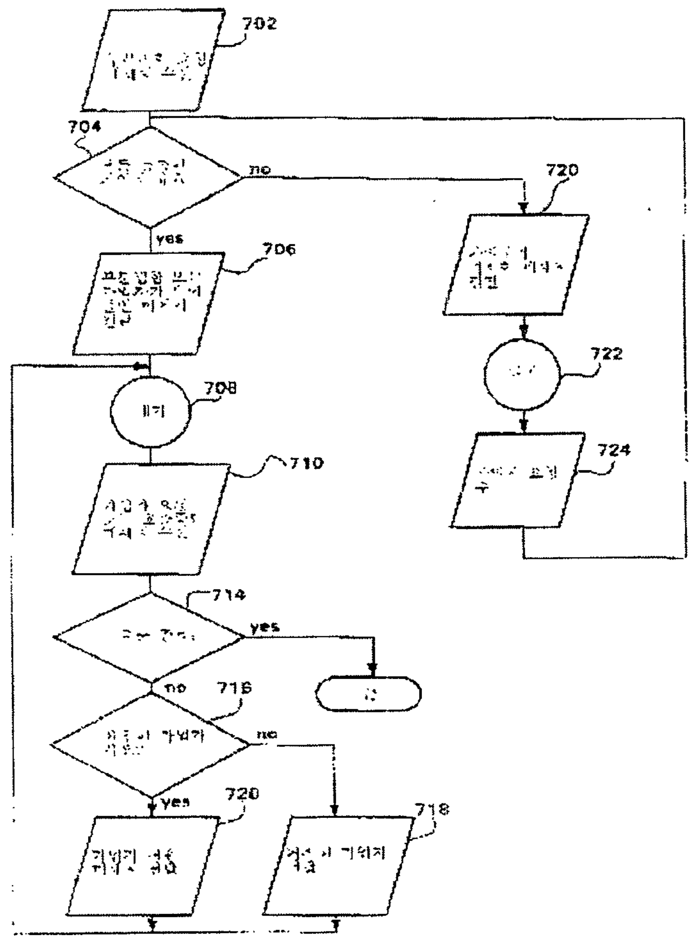
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(54) **ADAPTIVE CHANNEL ALLOCATION IN A FREQUENCY DIVISION MULTIPLEXED SYSTEM**

ADAPTIVE KANALZUTEILUNG IN EINEM FREQUENZMULTIPLEXSYSTEM

AFFECTATION DYNAMIQUE DE VOIES DANS UN SYSTEME DE MULTIPLEXAGE PAR REPARTITION EN FREQUENCE

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WO-A-95/10144
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US-A- 5 295 138

- **ELECTRONICS LETTERS, 27 OCT. 1994, UK, vol. 30, no. 22, ISSN 0013-5194, pages 1831-1832, XP000490811 CHAN C -K ET AL: "Efficient frequency assignment scheme for intermodulation distortion reduction in fibre-optic microcellular systems"**

EP 0 882 377 B1

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention relates to cellular telecommunications systems and, more particularly, to a method and system of adaptive channel allocation in a frequency division multiplexed cellular system.

Description of the Prior Art

[0002] In a cellular telecommunications system the user of a mobile station communicates with the system through a radio interface while moving about the geographic coverage area of the system. The radio interface between the mobile station and system is implemented by providing base stations dispersed throughout the coverage area of the system, each capable of radio communication with the mobile stations operating within the system. In a typical cellular telecommunications system each base station of the system controls communications within a certain geographic coverage area termed a cell, and a mobile station which is located within a particular cell communicates with the base station controlling that cell. As a mobile station moves throughout the system control of the communication between the system and mobile station are transferred from cell to cell according to the movement of the mobile station throughout the system. Existing cellular telecommunications systems operate according to various air interface standards which assure the compatibility of equipment designed to operate in a particular system. Each standard provides specific details of the processes that take place between the mobile stations and base stations of the system in all modes of operation, including during idle states, during rescan of control channels, during registration, and during connection to voice or traffic channels. Advances in cellular systems technology have been rapid in recent years. These advances in technology have been driven by increases in demand for the increasingly sophisticated services offered by cellular systems. As cellular systems technology and the total number of cellular systems has increased worldwide to meet this demand, there has also been an accompanying increase in the number of system standards according to which these cellular systems operate.

[0003] In cellular telecommunications systems, as in most radio systems, the frequency bandwidth available for use is a limited resource. Because of this, emphasis is often concentrated on making the most efficient use possible of the available frequency bandwidth when developing new cellular systems. Additionally, communications within cellular systems are often subject to certain types of RF signal distortion such as multipath propagation and co-channel interference. The development of new system standards has also emphasized the need to minimize the effect of these RF signal distortions on communications within the cells of a system.

[0004] Frequency division multiplexing (FDM) is a method of transmitting data that has application to cellular systems. Orthogonal frequency division multiplexing (OFDM) is a particular method of FDM that is particularly suited for cellular systems. An OFDM signal consists of a number of subcarriers multiplexed together, each subcarrier at a different frequency and each modulated by a signal which varies discretely rather than continuously. Because the level of the modulating signal varies discretely, the power spectrum of each subcarrier follows a $(\sin x/x)^2$ distribution. The spectral shape transmitted on each subcarrier is such that the spectra of the individual sub-channels are zero at the other subcarrier frequencies and interference does not occur between subcarriers. Generally, N serial data elements modulate N subcarrier frequencies, which are then frequency division multiplexed. Each of the N serial data elements comprises a data block with a duration of $T=1/fs$, where fs is the bandwidth of the OFDM signal. The subcarriers of the OFDM system are separated in frequency by multiples of $1/T$. Although the frequency spectrum of the subcarriers overlap, this frequency spacing makes the subcarriers orthogonal over one symbol interval so that the peak of power of each modulated carrier occurs at frequencies corresponding to nulls in the power spectrum of the other carriers. The overall spectrum of an OFDM signal is close to rectangular when a large number of OFDM carriers are contained in the OFDM signal.

[0005] During the time period, T, the OFDM signal may be represented by a block of N samples. The value of the N samples is as follows:

$$x(n) = \sum_{k=0}^{N-1} X(k)\, e^{2jnk/N}$$

[0006] The N values X(k) represent the respective data during period T, of the discretely-varying signals modulating the OFDM carriers $e^{2jnK/N}$. From the above, the OFDM signal corresponds to the inverse Discrete Fourier Transform of the set of data samples X(k). To convert a data stream into an OFDM signal, the data stream is split up into blocks of N samples X(k) and an inverse Discrete Fourier Transform is performed on each block. The string of blocks that appears at a particular sample position over time constitutes a discretely-varying signal that modulates a certain subcarrier at a frequency fn.

[0007] OFDM offers several advantages that are desirable in a cellular system. In OFDM the orthogonality of the subcarriers in the frequency spectrum allows the overall spectrum of an OFDM signal to be close to rectangular. This results in efficient use of the bandwidth available to a system. OFDM also offers advantages in that interference caused by multipath propagation effects is reduced. Multipath propagation effects are caused by radio wave scattering from buildings and other structures in the path of the radio wave. Multipath propagation may result in frequency selective multipath fading. In an OFDM system the spectrum of each individual data element normally occupies only a small part of the available bandwidth. This has the effect of spreading out a multipath fade over many symbols. This effectively randomizes burst errors caused by the frequency selective multipath fading, so that instead of one or several symbols being completely destroyed, many symbols are only slightly distorted. Additionally, OFDM offers the advantage that the time period T may be chosen to be relatively large as compared with symbol delay time on the transmission channel. This has the effect of reducing intersymbol interference caused by receiving portions of different symbols at the same time.

[0008] The use of OFDM in cellular systems has been proposed by Cimini, "Analysis and Simulation of a Digital Mobile Channel Using Orthogonal Frequency Division Multiplexing", IEEE Trans. Commun., Vol. 33, No. 7, pp. 665-675 (July, 1985). A similar application of OFDM in a mobile system has also been proposed by Casa, "OFDM for Data Communication Over Mobile Radio FM-Channels-Part I: Analysis and Experimental Results", IEEE Trans. Commun., Vol. 39. No. 5, pp. 783-793 (May, 1991). In these OFDM cellular systems a set of subcarrier frequencies is assigned to each communications link created for transmission from a base station to a mobile station (downlink) and from a mobile station to a base station (uplink) operating within a cell. The set of subcarrier frequencies allocated to each communications link is chosen from all subcarrier frequencies available to the system. Within a cell the same subcarrier frequency cannot be assigned to more than one communications link. Thus, co-channel interference between subcarriers within the same cell does not occur. However, it is possible in such an OFDM system that a communications link in a cell of the system is assigned a set of subcarriers frequencies that includes one or more subcarriers frequencies also assigned to a communications link set up in another cell within the system. Each of these commonly assigned subcarriers frequencies may be subject to co-channel interference caused by the use of the same subcarrier frequency in the other cells. In these OFDM systems no method or system exists for coordinating the assignment of subcarrier frequencies to communications links created within different cells. In such a system the co-channel interference in a communications link caused by a subcarrier used in a neighboring cell could be very large.

[0009] Methods of allocating channel frequencies among cells in non-OFDM systems have been developed that reduce or minimize co-channel interference. Adaptive Channel Allocation (ACA) is such a method. In ACA any channel frequency allocated to a cellular system may be used to set up a link in any cell of the system regardless of whether or not the frequency is used elsewhere in the system as long as certain interference criteria are met. The channel frequencies may also be freely reused throughout the system as long as the interference criteria are met.

[0010] In Adaptive Channel Allocation various measurements of signal quality and interference levels on dynamically allocated channel frequencies are performed within the coverage area of a cell to build a list of traffic or voice channels that may be assigned to communications links to be created within the cell. The base station controlling the cell and mobile stations within the cell's coverage area perform measurements on the set of channel frequencies that the system operator has allocated to be dynamically allocated for communications within the system. Generally, both uplink and downlink measurements are performed. Based on these measurements, when a new link is to be created, a channel frequency is assigned to the link based on some rule. For example, in minimum interference ACA the system builds a table of channels from the least interfered (highest quality) to the most interfered (lowest quality) channels as measured within each cell. The system then selects a certain number of least interfered channel frequencies from that list to allocate to communication in that cell. Other criteria, such as certain required frequency separation between the channels chosen and avoiding certain combinations of channels whose frequencies create intermodulation are also considered. As an example of ACA, H. Eriksson, "Capacity Improvement by Adaptive Channel Allocation", IEEE Global Telecomm. Conf., pp. 1355-1359, Nov. 28-Dec. 1, 1988, illustrates the capacity gains associated with a cellular radio system where all of the channels are a common resource shared by all base stations. In the above-referenced report, the mobile measures the signal quality of the downlink, and channels are assigned on the basis of selecting the channel with the highest carrier to interference ratio (C/I level).

[0011] Existing ACA algorithms which have been created for non-OFDM cellular systems using one carrier frequency for each link cannot be effectively used in a cellular system using OFDM. One problem with the existing ACA techniques is that the number of subcarriers in an OFDM system is large compared to the number of carriers in the system that uses a single carrier for each communications link. This requires an extensive measurement effort that expends both time and system resources to obtain the uplink and downlink measurement results necessary for ACA. In addition, in order to transfer the results of the large number of downlink measurements made at a mobile station to the system for processing, use of a large amount of signaling resources is necessary.

[0012] WO-95/10144 describes an OFDM based system with one base station and several outstations. The channel allocation algorithm is based on the finding that carrier waves may be attenuated to a varying degree depending on the location wherefrom or whereto signals are transmitted. WO-95/10144 discloses an adaptive channel allocation algorithm comprising the steps of: 1) finding among unallocated carrier waves the one with the lowest amplitude; 2) allocating the found carrier wave to the user who has most to gain; 3) repeating 1) and 2) until all users have been allocated as many carrier waves as are needed; 4) repeating 1) - 3) as often as needed. Hence, WO95/10144 aims at distributing remaining unallocated carrier waves during the allocation algorithm.

[0013] US-5295138 deals with an adaptive channel allocation algorithm (ACA) for frequency division multiplexing (FDM) for finding an optimal channel plan for a satellite-based system. A number of random channel configurations are tried out in a single channel optimisation search. Once all of the random searches are performed, the best of the local optimum frequency plans is taken as the initial global optimum frequency plan. Subsequently a dual-channel search is used to fine-tune the initial global optimisation search.

SUMMARY OF THE INVENTION

[0014] It is a first object of the present invention to set forth an efficient adaptive channel allocation method, which minimizes the use of signalling resources.

[0015] This object has been accomplished by the method defined in claim 1. Additional objects and advantages will appear from the following detailed description of preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 illustrates a cellular telecommunications network within which the present invention may be implemented;

FIG. 2A illustrates the allocation of subcarriers in accordance with the present invention in an orthogonal frequency division multiplexed system;

FIG. 3A is a block diagram of a system according to an embodiment of the present invention;

FIGS. 3B and 3C are block diagrams of a link transmitter and link receiver, respectively, according to an embodiment of the present invention;

FIGS. 4A and 4B are flow diagrams of process steps according to an embodiment of the present invention performed by a link receiver; and

FIG. 5 is a flow diagram of process steps according to an embodiment of the present invention performed within a cellular telecommunications network.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Referring to FIG. 1, there is illustrated a frequency division multiplexed (FDM) cellular telecommunications system of the type to which the present invention generally pertains. In FIG. 1, an arbitrary geographic area may be divided into a plurality of contiguous radio coverage areas, or cells C1-C10. While the system of FIG. 1 is illustratively shown to include only 10 cells, it should be clearly understood that in practice, the number of cells will be much larger.

[0018] Associated with and located within each of the cells C1-C10 is a base station designated as a corresponding one of a plurality of base stations B1-B10. Each of the base stations B1-B10 includes a transmitter, a receiver, and a base station controller as are well known in the art. In FIG. 1, the base stations B1-B10 are illustratively located at the center of each of the cells C1-C10, respectively, and are equipped with omni-directional antennas. However, in other configurations of the cellular radio system, the base stations B1-B10 may be located near the periphery, or otherwise away from the center of the cells C1-C10 and may illuminate the cells C1-C10 with radio signals either omni-directionally or directionally. Therefore, the representation of the cellular radio system of FIG. 1 is for purposes of illustration only and is not intended as a limitation on the possible implementations of the cellular telecommunications system within which the present invention is implemented.

[0019] With continuing reference to FIG. 1, a plurality of mobile stations M1-M10 may be found within the cells C1-C10. Again, only 10 mobile stations are shown in FIG. 1 but it should be understood that the actual number of mobile stations will be much larger in practice and will invariably greatly exceed the number of base stations. Moreover, while none of the mobile stations M1-M10 may be found in some of the cells C1-C10, the presence or absence of the mobile stations M1-M10 in any particular one of the cells C1-C10 should be understood to depend in practice on the individual desires of the users of mobile stations M1-M10 who may roam from one location in the cell to another or from one cell to an adjacent cell or neighboring cell, and even from one cellular radio system served by a particular MSC to another such system.

[0020] Each of the mobile stations M1-M10 is capable of initiating or receiving a telephone call through one or more of the base stations B1-B10 and a mobile station switching center MSC. A mobile station switching center MSC is connected by communication links, e.g., cables, to each of the illustrative base stations B1-B10 and to the fixed public switched telephone network PSTN, not shown, or a similar fixed network which may include an integrated system digital network (ISDN) facility. The relevant connections between the mobile station switching center MSC and the base stations B1-B10, or between the mobile station switching center MSC and the PSTN or ISDN, are not completely shown in FIG. 1 but are well known to those of ordinary skill in the art. Similarly, it is also known to include more than one mobile station switching center in a cellular radio system and to connect each additional mobile station switching center to a different group of base stations and to other mobile station switching center via cable or radio links.

[0021] Each MSC may control in a system the administration of communication between each of the base stations B1-B10 and the mobile stations M1-M10 in communication with it. As a mobile station roams about the system, the mobile station registers its location with the system through the base station that controls the area in which the mobile station is located. When the mobile station telecommunications system receives a call addressed to a particular mobile station, a paging message addressed to that mobile station is broadcast on control channels of the base stations which control the area in which the mobile station is believed to be located. Upon receiving the paging message addressed to it, the mobile station scans system access channels and sends a page response to the base station from which it received the strongest access channel signal. The process is then initiated to create the call connection. The MSC controls the paging of a mobile station believed to be in the geographic area served by its base stations B1-B10 in response to the receipt of a call for that mobile station, the assignment of radio channels to a mobile station by a base station upon receipt of a page response from the mobile station, as well as the handoff communications with a mobile station from one base station to another in response to the mobile station traveling through the system, from cell to cell, while communication is in progress.

[0022] Each of the cells C1-C10 is allocated a plurality of FDM subcarrier frequencies and at least one dedicated control channel. The control channel is used to control or supervise the operation of mobile stations by means of information transmitted to and received from those units. Such information may include incoming call signals, outgoing call signals, page signals, page response signals, location registration signals and voice and traffic subcarrier assignments.

[0023] The present invention involves implementation of a method and system of adaptive channel allocation (ACA) into an FDM cellular system as shown in FIG. 1. In an exemplary embodiment of the invention, ACA is implemented into an OFDM system operating with a total system bandwidth of 5MHz and a subcarrier spacing of 5KHz. The total number of subcarriers available for this system is approximately 5MHz/5KHz = 1000. The subcarriers are modulated onto a system RF carrier with a frequency of 2GHz for transmission over the system RF channel and the frequency spectra of the transmitted signal is centered around the RF carrier. All subcarriers are available for use in each cell but a subcarrier may not be used simultaneously on more than one link in a cell. Frequency division duplex (FDD) is used for separation of the uplink and downlink subcarriers frequencies. The system includes a dedicated control channel (DCCH) that is both an uplink and downlink channel for transmitting control information for handovers, long term channel allocation information, long term power control information and measurement messages and measurement results. The system also includes a physical control channel (PCCH) that is both an uplink and downlink channel for transmitting short term channel allocation information, short term power control information, measurement messages and measurement results.

[0024] In the ACA of the invention, for each up/down link between a mobile station and base station, the system chooses a subset of a number (M) of subcarriers from a set of a number (N) of subcarriers. The set of N subcarriers is the set of subcarriers available within the system for each link, where N>M. The set of N subcarriers does not change during a communication. The set of N subcarriers may include all subcarriers of the system. Alternatively, the set of N subcarriers may be a set less in number than the total number of subcarriers available but greater in number than the number of carriers in the subset of M subcarriers.

[0025] Referring now to FIG. 2 therein is illustrated the allocation of subcarriers in accordance with the present invention in an OFDM system. Base station 200 communicates with mobile station 202 over downlink 206 and uplink 208. Base station 200 also communicates with mobile station 204 over downlink 210 and uplink 212. Transmissions on links 206, 208, 210 and 212 are made over the system RF channel. Voice and data to be transmitted on each link are modulated onto a number (M) subcarriers. The M subcarriers are then modulated onto the system RF carrier for transmission over the system RF channel. Each link 206, 208, 210 and 212, within the cell uses a separate subset of M subcarriers. The subcarriers can only be used once within a cell.

[0026] Referring now to FIG. 3A, therein is shown a block diagram of a system according to the present invention. The system consists of a link transmitter 300, link receiver 330, ACA processing portion 360 and RF channel 380. The receiver 330 and transmitter 300 of a particular link are located at opposite ends of the link. In the downlink the receiver 330 is located in the mobile station and the transmitter 300 is located in the base station. In the uplink the receiver 330 is located in the base station and the transmitter 300 is located in the mobile station. RF channel has a set of N available subcarriers. The link receiver 330 and link transmitter communicate over RF channel 380 using a subset of M of the available subcarriers.

[0027] Referring now to FIGS. 3B and FIG. 3C, therein are shown functional block diagrams of transmitter 300 and receiver 330, respectively, of FIG. 3A. The functional features that are shown in FIG. 3B and FIG. 3C are common to both the base and mobile station receivers and transmitters.

[0028] Transmitter 300 includes a serial to parallel converter 302, mapping circuitry (MAP) 304, inverse fast fourier transform (IFFT) circuitry 306, a frequency multiplexer (MuX) 308, and modulator 310. In transmitter operation, serial to parallel converter 302 converts a serial digital data stream 312 into blocks of M symbols 314 where M is determined by the symbol size and data rate of the system. The M symbols are then input to the MAP circuitry 304, where each of the M symbols is mapped onto a subcarrier input of the IFFT circuitry 306. An inverse fast fourier transform (IFFT) is then performed on the blocks of data input to the IFFT circuitry 306. The signals 318 generated at the N outputs of the IFFT circuitry 306 are then multiplexed in MuX 308 to create a signal 320 containing M multiplexed subcarriers, each of which carries the data contained in one symbol of the M symbols 314. The signal 320 is then modulated onto the system RF carrier 324 at modulator 310 and transmitted as an OFDM signal over the system RF channel 322.

[0029] Receiver 330 includes demodulator 332, frequency demultiplexer (DEMUX) 334, fast fourier transform (FFT) circuitry 336, de-mapping circuitry (DEMAP) 338, a parallel to serial converter 340, interference measuring means 344, signal quality measurement means 342 and processor 346. In receiver operation, the system RF carrier is received on the system RF channel 322 and then demodulated at demodulator 332, and demultiplexed at DEMUX 334 to obtain N samples 348 of the signal containing, the M multiplexed subcarriers. A fast fourier transform (FFT) is then performed by FFT circuitry 336 with the N samples 348 as inputs to generate data signals 350 containing any modulating data that was transmitted on each subcarrier. The N subcarriers demodulated and subjected to the FFT are determined by parameters input to DEMUX 334 and FFT circuitry 336 from processor 346. Interference measurement means 344 measures the interference (I) level on each of the data signals 350 recovered from each of the N samples 348. The N received data signals 350 are then input to the de-mapping block 338 where the M data signals 352 received on the M subcarrier frequencies currently assigned to link communications are de-mapped from the N data signals 350. The de-maping is done according to parameters input to DEMAP block 338 from processor 346. The M de-mapped data signals 352 are then input to the parallel to serial converter 340 and converted into serial received data 354. Signal quality (C/I) is measured at the output of the de-mapping block 338 for each of the M de-mapped data signals 352 received on the M subcarrier frequencies currently assigned to the link on which receiver 330 is receiving.

[0030] The adaptive channel allocation for each link is implemented by ACA processing portion 360 of FIG. 3A which operates on results of measurements performed in the link receiver. In the embodiment shown, processor 346 receives interference measurements from interference measurement means 344 and signal quality measurement results from signal quality measurement means 342. The processor 346 operates on the measurement results to generate data for input to ACA processing portion 360 of the system. The data generated by processor 346 will then be transferred to ACA processing portion 360 over interface 362. In the embodiment shown, ACA processing portion 360 is located within the MSC. ACA processing portion 360 may be alternatively located within the base stations of the system. It is also conceivable the functions performed by the ACA processing portion be distributed among the mobile station, base station and MSC. Methods of configuring memories to store the necessary data, and methods of configuring microprocessors and software to perform these types of functions are well known to those skilled in the art.

[0031] When a mobile station functions as link receiver, the processor 346 transfers the ACA data to the mobile station transmitter for transmission to the system over interface 362 which comprises the uplink on the appropriate control channel. In a base station as link receiver, the processor 346 transfers the ACA data to the MSC over interface 362 which comprises landline or other connections. ACA processing portion 360 operates on the data and then returns appropriate subcarrier assignment commands to link receiver 330 over interface 364 which comprises landline or other connections when the base station is the link receiver, or the down link on the appropriate control channel when the mobile station is the link receiver. Processor 346 of link receiver 330 receives the commands and then generates the correct input parameters for the receiver so that the correct subcarriers for the link are received. ACA processing portion 360 also sends commands to MAP circuitry 304 associated with link transmitter 300 over interface 366. MAP circuitry 304 then maps the M symbols to the appropriate outputs of MAP circuitry 304 so that the correct subset of M subcarriers is transmitted on.

[0032] The necessary data transfer between the mobile stations, base stations and MSCs of the system may be accomplished by known methods. In the described embodiment the DCCH and PCCH channels may be used on both the uplink and downlink to transfer measurement results or subcarrier assignment messages between a mobile station and the system. The use of control channels to carry such information is known to those skilled in the art.

[0033] Referring now to FIG. 4A, therein is shown a flow diagram illustrating the steps performed by the link receiver 330 during the ACA process. The steps performed by a mobile station receiving on a downlink and the steps performed by a base station receiving on an uplink are essentially identical and FIG. 4A can be used to describe the steps performed by the link receiver 330 in both cases. The differences between the process steps performed in the mobile station and base station involve step 428 of FIG. 4A. FIG. 4B is a flow diagram that illustrates additional steps performed by the mobile station during step 428 of the ACA measurement process. These extra steps will be described with reference to FIG. 4B as the process of FIG. 4A is described.

[0034] The ACA process begins when it is necessary for the system to create a communications link between a mobile station base station pair on either the uplink or the downlink. Referring again to FIG. 4A, at step 402 the link receiver receives from the system a measurement order message to measure interference (I) on each of a group of N subcarriers available for the link. The N subcarriers may be all subcarriers available within the system or a smaller group of subcarriers chosen from all subcarriers available within the system. Next, at step 404 the I measurements are performed. Then, from step 404 the process moves to step 406 where the I measurement results are sent to the system. When a mobile station is the link receiver, the I measurement results are transmitted over the DCCH or PCCH channel to the base station and then transferred to the MSC. When a base station is the link receiver, the I measurement results are transferred to the MSC via the appropriate overland means. After transmitting the I measurement results the process moves to step 408 where the link receiver waits for a response from the system. The process steps that take place when the link receiver is in the wait state at step 408 will now be described with reference to FIG. 5.

