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Methods and apparatus for frequency offset estimation

Abstract

Methods and apparatus for frequency offset estimation are disclosed. In an exemplary embodiment, a method includes determining a demodulation reference signal (DMRS) frequency offset estimate from DMRS symbols in a received signal, and determining a cyclic prefix (CP) frequency offset estimate from cyclic prefix values in the received signal. The method also includes combining the DMRS and CP frequency offset estimates to determine a final frequency offset estimate. In an exemplary embodiment, an apparatus includes a DMRS frequency offset estimator that determines a DMRS frequency offset estimate based on DMRS symbols received in an uplink transmission, and a cyclic prefix (CP) frequency offset estimator that determines a CP frequency offset estimate based on cyclic prefix values in the uplink transmission. The apparatus also includes an offset combiner that combines the DMRS frequency offset estimate with the CP frequency offset estimate to generate a final frequency offset estimate.

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Background/Summary

PRIORITY (1) This patent application is a continuation patent application of a U.S. patent application having a U.S. patent application Ser. No. 16/744,074, filed on Jan. 15, 2020 in the name of the same inventor and entitled "Methods and Apparatus for Frequency Offset Estimation," issued into a U.S. patent with a U.S. Pat. No. 11,095,491, which is a continuation application of a U.S. application having a U.S. patent application Ser. No. 16/237,635, filed on Dec. 31, 2018 in the name of the same inventor and entitled "Methods and Apparatus for Frequency Offset Estimation,"

which has been issued into a U.S. patent with a U.S. Pat. No. 10,554,469, which is a continuation application with a U.S. patent application Ser. No. 15/592,087, filed on May 10, 2017 in the name of the same inventor and entitled "Methods and Apparatus for Frequency Offset Estimation," which has been issued into a U.S. patent with a U.S. Pat. No. 10,171,278, which further claims the benefit of priority based upon U.S. Provisional Patent Application having Application No. 62/335,366, filed on May 12, 2016 in the name of the same inventor and entitled "FREQUENCY OFFSET ESTIMATOR." All mentioned U.S. applications are hereby incorporated by reference.

FIELD

(1) The exemplary embodiments of the present invention relate to telecommunications networks. More specifically, the exemplary embodiments of the present invention relate to receiving and processing data streams via a wireless communication network.

BACKGROUND

(2) With a rapidly growing trend of mobile and remote data access over high-speed communication networks, such as provided by long term evolution (LTE) cellular networks, accurate delivery and deciphering of data streams has become increasingly challenging and difficult. For example, in a multi-user LTE system, the frequency offset associated each user is independent of the other users. Frequency offset causes clockwise or counter clockwise incremental phase rotation of the received signal samples. The current LTE standard constrains the frequency offset that can be estimated to a range of (−1 kHz to 1 kHz). However, performance requirements specified in the LTE specification forces baseband system manufacturers to extend the frequency offset estimation range. For example, to provide communications to users riding on high speed trains, expanding the frequency offset estimation to a range that covers (−1.7 kHz to 1.7 kHz) may be necessary.

(3) Therefore, it is desirable to have a mechanism for frequency offset estimation that can accurately estimate a wider range of frequency offset to satisfy high speed performance requirements of wireless communication systems.

SUMMARY

(4) The following summary illustrates simplified versions of one or more aspects of present invention. The purpose of this summary is to present some concepts in a simplified description as more detailed description that will be presented later.

(5) Methods and apparatus for frequency offset estimation are disclosed. For example, the frequency offset estimation for use in an LTE uplink can be performed. The exemplary embodiments of the frequency offset estimation support frequency offset estimation with 15 times wider range than the conventional schemes. The exemplary embodiments of the frequency offset estimation utilize joint frequency offset estimation that comprises both fine and coarse frequency offset estimation. The exemplary embodiments of the frequency offset estimation can be implemented with a single pipeline and the frequency offset can be estimated up to subcarrier level (smallest element of the FFT output).

(6) The exemplary embodiments of the frequency offset estimation can use the user allocation information in layer 2 (MAC layer), such that the estimation accuracy can be improved through the average of the estimate of each sub-frame.

(7) The exemplary embodiments of the frequency offset estimation can be applied to LTE uplink MIMO cases where the cyclic prefix is not completely orthogonal to the other part of a symbol by including the normal data part to keep the orthogonality.