[0035] Referring now to FIG. 5, therein are shown the process steps performed within the ACA processing portion of system during the ACA process. At step 502 the results of the I measurement performed on the N subcarriers at the link receiver are received by the ACA processor. Next, at step 504 the ACA processor determines the M least interfered unused subcarriers from the results of the I measurements made on the N subcarriers. From step 504 the process then moves to step 506 where a subcarrier assignment message assigning the subset of the least interfered M subcarriers to the link is sent to both the link receiver and the link transmitter. The ACA processor now moves to step 508 and waits for further input from the link receiver. The process flow now returns to step 408 FIG. 4A. Alternative methods of determining the M subcarriers for the subcarrier assignment message may be used in place of step 506. For example, the subcarriers could be assigned on the basis of how their use effects transmissions in neighboring cells. If one of the least interfered M subcarriers was used in a neighbor cell, the subcarrier would not be used. In this case the M subcarriers may not be the least interfered M subcarriers.

[0036] Referring again to FIG. 4A, the link receiver which has been in the wait state at 408 now moves to step 410 and receives the channel assignment message assigning the subset of M subcarriers to the link. Next, the process moves to step 412 as the link receiver begins receiving on the link using the assigned subset of M subcarriers. From step 412 the process now moves to step 414 and waits for further input. At step 416 an input is received. The link receiver may receive three types of inputs while receiving using the assigned subset of M subcarriers. At decision step 418 the link receiver determines if a call end signal has been received. If a call end signal has been received the process ends. The call end signal may have been transmitted by the system to the link receiver or initiated at the link receiver itself. A call end signal indicates to the process that communications on the link have terminated. If a call end has not been received, the process moves to step 420 and the link receiver determines whether a measurement timer message has been received. The measurement timer is contained in the processor associated with the link receiver. The measurement timer generates a measurement message at periodic intervals informing the link receiver to make measurements. Each measurement timer signal defines a measurement interval. If a measurement timer message has been received the process moves to step 424. At step 424 the link receiver measures I on the set of N subcarriers. The I measurements may be averaged with the results of a certain number of previous I measurements for each subcarrier to obtain accuracy. The first time through step 424 the measurements are averaged with the results obtained in step 404. On subsequent passes through step 424 the measurement results are averaged with the last n previous measurements, where n is a value allowing an accurate following of a subcarrier's interference level within the system. From step 424 the process moves to step 426 and the link receiver measures C/I on each of the subset of M carriers. The C/I measurements are also averaged with the last n previous C/I measurements. Then, at step 428 the link receiver sends the I and C/I measurement results to the ACA processing portion of the system. Depending on whether the link receiver is the base station or mobile station, step 428 may be performed in differing ways. If the link receiver is a base station the averaged measurement results may be sent directly to the ACA processor. If the link receiver is a mobile station in a downlink the substeps shown in FIG. 4B may be used to reduce signaling traffic as the results are transmitted to the system over the uplink via the base station.

[0037] Referring now to FIG. 4B, therein is shown a flow diagram illustrating process substeps performed by a mobile station performing step 428 of FIG. 4A. Signaling traffic on the uplink is reduced by transmitting differing sets of measurement results to the system over differing time intervals. Over long reporting intervals all I measurement and C/I measurement results are transmitted to the system. Over shorter reporting intervals a reduced set of each of the I measurement and C/I measurement results are transmitted. The long and short intervals may be defined so that a long interval occurs every nth short interval or every nth measurement period, where n is a number such as, for example, 25. At step 428a the mobile station determines whether the measurement period involves a short time interval for reporting measurement results. If it is determined that the measurement period involves a short time interval for reporting measurement results the process moves to step 428b, where the mobile station transmits the C/I measurements for the Y worst quality subcarriers of the subset of M subcarriers, where Y<M, and the I measurements for the Z least interfered of the N subcarriers to the system, where Z<N. The values of Y and Z are chosen to allow adequate information for effective ACA while minimizing signaling traffic. Y may be set to 1 and Z may be set to a number calculated to contain on average the I measurement results of at least one subcarrier not used within the same cell. The process then moves to step 414 where the mobile station waits for further input. However, if, at step 428a, it is determined that the measurement period does not involve a short time interval for reporting measurement results the process moves to step 428c. At step 428c the mobile station transmits the C/I measurements for the whole subset of M subcarriers and the I measurements for all N subcarriers to the system. The process then moves to step 414 where the mobile station waits for further input. The process flow now moves to FIG. 5 as the ACA processor receives the measurement results from the link receiver.

[0038] Referring again to FIG. 5, the ACA processor which has been in the wait state at step 508, receives an input from the link receiver at step 510. The ACA processor may receive measurement results or a call end signal at step 510. When an input is received the process moves to step 512 where it is determined what type of input was received. If a call end signal is received the process ends. In this example the received message is measurement results so the process moves to step 514. At step 514 the ACA processor determines the subcarrier of the subset of M used subcarriers with the lowest C/I measurement value. Next, at step 516 it is determined if the C/I of the lowest C/I measurement value of the subset of M subcarriers is below the ACA C/I trigger threshold. If, at step 516, it is determined that the lowest C/I measurement value is not below the ACA C/I trigger threshold the process flow will return to step 508 where the ACA processor will wait for further input. If, however, at step 516 it is determined that the lowest C/I measurement value is below the ACA C/I trigger threshold the process flow will instead move to step 518. At step 518 the ACA processor determines whether an unused subcarrier of the set of N subcarriers exists which has an I measurement value less than the I measurement value of the subcarrier of the subset of M with the lowest C/I measurement value. If at step 518 it is determined that no unused subcarrier exists with a lower I measurement value, the process flow will return to step 508 where the ACA processor will wait for further input. If, however, at step 518 an unused subcarrier exists with a lower I measurement value, a more preferred subcarrier exists and, the process moves to step 520. At step 520 the ACA processor inserts the least interfered unused subcarrier into the subset of M subcarriers and removes the subcarrier of the subset of M with the lowest C/I measurement value from the subset. To avoid hysterisis effects the change of subcarriers may be performed after calculating a C/I for the least interfered unused subcarrier during step 518 and determining that the calculated C/I is a minimum amount above the C/I of the subcarrier to be removed. If the G/I for the least interfered unused subcarrier is not a minimum amount above the C/I of the subcarrier to be removed the unused subcarrier can be considered not acceptable as a replacement. From step 520 the process moves to step 522 where the system sends a reconfigure subset message to the link receiver instructing the link receiver to reconfigure the subset of M subcarriers assigned to the link to conform to the changes made by the processor. Then the ACA processor moves to step 508 and waits for further input from the link receiver. The procedure given by steps 514-520 could alternately be performed by determining a plurality of less interfered unused subcariers and exchanging these with a plurality of used subcarriers having an interference level below the C/I threshold. The subset could also be reconfigured according to other criteria. For example, the subset of M could be reconfigured on the basis of the effect of using the subset, in the cell of the link, on communications occurring in neighbor cells. If some of the M subscarriers used in the cell were also used in neighbor cells, these could be replaced with subcarriers unused in the cell and also not used in neighbor cells. Reconfiguration could take place even if the used subcarriers were not below a C/I threshold or even if the unused subcarrier had an interference level greater than the replaced subcarriers.

[0039] The process continues as long as a call is ongoing and communications on the link continue. The link receiver will next move from the wait state at step 408 upon receiving an input and the process steps shown in FIGS. 4A, 4B and 5 will be repeated until the call ends and a call end signal is received by the link transmitter, link receiver and ACA processing portion of the system.

[0040] In an alternative embodiment of the invention, a mobile station as link receiver transmits request messages requesting a certain subset of M subcarriers, or requesting replacements for the M subcarriers, to be used on the link. Signal measurement results need not be transmitted from the mobile station to the system. The system in turn transmits subset accepted or subcarrier accepted messages to the mobile station. The downlink ACA processing mainly takes place in the processor 346 of the receiver in the mobile station. In this alternative embodiment steps 504, 514, 516, 518 and 520 shown in FIG. 5, which are performed by the system in the first embodiment, would be performed by processor 346 in the mobile station. The base station ACA process flow for uplink measurements remains as illustrated in FIGS. 4A, 4B and 5.

[0041] As can be seen from the above description, the invention provides a method of adaptive channel allocation. Use of the invention will enhance the performance of OFDM systems. The adaptive channel allocation according to the invention minimizes the signalling resources on the system uplinks while it maintains the benefits of adaptive channel allocation. As a result, better spectral efficiency, less dropped calls and better quality communications for each link are accomplished.

Claims

1. A method of allocating subcarriers for communications on a link in a telecommunications system in which communications from a link transmitter to a link receiver are transmitted over a subset (M) of a set (N) of a plurality of subcarriers available to a link, said method comprising the steps of:

   allocating a plurality of sub-carriers from said set to provide said subset (M);
   repeating the steps of
   measuring a received signal (I, 424; C/I, 426) on each subcarrier of at least said subset (N, M);
   transmitting a plurality of results (428) from said link receiver to said system,
   determining (514, 516, 518, 520) if at least one unused subcarrier exists that is more preferred for use on said link than a subcarrier of said subset (N),
   reconfiguring (422) said subset in response to an affirmative determination (416, 420), wherein
   a first set of measurement results is transmitted at first intervals (428c) and a second reduced set of results (Z, Y) is transmitted at second shorter intervals (428b).

2. The method of claim 1 in which said step of measuring comprises the steps of:

   measuring the interference level (I) on each subcarrier (N; 424).

3. The method of claim 1 wherein the step of measuring comprises the steps of:

   measuring the signal quality (C/I) on each subcarrier of said subset (M; 426).

4. The method of claim 2 in which the second reduced set of results (428b) comprises the interference (I) measurement results for Z least interfered subcarriers of the N set of subcarriers (N), where Z is less than N.

5. The method of claim 3 in which the second reduced set of results (428b) comprises the signal quality (C/I) measurement results for Y worst quality subcarriers of the subset of M subcarriers (M), where Y is less than M.

6. The method of claim 1, in which said step of reconfiguring (416/522) comprises the steps of:

   determining (520) a subcarrier of said subset with a lowest signal quality level (C/I) (514); and determining if an unused subcarrier (518) of said subset exists that has an interference level (I) lower than the interference level (I) of said subcarrier of said subset with said lowest signal quality level (C/I).

7. The method of claim 6 in which said step of reconfiguring (416/522) comprises the steps of.

   removing (520) said subcarrier with said lowest signal quality (C/I) from said subset in response to an affirmative determination; and
   inserting said unused subcarrier into said subset.

Patentansprüche

1. Verfahren zum Zuordnen von Unterträgern für eine Kommunikation auf einer Strecke in einem Telekommunikationssystem, in dem Kommunikationen von einem Streckensender an einen Streckenempfänger über einen Untersatz (M) eines Satzes (N) einer Vielzahl von Unterträgem, die für eine Strecke verfügbar sind, übertragen werden, wobei das Verfahren die folgenden Schritte umfasst:

   Zuordnen einer Vielzahl von Unterträgern von dem Satz, um den Untersatz (M) bereitzustellen;
   Wiederholen der Schritte zum
   Messen eines empfangenen Signals (I, 424; C/I, 426) auf jedem Unterträger von wenigstens dem Untersatz (N, M);
   Übertragen einer Vielzahl von Ergebnissen (428) von dem Streckenempfänger an das System,
   Bestimmen (514, 516, 518, 520), ob wenigstens ein nicht verwendeter Unterträger existiert, der zur Verwendung auf der Strecke bevorzugter als ein Unterträger des Untersatzes (N) ist,
   Rekonfigurieren (422) des Untersatzes im Ansprechen auf eine bestätigende Bestimmung (416, 420), wobei
   ein erster Satz von Messergebnissen bei ersten Intervallen (428c) übertragen wird und ein zweiter verringerter Satz von Ergebnissen (Z, Y) bei zweiten kürzeren Intervallen (428b)

übertragen wird.

2. Verfahren nach Anspruch 1, bei dem der Schritt zum Messen die folgenden Schritte umfasst:

   Messen des Störungspegels (I) auf jedem Unterträger (N; 424).

3. Verfahren nach Anspruch 1, wobei der Schritt zum Messen die folgenden Schritte umfasst:

   Messen der Signalqualität (C/I) auf jedem Unterträger des Untersatzes (M; 426).

4. Verfahren nach Anspruch 2, bei dem der zweite verringerte Satz von Ergebnissen (428b) die Störungs-(I)-Messergebnisse für Z am wenigsten gestörte Unterträger des N Satzes von Unterträgern (N) umfasst, wobei Z kleiner als N ist.

5. Verfahren nach Anspruch 3, bei dem der zweite verringerte Satz von Ergebnissen (428b) die Signalqualitäts-(C/I)-Messergebisse für Y Unterträger mit der schlechtesten Qualität des Untersatzes der M Unterträger (M) umfasst, wobei Y kleiner als M ist.

6. Verfahren nach Anspruch 1, bei dem der Schritt zum Rekonfigurieren (416/522) die folgenden Schritte umfasst:

   Bestimmen (520) eines Unterträgers des Untersatzes mit einem niedrigsten Signalqualitätspegel (C/I) (514); und

   Bestimmen, ob ein nicht verwendeter Unterträger (518) des Untersatzes existiert, der einen Störungspegel (I) niedriger als der Störungspegel (I) des Unterträgers des Untersatzes mit dem niedrigsten Signalqualitätspegel (C/I) aufweist.

7. Verfahren nach Anspruch 6, bei dem der Schritt zum Rekonfigurieren (416/522) die folgenden Schritte umfasst:

   Entfernen (520) des Unterträgers mit der niedrigsten Signalqualität (C/I) von dem Untersatz im Ansprechen auf eine bestätigende Bestimmung; und

   Einfügen des nicht verwendeten Unterträgers in den Untersatz.

Revendications

1. Procédé d'allocation de sous-porteuses pour des communications sur une liaison dans un système de télécommunication dans lequel des communications depuis un émetteur de liaison jusqu'à un récepteur de liaison sont transmises sur un sous-jeu (M) d'un jeu (N) d'une pluralité de sous-porteuses disponibles pour une liaison, ledit procédé comprenant les étapes de:

   allocation d'une pluralité de sous-porteuses prises parmi ledit jeu afin de constituer ledit sous-jeu (M);

   répétition des étapes de:

      mesure d'un signal reçu (I, 424; C/I, 426) sur chaque sous-porteuse d'au moins ledit sous-jeu (N, M);

      transmission d'une pluralité de résultats (428) depuis ledit récepteur de liaison jusqu'audit système;

      détermination (514, 516, 518, 520) de s'il existe au moins une sous-porteuse inutilisée qui est davantage préférable pour une utilisation sur ladite liaison qu'une sous-porteuse dudit sous-jeu (N);

      reconfiguration (422) dudit sous-jeu en réponse à une détermination affirmative (416, 420),

   dans lequel:

   un premier jeu de résultats de mesure est transmis selon des premiers intervalles (428c) et un second jeu réduit de résultats (Z, Y) est transmis selon des seconds intervalles plus courts (428b).

2. Procédé selon la revendication 1, dans lequel ladite étape de mesure comprend les étapes de:

   mesure du niveau d'interférence (I) sur chaque sous-porteuse (N; 424).

3. Procédé selon la revendication 1, dans lequel l'étape de mesure comprend les étapes de:

   mesure de la qualité de signal (C/I) sur chaque sous-porteuse dudit sous-jeu (M; 426).

4. Procédé selon la revendication 2, dans lequel le second jeu réduit de résultats (428b) comprend les résultats de mesure d'interférence (I) pour Z sous-porteuses les moins en interférence du jeu de N sous-porteuses (N), où Z est inférieur à N.

5. Procédé selon la revendication 3, dans lequel le se-

cond jeu réduit de résultats (428b) comprend les résultats de mesure de qualité de signal (C/I) pour Y sous-porteuses de qualité la pire du sous-jeu de M sous-porteuses (M), où Y est inférieur à M.

6. Procédé selon la revendication 1, dans lequel ladite étape de reconfiguration (416/522) comprend les étapes de:

détermination (520) d'une sous-porteuse dudit sous-jeu présentant un niveau de qualité de signal le plus bas (C/I) (514); et

détermination de s'il existe une sous-porteuse inutilisée (518) dudit sous-jeu qui présente un niveau d'interférence (I) qui est inférieur au niveau d'interférence (I) de ladite sous-porteuse dudit sous-jeu présentant ledit niveau de qualité de signal le plus bas (C/I).

7. Procédé selon la revendication 6, dans lequel ladite étape de reconfiguration (416/522) comprend les étapes de:

enlèvement (520) de ladite sous-porteuse présentant ladite qualité de signal la plus faible (C/I) dudit sous-jeu en réponse à une détermination affirmative; et

insertion de ladite sous-porteuse inutilisée dans ledit sous-jeu.

FIG. 1

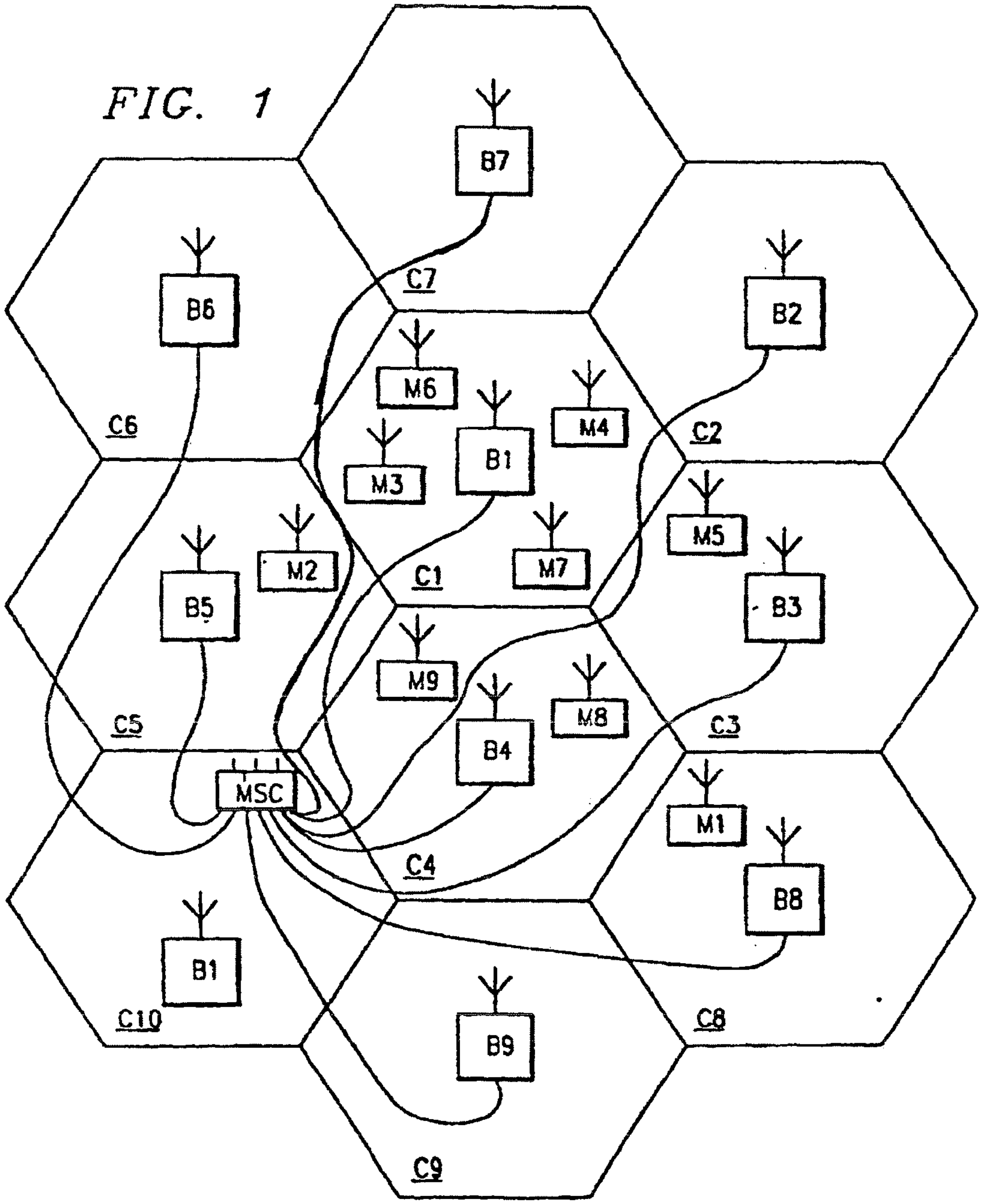

B7
C7
B6
C6
M6
M4
B2
C2
M3
B1
M5
B5
M2
C1
M7
B3
M9
M8
C5
B4
C3
MSC
M1
C4
B8
B1
C10
B9
C8
C9

FIG. 2

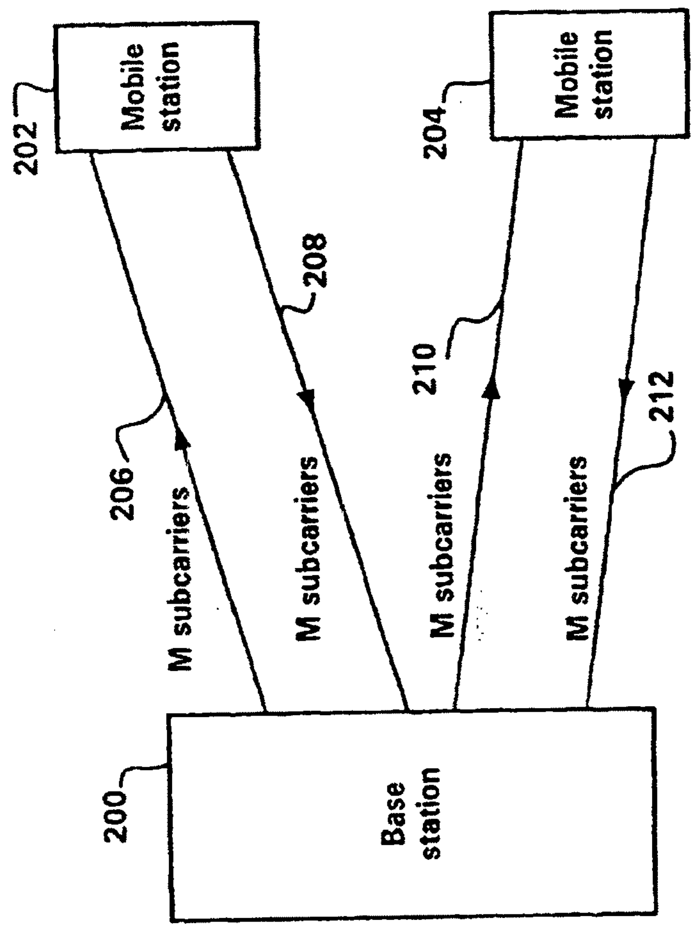

202
Mobile station
204
Mobile station
208
206
210
212
M subcarriers
M subcarriers
M subcarriers
M subcarriers
200
Base station

FIG. 3A

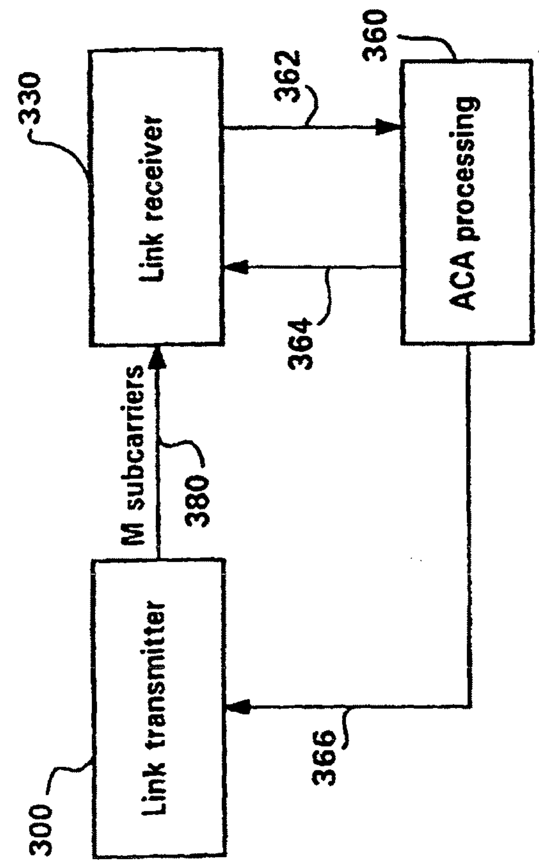

Link transmitter
300
M subcarriers
380
Link receiver
330
362
364
ACA processing
360
366

FIG. 3B

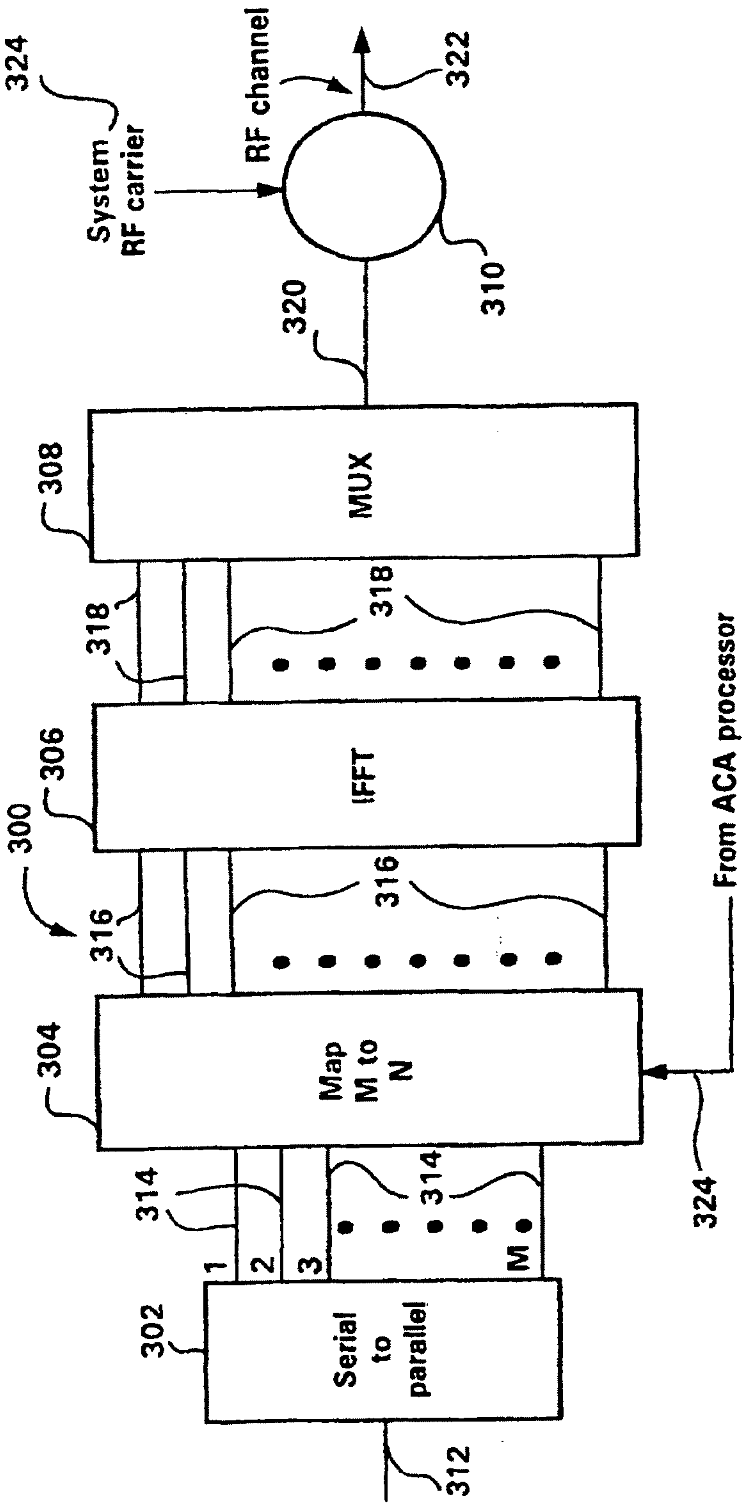

300
302
Serial to parallel
312
1
2
3
M
314
304
Map M to N
324
From ACA processor
316
306
IFFT
318
308
MUX
320
310
System RF carrier
324
RF channel
322

FIG. 3C

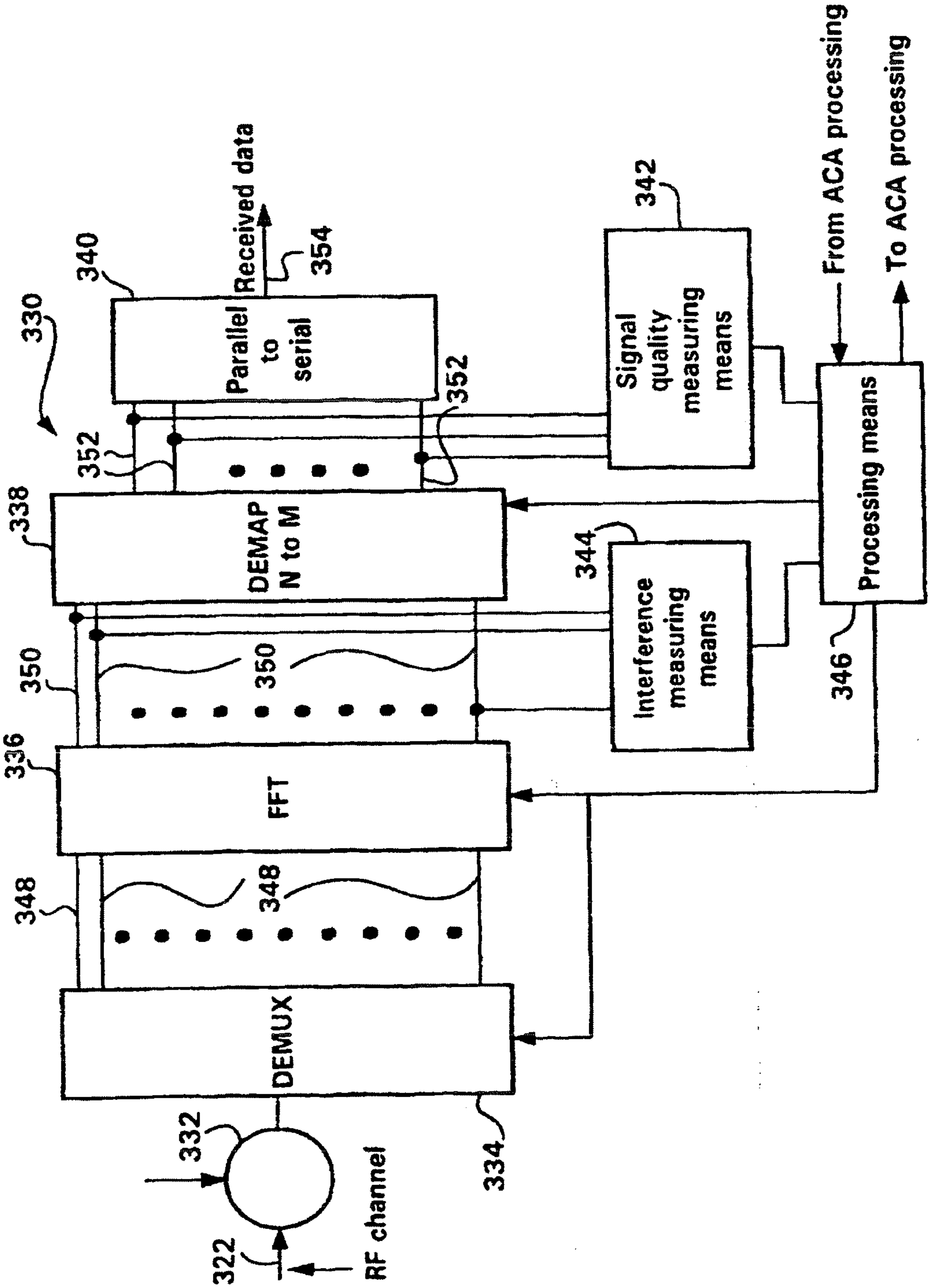

330
340
Received data
354
Parallel to serial
352
352
338
DEMAP N to M
342
Signal quality measuring means
From ACA processing
To ACA processing
Processing means
346
344
Interference measuring means
350
350
336
FFT
348
348
DEMUX
332
334
322
RF channel

FIG. 4A

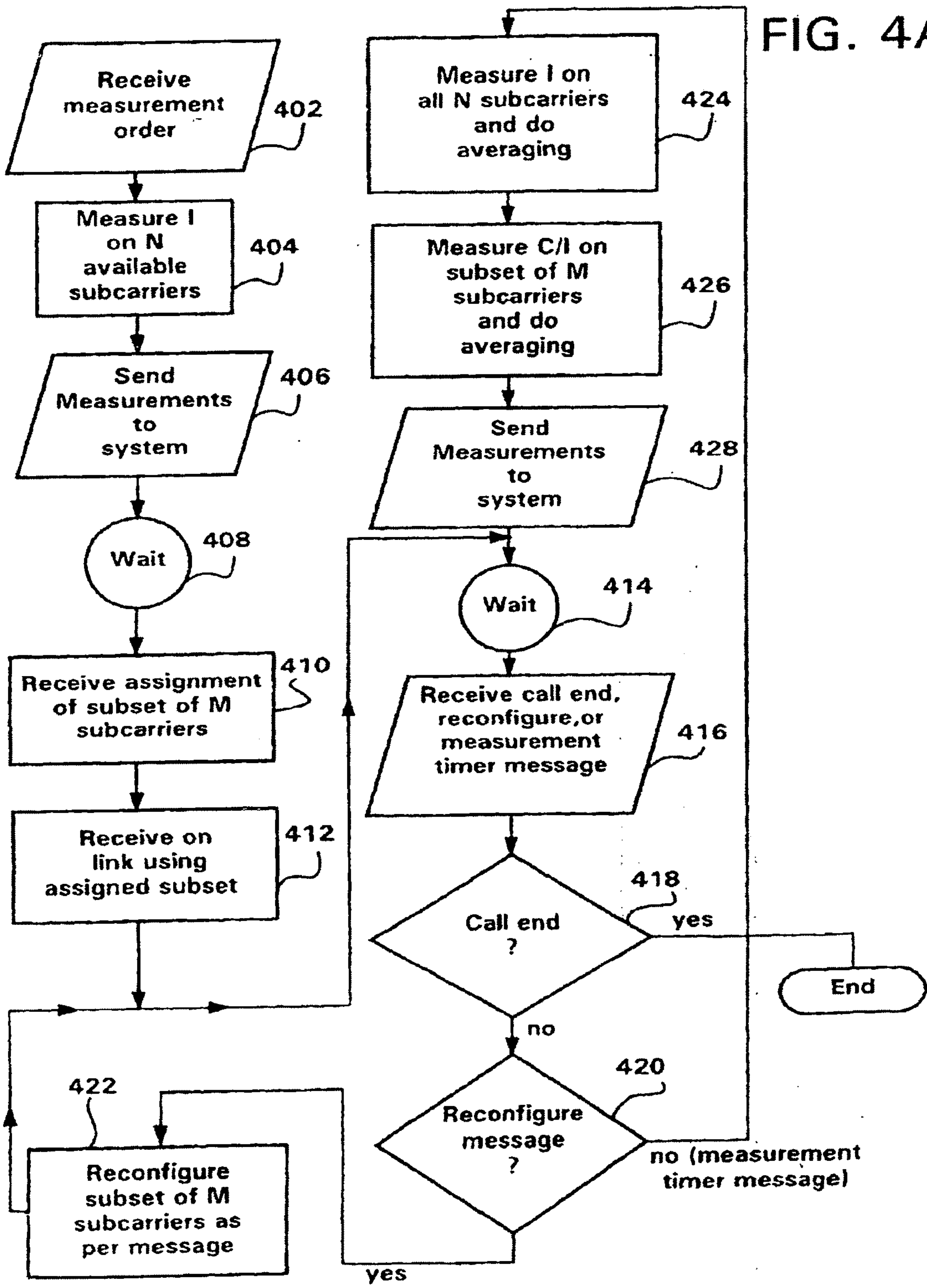

Receive measurement order
402
Measure I on N available subcarriers
404
Send Measurements to system
406
Wait
408
Receive assignment of subset of M subcarriers
410
Receive on link using assigned subset
412
422
Reconfigure subset of M subcarriers as per message
Measure I on all N subcarriers and do averaging
424
Measure C/I on subset of M subcarriers and do averaging
426
Send Measurements to system
428
Wait
414
Receive call end, reconfigure, or measurement timer message
416
418
Call end ?
yes
End
no
420
Reconfigure message ?
no (measurement timer message)
yes

FIG. 4B

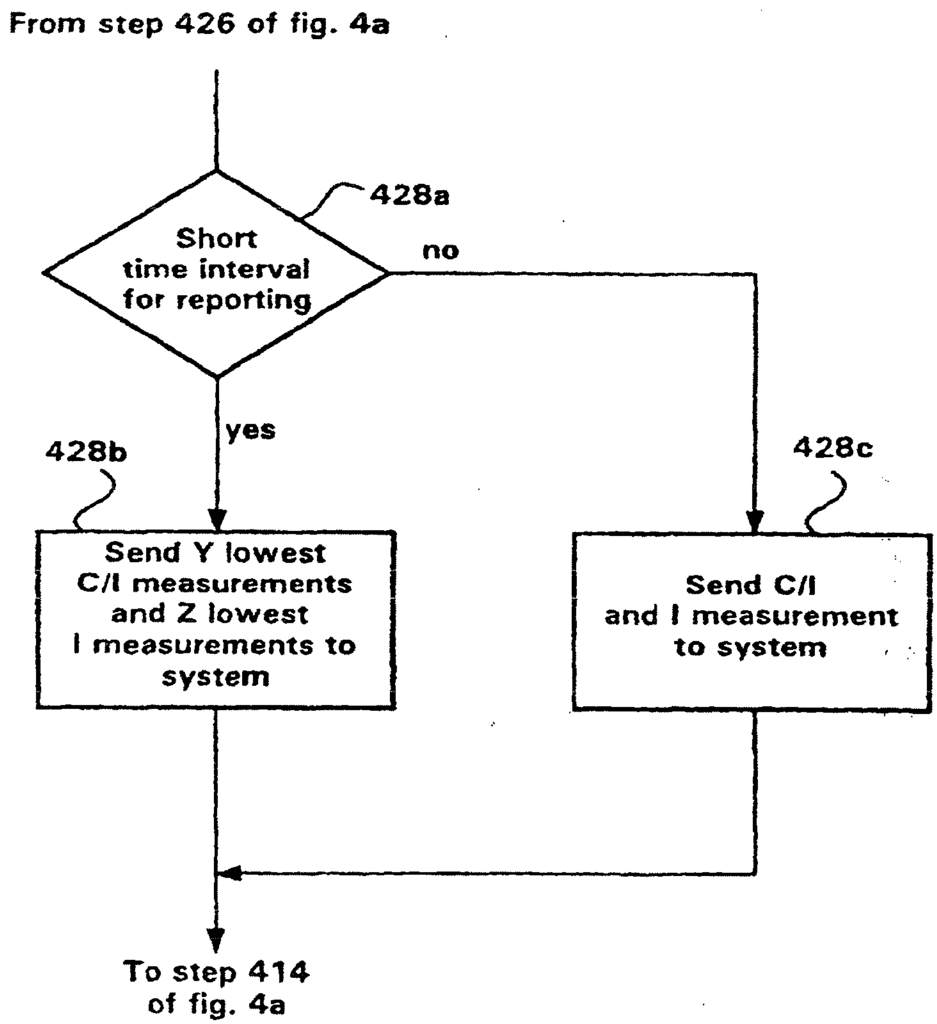
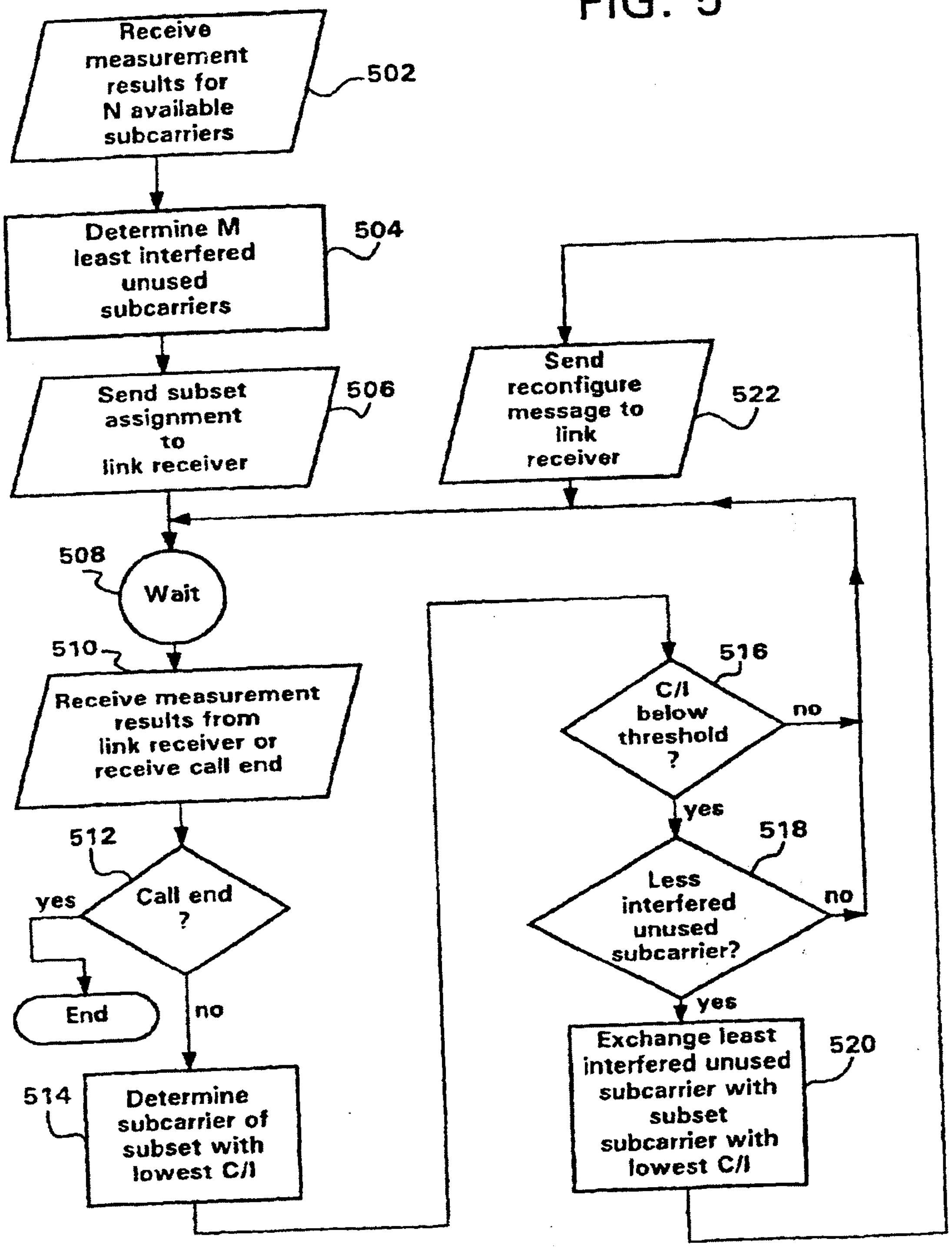

From step 426 of fig. 4a
428a
Short time interval for reporting
no
yes
428b
428c
Send Y lowest C/I measurements and Z lowest I measurements to system
Send C/I and I measurement to system
To step 414 of fig. 4a

FIG. 5


Receive measurement results for N available subcarriers
502
Determine M least interfered unused subcarriers
504
Send subset assignment to link receiver
506
508
Wait
510
Receive measurement results from link receiver or receive call end
512
Call end ?
yes
End
no
514
Determine subcarrier of subset with lowest C/I
Send reconfigure message to link receiver
522
516
C/I below threshold ?
no
yes
518
Less interfered unused subcarrier?
no
yes
Exchange least interfered unused subcarrier with subset subcarrier with lowest C/I
520

KOREANA PATENT FIRM SINCE 1970
Patent Attorneys & Counselors of Law

(Translation)

Issuance Date: September 27, 2006
Submission Due Date: November 27, 2006

THE KOREAN INTELLECTUAL PROPERTY OFFICE
NOTICE OF GROUNDS FOR REJECTION

Applicant : ADAPTIX, INC.

Agency : Koreana Patent Firm

Application No. : Korean Patent Application No. 2003-7007961

Title of Invention: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

This application shall be rejected on the following grounds pursuant to Article 63 of the Korean Patent Law. If you have any objection, please submit an Argument or Amendment to the KIPO by **November 27, 2006**. (The term can be extended by one month each, however, a separate Acknowledgement of Extension of Time will not be issued.)

GROUNDS FOR REJECTION

The invention set forth in Claims 1-7, 12, 14-15, 17-20, 23-24, 29-37, 43-49, 52, 58-61 and 62 of the present application can be easily invented by a person having ordinary skill in the art to which the present invention pertains as indicated below. Accordingly, this application cannot be patented pursuant to Article 29(2) of the Korean Patent Law.

[below]

The present invention relates to OFDMA with adaptive subcarrier-cluster configuration and selective loading on multi-cell, multi-subscriber wireless systems using orthogonal frequency division multiplex (OFDM).

However, a part of the claims of the present invention is a similar technology to Korean Patent Laid-Open No. 1999-28244 (April 15, 1999; hereinafter "cited invention 1"), U.S. Patent No. 5,479,447 (December 26, 1995; hereinafter "cited invention 2"), EP0869647 (October 7, 1998; hereinafter "cited invention 3") and EP0929202 (July 14, 1999; hereinafter "cited invention 4") described below. Please see below for a detailed comparison:

A. Configuration

(1) Claims 1-7, 12, 14-15, 17-20 and 23-24

Claim 1 of the present invention is a configuration relating to a method for subcarrier selection for an OFDM system comprising: a subscriber measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station; the subscriber selecting a set of candidate subcarriers; the subscriber providing feedback information on the set of candidate suncarriers to the base station; and the subscriber receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber. Claims 2-7, 12, 14-15, 17-20 and 23-24 are dependent claims directly/indirectly citing Claim 1 and relate to configurations that add or limit the configuration of Claim 1.

However, said claims can easily be invented by a skilled person in the art from a combination of technologies in the cited inventions 1 and 2: where the former relates to a configuration wherein; a mobile station regularly measures the signal quality level(C/I) of sub-carriers within a subset of M subcarriers and the interference level(I) of useful N subcarriers, transmits request messages to the system requesting replacements for candidate subcarriers to be used on the link, determines candidate replacement subcarriers for the link based on C/I and I measurement, transmits request messages to the system requesting allocation for candidate subcarriers to be used on the link, and reconfigures a subset of M subcarriers to include candidate subcarriers upon receiving subscriber permission messages; and the latter relates to a configuration measuring channel information for subcarriers based on received signals and allocating subcarriers based on this.

Said claims and the cited inventions 1 & 2 have the same technical characteristic in their configuration that relates to a method of transmitting request messages to the system requesting replacements for candidate subcarriers to be used on the link, selecting candidate subcarrier set based on C/I and I measurement to provide feedback information on candidate subcarrier set to the base station, and then allocating subcarriers in OFDM system receiving indication of subcarriers of a subcarrier set selected by the base station.

(2) <u>Claims 29-37, 43-49 and 52</u>

Said claims of the present invention relates to an apparatus comprising; a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers, and a first base station in the first cell; to measure channel and interference information for the plurality of subcarriers based on pilot symbols received, to select a set of candidate subcarriers, and to provide feedback information on the set of candidate subcarriers to the base station and to receive an indication of subcarriers.

However, said invention can easily be invented by a skilled person in the art from a combination of technologies in the cited inventions 1 and 2, as described above, that relates to a method of transmitting request messages to the system requesting replacements for candidate subcarriers to be used on the link, selecting candidate subcarrier set based on C/I and I measurement to provide feedback information on candidate subcarrier set to the base station, and then allocating subcarriers in OFDM system receiving indication of subcarriers of a subcarrier set selected by the base station.

(3) <u>Claims 58-61</u>

Claims 58-59 relate to a configuration comprising: before and after the base station allocating a first portion of the subcarriers to a cell subcarrier to establish a data link between the base station and the subscriber, allocating a second portion of the subcarriers to the subscriber. Claims 60-61 relate to a base station comprising: means for allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and means for allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

However, said claims can easily invented by a skilled person in the art from a similar technology of the cited invention 3 comprising a method for adaptively allocating subcarriers to allocate the data link and subscribers between the base station and subscribers, and the base station.

(4) Claim 62

Said claim relates to an apparatus comprising: a plurality of subscribers in a cell; and a base station to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing.

However, said claim can easily be invented by a skilled person in the art from a configuration in the cited invention1, as described above, that relates to the base station allocating OFDMA subcarrier in clusters to the plurality of subscribers. Also, said claim can easily be invented by a skilled person in the art from an apparatus in the cited invention 4 that relates to the base station allocating OFDMA subcarriers in cluster to the plurality of subscribers.

B. Aim and Effect

The present invention aims to effectively allocate subcarriers by adaptively locate subcarriers in OFDM system. And the cited inventions with similar technical background can also achieve the same aim and effect with the similar configuration.

C. Conclusion

Thus, Claims 1-7, 12, 14-15, 17-20, 23-24, 29-37, 43-49, 52, 58-61 and 62 of the present invention can easily be invented by a skilled person in the art from similarity in technology, configuration, aim and effect with the cited inventions 1, 2, 3 and 4.

*For your reference, it is necessary to confirm if "during selection" and "one subscriber" recited in Claim 39 are a simple clerical error of "at least one subscriber" recited in other claims.

[Attachment]
Attached 1 A copy of Korean Patent Laid-Open No. 1999-28244 (April 15, 1999)
Attached 2 A copy of U.S. Patent No. 5,479,447
Attached 3 A copy of EP0869647
Attached 4 A copy of EP0929202

Dated September 27, 2006

Information and Communications Examination Bureau
of Korean Intellectual Property Office

Examiner(s)-in-charge Hwan-cheol Yu

발송번호: 9-5-2006-056245532
발송일자: 2006.09.27
제출기일: 2006.11.27

수신 서울 강남구 역삼1동 824-19 동경빌딩(특허법인 코리아나)
특허법인코리아나[박해선]
135-934

2006. 09. 28

특 허 청
의견제출통지서

NOTICE OF GROUNDS FOR REJECTION

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주소 미국 워싱턴 98104, 시애틀, 스위트 800, 에비뉴 에스. 605-5
대리인 명칭 특허법인코리아나
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지정된변리사 박해선 외 1명

출원번호 10-2003-7007961 Korean Pat. Appln. No.
발명의 명칭 적응형 서브캐리어-클러스터 구성과 선택적 로딩을이용하는 OFDMA

이 출원에 대한 심사결과 아래와 같은 거절이유가 있어 특허법 제63조의 규정에 의하여 이를 통지하오니 의견이 있거나 보정이 필요할 경우에는 상기 제출기일까지 의견서[특허법시행규칙 별지 제25호의2서식] 또는/및 보정서[특허법시행규칙 별지 제5호서식]를 제출하여 주시기 바랍니다.(상기 제출기일에 대하여 매회 1월 단위로 연장을 신청할 수 있으며, 이 신청에 대하여 별도의 기간연장승인통지는 하지 않습니다.)

[이유]

이 출원의 특허청구범위 제1-7, 12, 14-15, 17-20, 23-24, 29-37, 43-49, 52, 58-61, 62항에 기재된 발명은 그 출원전에 이 발명이 속하는 기술분야에서 통상의 지식을 가진 자가 아래에 지적한 것에 의하여 용이하게 발명할 수 있는 것이므로 특허법 제29조제2항의 규정에 의하여 특허를 받을 수 없습니다.

-아래-

본 발명은 OFDM을 이용하는 멀티-셀, 멀티-가입자 무선 시스템에 관한 적응형 서브캐리어-클러스터 구성과 선택적 로딩을 이용하는 OFDMA에 관한 기술입니다.

그러나 본 발명의 일부 청구항들은 후술하는 한국공개특허공보 1999-28244(1999.4.15, 인용발명1), 미국특허공보 5479447(1995.12.26, 인용발명2), 유럽공개특허공보 0869647(1998.10.07, 인용발명3), 유럽공개특허공보 929202(1999.07.14, 인용발명4)과 유사한 기술입니다. 이를 구체적으로 비교하면,

가. 구성

(1) 청구항 제1-7, 12, 14-15, 17-20, 23-24항

본 발명 청구항 제1항은 가입자가 기지국으로부터 수신한 파일럿 심볼에 기초하여 복수의 서브캐리어에 대한 채널 및 간섭 정보를 측정하고 후보 가입자 세트를 선택하여 후보 가입자 세트에 대한 피드백 정보를 기지국에 제공하고 기지국에 의해 선택된 서브캐리어 세트의 서브캐리어의 지시를 수신하는 단계를 포함하는 OFDM 시스템에 대한 서브캐리어 선택 방법에 관한 구성이고, 청구항 2-7, 12, 14-15, 17-20, 23-24항은 제1항을 직간접적으로 인용하는 종속항들로 제1항의 구성요소를 부가하거나 한정하는 구성에 관한 것입니다.

그러나 상기 청구항들은 인용발명1에서 이동국은 M가입자의 부분집합내의 가입자의 신호품질레벨(C/I) 및 유용한 N가입자의 간섭레벨(I)을 주기적으로 측정하고, 가입자 요구 메시지를 후보 가입자가 링크의 가입자를 대체하도록 요청하는 시스템에 전송한 다음, 이동국은 C/I 및 I측정을 기반으로 한 링크에 대한 후보대체 가입자를 결정하고 후보 가입자가 링크의 가입자를 대체하기 위해 할당되는 것을 요청하는 시스템에 가입자 요청 메세지를 전달하여 가입자 허용 메시지가 수신되는 경우 이동국은 후보 가입자를 포함하도록 M가입자의 부분집합을 재구성하는 OFDM 시스템에서의 적응채널할당에 관한 구성과 인용발명2에서 수신신호에 기초하여 서브캐리어에 대한 채널정보를 측정하고 이를 기초로 선택된 서브캐리어를 할당하는 관한 구성의 결합 기술로부터 본 발명이 속하는 기술분야에서 통상의 지식을 가진 자가 용이하게 유추 가능합니다.

상기 청구항들과 인용발명1, 2의 결합구성은 모두 가입자 요구 메시지를 후보 가입자가 링크의 가입자를 대체하도록 요청하는 시스템에 전송한 다음, 기지국은 C/I 및 I측정을 기반으로 후보 가입자 세트를 선택하여 후보 가입자 세트에 대한 피드백 정보를 기지국에 제공하고 기지국에 의해 선택된 서브캐리어 세트의 서브캐리어의 지시를 수신하는 OFDM 시스템에서 서브캐리어를 할당방법에 관한 기술적 특징이 일치합니다.

(2) 청구항 제29-37, 43-49, 52항

본 발명의 상기 청구항들은 복수의 가입자에 의한 이용을 위하여 원하는 서브캐리어의 클러스터를 지시하는 피드백 정보를 발생시키는, 제 1 셀에 있는 복수의 가입자 및 제 1 기지국을 포함하며,-수신한 파일럿 심볼에 기초하여 복수의 서브캐리어에 대한 채널 및 간섭 정보를 측정하고, 후보 서브캐리어 세트를 선택하여 하나의 세트에 대한 피드백 정보를 기지국에 제공하여 서브캐리어의 지시를 수신하는 것을 특징으로 하는 장치에 관한 구성입니다.

그러나 이는 이미 소개된 인용발명1과 인용발명2의 결합구성에서 가입자 요구 메시지를 후보 가입자가 링크의 가입자를 대체하도록 할당하게 요청하는 시스템에 전송한 다음, 기지국은 C/I 및 I측정을 기반으로 후보 가입자 세트를 선택하여 후보 가

입자 세트에 대한 피드백 정보를 기지국에 제공하고 기지국에 의해 선택된 서브캐리어 세트의 서브캐리어의 지시를 수신하는 OFDM 시스템에서 서브캐리어를 할당장치의 구성으로부터 본 발명이 속하는 기술분야에서 통상의 지식을 가진 자가 용이하게 발명할 수 있는 것입니다.

(3) 청구항 제58-61항

청구항 제58-59항은 기지국이 기지국과 가입자간에 데이터링크를 확립하기 위해서 서브캐리어의 제1 부분을 셀 서브캐리어에 할당 전후에 서브캐리어의 제2 부분을 가입자에게 할당하는 것을 특징으로 하는 방법에 관한 구성이고 청구항 제60-61항은 기지국과 가입자간에 데이터링크를 확립하기 위해서 서브캐리어의 제1 부분을 셀 서브캐리어에 할당하는 수단 및 통신 대역폭을 증가시키기 위해서 서브캐리어의 제2 부분을 가입자에게 할당하는 수단을 구비하는 기지국에 관한 구성입니다.

그러나 상기 청구항들은 인용발명3에서 기지국과 가입자간에 데이터링크와 가입자 할당을 위해 서브캐리어를 적응적으로 할당하는 방법 및 기지국에 관한 유사한 구성으로부터 본 발명 기술 분야에서 통상의 지식을 가진 자의 수준에서 용이하게 유추 가능합니다.

(4) 청구항 제62항

상기 청구항은 셀간 간섭 방지와 셀내 트래픽 로드 밸런싱에 기초하여 복수의 가입자에게 OFDMA 서브캐리어를 클러스터로 할당하는 기지국을 포함하는 장치에 관한 구성입니다.

그러나 이는 이미 소개된 인용발명1에서 복수의 가입자에게 OFDMA 서브캐리어를 클러스터로 할당하는 기지국과 관련한 장치의 구성으로부터 본 발명 기술 분야에서 통상의 지식을 가진 자의 수준에서 용이하게 유추 가능합니다. 또한, 상기 청구항은 인용발명4에서 복수의 가입자에게 OFDMA 서브캐리어를 클러스터로 할당하는 기지국 장치로부터도 본 발명 기술 분야에서 통상의 지식을 가진 자의 수준에서 용이하게 유추 가능합니다.

나. 목적 및 효과

본 발명은 OFDM 시스템에서 서브캐리어를 적응적으로 배치하여 서브캐리어를 효율적으로 할당하는데 그 목적 및 효과를 가지고, 유사한 기술적 배경을 가지는 인용발명들 또한 위에서 밝힌 유사한 구성에 의해 동일한 목적 및 효과를 달성할 수 있습니다.

다. 결론

따라서 본 발명 청구항 제1-7, 12, 14-15, 17-20, 23-24, 29-37, 43-49, 52,

58-61, 62항은 위에서 밝힌 바와 같이 인용발명1, 2, 3, 4를 선택적으로 결합하는 기술과 구성, 목적 및 효과의 유사성으로 인해 본 발명이 속하는 기술분야에서 통상의 지식을 가진 자가 용이하게 발명할 수 있습니다.

※ 참고로 청구항 제39항에 기재된 " 선택동안, '하나의 가입자'는 다른 청구항에 기재된 '하나 이상의 가입자'의 단순한 오기인지 확인할 필요가 있습니다.

[첨 부]
첨부1 공개특허 제1999-28244호(1999.04.15) 1부.
첨부2 US05479447호 1부.
첨부3 EP00869647호 1부.
첨부4 EP00929202호 1부. 끝.

2006.09.27

특허청 정보통신심사본부
영상기기심사팀 심사관 유환철

<< 안내 >>

명세서 또는 도면 등의 보정서를 전자문서로 제출할 경우 매건 3,000원, 서면으로 제출할 경우 매건 13,000원의 보정료를 납부하여야 합니다. 보정료는 접수번호를 부여받아 이를 납부자번호로 "특허법·실용신안법·디자인보호법및상표법에 의한 특허료·등록료와 수수료의 징수규칙" 별지 제1호서식에 기재하여, 접수번호를 부여받은 날의 다음 날까지 납부하여야 합니다. 다만, 납부일이 공휴일(토요휴무일을 포함한다)에 해당하는 경우에는 그날 이후의 첫 번째 근무일까지 납부하여야 합니다. 보정료는 국고수납은행(대부분의 시중은행)에 납부하거나, 인터넷지로(www.giro.or.kr)로 납부할 수 있습니다. 다만, 보정서를 우편으로 제출하는 경우에는 보정료에 상응하는 통상환을 동봉하여 제출하시면 특허청에서 납부해드립니다. 기타 문의사항이 있으시면 ☎481-5406로 문의하시기 바랍니다. 서식 또는 절차에 대하여는 특허고객 콜센터(☎1544-8080)로 문의하시기 바랍니다.

Docket No.:
68144/P014C1/10503148
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Xiaodong Li et al.

Application No.: 11/199,586 — Confirmation No.: 1128

Filed: August 8, 2005 — Art Unit: 2683

For: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING — Examiner: M. N. Zewdu

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT (IDS)

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In accordance with 37 CFR 1.97, Applicant(s) hereby make of record the following additional documents. A PTO Form SB/08 and a full copy of each of the documents required under 37 CFR 1.98(a)(2) accompany this statement.

Applicant(s) have become aware of the following documents, cited in a Korean Office Action issued September 27, 2006, during the prosecution of Korean Patent Application No. KR 2003-7007961, which corresponds to the above referenced application, and in accordance with 37 CFR 1.97(c) and (e)(1) or (b)(3), hereby submit(s) these documents for the Examiner's consideration. These documents are cited on the enclosed PTO Form SB/08, and a copy of Korean Office Action with the English Language translation and of each document required under 37 CFR 1.98(a)(2) cited thereon are enclosed as well.

This statement is not to be interpreted as a representation that the cited documents are material, that an exhaustive search has been conducted, or that no other relevant information exists. Nor shall the citation of any document herein be construed *per se* as a representation that such document is prior art. Moreover, Applicant(s) understand(s) the Examiner will make an independent evaluation of the cited documents.

This Information Disclosure Statement is filed more than three months after the U.S. filing date, OR more than three months after the date of entry of the national stage of a PCT application, AND after the mailing date of the first Office Action on the merits, whichever occurs first, but before the mailing date of a Final Office Action or Notice of Allowance (37 CFR 1.97(c)).

I hereby certify, pursuant to 37 CFR 1.97(e)(1), that each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement.

Applicant believes no fee is due with this response. However, if a fee is due, the Director is hereby authorized to charge any deficiency in the fees filed, asserted to be filed or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our Deposit Account No. 06-2380, under Order No. 68144/P014C1/10503148.

Dated: December 22, 2006

Respectfully submitted,

By [signature]

R. Ross Viguet
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PTO/SB/08A (10-01)
Approved for use through 10/31/2002.OMB 0651-0031
U. S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449A/PTO	Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	11/199,586
	Filing Date	August 8, 2005
	First Named Inventor	Xiaodong Li
	Art Unit	2683
(use as many sheets as necessary)	Examiner Name	M. N. Zewdu
Sheet 1 of 1	Attorney Docket Number	68144/P014C1/10503148

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number: Number-Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document: Country Code[3]-Number[4]-Kind Code[5] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
	BA	KR 1999-28244 / EP 0882377B1	04-15-1999	Telefonaktiebolaget LM		

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

[1] Applicant's unique citation designation number (optional). [2] See attached Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the application number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	CA	Office Action issued for Korean Patent Application No. 2003-7007961, dated September 27, 2006.	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] Applicant's unique citation designation number (optional). [2] Applicant is to place a check mark here if English language Translation is attached.

Examiner Signature		Date Considered	

25729627.1

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/199,586	08/08/2005	Xiaodong Li	68144/P014C1/10503148	1128

29053 7590 02/23/2007

DALLAS OFFICE OF FULBRIGHT & JAWORSKI L.L.P.
2200 ROSS AVENUE
SUITE 2800
DALLAS, TX 75201-2784

EXAMINER	
ZEWDU, MELESS NMN	
ART UNIT	PAPER NUMBER
2617	

SHORTENED STATUTORY PERIOD OF RESPONSE	MAIL DATE	DELIVERY MODE
3 MONTHS	02/23/2007	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

If NO period for reply is specified above, the maximum statutory period will apply and will expire 6 MONTHS from the mailing date of this communication.

Office Action Summary	Application No.	Applicant(s)
	11/199,586	LI ET AL.
	Examiner	Art Unit
	Meless N. Zewdu	2617

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *22 November 2006*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-4,7,8,12-20,23,26,27,29-33,36,37,43-50,55,56 and 58-62* is/are pending in the application.

4a) Of the above claim(s) ______ is/are withdrawn from consideration.

5)☐ Claim(s) ______ is/are allowed.

6)☒ Claim(s) *1-4,7,8,12-20,23,26,27,29-33,36,37,43-50,55,56 and 58-62* is/are rejected.

7)☐ Claim(s) ______ is/are objected to.

8)☐ Claim(s) ______ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on ______ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. ______.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date *12/22/06*.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. ______ .

5) ☐ Notice of Informal Patent Application

6) ☐ Other: ______.

DETAILED ACTION

1. This action is in response to the communication filed on 11/22/06.

2. Claims 5-6, 9-11, 21-22, 24-25, 28, 34-35, 38-42, 50-51, 53-54 and 57 are cancelled in this amendment.

3. Claims 1-4, 7-8, 12-15, 17-20, 22, 26-27, 29-33, 36-37, 43-49, 52, 55-56 and 58-62 are pending in this action.

4. This action is final.

Claim Objections

Claim 59 is objected to because of the following informalities: the claim is mad dependant upon canceled claim 57. Appropriate correction is required.

Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory obviousness-type double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement.

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

Claims 1-62 are rejected on the ground of nonstatutory double patenting over claims 1-119 of U. S. Patent No. 6,904,283 B2 since the claims, if allowed, would improperly extend the "right to exclude" already granted in the patent.

The subject matter claimed in the instant application is fully disclosed in the patent and is covered by the patent since the patent and the application are claiming common subject matter, as follows: the difference between the claims in the instant application and the claims in the patent is that the claims in the instant application are more broader than the claims in the patent.

Furthermore, there is no apparent reason why applicant was prevented from presenting claims corresponding to those of the instant application during prosecution of the application which matured into a patent. See *In re Schneller*, 397 F.2d 350, 158 USPQ 210 (CCPA 1968). See also MPEP § 804.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

Claims 1, 12, 14, 17-18, 30, 43 and 46-47 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter (DE 19800953 C1) in view of Larsson et al. (Larsson) (US 5,956,642).

As per claim 1: Ritter discloses a method for sub-carrier selection for a system employing orthogonal frequency division multiple access (OPDMA) (see abstract), comprising:

the subscriber selecting a set of candidate sub-carriers reads on '953 (see abstract). Each mobile station, determining the quality of a preferred segment, suitable for its own connection, is same as selecting a set of desirable sub-carriers.

the subscriber providing feedback information on the set of candidate sub-carriers to the base station reads on '953 (see abstract).

the subscriber receiving an indication of sub-carriers of the set of sub-carriers selected by the base station for use by the subscriber reads on '953 (see abstract). Since a segment includes a plurality of sub-carriers, it can be considered as a set of sub-carriers. Furthermore, Ritter discloses that a mobile measures channel/segment quality based on received data symbols transmitted by a base station. But, Ritter does not explicitly teach about a subscriber measuring channel and interference information for a plurality of sub-carriers, as claimed by applicant. However, in the same field of endeavor, Larsson teaches that a mobile can measure a signal quality level (C/I) of the channels within the subset of M channels, and the interference level (I) of all the N available channels (see col. 5, lines 6-21). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify the teaching of Ritter with that of Larsson for the advantage of enabling Ritter's communication system to allocate resources adaptively (see col. 16-19). Note: when the references are combined as shown above, the measurement or the parameters in question will be based on pilot symbols/data received from a base station.

As per claim 30: the features of claim 30 are similar to the features of claim 1, except claim 30 is directed to an apparatus intended to perform the steps of method claim 1. Hence, since the method steps of claim 1 are taught and the apparatus of claim 30 is required to perform the steps of claim 1, claim 30 has been rejected on the same ground and motivation as claim 1.

As per claim 12: Ritter teaches a method, wherein the pilot symbols occupy an entire OFDM frequency bandwidth reads on '953 (see abstract). In the prior, the pilot symbols occupy the entire OFDM frequency bandwidth.

As per claim 14: Larsson teaches a method, further comprising a base station selecting sub-carriers from a set of candidate sub-carriers (see col. 7, lines 43-54). When the references are combined, the selection would be based on information available to the base station, as a feedback from the mobile station, as provided in Ritter. Furthermore, the recited, **additional** information reads on Ritter's channel quality of measurement on different channels/segments.

As per claim 17: Ritter teaches a method wherein the indication of sub-carriers is received via a downlink control channel reads on '953 (see abstract).

As per claim 18: Ritter teaches a method wherein the plurality of sub-carriers comprises all sub-carriers allocable by a base station reads on '953 (see abstract). In the prior, the pilot symbols occupy the entire OFDM frequency bandwidth.

As per claim 43: the feature of claim 43 is similar to the feature of claim 14. Hence, claim 43 is rejected on the same ground and motivation as claim 14.

As per claim 46: Ritter teaches an apparatus wherein the indication of sub-carriers is received via a downlink control channel between the base station and the at least one subscriber reads on '953 (see abstract).

As per claim 47: Ritter teaches an apparatus wherein the plurality of sub-carriers comprises all sub-carriers allocable by a base station reads on '953 (see abstract). In the prior, the pilot symbols occupy the entire OFDM frequency bandwidth.

Claims 2-4, 8, 13, 31-33 and 37 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter as applied to the claims above, and further in view of Wong (US 6,330,460 B1).

As per claim 2: Ritter teaches a method, further comprising:

the subscriber continuously monitoring reception of the pilot symbols known to the base station reads on '953 (see abstract). The subscriber/s must continuously monitor for the pilot symbols transmitted by a base station in order to acquire a communication channel. But, Ritter does not explicitly teach about a subscriber measuring signal-plus-interference-to-noise ratio (SINR) of each cluster of sub-carriers, as claimed by applicant. However, in the same field of endeavor, Wong teaches that a subscriber station/mobile station is capable of measuring signal-plus-interference-to-noise ratio (SINR) (see col. 8, lines 11-26). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify Ritter's reference with the teaching of Wong for the advantage enabling Ritter's base station determine the highest acceptable traffic data rate for a particular mobile station.

As per claim 3: Wong teaches a method, further comprising the subscriber measuring inter-cell interference, wherein the subscriber selects candidate sub-carriers based on the inter-cell interference (see col. 8, lines 11-26). In Ritter, the mobile station selects suitable segment/sub-carrier. When the references are combined as shown in the rejection of claim 2, the selection will be based on the inter-cell interference as measured by the mobile station/subscriber, according to the teaching of Wong.

As per claim 4: Wong teaches a method further comprising the base station selecting sub-carriers for the subscriber based on inter-cell interference avoidance (see col. 8, lines 11-26).

As per claim 8: Wong teaches a method further comprising the subscriber using information from pilot symbol periods and data periods to measure channel and interference information (see col. 8, lines 11-26). In Ritter, the subscriber receives pilot symbols which it can use to measure channel and interference, as taught by Wong.

As per claim 13: Wong teaches a method wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other (see col. 8, lines 11-26). The combined prior art teaches measuring interference based on information extracted (in Ritter) from pilot symbols transmitted by a base station. Interference, in the context of the prior art, is measured so as to avoid, by being aware of it, communication loss if it occurs to the extent of undesired degree. It is obvious that if two pilot symbols from neighboring cells sites are allowed to collide, they will. But, what will be the benefit? Hence, colliding two signals, as claimed, does not carry patentable weight.

As per claim 31: Ritter teaches an apparatus wherein each of the plurality of subscribers continuously monitors reception of the pilot symbols known to the base station (see abstract). The subscriber/s must continuously monitor for the pilot symbols transmitted by a base station in order to acquire a communication channel. But, Ritter does not explicitly teach about a subscriber measuring signal-plus-interference-to-noise ratio (SINR) of each cluster of sub-carriers, as claimed by applicant. However, in a related field of endeavor, Wong teaches that a subscriber station/mobile station is capable of measuring signal-plus-interference-to-noise ratio (SINR) (see col. 8, lines 11-26). Since the features of claim 31 are similar to the features of claim 2, claim 31 is rejected on the same ground and motivation as claim 2.

As per claim 32: Wong teaches an apparatus wherein each of the plurality of subscribers measures inter-cell interference, wherein the at least one subscriber selects candidate sub-carriers based on the inter-cell interference (see col. 8, lines 11-26). In Ritter, the mobile station selects suitable segment/sub-carrier. When the references are combined as shown in the rejection of claims 2 and 31, the selection will be based on the inter-cell interference as measured by the mobile station/subscriber, according to the teaching of Wong.

As per claim 33: Wong teaches an apparatus defined in Claim 32 wherein the base station selects sub-carriers for the one subscriber based on inter-cell interference 3 avoidance (see col. 8, lines 11-26).

As per claim 37: Wong teaches an apparatus defined in Claim 30 wherein the at least one subscriber uses information from pilot symbol periods and data periods to measure channel and interference information reads on '460 (see col. 8, lines 11-26). In Ritter, the subscriber receives pilot symbols which can used to measure channel and interference, as taught by Wong.

Claims 15, 16, 44 and 45 are rejected under 35 U.S.C. 103(a) as being unpatentable over the references applied to the claims above, and further in view of Westroos et al. (Westroos) (US 6,327,472).

As per claim 15: but, the above mentioned references do not explicitly teach about a base station having additional information that comprises traffic load information on each cluster of sub-carriers, as claimed by applicant. However, in the same field of endeavor, Westroos teaches about the use of a load monitoring device that collects and holds traffic information on neighboring cells (see col. 2, line 44-col. 3, line 10; col.5, lines 19-65). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to further modify the above references with the teaching of Westroos for the advantage of making load dependent channel allocation. Note: although Westroos' traffic load information collector/holder is residing in the MSC, it is by choice of design. It could have been placed in, for example, the BSC or BS, as well.

As per claim 16: Westroos teaches a method wherein the traffic load information is provided by a data buffer in the base station (see col. 5, lines 45-65). Also, see the explanation above.

As per claim 44: but, the above mentioned references do not explicitly teach about a base station having additional information that comprises traffic load information on each cluster of sub-carriers, as claimed by applicant. However, in a related field of endeavor, Westroos teaches about the use of load monitoring device that collects and holds traffic information on neighboring cells (see col. 2, line 44-col. 3, line 10; col.5, lines 19-65). Motivation is same as provided in the rejection of claim 15 above.

As per claim 45: Westroos teaches an apparatus wherein the traffic load information is provided by a data buffer in the base station (see col. 5, lines 45-65). Also, see the explanation above.

Claims 19, 20, 23, 48, 49 and 52 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter as applied to claim 1 above, and further in view of Bodin et al. (Bodin) (US 5,507,034).

As per claim 19: Ritter discloses about a subscriber sending feedback information to a base station in an OFDMA communication system using segmented spectrum channels, which is same as sub-carriers (see abstract). But, Ritter does not explicitly teach about arbitrarily ordering the set of candidates of sub-carriers as cluster of sub-carriers, as claimed by applicant. However, in a related field of endeavor, Bodin teaches that frequencies can be sequentially ordered and assigned priorities (see col. 3, lines 44-64). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify Ritter's reference with the teaching of Bodin for the advantage of selecting a bandwidth/channel for a pending communication.

As per claim 20: Bodin teaches a method wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first (see col. 3, lines 44-64).

As per claim 23: Bodin teaches a method wherein providing feedback information comprises sequentially ordering candidate clusters (see col. 3, lines 44-64).

As per claim 48: Ritter discloses about a subscriber/subscribers sending feedback information to a base station in an OFDMA communication system using segmented spectrum channels, which is same as sub-carriers (see abstract). But, Ritter does not explicitly teach about arbitrarily ordering the set of candidates of sub-carriers as cluster of sub-carriers, as claimed by applicant. However, in a related field of endeavor, Bodin teaches that frequencies can be sequentially ordered and assigned priorities (see col. 3, lines 44-64). Motivation is same as provided in the rejection of claim 19 above.

As per claim 49: Bodin teaches an apparatus wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first reads on '034 (see col. 3, lines 44-64).

As per claim 52: Bodin teaches an apparatus wherein providing feedback information comprises sequentially ordering candidate clusters reads on '034 (see col. 3, lines 44-64).

Claims 29 and 62 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter In view of Feuerstein et al. (Feuerstein) (US 6,141,565).

As per claim 29: Ritter discloses an apparatus (see abstract), comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of sub-carriers desired for use by the plurality of subscribers reads on '953 (see abstract). The mobile station of the prior art is in a cell. Furthermore, since, there is not a second cell mentioned, the prior art cell can be considered as a first cell.

a first base station in the first cell, the first base station performing sub-carrier allocation for OFDMA to allocate OFDMA sub-carriers in clusters to the plurality of subscribers reads on '953 (see abstract). Segments of the frequency spectrum in the prior art are sub-carriers/clusters. Since there is no mention of a second base station, '<u>a first base station</u>' is read as a base station; hence, a base station in a cell.

But Ritter does not explicitly teach about inter-cell interference avoidance and intra-cell traffic load balancing, as claimed by applicant. However, in a related field of endeavor, Feuerstein teaches about network optimization based on measured local interference and/or local traffic load conditions (see col. 2, lines 27-37). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify Ritter's reference with the teaching of Feuerstein's for the advantage of optimizing network parameters based on dynamic communication and network conditions such as traffic load and balancing conditions and/or changing interference conditions (see col. 1, lines 20-26).

As per claim 62: the features of claim 62 are similar to the features of claim 29. Hence, claim 62 is rejected on the same ground and motivation as claim 29.

Claims 7, 26, 36 and 55 are rejected under 35 U.S.C. 103(a) as being unpatentable over the references applied to claims 1 and 30 above and further in view of Frodigh.

As per claim 7: But, the references applied to claims 1 and 30 do not explicitly teach about a subscriber unit submitting a new feedback information after being allocated the set of subscriber units to be allocated a new set of sub-carriers and thereafter the subscriber unit receiving another indication of the new set of sub-carriers, as claimed by applicant. However, in the same field of endeavor, Fordigh teaches a method/technique of dynamically allocating subcarriers to a subscriber based on periodically measured and reported signal quality (C/I) (see col. 4, lines 32-67). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to further modify the above references with the teaching of Frodigh for the advantage of providing an allocation of sub-carriers to each link of an OFDM system that lessens co-channel interference between cells of the system (see col. 4, lines 27-31).

As per claim 26: the features of claim 26 are similar to the features of claim 7. In that allocating a first portion and a second portion in claim 26 is similar to the 'old' and the 'new' set of sub-carriers in claim 7.

As per claim 27: Frodigh teaches a method wherein the base station allocates the second portion after allocating each subscriber in the cell sub-carriers to establish a data link between the base station and said each subscriber (see col. 4, lines 32-49). Adaptive allocation includes/considers the needs of subscribers operating under the adaptively allocating base station. Motivation is same as provided in the rejection of claim 7.

As per claim 36: Frodigh teaches an apparatus wherein the subscriber submits new feedback information after being allocated the set of subscribers to receive a new set of sub-carriers and thereafter receives another indication of the new set of sub-carriers (see col. 4, lines 32-49). When the references are combined as shown above, bandwidth will be allocated adaptively—which can include allocating a first and a second portion as needed. Motivation is same as provided in the rejection of claim 7.

As per claim 55: the modified Ritter's reference, as applied to claims 1 and 30 above, teaches an apparatus wherein the base station allocates the sub-carriers to establish a data link between the base station and the subscriber (see Ritter, abstract). But, the Ritter's reference does not explicitly teach about a base station allocating a second portion, after a first portion has been allocated, of the sub-carriers to the subscriber to increase communication bandwidth However, in a related field of endeavor, Frodigh teaches that in an OFDMA system sub-carriers can be selected and adaptively allocated based on set allocation criteria (see col. 4, lines 32-49). The motivation is same as provided in the rejection of claim 7.

As per claim 56: Fordigh teaches an apparatus wherein the base station allocates the second portion after allocating each subscriber in the cell sub-carriers to establish a data link between the base station and said each subscriber (see col. 4, lines 32-49). Adaptive allocation can allow the base station to perform this feature priority.

Claims 58, 60 and 61 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ritter in view of Frodigh et al. (Frodigh) (US 5,726,978). For examination purpose, claim 58 is considered first.

As per claim 58: Ritter discloses a method comprising:

the base station allocating sub-carriers to establish a data link between the base station and the subscriber reads on '953 (see abstract). But, Ritter does not explicitly teach about a base station allocating a first portion of the sub-carriers and allocating a second portion of the sub-carriers to the subscriber to increase communication bandwidth, as claimed by applicant. However, in the same field of endeavor, Frodigh advantageously teaches about a method of adaptively allocating selected sub-carriers to subscribers (see col. 4, lines 32-49). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify Ritter's reference with the teaching of Frodigh for the advantage of lessening co-channel interference between cells of the system (see col. 4, lines 25-31). Note: adaptive allocation of sub-carriers can increase or decrease a communication bandwidth.

As per claim 59: Frodigh teaches an method wherein the base station allocates the second portion after allocating each subscriber in the cell sub-carriers to establish a data link between the base station and said each subscriber (see col. 4, lines 32-49). Adaptive allocation can allow the base station to perform this feature priority.

As per claim 60: Ritter discloses a base station (see abstract), comprising:

means for allocating sub-carriers to establish a data link between the base station and the subscriber (see abstract). But, Ritter does not explicitly teach about a means for allocating a first portion and a second portion of the sub-carriers to a subscriber to increase communication bandwidth, as claimed by applicant. However, in a related field of endeavor, Frodigh teaches that in an OFDMA system subcarriers can be selected and adaptively allocated based on set allocation criteria (see col. 4, lines 32-49). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to modify the teaching of Ritter with that of Frodigh for the advantage of lessening co-channel interference between cells of the system (see col. 4, lines 25-31). Note: adaptive allocation of sub-carriers can increase or decrease a communication bandwidth.

As per claim 61: Frodigh teaches an apparatus defined in Claim 60 wherein the base station allocates the second portion after allocating each subscriber in the cell sub-carriers to establish a data link between the base station and said each subscriber (see col. 4, lines 32-49). When the references are combined as shown above, bandwidth will be allocated adaptively.

Allowable Subject Matter

For the record, claims 5, 6, 9-11, 21, 22, 24, 25, 34, 35, 38-42, 50, 51, 53 and 54 were previously indicated as allowable have been cancelled in the current amendment.

Response to Arguments

Applicant's arguments filed 11/22/06 have been fully considered but they are not persuasive. Arguments and responses are provided in the following paragraphs.

Argument I: with regard to a non-statutory double patenting rejection issue, in view of 6,904,283 B2, applicant argues that examiner's assertion that the pending claims are broader than the issued patent claims does not show distinctness and thus, is not determinative.

Response I: examiner respectfully disagrees with the argument. In that when examiner asserts that the difference between the claims in the pending application and the claims in the patent is that the claims in the pending application are broader than the claims in the patent is to mean there is no distinctness between the two. To that effect one could see claim 1 in the pending application in view of the patent claims 1 (sub-carrier selection and feedback), claim 9 (feedback information comprising SINR), as an instance. Hence, this line of argument is not persuasive for the examiner to withdraw the double patenting rejection as requested by applicant.

Argument II: with regard to independent claims 1 and 30, applicant asserts 'there is not suggestion in either reference of a subscriber unit measuring channel information based on pilot symbols received from a base station.

Response II: examiner respectfully disagrees with the argument. In that Ritter, in an OFDMA transmission method that involves transmission of data symbols, states that the quality of different segments (subcarriers) of the frequency spectrum is measured through each mobile station (see abstract). Hence, the argument is not persuasive.

Argument III: with regard to claims12, applicant asserts that neither Ritter neither or Larsson teach or suggest pilot symbols occupying an OFDM frequency bandwidth, as set forth in the claim.

Response III: examiner respectfully disagrees with the argument. Ritter, as shown in the abstract, provides an OFDMA multi-carrier transmission method, wherein it is self evident that the multi-carrier frequencies occupy the entire OFDM spectrum. Furthermore, it is also self evident from that fact that each mobile station determines the quality of different segments/subcarriers, that the base station transmits pilot symbols which enables the mobile/s to determine channel/subcarrier quality. Hence, the argument is based on a mere absence of identical word/s and thus, found not to be persuasive.

Argument IV: with regard to claims 17 and 46, applicant asserts "applicant points out that Ritter does not mention how an indication of subcarriers is received from the base station. There is not mention at all as to the channel (i.e., control, data, etc.) used in Ritter's abstract."

Response IV: examiner respectfully disagrees with the argument. In that a careful observation shows that the phrase, 'data symbols', which 'assigns respectively several sub-carriers', indicates 'data' and 'control'. Hence, the argument is not persuasive.

Argument V: with regard to claims 18 and 47, applicant asserts that 'Ritter is wholly silent as to "all subcarriers allocable by a base station," as set forth in the claims.

Response V: examiner respectfully disagrees with the argument. The term OFDMA in itself is an evidence that the sub-carriers are allocable for multiple access use and the allocator is a base station.

Argument VI: with regard to claim 2, applicant asserts that Ritter doe not mention that the mobile stations send indication to the mobile station, as set forth in the claim.

Response VI: examiner respectfully disagrees with the argument. In that Ritter states that information indicative of channel quality is sent by a mobile station to the base station (see abstract). Hence, the argument is not persuasive.

Argument VII: with regard to claim 3, applicant argues by saying Ritter and Wong are silent as to sending an indication of a group of clusters selected by the base station for use by the subscriber, as set forth in the claim.

Response VII: examiner respectfully disagrees with the argument. In that, in Ritter the it is mentioned that "at least one preferred segment, suitable for its own connection, is determined through each mobile station, and a corresponding information/indicator is transmitted to the base station." Furthermore, the base station having received this information/indication assigns (which is a function of selection) a segment (sub-carrier) for the respective connection to each mobile station. This feature invalidates the argument forwarded by applicant regarding claims 4 and 33. Hence, the argument regarding claims 3, 4 and 33 is not found to be persuasive.

Argument VIII: with regard to claims 15, 16, 44 and 45 (particularly with regard to claim 16), applicant asserts that, in the proposed combination of references used, Westroos does not describe what mechanism is used to make the traffic assignment, or even if the assignment is necessarily made at the base station.

Response VIII: examiner respectfully disagrees with the argument. In that, Westroos teaches about assigning traffic channel based on stored parameter (mechanism) cell parameter information (traffic load) and the assignment is provided by the network which is defined by Westroos as a mobile switching center or a base station controller, which must include a base station in order to provide access. Hence, the argument is not persuasive.

Argument VIX: with regard to claims 29 and 62, applicant argues by saying Feuerstein does not contemplate evaluating load balancing within each cell. As such, Feuerstein doe not teach or suggest performing subcarrier allocation based on intra-cell traffic balancing, as set forth in the claim.

Response VIX: examiner respectfully disagrees with the argument. In that, Feuerstein teaches about dynamically optimizing a network based on network condition such as traffic load and balancing conditions and/or changing interference conditions (see col. 1, lines 20-25) including measuring local interference and/or local traffic load conditions (see col. 2, lines 27-36). Hence, the argument has not basis.

Argument X: with regard to claim 58, applicant argues by saying, Frodigh falls short of disclosing allocating a second portion of subcarriers to increase a communication bandwidth.

Response X: examiner respectfully disagrees with the argument. In that, Frodigh teaches a dynamic subcarrier channel allocation that includes allocating a plurality of subcarrier (see for instance, claims 1 and 11). Note: a plurality of sub-carriers include more than one sub-carrier which can be considered as additional sub-carrier. Hence, the argument is not found to be persuasive.

Argument XI: with regard to claims 7, 26, 36 and 55, applicant argues, "according to examiner's own rationale, Larsson is required to satisfy every limitation of claims 1 and 30."

Response XI: As can be seen from the written Office Action, claims 1 and 30 are rejected using Ritter in view of Larsson. On the other hand, examiner agrees with applicant that claims 7, 26, 36 and 55 should have been grouped separately from claims 58, 60 and 61, as implicitly suggested by applicant. Thus, examiner has regrouped claims 7, 26, 36 and 55, as shown in the body of the rejection of the claims, and thereby, applicant's argument and conclusion based on the assertion, "therefore, according to examiner's own rationale, the ejection of claims 7, 26, 36 and 55 is insufficient under 35 U.S C. § 103" has been treated properly.

Argument XII: with regard to claims 7 and 36, applicant argues by saying the applied references do not teach "the subscriber unit submitting a new feedback information after being allocated the set of subscriber units to be allocated the new subcarriers."

Response XII: examiner respectfully disagrees with the argument. In that Frodigh's adaptive channel (subcarrier) allocation requires adaptive subcarrier measurement and reporting by the mobile unit at different intervals (see col. 11, lines 17-53). Hence, examiner did not find this argument persuasive.

Argument XIII: with regard to claims 26 and 55, applicant argues by saying the references do not teach "the base station allocating a second portion of the subcarriers to the subscriber unit to increase communications bandwidth."

Response XIII: examiner notes that this argument is same as presented regarding claim 58 and hence applicant is respectfully referred to argument X and the corresponding response X.

Conclusion

THIS ACTION IS MADE FINAL. Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Meless N. Zewdu whose telephone number is (571) 272-7873. The examiner can normally be reached on 8:30 am to 5:00 pm..

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Appiah Charles can be reached on (571) 272-7904. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Any inquiry of a general nature relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is (571) 272-2600.

Meless zewdu

Examiner

18 February 2007.

Search Notes	Application/Control No. 11/199,586	Applicant(s)/Patent under Reexamination LI ET AL.
	Examiner Meless N. Zewdu	Art Unit 2617

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SEARCHED

Class	Subclass	Date	Examiner

SEARCH NOTES (INCLUDING SEARCH STRATEGY)

	DATE	EXMR
Search has been updated.	2/19/2007	M.Z.

INTERFERENCE SEARCHED

Class	Subclass	Date	Examiner

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Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
11/199,586	LI ET AL.
Examiner	**Art Unit**
Meless N. Zewdu	2617

√	**Rejected**	–	**(Through numeral) Cancelled**	**N**	**Non-Elected**	**A**	**Appeal**
=	**Allowed**	÷	**Restricted**	**I**	**Interference**	**O**	**Objected**

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PTO/SB/08A (10-01)
Approved for use through 10/31/2002.OMB 0651-0031
U. S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449A/PTO	Complete If Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	11/199,586
	Filing Date	August 8, 2005
	First Named Inventor	Xiaodong Li
	Art Unit	2683
(use as many sheets as necessary)	Examiner Name	M. N. Zewdu
Sheet 1 of 1	Attorney Docket Number	68144/P014C1/10503148

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]-Number[4]-Kind Code[5] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
MZ	BA	KR 1999-28244 / EP 0882377B1	04-15-1999	Telefonaktiebolaget LM		

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

[1] Applicant's unique citation designation number (optional). [2] See attached Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the application number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
MZ	CA	Office Action issued for Korean Patent Application No. 2003-7007961, dated September 27, 2006.	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] Applicant's unique citation designation number (optional). [2] Applicant is to place a check mark here if English language Translation is attached.

Examiner Signature	/Meless Zewdu/	Date Considered	02/17/2007

25729827.1

Electronic Acknowledgement Receipt

EFS ID:	1707932
Application Number:	11199586
International Application Number:	
Confirmation Number:	1128
Title of Invention:	OFDMA with adaptive subcarrier-cluster configuration and selective loading
First Named Inventor/Applicant Name:	Xiaodong Li
Customer Number:	29053
Filer:	David H. Tannenbaum/Carol Martin
Filer Authorized By:	David H. Tannenbaum
Attorney Docket Number:	68144/P014C1/10503148
Receipt Date:	23-APR-2007
Filing Date:	08-AUG-2005
Time Stamp:	17:06:26
Application Type:	Utility

Payment information:

Submitted with Payment	yes
Payment was successfully received in RAM	$250
RAM confirmation Number	849
Deposit Account	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)	Multi Part /.zip	Pages (if appl.)

1		AdapP014C1NoApp.pdf	214984	yes	7

Multipart Description/PDF files in .zip description

Document Description	Start	End
Notice of Appeal Filed	1	1
Appeal Brief Filed	2	7

Warnings:

Information:

2	Fee Worksheet (PTO-06)	fee-info.pdf	8182	no	2

Warnings:

Information:

Total Files Size (in bytes):	223166

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>**New Applications Under 35 U.S.C. 111**</u>

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>**National Stage of an International Application under 35 U.S.C. 371**</u>

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>**New International Application Filed with the USPTO as a Receiving Office**</u>

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Patent Application Fee Transmittal

Application Number:	11199586
Filing Date:	08-Aug-2005
Title of Invention:	OFDMA with adaptive subcarrier-cluster configuration and selective loading
First Named Inventor/Applicant Name:	Xiaodong Li
Filer:	David H. Tannenbaum/Carol Martin
Attorney Docket Number:	68144/P014C1/10503148

Filed as Small Entity

Utility Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Notice of appeal	2401	1	250	250
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
		Total in USD ($)		**250**

Doc Code: AP.PRE.REQ

PRE-APPEAL BRIEF REQUEST FOR REVIEW

Docket Number (Optional)	68144/P014C1/10503148	
Application Number	11/199,586-Conf. #1128	Filed: August 8, 2005
First Named Inventor	Xiaodong Li et al.	
Art Unit	2617	Examiner: M. N. Zewdu

Applicant requests review of the final rejection in the above-identified application. No amendments are being filed with this request.

This request is being filed with a notice of appeal.

The review is requested for the reason(s) stated on the attached document.
Note: No more than five (5) pages may be provided.

I am the

- [ ] applicant /inventor.
- [ ] assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)
- [x] attorney or agent of record. Registration number 42,203
- [ ] attorney or agent acting under 37 CFR 1.34. Registration number if acting under 37 CFR 1.34. ______

[signature]
Signature

R. Ross Viguet
Typed or printed name

(214) 855-8185
Telephone number

April 23, 2007
Date

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

- [ ] *Total of 1 forms are submitted.

Pre-Appeal Brief Request for Review

I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being transmitted via the Office electronic filing system in accordance with § 1.6(a)(4).

Dated: April 23, 2007 Signature: [signature] (Carol A. Martin)

25764265.1

Docket No.: 68144/P014C1/10503148
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Xiaodong Li et al.

Application No.: 11/199,586 Confirmation No.: 1128

Filed: August 8, 2005 Art Unit: 2617

For: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING Examiner: M. N. Zewdu

APPELLANT'S ARGUMENTS FOR PRE-APPEAL BRIEF REQUEST FOR REVIEW

Board of Patent Appeals and Interferences
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

INTRODUCTORY COMMENTS

Appellant hereby requests that a panel of Examiners formally review the legal and factual basis of the rejections of record prior to the filing of an Appeal Brief. This Request is filed concurrently with a Notice of Appeal.

REMARKS

I. Issues

- Is the Double Patenting rejection of record proper?
- Are the 35 U.S.C. § 103 rejections of record proper?

II. Double Patenting Rejection

In the Final Action, the Examiner bases the non statutory double patenting rejection upon the notion that "the difference between the claims in the instant application and the claims in [U.S. Patent No. 6,904,283] is that the claims in the instant application are more broader than the claims in the [issued] patent." *See* Final Action, pgs. 3 & 17. Appellant submits that the idea that the pending claims may be broader than the issued claims (which form the basis of the rejection) is not, by itself, appropriate rationale for a double patenting rejection. Non statutory double patenting requires rejection of an application claim "when the claimed subject matter is not patentably distinct from the subject matter claim in the commonly owned patent." *See* M.P.E.P. 804(B)(1). In the case at hand, the Examiner's assertion that the pending claims are broader than the issued claims is not determinative as to whether or not the pending claims are patentably distinct in view of the issued claims. Appellant respectfully notes that the Examiner's statement is immaterial with respect to double patenting. As the Manual of Patent Examining Procedure correctly explains, "[d]omination and double patenting should not be confused . . . . Domination by itself, i.e., in the absence of statutory or nonstatutory double patenting grounds, cannot support a double patenting rejection." *In re Kaplan*, 789 F.2d 1574, 1577-78 (Fed. Cir. 1986), *cited in* M.P.E.P. § 804(II). As such, the Examiner has not provided a sufficient double patenting rejection. Therefore, Appellant requests reversal of the rejection of record.

III. Rejections under 35 U.S.C. § 103(a)

In the Office Action mailed February 23, 2007 (hereinafter the "Final Action"), the Examiner rejected claims 1, 12, 14, 17-18, 30, 43, and 46-47 under 35 U.S.C. §103(a) as being unpatentable over German Patent DE 198 009 53 to Ritter (hereinafter "Ritter") in view of U.S. Patent 5,956,642 to Larsson et al. (hereinafter "Larsson"). The Examiner rejected claims 2-4, 8, 13, 31-33, and 37 under 35 U.S.C. §103(a) as being unpatentable over Ritter as applied to the claims above, and further in view of U.S. Patent 6,330,460 to Wong (hereinafter "Wong"). The Examiner rejected claims 15, 16, 44, and 45 under 35 U.S.C. §103(a) as being unpatentable over the references applied to the claims above, and further in view of U.S. Patent 6,327,472 to Westroos (hereinafter "Westroos"). The Examiner rejected claims 19, 20, 23, 48, 49, and 52 under 35 U.S.C. §103(a) as being unpatentable over Ritter as applied to Claim 1 above, and further in view of U.S. Patent 5,507,034 to Bodin et al. (hereinafter "Bodin"). The Examiner rejected claims 29 and 62 under 35 U.S.C. §103(a) as being unpatentable over Ritter in view of U.S. Patent 6,141,565 to Feuerstein et al. (hereinafter "Feuerstein"). The Examiner rejected claims 7, 26, 36, 55, 58, 60, and 61 under 35 U.S.C. §103(a) as being unpatentable over Ritter in view of U.S. Patent 5,726,978 to Frodigh et al. (hereinafter "Frodigh").

Independent claim 1 recites "measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station." Independent claim 30 recites a similar limitation. In the Final Action, the Examiner seems to acknowledge that neither Ritter or Larsson teach or suggest these limitations. Instead, the Examiner simply notes "when the references are combined as shown above, the measurement or the parameters in question will be based on pilot symbols/data received from a base station." *See* Final Action, pg. 5. The Examiner further implies that the claim limitations are satisfied because Ritter measures frequency spectrum segments "through each mobile station." *Id.* at pg. 18. As an initial matter, Appellant submits that the Examiner's mere conclusion, apparently drawn without support from the references, does not serve as an appropriate basis for a 35 U.S.C. §103 rejection. Appellant notes that M.P.E.P. § 2143 requires that the <u>prior art cited</u> must teach or suggest all the claim limitations. (emphasis added)

Nevertheless, Appellant points out there is no suggestion in either reference of a subscriber unit measuring channel information based on pilot symbols received from a base station. For instance, Ritter generally describes OFDM communication between a base station and subscriber. However, Ritter does not mention a subscriber unit measuring anything based on pilot symbols received from a base station, much less interference information for a plurality of subcarriers, as set forth in the claims. Also, Larsson is silent as to pilot channels at all, much less those received from a base station. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Appellant requests reversal of the rejection of record.

Independent claims 29 and 62 recite performing subcarrier allocation based on intra-cell traffic load balancing. In the Final Action, the Examiner acknowledges that Ritter does not teach or suggest this claim limitation. Instead, the Examiner points to Feuerstein, at col. 2 lines 27-37 and col. 1 lines 20-25, as satisfying this limitation. *See* Final Action , pgs. 12 & 20. However, at the Examiner's citations, Feuerstein describes changing network parameters according to "local interference and/or local traffic conditions" in order to optimize the network parameters. *See* Feuerstein at col. 2 lines 32-33. In discussing "local interference," Feuerstein contemplates traffic density distribution, etc. between cells. *Id.* at col. 2 lines 50-52. For example, according to Feuerstein, a mobile unit may request handoff based on the relative traffic loads between two cells. *Id.* at col. 6 lines 51-57. However, Appellant notes that merely evaluating relative traffic loads between two cells is not the same as allocating subcarriers based on traffic load balancing within a cell. Feuerstein does not contemplate evaluating load balancing within each cell. As such, Feuerstein does not teach or suggest performing subcarrier allocation based on intra-cell traffic load balancing, as set forth in the claim.

Independent claim 58 recites "the base station allocating a second portion of said plurality of subcarriers to the subscriber unit to increase communication bandwidth." Independent claim 60 recites a similar limitation. In the Final Action, the Examiner acknowledges that Ritter does not teach or suggest this limitation. *See* Final Action, pg. 15. Instead, the Examiner relies upon Frodigh, at col. 4 lines 32-49 and claims 1 and 11, as satisfying this limitation. *Id* at pgs. 15 and 20. Generally, Frodigh "selectively chooses" a group of subcarriers to be adaptively allocated to avoid requiring that all OFDM subcarriers be adaptively allocated. *See* Frodigh at col. 4 lines 44-49. According to Frodigh, choosing a single group of subcarriers, as opposed to all available subcarriers, minimizes the use of system resources. *Id.* As such, Frodigh merely describes minimizing the use of resources by adaptively allocating only a single portion of (as opposed to all) subcarriers. However, Frodigh does not suggest allocating a second portion of subcarriers at all, much less to increase communication bandwidth. Generally, Frodigh concentrates on minimizing system resources, but does not allocate subcarriers in a particular manner to increase communication bandwidth. Frodigh is silent as to how merely selecting a single portion of available subcarriers will be used to affect communication between a base station and subscriber, and fails to discuss allocating a second portion of subcarriers. As such, Frodigh falls short of disclosing allocating a second portion of subcarriers to increase communication bandwidth. As shown, the Examiner's proposed combination fails to teach or suggest every claim limitation. Therefore, Appellant requests reversal of the rejection of record.

III. Conclusion

Appellant respectfully traverses the rejections of record and requests reconsideration and reversal of such in view of the remarks contained herein. The fees required under 37 C.F.R. § 41.20(b)(2) are dealt with in the accompanying transmittal. If any additional fee is due, please charge Deposit Account No. 06-2380, under Order No. 68144/P014C1/10503148 from which the undersigned is authorized to draw.

Dated: April 23, 2007

Respectfully submitted,

By [signature]

R. Ross Viguet
Registration No.: 42,203
FULBRIGHT & JAWORSKI L.L.P.
2200 Ross Avenue, Suite 2800
Dallas, Texas 75201-2784
(214) 855-8185
Attorney for Appellant

This document is being electronically transmittted to the U.S. Patent & Trademark Office.
Date of Transmission: April 23, 2007

Signature: [signature]
Carol A. Martin

PTO/SB/31 (09-06)
Approved for use through 03/31/2007. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

NOTICE OF APPEAL FROM THE EXAMINER TO THE BOARD OF PATENT APPEALS AND INTERFERENCES	Docket Number (Optional) 68144/P014C1/10503148

	In re Application of Xiaodong Li et al.	
	Application Number 11/199,586-Conf. #1128	Filed August 8, 2005
	For OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING	
	Art Unit 2617	Examiner M. N. Zewdu

Applicant hereby **appeals** to the Board of Patent Appeals and Interferences from the last decision of the examiner.

The fee for this Notice of Appeal is (37 CFR 41.20(b)(1)) $ 500.00

[x] Applicant claims small entity status. See 37 CFR 1.27. Therefore, the fee shown above is reduced by half, and the resulting fee is: $ 250.00

[ ] A check in the amount of the fee is enclosed.

[x] Payment by credit card.

[ ] The Director has already been authorized to charge fees in this application to a Deposit Account. I have enclosed a duplicate copy of this sheet.

[x] The Director is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. 06-2380. I have enclosed a duplicate copy of this sheet.

[ ] A petition for an extension of time under 37 CFR 1.136(a) (PTO/SB/22) is enclosed.

I am the

[ ] applicant /inventor.

[ ] assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)

[x] attorney or agent of record.
Registration number 42,203

[ ] attorney or agent acting under 37 CFR 1.34.
Registration number if acting under 37 CFR 1.34. ______

R. Ross Viguet
Signature

R. Ross Viguet
Typed or printed name

(214) 855-8185
Telephone number

April 23, 2007
Date

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

[ ] *Total of 1 forms are submitted.

Notice of Appeal

I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being transmitted via the Office electronic filing system in accordance with § 1.6(a)(4).

Dated: April 23, 2007 Signature: Carol A. Martin (Carol A. Martin)

25764263.1

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
11/199,586	08/08/2005	Xiaodong Li	68144/P014C1/10503148	1128

29053 7590 06/25/2007
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EXAMINER	
ZEWDU, MELESS NMN	

ART UNIT	PAPER NUMBER
2617	

MAIL DATE	DELIVERY MODE
06/25/2007	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Application Number	Application/Control No.	Applicant(s)/Patent under Reexamination	
	11/199,586	LI ET AL.	
		Art Unit	
	Meless Zewdu	2617	

Document Code - AP.PRE.DEC

Notice of Panel Decision from Pre-Appeal Brief Review

This is in response to the Pre-Appeal Brief Request for Review filed 04/23/07.

1. ☐ **Improper Request** – The Request is improper and a conference will not be held for the following reason(s):

   ☐ The Notice of Appeal has not been filed concurrent with the Pre-Appeal Brief Request.
   ☐ The request does not include reasons why a review is appropriate.
   ☐ A proposed amendment is included with the Pre-Appeal Brief request.
   ☐ Other:

   The time period for filing a response continues to run from the receipt date of the Notice of Appeal or from the mail date of the last Office communication, if no Notice of Appeal has been received.

2. ☐ **Proceed to Board of Patent Appeals and Interferences** – A Pre-Appeal Brief conference has been held. The application remains under appeal because there is at least one actual issue for appeal. Applicant is required to submit an appeal brief in accordance with 37 CFR 41.37. The time period for filing an appeal brief will be reset to be one month from mailing this decision, or the balance of the two-month time period running from the receipt of the notice of appeal, whichever is greater. Further, the time period for filing of the appeal brief is extendible under 37 CFR 1.136 based upon the mail date of this decision or the receipt date of the notice of appeal, as applicable.

   ☐ The panel has determined the status of the claim(s) is as follows:
   Claim(s) allowed: _____.
   Claim(s) objected to: _____.
   Claim(s) rejected: _____.
   Claim(s) withdrawn from consideration: _____.

3. ☐ **Allowable application** – A conference has been held. The rejection is withdrawn and a Notice of Allowance will be mailed. Prosecution on the merits remains closed. No further action is required by applicant at this time.

4. ☒ **Reopen Prosecution** – A conference has been held. The rejection is withdrawn and a new Office action will be mailed. No further action is required by applicant at this time.

All participants:

CHARLES N. APPIAH
SUPERVISORY PATENT EXAMINER

(1) Charles N. Appiah. (3)_____.

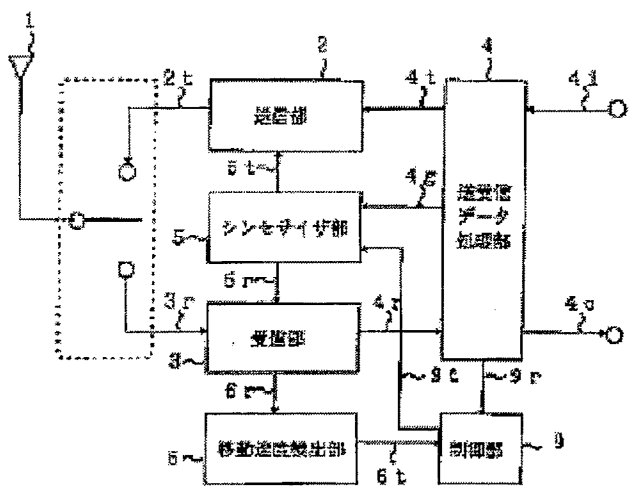
(2) Meless Zewdu. (4)_____.

FREQUENCY HOPPING SYSTEM

Publication number: JP11308153
Publication date: 1999-11-05
Inventor: YAMAUCHI NAOHISA; SHIBUYA AKIHIRO
Applicant: MITSUBISHI ELECTRIC CORP
Classification:
- international: ***H04B1/713; H04B7/26; H04Q7/22;*** **H04B1/69; H04B7/26; H04Q7/22;** (IPC1-7): H04B1/713; H04B7/26; H04Q7/22
- European:
Application number: JP19980115287 19980424
Priority number(s): JP19980115287 19980424

Abstract of **JP11308153**

PROBLEM TO BE SOLVED: To reduce processings at the time of hand-off required at the time of high-speed movement by not using frequency hopping based on a prescribed frequency hopping sequence communicated by a base station and a mobile station in the case that the detected moving speed of the mobile station is more than a prescribed value and using it in the case that it is less than the prescribed value. SOLUTION: A moving speed detection part 6 outputs the moving speed detection data 6t of the mobile station to a control part 9 based on moving speed information 6r from an antenna 1 and a reception part 3. The control part 9 performs or does not perform the frequency hopping between the mobile station and the base station depending on whether or not the moving speed exceeds the prescribed value determined beforehand. At the time of performing the frequency hopping, by frequency data 9t for which a frequency is decided by frequency hopping sequence data 9r from a transmission/reception data processing part 4 by the control part 9, a synthesizer part 5 switches the frequency. Thus, the frequency used in the mobile station is switched and the communication of high quality is more easily performed.



(Translation)

Dispatched on May 21, 2007

Notification of Reason for Rejection

Dated: May 14, 2007

To: Mr. M. Nakamura, et al., agents for the applicant

From: H. Takano, Examiner of the Patent Office

Patent Application No. 2002-550747

The above mentioned application is considered to be subject to rejection on the grounds set out hereunder. If the applicant has anything to say, he should file an argument within three months from the date of dispatch of this document.

Ground A

The invention under the present application is considered to have been easy to invent for those skilled in the art on the basis of the inventions described in the following publications which were circulated or made available to the public through telecommunication lines in Japan or elsewhere prior to the present application and, therefore, it is considered unpatentable in view of the provisions of Article 29, Para. 2 of the Patent Law.

Reference 1: Japanese Patent Laid-Open Publication No. 11-508417
Reference 2: Japanese Patent Laid-Open Publication No. 10-303849
Reference 3: Japanese Patent Laid-Open Publication No. 11-308153
Reference 4: Japanese Patent Laid-Open Publication No. 1-317035
Reference 5: Japanese Patent Laid-Open Publication No. 11-88244

As regards claims 1-3 and 5, please refer to Refs. 1-3.
Remarks:

As disclosed in Refs. 1 and 2, it is well known in the art to allocate subcarriers to a subscriber by utilizing an OFDMA.

A frequency hopping is commonly used as a communication method for obtaining a diversity effect. Further, Ref. 3 discloses that a frequency hopping can be performed or not performed in response to a moving speed.

In addition, a channel coding is commonly used in an OFDM art.

Consequently, it would have been easy for those skilled in the art to make the inventions claimed in the above claims by applying the technique in Ref. 3 to Refs. 1 and 2.

As regards claims 1, 3, 5, 7, and 15-18, please refer to Refs. 1-4.
Remarks:

As disclosed in the bottom right column in page 44, line 13 to up left column in page 45, line 2, the bottom left column in page 45, lines 13-17, etc., it is commonly used to determine the pros and cons of the diversity when the moving speed is high (corresponding to "moving" of the present invention).

In addition, a channel coding is commonly used in an OFDM art.

Consequently, it would have been easy for those skilled in the art to make the inventions claimed in the above claims by applying the technique in Ref. 4 to Refs. 1 and 2.

As regards claims 8, 9, and 12, please refer to Refs. 1-5.
Remarks:

As shown in Ref. 5, it is a commonly used art to detect a fluctuation of the pilot signals and determine the moving speed.

Ground B

It is considered that this application does not fulfill the requirements as prescribed in Article 36, Para. 4 of the Patent Law, since the detailed descriptions of the invention are incomplete in the following points:

1. It is considered that support for claim 4 is found in the last of column [0102] bridging pages 25 and 26 of the PCT published application. However, even after studying the descriptions, it is not possible to clearly understand what invention is claimed in claim 4. Thus, it is considered that claim 4 is not fully explained in such a manner that it may be carried out.

(If any other portions in the specification concretely describe the claimed invention, please point out the portions. Further, if you think that the descriptions in the claimed invention are sufficient for the skilled person to clearly understand the claimed invention, please clarify, by the argument to be filed etc., the basis and the concrete contents thereof.

Since the concrete contents of claim 4 are not clear, claim 4 has not yet been examined for novelty /inventive step.)

2. It is considered that support for claim 6 is found in column [0113] at page 28 of the PCT published application and Fig. 12 thereof. However, even after studying the descriptions, it is not possible to clearly understand what invention is claimed in claim 6. Thus, it is considered that claim 6 is not fully explained in such a manner that it may be carried out.

(If any other portions in the specification concretely describe the claimed invention, please point out the portions. Further, if you think that the descriptions in the claimed invention are sufficient for the skilled person to clearly understand the claimed invention, please clarify, by the argument to be filed etc., the basis and the concrete contents thereof.

Since the concrete contents of claim 6 are not clear, claim 6 has not yet been examined for novelty /inventive step.)

<Claims having no reasons for refusal>

As to the invention claimed in claims 10, 11, 13 and 14, there are no reasons for refusal at this point. The applicant will be informed if other reasons for refusal are found later.

Page 6

Partial English translation of Ref. 4:

-----------------------------(not translated) -----------------------------

In Fig. 14, the mobile radio equipments 50 (B, C, D) in the high-speed moving mode are located at a point A or point B on the road, and the mobile radio equipments 50 (B, C, D) at the point A or point B are moving at high speed in the right direction. Further, points P0 to P3, L1, L2 and Q0 to Q2 indicate the positions of the radio base stations 30 (B, C, D, E) installed on posts facing the road. Further, small zones indicated by dotted lines represent service areas of the radio base stations 30 (B, C, D, E) placed at the positions of P0, P1, P2, P3, L1 and L2.

-----------------------------(not translated) -----------------------------

However, in the high-speed moving mode, the same signal is transmitted at the same channel simultaneously or sequentially from a plurality of transceivers (or a transceiver which implements the same function as that of a plurality of transceivers by time division) provided in a radio base station 30 (B, C, D, E). When the signal is received by the mobile radio equipments 50 (B, C, D), a kind of space diversity effect is obtained when it is transmitted from a plurality of transceivers, or a time diversity effect is obtained when it is transmitted from a transceiver using time division.

-----------------------------(not translated) -----------------------------

As described above, it has been revealed that the diversity effect is obtained for transmission and reception of the control signal in the high-speed moving mode. The reason why this is not used in the low-speed moving mode which is the normal state of the mobile radio equipments (B, C, D) is as follows.

-----------------------------(not translated) -----------------------------

Fig. 14 is a diagram for illustrating the operation of the system of the present invention in the high-speed moving mode which shows the positions of radio base stations placed along a road and mobile radio equipments.

-----------------------------(not translated) -----------------------------

Docket No.:
68144/P014C1/10503148
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Xiaodong Li et al.

Application No.: 11/199,586

Confirmation No.: 1128

Filed: August 8, 2005

Art Unit: 2683

For: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

Examiner: M. N. Zewdu

INFORMATION DISCLOSURE STATEMENT (IDS)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Pursuant to 37 CFR 1.56, 1.97 and 1.98, the attention of the Patent and Trademark Office is hereby directed to the references listed on the attached PTO/SB/08. It is respectfully requested that the information be expressly considered during the prosecution of this application, and that the references be made of record therein and appear among the "References Cited" on any patent to issue therefrom.

This Information Disclosure Statement is filed more than three months after the U.S. filing date, OR more than three months after the date of entry of the national stage of a PCT application, AND after the mailing date of the first Office Action on the merits, whichever occurs first, but before the mailing date of a Final Office Action or Notice of Allowance (37 CFR 1.97(c)).

A summary/abstract translation of the non-English language references is enclosed.

In accordance with 37 CFR 1.98(a)(2)(ii), Applicant has not submitted copies of U.S. patents and U.S. patent applications. Applicant submits herewith copies of foreign patents and non-patent literature in accordance with 37 CFR 1.98(a)(2).

In accordance with 37 CFR 1.97(g), the filing of this Information Disclosure Statement shall not be construed to mean that a search has been made or that no other material information as defined in 37 CFR 1.56(a) exists. In accordance with 37 CFR 1.97(h), the filing of this Information Disclosure Statement shall not be construed to be an admission that any patent, publication or other information referred to therein is "prior art" for this invention unless specifically designated as such.

It is submitted that the Information Disclosure Statement is in compliance with 37 CFR 1.98 and the Examiner is respectfully requested to consider the listed references.

The fee set forth in 37 CFR 1.17(p) will be paid by credit card. However, the Director is hereby authorized to charge any deficiency in the fees filed, asserted to be filed or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our Deposit Account No. 06-2380, under Order No. 68144/P014C1/10503148.

Dated: June 27, 2007

Respectfully submitted,

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Used in Lieu of PTO/SB/08A/B
(Based on PTO 04-07 version)

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet	1	of	1

Complete if Known	
Application Number	11/199,586-Conf. #1128
Filing Date	August 8, 2005
First Named Inventor	Xiaodong Li
Art Unit	2683
Examiner Name	M. N. Zewdu
Attorney Docket Number	68144/P014C1/10503148

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number: Number-Kind Code[2] (*if known*)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	AA	US-5,479,447	12-26-1995	Chow et al.	
	AB	US-5,726,978	03-10-1998	Frodigh et al.	
	AC	US-5,914,933	06-22-1999	Cimini et al.	
	AD	US-7,146,172	12-2006	Li et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document: Country Code[3]-Number[4]-Kind Code[5] (*if known*)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear	T[6]
	BA	EP-0 869 647	10-07-1998	Lucent Technologies Inc.		
	BB	WO-/97/01256 (abstract- takes place of JP Publication 11-508417)	01-09-1997	Ericsson Telefon AB		
	BC	JP-Publication 7-322219 (abstract and partial translation)	12-08-1995	Matsushita Electric IND CO		
	BD	JP-Publication 10-303849 (Abstract)	11-13-1998	Lucent Technologies		
	BE	JP-Publication 11-308153 (Abstract)	11-5-1999	Mitsubishi Electric Corp		
	BF	JP-Publication 1-317035 (Abstract)	12-21-1989	Iwatsu Electric Co Ltd		
	BG	JP-Publication 11-088244 (Abstract)	3-30-1999	Nippon Electric Co		

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. * CITE NO.: Those application(s) which are marked with an single asterisk (*) next to the Cite No. are not supplied (under 37 CFR 1.98(a)(2)(iii)) because that application was filed after June 30, 2003 or is available in the IFW. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	CA	European Office Action from Application No.: 01 986 165.7, dated March 29, 2007 5 ppgs.	
	CB	English translation of Japanese Office Action for Application No.: 2002-550683, dispatched May 7, 2007, 2 ppgs.	
	CC	English translation of Japanese Office Action for Application No.: 2002-550747, dispatched May 21, 2007, 4 ppgs.	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached.

Examiner Signature		Date Considered	

25783361.1

PILOT SIGNAL RECEPTION LEVEL AVERAGING SYSTEM

Publication number: JP11088244

Publication date: 1999-03-30

Inventor: FURUKAWA HIROSHI

Applicant: NIPPON ELECTRIC CO

Classification:

- international: ***H04B7/005; H04B7/26; H04B17/00;*** **H04B7/005; H04B7/26; H04B17/00;** (IPC1-7): H04B7/005; H04B7/26

- European: H04B7/005B2P; H04B17/00B1; H04B17/00B7

Application number: JP19970237268 19970902

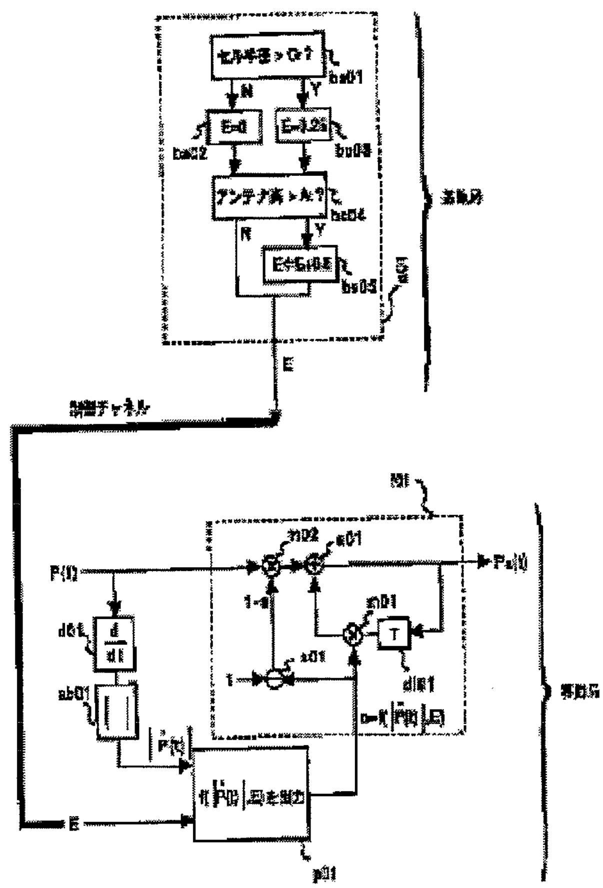
Priority number(s): JP19970237268 19970902

Also published as:

- EP0901239 (A2)
- US6115614 (A1)
- EP0901239 (A3)
- EP0901239 (B1)

Abstract of **JP11088244**

PROBLEM TO BE SOLVED: To allow a mobile station of cellular mobile radio communication system to extract a propagation loss component accurately based on a pilot reception level. SOLUTION: A pass band characteristic of an averaging filter f01 is controlled based on an estimated occupancy band width in a propagation loss fluctuation obtained by a propagation loss fluctuation band width prediction device p01. To predict the propagation loss fluctuation band width, a fluctuation speed of a pilot reception level measured by a mobile station, a radius of a cell and a height of an antenna are used. As the fluctuation speed in the pilot reception level is faster, as the radius of the cell is smaller and the height of the antenna is lower, it is predicted that the propagation loss is fluctuated at a higher speed and the pass band of the averaging filter f01 is extended.

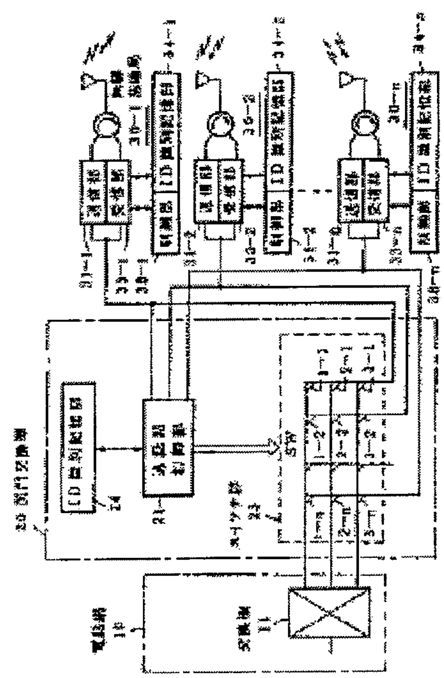


COMMUNICATION METHOD FOR COMMUNICATION WITH MOBILE OBJECT

Publication number: JP1317035
Publication date: 1989-12-21
Inventor: ITO SADAO
Applicant: IWATSU ELECTRIC CO LTD
Classification:
- international: *H04Q7/34; H04B7/26; H04Q7/22; H04Q7/28;* **H04Q7/34; H04B7/26; H04Q7/22; H04Q7/28;** (IPC1-7): H04B7/26
- European:
Application number: JP19880149378 19880617
Priority number(s): JP19880149378 19880617

Abstract of **JP1317035**

PURPOSE:To attain no-hit processing of channel switching by selecting other channel when the quality of communication is deteriorated and applying communication using plural channels. CONSTITUTION:The system consists of plural radio base stations 30-1 to 30-n provided with radio transmitters-receivers 31-1 to 31-n and ID identification storage sections 34-1 to 34-n, a switch group 23 connecting the plural radio base stations 30-1 to 30-n and a telephone network 10, a gate exchange 20 including a channel control section 21 controlling the switch group 23 and an ID identification storage section 24, a radio reception circuit receiving plural channels simultaneously to communicate the plural radio base stations 30-1 to 30-n while being moved in the service area covered by the plural radio base stations 30-1 to 30-n and a mobile radio equipment including a radio transmission circuit sending the signal simultaneously through plural channels. When a channel whose communication quality is a prescribed value or below takes place, the other channel is selected and the same content of communication is communicated through plural channels. Thus, no-bot channel switching during talking (communication) is attained.



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(54) **System of multicarreir modulation with dynamically scalable operating parameters**

(57) The scaleable OFDM system according to the principles of the present invention provides increased flexibility and adaptability by providing scaling of the operating parameters and/or characteristics for the OFDM system. For example, control circuitry can scale the bit rate by scaling of the OFDM symbol duration, the number of carriers and/or the number of bits per symbol per carrier. Scaleability permits the scaleable OFDM system to operate in various communications environments requiring various operating parameters and/or characteristics. By scaling the operating parameters and/or characteristics of the OFDM system when control circuitry determines that different operating parameters and/or characteristics are necessary or advantageous, the control circuitry can dynamically change the operating parameters and/or characteristics, thereby providing compatibility or the desired performance. For example, by dynamically scaling the bit rate, widely varying signal bandwidths, delay spread tolerances and signal-to-noise ratio (SNR) requirements can be achieved. As such, a scaleable OFDM system is particularly suitable for application in mobile, wireless communication devices, which support a variety of services, in a variety of environments, indoor as well as outdoor and in radio channels with differing bandwidths.

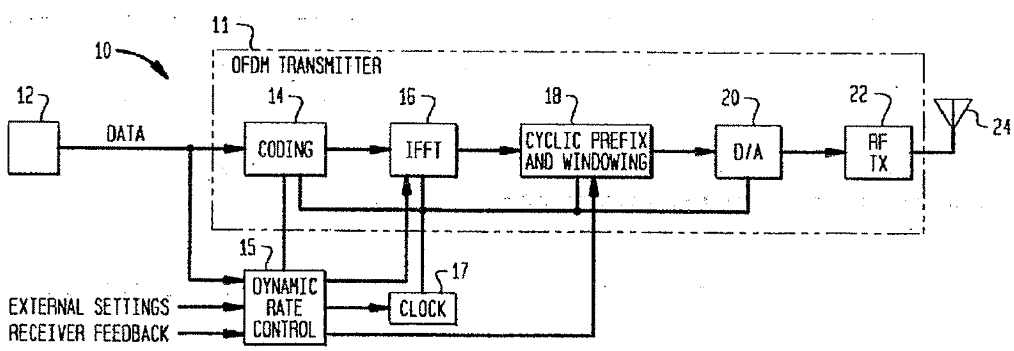

FIG. 1

EP 0 869 647 A2

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Description

BACKGROUND OF THE INVENTION

1. Field of The Invention

This invention relates to communication systems and, more particularly, OFDM (Orthogonal Frequency Division Multiplexing) modulation schemes which are suitable to provide a wide range of information transfer rates in a wide range of physical environments.

2. Description of Related Art

OFDM is a block-oriented modulation scheme that maps N data symbols into N orthogonal carriers separated by a distance of 1/T, where T is the block period. As such, multi-carrier transmission systems use OFDM modulation to send data bits in parallel over multiple, adjacent carriers (also called tones or bins). An important advantage of multi-carrier transmission is that inter-symbol interference due to signal dispersion (or delay spread) in the transmission channel can be reduced or even eliminated by inserting a guard time interval between the transmission of subsequent symbols, thus avoiding an equalizer as required in single carrier systems. This gives OFDM an important advantage over single carrier modulation schemes. The guard time allows delayed copies of each symbol, arriving at the receiver after the intended signal, to die out before the succeeding symbol is received. OFDM's attractiveness stems from its ability to overcome the adverse effects of multi-channel transmission without the need for equalization. A need exists for a flexible OFDM system which provides the advantages of OFDM to a variety of communication environments.

SUMMARY OF THE INVENTION

The scaleable OFDM system according to the principles of the present invention provides increased flexibility and adaptability by providing scaling of the operating parameters and/or characteristics for the OFDM system. For example, control circuitry can scale the transmission rate by scaling of the OFDM symbol duration, the number of carriers and/or the number of bits per symbol per carrier. Scaleability permits the scaleable OFDM system to operate in various communications environments requiring various operating parameters and/or characteristics. By scaling the operating parameters and/or characteristics of the OFDM system when control circuitry determines that different operating parameters and/or characteristics are necessary or advantageous, the control circuitry can dynamically change the operating parameters and/or characteristics, thereby providing compatibility or the desired performance. For example, by dynamically scaling the bit rate, widely varying signal bandwidths, delay spread tolerances and signal-to-noise ratio (SNR) requirements can be achieved. As such, a scaleable OFDM system is particularly suitable for application in mobile, wireless communication devices, which support a variety of services, in a variety of environments, indoor as well as outdoor and in radio channels with differing bandwidths.

In accordance with aspects of certain embodiments of the scaleable OFDM modulation system, a coded OFDM modulation system can be designed with an upper limit on the number of carriers and a variable symbol duration. The control circuitry can dynamically scale the number of carriers below the upper limit on the number of carriers to decrease the signal bandwidth and the transmission rate while delay spread tolerance remains the same. The control circuitry can also dynamically increase the symbol duration to decrease the transmission rate and the signal bandwidth and provide an increase in delay spread tolerance. In accordance with other embodiments, the scaleable OFDM modulation system achieves variable transmission rates using adaptive coding where different coding schemes are used to improve the link reliability and/or to decrease the peak-to-average power ratio.

In accordance with yet other embodiments of the scaleable OFDM modulation system, scaleable transmission rates permit asymmetric data rates between mobile units and base stations. For example, the mobile units can have lower data rates than the base stations by allocating only a fraction of the total number of carriers to each mobile, while the base stations transmit at all carriers simultaneously. Additionally, during data downloading for example, a mobile unit could have a larger downlink data rate than uplink data rate. In accordance with other aspects of a scaleable OFDM system, mobile units and base stations using the same antennas for both transmit and receive can benefit from adaptive antennas with any additional processing done at the base station, thereby keeping the mobile as simple as possible. The scaleable OFDM modulation system can use an adaptive antenna at the base by sending feedback through the uplink, for example, when channel characteristics of uplink and downlink are not identical.

BRIEF DESCRIPTION OF THE DRAWINGS

Other aspects and advantages of the present invention may become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 shows a block diagram of an embodiment of an OFDM transmitter according to certain principles of the present invention;
FIG. 2 shows a diagram for explaining the windowing of OFDM symbols;
FIG. 3 shows a plot of an OFDM power spectrum for explaining the effects of changes to certain parameters of an OFDM transmitter;
FIG. 4 shows a block diagram of an embodiment of an OFDM receiver according to certain principles of the present invention; and
FIG. 5 shows an OFDM system using OFDM transmitters and receivers according to the principles of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Illustrative embodiments of the improved OFDM system with scaleable operating parameters and/or characteristics according to the principles of the present invention are described below as the improved OFDM system might be implemented to provide a flexible communications system for use in a variety of communication environments. Scaleability permits the scaleable OFDM system to operate in various communications environments requiring various operating parameters and/or characteristics. By scaling the operating parameters and/or characteristics of the OFDM system when control circuitry determines that different operating parameters and/or characteristics are necessary or advantageous, the control circuitry can dynamically change the operating parameters and/or characteristics, thereby providing compatibility or the desired performance. For example, by dynamically scaling the bit rate, widely varying signal bandwidths, delay spread tolerances and signal-to-noise ratio (SNR) requirements can be achieved.

The scaleable OFDM systems can be characterized by various operating parameters, including the following:

number of carriers (N);
symbol duration (T_s);
number of bits per symbol per carrier (m);
forward error correction coding scheme;
coding rate; and
the fraction of the symbol duration that is used as guard time.

By varying these parameters, various operating characteristics can be scaled, including the following:

transmission rate (bit rate or data rate);
signal-to-noise ratio (the larger the SNR, the lower the bit error rate);
delay-spread tolerance;
signal bandwidth; and
implementation complexity

The scaleable OFDM system can scale operating parameters and/or characteristics in various ways. For example, to dynamically scale the transmission rate, the scaleable OFDM system can dynamically adjust the symbol duration, coding rate, the number of bits per symbol per carrier and/or the number of carriers depending upon the required or desired operating parameters and/or characteristics. In this particular example, depending upon how the control circuitry scales transmission rate, the scaleable OFDM system scales delay spread tolerance, signal to noise ratio, and signal bandwidth in different ways, making the scaleable OFDM system an attractive scheme for the implementation of flexible, (dynamically) scaleable communication systems.

For example, to double the transmission rate of the scaleable OFDM system the following operating parameters and/or characteristics of the system can be dynamically scaled or adjusted:

1. The coding rate. In general, a channel code is applied to reduce the rate of bit errors caused by OFDM-specific channel impairments, such as multipath among the carriers. The rate of such a code can be varied to trade off bit rate against bit error rate.
2. The carrier modulation scheme. By doubling the number of bits per symbol per carrier, the bandwidth and delay spread tolerance does not change, but the SNR is reduced, thereby resulting in a higher bit error rate.
3. The symbol duration. By halving the symbol duration, the delay spread tolerance is halved, signal bandwidth is doubled, but implementation complexity is only increased by a factor of 2 (due to the speed-up by a factor of two).
4. The number of carriers. By doubling the number of carriers, delay spread tolerance remains the same, the signal

bandwidth doubles and the implementation complexity is quadrupled (both number of operations and speed are doubled) for an IDFT implementation or by 2(n+1)/n if an IFFT implementation is used.

An additional scaling parameter which can be changed is the ratio of guard time and symbol time. Changing this ratio affects SNR (a larger relative guard time claims energy that would otherwise go into the signal) and transmission rate (a larger relative guard time reduces the bit rate) and the delay-spread tolerance (a larger relative guard time improves the resistance against delay-spread).

FIG. 1 shows an OFDM transmitter 10 having signal circuitry 11 which receives a data stream of data bits from a data source 12. The coding block 14 receives the data stream and partitions the data stream into successive groups or blocks of bits. The coding block 14 introduces redundancy for forward error correction coding. In certain embodiments according to other aspects of the present invention, variable data rates with OFDM are achieved by using different forward error correction coding schemes and/or variable modulation schemes for each carrier as controlled by dynamic control circuitry 15. For example, if a mobile unit is at the edge of a coverage zone, the dynamic control circuitry can decrease the coding rate to lower the data rate with the advantage of increased delay spread tolerance and better SNR performance. Such a decrease in coding rate is followed by a decrease in spectral efficiency (amount of bits per second which can be transmitted in a certain bandwidth) proportional to the decrease in coding rate.

In accordance with the principles of the present invention, the dynamic control circuitry 15 can be responsive to any of a number of possible inputs to set the coding block 14 to the appropriate coding rate. For example, in a transceiver embodiment, the dynamic rate control circuitry 15 can detect transmission errors, such as through feedback from an OFDM receiver (FIG. 4) and dynamically reduce the coding rate. Alternatively, each data packet could have a fixed code indicating the appropriate coding rate, or in a transceiver application, the coding scheme could mirror the coding rate of the received input from another transmitter (not shown). Finally, the dynamic rate control circuitry 15 could be responsive to external settings to set the coding rate.

In similar fashion, the control circuitry 15 can respond to a variety of inputs by scaling the number of bits per symbol per carrier (for example, by changing the constellation size in embodiments using phase shift keying (PSK) modulation). By increasing the number of bits per symbol per carrier, the bandwidth and delay spread tolerance do not change, but the SNR is reduced resulting in a higher bit error rate. To scale the number of bits per symbol per carrier, for example, the dynamic rate control circuitry 15 can change from QPSK (quaternary or 4-PSK) modulation to other phase modulations, such as 8-PSK, or to other modulation schemes, such as QAM (quadrature amplitude modulation, e.g., 16-QAM).

The blocks of coded data bits are input into an N-points complex IFFT (Inverse Fast Fourier Transform) 16, where N is the number of the OFDM carriers. In this particular embodiment, the IFFT 16 is performed on blocks of 2N coded data bits received from the coding block 14. In practice, the transmitter 10 has to use oversampling to produce an output spectrum without aliasing which introduces unwanted frequency distortion due to (intended or unintentional) low pass filtering in subsequent stages of the transmitter or in the transmission channel. Thus, instead of an N-points IFFT 16, an M-points IFFT 16 is actually done where M>N to perform the oversampling. These 2N bits are converted into N complex numbers, and the remaining M-N input values are set to zero.

A clock 17 provides a time base for the IFFT 16, and the output of the IFFT 16 is parallel-to-serial converted to produce an OFDM symbol. In particular embodiments according to the principles of the present invention, the control circuitry 15 scales operating parameters and characteristics, such as transmission rate, by changing the symbol duration T_s, while keeping the number of carriers N constant. In this particular embodiment, the control circuitry 15 accomplishes this by controlling the clock 17 to adjust the time base to the IFFT 16. By decreasing the symbol duration, an inversely proportional increase in the transmission rate is achieved. At the same time, the delay spread tolerance is decreased. However, this is usually not a problem, because the higher data rate also means a decrease in range, and lower range means lower delay spread values.

As an example, consider an OFDM system which has to support applications ranging from mobile telephony, with raw data rates in the order of 270 kbps, to indoor wireless LANs, with data rates up to 20 Mbps. Maximum delay spread requirements are 16 µs for mobile telephony down to about 200 ns for wireless LANs. Further, we require the OFDM signal to occupy a bandwidth of 200 kHz for the mobile telephony case, in order to be compatible with GSM channel spacing. All these requirements can be met by using OFDM with 32 carriers and a variable symbol duration T_s, of 200 µs down to 2 µs. For a symbol duration of 200 µs, a guard time of 20 µs is included to deal with the delay spread. This gives a carrier spacing of 1/(180 µs) ≅ 55.6 kHz. This means there are exactly 36 carriers possible in a bandwidth of 200 kHz. By using 4 carriers as guard band, in order to fulfill spectrum requirements, 32 carriers remain for data transmission. Using QPSK with 2 bits per carrier per symbol, this gives a raw data rate of 32.2/(200 µs) = 320 kpbs.

By decreasing the OFDM symbol duration in the above described example, the data rate can be increased at the cost of a decreased delay spread tolerance. The maximum allowable delay spread is proportional to the OFDM guard time. Hence, for wireless LANs with a maximum tolerable delay spread of 200 ns, the symbol duration can be decreased to 2.5 µs, including a guard time of 250 ns. These parameters give an occupied bandwidth of 16 MHz and a raw data of 25.6 Mbps.

Table 1 lists several parameter options for various scaleable transmission or data rates. The first three options are for 32 carriers, the next three for 64 carriers, showing larger delay spread tolerance and a slightly smaller occupied bandwidth.

Table 1:

Examples of parameter options for scaleable data rates, assuming QPSK modulation of all carriers.				
Symbol duration [μs]	Guard time [μs]	Number of carriers	Bandwidth [MHz]	Raw data rate [Mbps]
200	20	32	0.2	0.32
10	1	32	4	6.4
2.5	0.25	32	16	25.6
400	40	64	0.19	0.32
20	2	64	3.78	6.4
5	0.5	64	15.11	25.6

The advantage of this OFDM modulation system over the existing GMSK modulation of GSM is higher spectrum efficiency and better spectrum properties in terms of adjacent channel interference. OFDM can have relatively large peak-to-average power ratio, but dynamically scaling the number of carriers can reduce the peak-to-average power ratio.

In this particular embodiment, the control circuitry 15 can provide variable transmission rates as well as other operating features by scaling the number of carriers. By transmitting a subset of the maximum number of carriers designed for the particular OFDM system, the decrease in data rate is proportional to the decrease in the number of transmitted carriers. Decreasing the number of transmitted carriers can also combine modulation technique and Medium Access Control (MAC), since multiple users can transmit simultaneously in the same band, using different sets of carriers. An additional advantage of such an approach is that the peak-to-average power ratio per user is reduced. This means a better power efficiency can be achieved, which is very important for battery-driven devices. Alternatively, the dynamic control circuit 15 can scale the number of carriers by directing the modulation of only part of the phases onto adjacent carriers. Such a result is advantageous if the encoder has to operate in a channel with a smaller available bandwidth.

In accordance with certain embodiments of the present invention, the dynamic control circuitry 15 can dynamically change N to vary the number of carriers. For example, the N-points IFFT 16 can be dynamically reduced to a X-points IFFT 16 where X<N. In this particular example, the IFFT 16 is designed to handle the N carriers as the maximum number of carriers and dynamically scaled to less than N carriers by performing an X-point IFFT 16 according to the control signals from the dynamic rate control circuitry 15. Alternatively, the dynamic control circuitry 15 can dynamically direct the OFDM transmitter 10 to transmit fewer than N carriers by calculating the IFFT for less than 2N input bits, leaving the other values zero and thereby permitting multiple access.

To decrease the sensitivity to inter-symbol interference, the cyclic prefixer and windowing block 18 copies the last part of the OFDM symbol and augments the OFDM symbol with the copied portion of the OFDM symbol. This is called cyclic prefixing. The control circuitry 15 can control the cyclic prefixer and windowing block 18 to adjust the guard time and/or the fraction of the guard time to symbol duration, for example, to the values listed for the above OFDM system example. To reduce spectral sidelobes, the cyclic prefixing and windowing block 18 performs windowing on the OFDM symbol by applying a gradual roll-off pattern to the amplitude of the OFDM symbol. The OFDM symbol is input into a digital-to-analog converter after which it is sent to the transmitter front-end 22 that converts the baseband wave form to the appropriate RF carrier frequency in this particular embodiment for transmission over antenna 24.

FIG. 2 shows a basic representation of the windowing of an OFDM symbol where T_s, is the total symbol duration, T is the FFT time, i.e., there are N samples in T seconds. The carrier spacing is 1/T in Hz, and T_G is the guard time which helps reduce the intersymbol interference caused by multipath. The roll-off time is represented by β T_s, where β is the roll-off factor. FIG. 3 shows an OFDM power spectrum in dB. The x-axis is normalized to carrier spacing, and the three (3) dB bandwidth has 16 carriers 60a-60p. Changing the FFT time T will change the spacing between the carriers 60a-p. Increasing the number of carriers N for a constant sampling rate 1/T will increase the number of carriers 60a-p while keeping the carrier spacing fixed, thereby increasing the width of the transmitted OFDM power spectrum. Decreasing the number of carriers N will similarly lead to decreasing the width of the transmitted OFDM power spectrum. Decreasing the sampling rate 1/T will increase T and decrease the carrier spacing, thereby decreasing the width of the transmitted OFDM symbol.

With particular reference to FIG. 4, the transmitted OFDM signal is received by an OFDM receiver 30 having signal circuitry 31 through a selected antenna 32. The OFDM signal is processed (down converted) using the receive circuitry 34 and automatic gain control (AGC) block 36. The processed OFDM signal is input into an analog-to-digital converter 38. The digital OFDM signal is received by a level detector 40 to provide a gain estimate feedback signal to the AGC 36. The digital OFDM signal is also received by a frequency compensation block 42 and a timing and frequency synchronization block 44. The timing and frequency synchronization block 44 acquires the OFDM symbol timing and provides a frequency estimate signal to the frequency compensation block 42 to correct for initial frequency offset and a timing signal to a Fast Fourier Transform (FFT) block 46.

In accordance with aspects of the present invention, dynamic control circuitry 47 provides scaleable operating parameters and/or characteristics at the receiver 30. The dynamic control circuitry 47 can receive inputs from the transmitter 10 (FIG. 1), from external settings and/or from the data destination block 51. In response, the dynamic rate control circuitry 47 controls the operation of the FFT 46 which is driven by a time base provided by clock 49. The dynamic control circuitry 47 can dynamically change the symbol duration by altering the time base from the clock 49 to the FFT 46. Additionally, the dynamic control circuitry 47 can respond to its inputs by controlling the operation of the FFT 46. The FFT 46 is designed to perform an N-point fast fourier transform on the OFDM symbol, but depending on the control signals from the dynamic control circuitry 47, can perform an X-point FFT where $X < N$ to dynamically change the number of carriers.

In the case of the maximum number of carriers, the resulting N complex carriers are input into a phase estimation block 48 and a phase compensation block 50. The phase estimation block 48 tracks the phases of the N carriers and provides phase estimates to the phase compensation block 50 which compensates the N carriers accordingly. The compensated carriers are input into decoding block 52 which decodes the forward error correcting code of the transmitter 10 (FIG. 1) and provides the data signals to the data destination block 51. Depending on its inputs, the dynamic control circuitry 47 can control the decoding block 52 to dynamically change the decoding rate and/or the demodulation scheme, thereby dynamically changing the operating parameters and/or characteristics, such as the data rate.

FIG. 5 shows an improved OFDM system 70 consisting of a base station 72 and a number of remote stations 74 which use dynamically scaleable OFDM transmitters 10 (FIG. 1) and receivers 30 (FIG. 4) according to the principles of the present invention to provide a dynamically scaleable OFDM system 70. The dynamic control circuitry 15 (FIG. 1) and 47 (FIG. 4) provides scaleability of operating parameters and/or characteristics between the base station 72 and the remote units 74. In the case of dynamically scaling the data rate, the improved OFDM system starts with low data rate between the base station 72 and a remote unit 74. Then, the dynamic control circuitry 15 (FIG. 1) of the transmitting station increases the data rate as the system design and signal quality permits. If the signal quality degrades, the dynamic control circuitry 15 (FIG. 1) decreases the data rate. The signal quality can be measured by one of the following: received signal strength, received signal to noise plus interference ratio, detected errors (CRC), the presence of acknowledgments (lack of acknowledgments the link for communication signals is bad). Additionally, other operating characteristics and/or parameters can be similarly monitored and scaled.

The OFDM receiver 30 (FIG. 4) of the receiving station 72 or 72 can perform these measurements on received signals, after which the dynamic control circuitry 47 determines what data rate or other operating characteristics and/or parameters to use and what data rate or other operating characteristics and/or parameters to use in the reverse direction. Accordingly, the receiver 30 provides feedback to the dynamic control circuitry 15 of the transmitter 10 of the receiving station 72 or 74 to dynamically scale the operating characteristics and/or parameters, such as the data rate, between the two stations. Alternatively, the receiver 30 (FIG. 4) of the receiving station 72 or 74 can perform the signal quality measurements and send back the quality information or a request for particular operating characteristics and/or parameters, such as data rate, through its transmitter 10 to the receiver 30 of the transmitting station 72 or 74. The receiver 30 of the transmitting station 72 or 74 then can provide feedback to the dynamic control circuitry 15 at the transmitting station 72 or 74 to dynamically scale the operating characteristics and/or parameters, such as the data rate, between the stations 72 or 74. Although this particular embodiment of the OFDM system 70 has a base station 72 and remote stations 74, the scaling features according to aspects of the present invention extend to a network of non-centralized OFDM transceivers.

Furthermore, in certain embodiments, the OFDM system 70 according to the principles of the present invention, can be used to implement multiple access of multi-rate systems by dynamically scaling the number of carriers. One remote station 74 could be sending on just one carrier, another remote station 74 on 4 other carriers, while a third remote station 74 could be sending on yet another 2 carriers, all at the same time. For proper decoding it is mandatory that the signals of all carriers (from different remote stations 74) are received with roughly the same relative delays by the base station 72.

In the case of certain embodiments of centralized systems which dynamically scale the number of carriers, the base station 72 receives from and transmits to all remote stations (mobile units 74 in this embodiment) within its range. Thus, the base station 72 of this particular embodiment should be capable of receiving and transmitting at all carriers simultaneously. This implies that the base station 72 faces a larger peak-to-average power ratio than the mobiles 74, but that is not really a drawback, since the base 72 is not battery-driven.

Transmitting on subsets of carriers provides the possibility of *asymmetric* data links, meaning that data rates can be different for uplink and downlink. Asymmetric links often occur in practice, e.g., downloading data. The OFDM system 70 can support such asymmetric links by dynamically providing remote stations 74 with a different number of carriers for uplink and downlink. Also, since in a centralized system the base station 72 can transmit at higher power levels than the mobiles 74, it is possible to use higher level modulation schemes on the carriers (e.g. 16 QAM), such that the downlink capacity is larger than the uplink capacity.

Advantages of using dynamic control circuitry 15 (FIG. 1) and 47 (FIG. 4) to achieve asymmetric rates are:

- Downlink capacity can be made larger than uplink capacity.
- Uplink capacity can be shared by dividing total number of carriers into subsets.
- Mobiles 74 can transmit longer packets at a lower rate compared to pure TDMA. This has the advantage that the average transmitted power is lower (simpler power amplifier) and also that the relative overhead caused by training is reduced.
- Mobiles 74 only have to transmit a limited number of carriers, which reduces the peak-to-average power of the transmitted signal. This means the mobiles 74 can achieve a better power efficiency, which is very important for battery-driven devices.

When different mobiles 74 are allowed to transmit simultaneously at different carriers, the following can arise:

- Symbol synchronization is necessary between mobiles and base station. Such synchronization is already present in TDMA systems like GSM. For the described OFDM example with a symbol duration of 200 μs, the synchronization offset should be limited to about 5 μs.
- Some power control is necessary to reduce near-far effects. The near-far effect is less serious than in CDMA systems, because the OFDM carriers are orthogonal, while CDMA codes usually have some non-zero cross-correlation. In OFDM, power control is only needed to reduce the dynamic range of A/D converters in the receiver, and to reduce multi-user interference caused by frequency offsets, which may introduce some correlation between carriers of different users.

In the previously described OFDM mobile phone option, with 32 carriers delivering 320 kbps in a bandwidth of 200 kHz, the band can be divided into 8 channels of 4 carriers each. Each channel then carries data at a raw rate of 40 kbps, which provides about 70% of redundancy for signaling overhead and forward error correction coding of a 13 kbps speech signal.

Thus, the OFDM system 70 can provide the advantages of asymmetric data rates when needed, such as during the downloading of data from the base station 72 to the remote station 74, by dynamically altering the number of carriers used for downlink to receiver 30 (FIG. 4) of the remote station 74 and for uplink from the transmitter 10 of the remote station 74. Additionally, the OFDM system 70 can dynamically scale various operating characteristics and/or parameters for the stations 72 and 74 and can provide different operating characteristics and/or parameters between the base. station 72 and different remote stations 74 or provide varying symmetric operating characteristics and/or parameters between the base station 72 and a remote unit 74. Alternatively, the dynamic scaling of operating parameters and/or characteristics between stations to provide different operating parameters and/or characteristics between the stations can be performed in a non-centralized OFDM system of transceivers.

In certain embodiment of the OFDM system 70 of FIG. 5, adaptive antennas 78 can be used at the base station 72 to make the antenna pattern adaptive and different for each carrier such that the signal-to-noise plus interference ratio is maximized for each carrier. In OFDM, the base 72 simply measures the amplitude of several carriers to obtain the spectrum of incoming signal which provides simultaneous adaptive antennas. Adaptive antenna control circuitry 80 can control the adaptive antennas 78 in the following manner to provide improved performance in the OFDM system 70:

- Base 72 measures uplink channel (N carrier amplitudes, SNR/SIR), assuming downlink channel equal to uplink channel;
- If downlink and uplink channels are not equal because they are at different frequencies for instance (as in UMTS), the mobile 74 can send measured downlink carrier amplitudes as feedback over the uplink to the base station 72;
- In uplink, base station 72 uses adaptive antenna to maximize signal-to-noise and interference ratio; and
- In downlink, base station 72 uses measured uplink channel or feedback from mobile to select amplitudes and phases for each carrier and each antenna of the adaptive antennas 78. In this way, the OFDM system 70 benefits from improved antenna gain for each carrier. By transmitting more power in relatively good carriers, power is not wasted in carriers which do not reach the mobile 74 anyway.

As such, the adaptive antenna control in the OFDM system 70 provides improved efficient performance. Together with the dynamic control aspects of the OFDM system 70, a flexible OFDM system 70 is provided which can improve the operation between the stations by using the adaptive antenna system in conjunction with the dynamic control to improve the OFDM system performance. For example, a certain subset of carriers can be dynamically chosen taking into account feedback from the adaptive antenna control circuitry. Alternatively, in an embodiment of a network of non-centralized OFDM transceivers, the transceivers or a subset of the transceivers could take advantage of adaptive antennas.

Thus, the improved OFDM (Orthogonal Frequency Division Multiplexing) modulation system provides increased flexibility and adaptability by using scaleable operating characteristics and/or parameters which allow the improved OFDM system to operate in various communications environments. The improved OFDM system accomplishes this by dynamically changing operating parameters, such as the number of carriers, the symbol duration, the coding rate, the modulation scheme and/or the number of bits per symbol per carrier, to scale the operating parameters and/or characteristics of the OFDM system. The dynamic rate control circuitry can dynamically scale the operating parameters and/or characteristics of the OFDM system or various subsets of the operating parameters and/or characteristics while maintaining other operating characteristics and/or parameters fixed to achieve the desired operation or performance for the OFDM system.

In addition to the embodiments described above, alternative configurations of the improved OFDM modulation system are possible which omit or add components or use different components in performing the dynamic scaling of the OFDM system parameters and/or characteristics or a variation thereof. For example, only portions of the described control circuitry can be used to provide a subset of the scaling features, or separate control circuitry can be used which are associated with the various transmitter components. Additionally, the above-described OFDM system has been described as being comprised of several components, but it should be understood that the OFDM system and portions thereof can be employed using application specific integrated circuits, software driven processing circuitry, or other arrangements of discrete components.

What has been described is merely illustrative of the application of the principles of the present invention. Those skilled in the art will readily recognize that these and various other modifications, arrangements and methods can be made to the present invention without strictly following the exemplary applications illustrated and described herein and without departing from the scope of the present invention.

Claims

1. A method for providing communication signals according to operating parameters using orthogonal frequency division multiplexing, said method **CHARACTERIZED** BY the step of:

   dynamically scaling at least one of said operating parameters for said method.

2. The method of claim 1 further **CHARACTERIZED** BY the steps of:

   providing said communication signals at a data rate; and
   dynamically changing said data rate.

3. The method of claim 1 further including the step of providing OFDM symbols from said communication signals, and **CHARACTERIZED** IN THAT said step of dynamically scaling includes the step of:

   dynamically changing symbol duration for said OFDM symbols.

4. The method of claim 3 **CHARACTERIZED** IN THAT said step of dynamically changing further includes the steps of:

   transforming said communication signals into an OFDM symbol using a fourier transformation; and
   altering a time base for said fourier transformation.

5. The method of claim 1 further including the step of providing OFDM symbols from said communication signals, and **CHARACTERIZED** IN THAT said step of dynamically scaling includes the step of:

   dynamically changing the number of carriers for said OFDM symbols.

6. The method of claim 1 CHARACTERIZED IN THAT said step of dynamically scaling includes the steps of:

coding communication signals according to a coding rate; and dynamically changing said coding rate.

7. The method of claim 1 **CHARACTERIZED** IN THAT said step of dynamically scaling includes the steps of:

modulating carriers according to a first modulation scheme; and
dynamically changing said first modulation scheme to a second modulation scheme.

8. The method of claim 1 further CHARACTERIZED BY the steps of:

transmitting OFDM symbols at an uplink data rate; and
receiving communication signals at a downlink data rate.

9. The method of claim 8 further **CHARACTERIZED** BY the steps of:

dynamically changing said downlink data rate.

10. The method of claim 9 **CHARACTERIZED** IN THAT said step of dynamically changing said downlink data rate includes the step of:

dynamically changing the number of carriers for said communication signals.

11. A method of receiving OFDM symbols according to operating parameters, said method CHARACTERIZED BY the step of:

dynamically changing at least one of said operating parameters for said method.

12. An OFDM system for providing communication signals according to operating parameters, said system CHARACTERIZED BY dynamic control circuitry provides control signals to signal circuitry to dynamically scale at least one of said operating parameters.

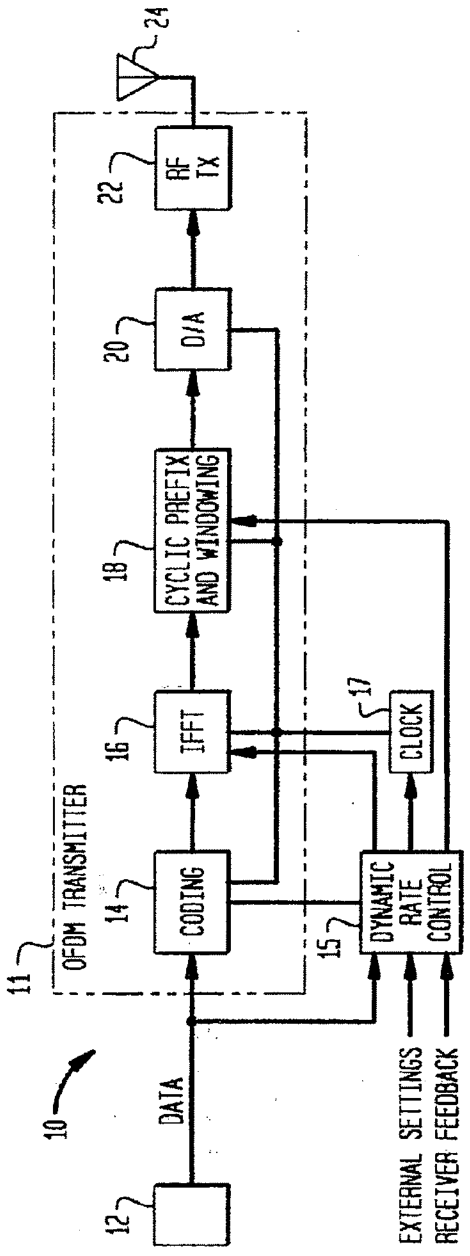
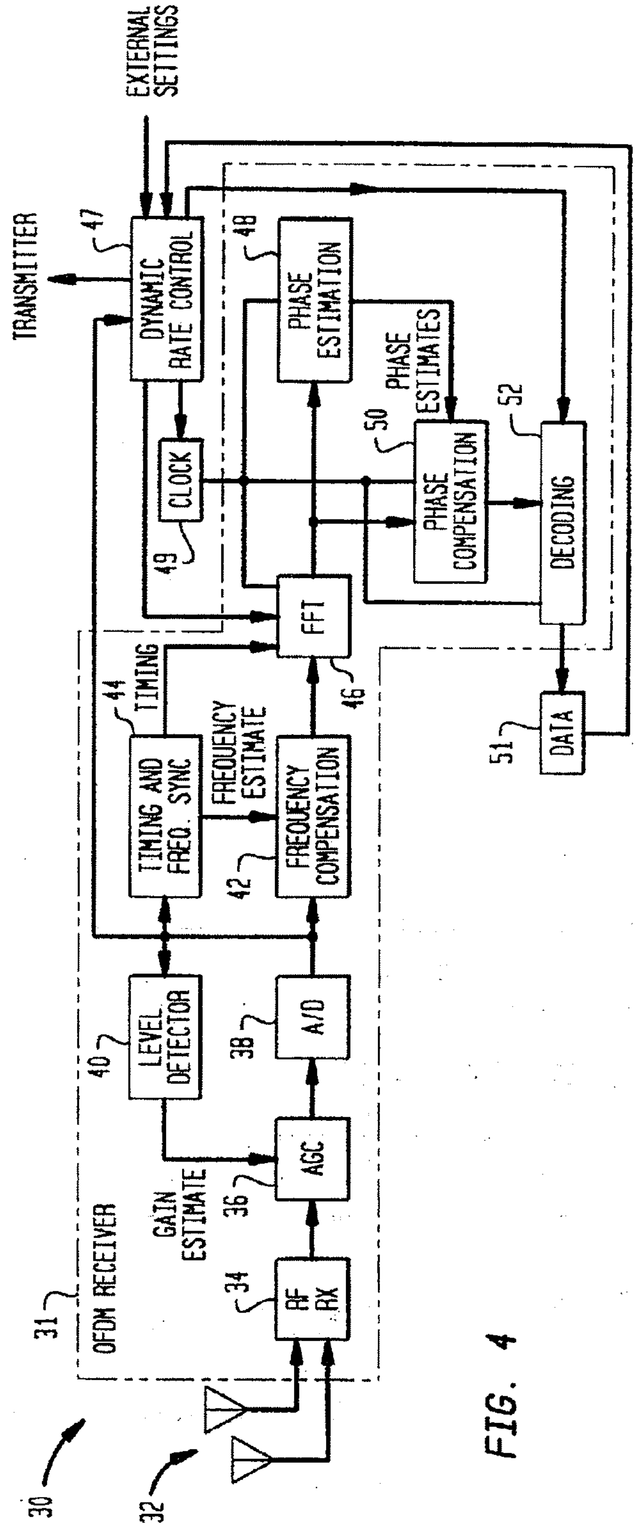

10
11
OFDM TRANSMITTER
12
DATA
14
CODING
16
IFFT
18
CYCLIC PREFIX AND WINDOWING
20
D/A
22
RF TX
24
17
CLOCK
15
DYNAMIC RATE CONTROL
EXTERNAL SETTINGS
RECEIVER FEEDBACK

FIG. 1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32
31
OFDM RECEIVER
34
RF RX
36
AGC
GAIN ESTIMATE
38
A/D
40
LEVEL DETECTOR
44
TIMING AND FREQ. SYNC
TIMING
FREQUENCY ESTIMATE
42
FREQUENCY COMPENSATION
46
FFT
48
PHASE ESTIMATION
PHASE ESTIMATES
50
PHASE COMPENSATION
52
DECODING
51
DATA
49
CLOCK
47
DYNAMIC RATE CONTROL
TRANSMITTER
EXTERNAL SETTINGS

FIG. 4

FIG. 2

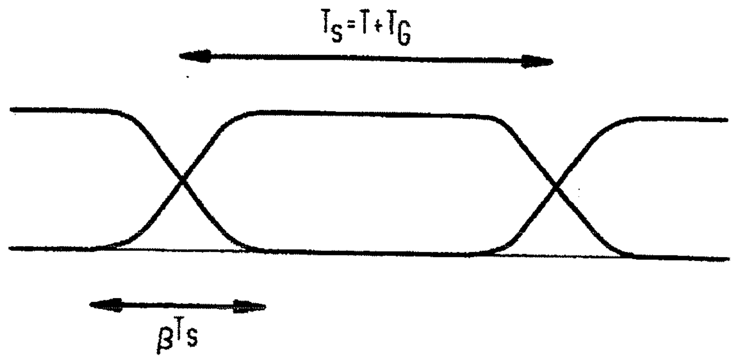
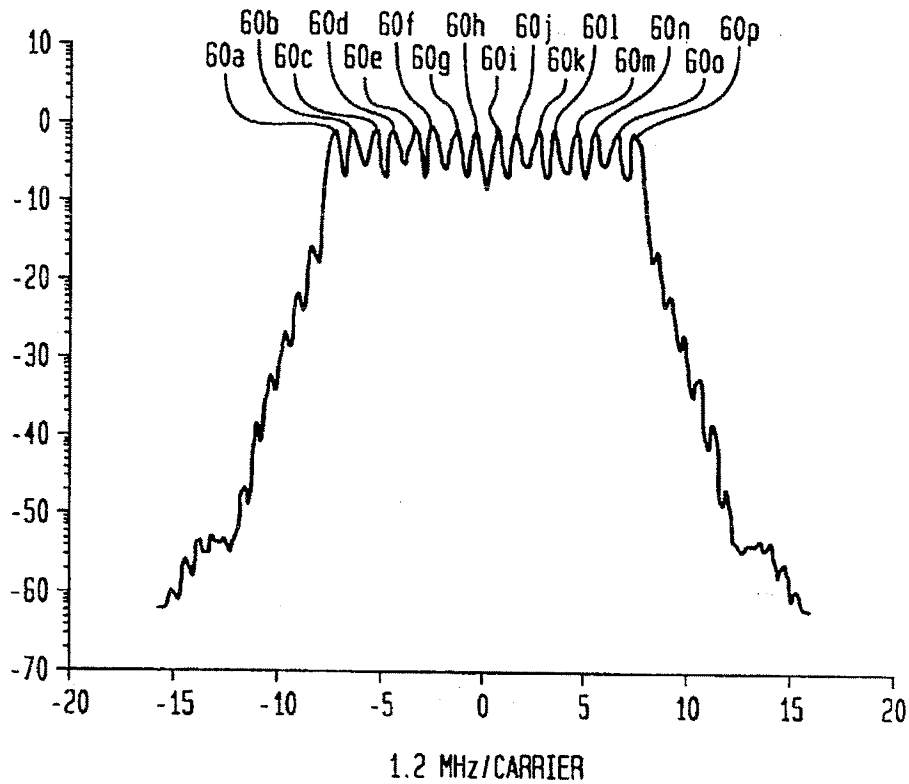

$T_S=T+T_G$
$\beta^{T}s$

FIG. 3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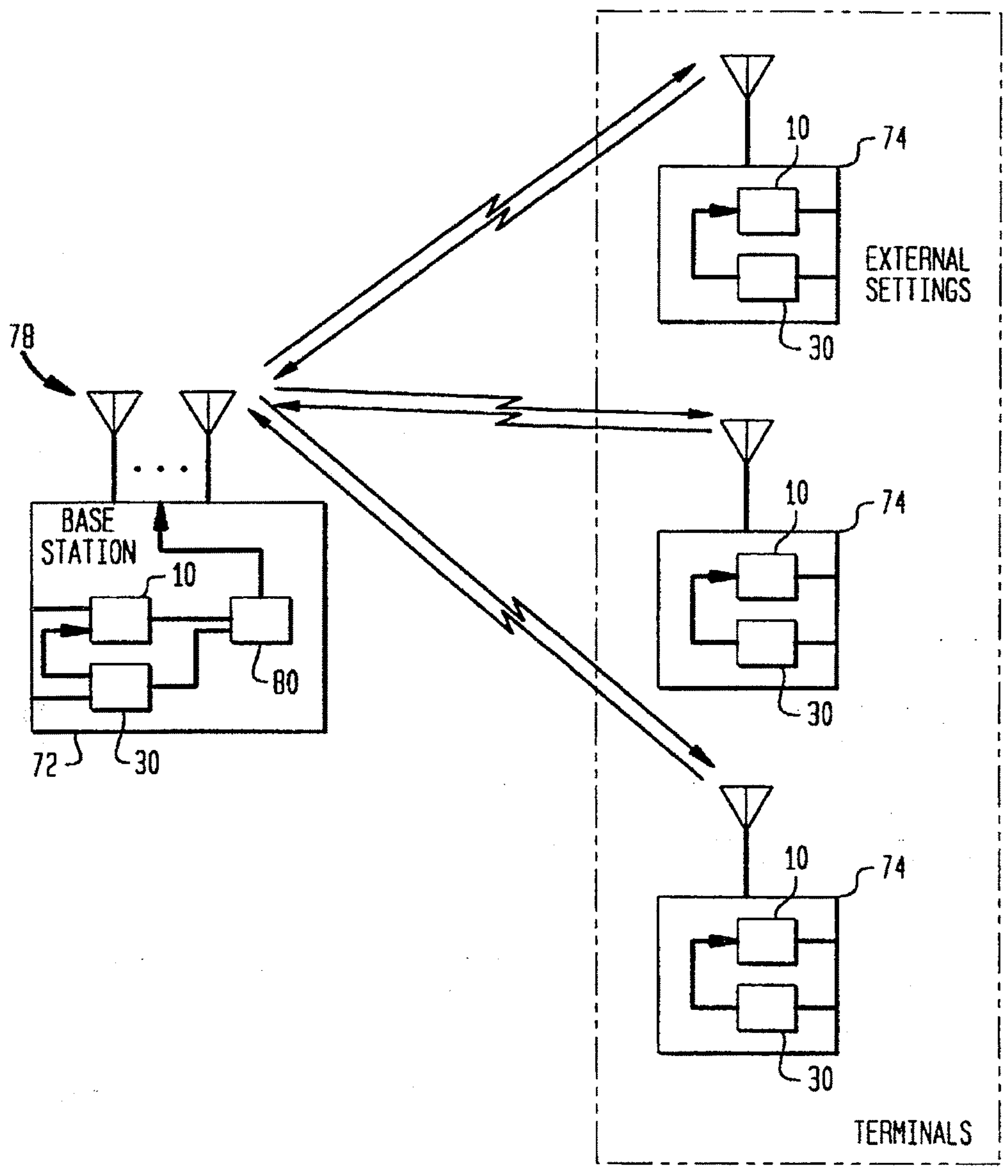
60b
60c
60d
60e
60f
60g
60h
60i
60j
60k
60l
60m
60n
60o
60p
10
0
-10
-20
-30
-40
-50
-60
-70
-20
-15
-10
-5
0
5
10
15
20
1.2 MHz/CARRIER

FIG. 5


78
BASE
STATION
10
80
72
30
10
74
EXTERNAL
SETTINGS
30
10
74
30
10
74
30
TERMINALS

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Application No.	Ref.	Date
01 986 165.7 - 2415	E3590.03	29.03.2007
Applicant Adaptix, Inc.		

Communication pursuant to Article 96(2) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(1) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 78(2) and 83(2) and (4) EPC.

One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (Rule 36(1) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Article 96(3) EPC).

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Palacián Lisa, Marta
Primary Examiner
for the Examining Division

Enclosure(s): 4 page/s reasons (Form 2906)

Registered Letter
EPO Form 2001 07.02CSX

The examination is being carried out on the **following application documents**:

Description, Pages
1-23 as published

Claims, Numbers
1-57 received on 08.07.2006 with letter of 05.07.2006

Drawings, Sheets
1/7-7/7 as published

The following documents are referred to in this communication; the numbering will be adhered to in the rest of the procedure:

D1: US-A-5 726 978
D2: US-A-5 914 933
D3: US-A-5 479 447
D4: EP-A-0 869 647

1. Claim 1 is not new in the sense of Article 54(1) and (2) EPC and, therefore, is not allowable (Article 52(1) EPC).

1.1 Document D1 discloses, in terms of the wording of claim 1, a method for subcarrier selection for a system employing orthogonal frequency division multiple access (see, e.g. column 4, lines 25-31) comprising:

- a subscriber measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station (see, e.g. column 13, lines 8-11);
- the subscriber selecting a set of candidate subcarriers (see, e.g. column 13, lines 12-13);
- the subscriber providing feedback information on a set of subcarriers to the base station (see, e.g. column 13, lines 14-18); and
- the subscriber receiving an indication of subcarriers of the set of subcarriers selected

by the base station for use by the subscriber (see, e.g. column 13, lines 18-21 and 37-45).

2. All the features of claim 1 are also disclosed by D2 (see, e.g. column 2, lines 1-20; page 8, lines 1-14; column 9, lines 1-26), D3 (see, e.g. abstract; column 5, line 42 to column 6, line 15; column 7, line 35 to column 8, line 57; column 12, lines 27-43) and D4 (see, e.g. page 3, lines 15-40; page 6, lines 9-54).

   Therefore, claim 1 also lacks novelty vis-à-vis D2, D3 or D4.

3. Independent apparatus claims 29 and 30 are directed to an apparatus comprising a plurality of subscribers and a base station which carries out the method steps of claim 1. Therefore, the objection of lack of novelty (documents D1-D4) is also applied to these claims.

4. It should be noted that even if novelty of the independent claims could be argued, based on minor differences between the features of these claims and those disclosed in D1, D2, D3 or D4, the subject-matter of claims 1, 29 and 30 would not involve an inventive step, Article 56 EPC, having regard to the disclosure of D1, D2, D3 or D4.

5. The dependent claims do not contain any additional feature which, in combination with the independent claims, meet the requirements of novelty and inventive step. These features are either known from the cited prior art (claims 2-8, 14-19, 26, 31-36, 43-47, 55 see citations in the International Search Report) or are common measures (claims 9-13, 20-25, 27, 28, 37-42, 48-54, 56, 57).

6. Claims 29 and 30. have been drafted as separate independent apparatus claims.

   Under Article 84 in combination with Rule 29(2) EPC an application may contain more than one independent claim in a particular category only if the subject matter claimed falls within one or more of the exceptional situations set out in paragraphs (a), (b) or (c) of Rule 29(2) EPC. However, this is not the case in the present application.

   The applicant is requested to file an amended set of claims which complies with Rule

29(2). Failure to do so, or to submit convincing arguments as to why the current set of claims does in fact comply with these provisions, will lead to refusal of the application under Article 97(1) EPC.multiplicity:

6.1 Claim 29 does not comprise all the essential features of the invention (i.e. those corresponding to method claim 1), Article 84 EPC and the applicant is therefore suggested to delete this claim.

7. Claims 29 to 57 do not meet the requirements of Article 84 EPC for the following reasons:

7.1 Claims 29 to 57 are directed to an apparatus comprising a plurality of subscribers and a first base station. The subscribers and the base station could be considered apparatus per se. Therefore, it appears more appropriate to direct these claims to a multi-subscriber wireless system instead to an apparatus to clarify the scope of protection of these claims, Article 84 EPC. Furthermore, claim 1 is directed to a method for subcarrier selection for a system.

7.2 All the features of claims 29 to 57 are formulated in terms of method steps (performing, monitors, selects, ...), thereby rendering also unclear their scope of protection.

7.3 The term "cluster" used throughout claims 29-57 has not been defined and could be interpreted in several ways (e.g. a group of subcarriers assigned to a cell, or to a certain group of subscribers). Its definition should be included in the claims. The applicant should also note that claim 1 does not include this term, only a plurality of subcarriers is mentioned therein. The independent claims are therefore not consistent.

8. The following requirements should also be met:

8.1 If new independent claims are filed, they should be in the two-part form as required by Rule 29(1) EPC, whereby the features already disclosed in document D1 should be placed in the preamble.

8.2 Reference signs in parentheses should be inserted in the claims to increase their intelligibility (Rule 29(7) EPC). This applies to both the preamble and characterising portion (see the Guidelines, C-III, 4.11).

8.3 To meet the requirements of Rule 27(1)(b) EPC, the document D1 should be identified in the description and its relevant contents should be briefly indicated.

8.4 When filing amended claims the applicant should at the same time bring the description into conformity with the amended independent claims (Rule 27 (1)(c) EPC).

8.5 In order to facilitate the examination of the conformity of the amended application with the requirements of Article 123(2) EPC, the applicant is requested to clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based.

If the applicant regards it as appropriate these indications could be submitted in handwritten form on a copy of the relevant parts of the application as filed.

(Translation)

Dispatched on May 7, 2007

Notification of Reason for Rejection

Dated: April 27, 2007

To: Mr. M. Nakamura, et al., agents for the applicant

From: H. Takano, Examiner of the Patent Office

Patent Application No. 2002-550683

The above mentioned application is considered to be subject to rejection on the grounds set out hereunder. If the applicant has anything to say, he should file an argument within three months from the date of dispatch of this document.

Ground

The invention under the present application is considered to have been easy to invent for those skilled in the art on the basis of the inventions described in the following publications which were circulated or made available to the public through telecommunication lines in Japan or elsewhere prior to the present application and, therefore, it is considered unpatentable in view of the provisions of Article 29, Para. 2 of the Patent Law.

Reference 1: Japanese Patent Laid-Open Publication No. 11-508417
Reference 2: Japanese Patent Laid-Open Publication No. 7-322219
Reference 3: Japanese Patent Laid-Open Publication No. 10-303849

As regards claims 1-4, 6, 8, 11-13 and 15-20, please refer to Ref. 1.
Remarks:

Ref. 1 disclose a method of measuring, at each user, a quality of a transmission channel by utilizing a standard signal, so as to determine a set of candidate carriers, and feeding it back to a base station and; the base station allocates, based on the information, a set of subcarriers to each user. Also, an inter-cell interference is used.

Therefore, it is considered that there are no significant differences between the invention claimed in the present claims and that disclosed in Ref. 1.

As regards claims 5, 7, 9, 10, 14 and 21, please refer to Refs. 1-3.

Remarks:

As disclosed in Ref. 2 (see columns 0334-0336 etc.), it is common to allocate channels in consideration of a traffic condition, and it would merely be a design modification for those skilled in the art to carry out a channel allocation to each user in consideration of a balance of a traffic load.

Further, as disclosed in Ref. 3, a coding and a modulation rate parameters for an adaptive behavior control in OFDM, is commonly used, and it is not so difficult to take such parameters into account for Ref. 1.

For your information, this application includes so many independent claims and the claims include so many similar expressions (all the parameters such as SINR, inter-cell interference, and traffic load which differentiate the claims from each other, are publicly used) that it is not certain the features defined in each of the claim are definitely correspond to the above indicated features and also it is not certain all the independent claims have technical features common to all of them.

Therefore, the application should clarify, for each of the independent claims, what the technical feature is, as compared with the combination of Refs. 1-3.