(8) In an exemplary embodiment, a method is provided that includes determining a demodulation reference signal (DMRS) frequency offset estimate from DMRS symbols in a received signal, and determining a cyclic prefix (CP) frequency offset estimate from cyclic prefix values in the received signal. The method also includes combining the DMRS and CP frequency offset estimates to determine a final frequency offset estimate.

(9) In an exemplary embodiment, an apparatus is provided that includes a DMRS frequency offset

estimator that determines a DMRS frequency offset estimate based on DMRS symbols received in an uplink transmission, and a cyclic prefix (CP) frequency offset estimator that determines a CP frequency offset estimate based on cyclic prefix values in the uplink transmission. The apparatus also includes an offset combiner that combines the DMRS frequency offset estimate with the CP frequency offset estimate to generate a final frequency offset estimate.

(10) Additional features and benefits of the exemplary embodiment(s) of the present invention will become apparent from the detailed description, figures and claims set forth below.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The exemplary aspects of 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.

(2) FIG. **1** shows a communication network comprising a transceiver having an exemplary embodiment of a frequency offset estimator (OE) configured to accurately measure frequency offset associated with uplink communications from a plurality of users;

(3) FIG. **2** shows an exemplary functional block diagram of the communication network shown in FIG. **1**;

(4) FIG. **3** shows an exemplary diagram of data symbols received at a receiver in uplink transmissions from a plurality of users;

(5) FIG. **4** shows an exemplary embodiment of a DMRS frequency offset estimator for use in an exemplary embodiment of the frequency offset estimator shown in FIGS. **1-2**;

(6) FIG. **5** shows an exemplary embodiment of a user data stream that includes data values having a cyclic prefix;

(7) FIG. **6** shows an exemplary embodiment of a frequency offset estimator constructed in accordance with the present invention; and

(8) FIG. **7** shows an exemplary method for performing frequency offset estimation in a receiver in accordance the present invention.

DETAILED DESCRIPTION

(9) Aspects of the present invention are described herein the context of methods and apparatus for frequency offset estimation.

(10) The purpose of the following detailed description is to provide an understanding of one or more embodiments of the present invention. Those of ordinary skills in the art will realize that the following detailed description is illustrative only and is not intended to be in any way limiting. Other embodiments will readily suggest themselves to such skilled persons having the benefit of this disclosure and/or description.

(11) In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be understood that in the development of any such actual implementation, numerous implementation-specific decisions may be made in order to achieve the developer's specific goals, such as compliance with application- and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another. Moreover, it will be understood that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking of engineering for those of ordinary skills in the art having the benefit of embodiments of this disclosure.

(12) Various embodiments of the present invention illustrated in the drawings may not be drawn to scale. Rather, the dimensions of the various features may be expanded or reduced for clarity. In addition, some of the drawings may be simplified for clarity. Thus, the drawings may not depict all

of the components of a given apparatus (e.g., device) or method. The same reference indicators will be used throughout the drawings and the following detailed description to refer to the same or like parts.

(13) In various exemplary embodiments, the disclosed methods and apparatus provide one or more of the following novel aspects.

(14) A. Frequency offset estimation using the cyclic prefix.

(15) B. Frequency offset estimation in frequency domain by measuring the phase difference of two FFT outputs generated with two input samples captured at normal and adjustable time offset.

(16) C. Phase difference measurement between a normal FFT output of an LTE uplink symbol and an FFT output of a cyclic-time shifted LTE uplink symbol, which is captured with an adjustable sample offset, which injects timing offset.

(17) D. The complex metrics for phase difference estimation are cross-correlation results (a product of complex values of each subcarrier), and they are averaged for each resource block (RB) as a basic unit. The unit (RB-wise) metrics are combined across the RBs for each user depending on uplink scheduling, and across several time slots (TTI) for better accuracy.

(18) FIG. **1** shows a communication network **100** comprising a transceiver **116** having an exemplary embodiment of a frequency offset estimator (OE) **118** configured to accurately measure frequency offset associated with uplink communications from a plurality of users. The communication network **100** includes a base station **114** that includes the transceiver **116**. The transceiver **116** has a transmitter portion **128** and a receiver portion **130**. The base station **114** communicates with radio towers **110** located in cell site **102**.

(19) User equipment (UE) **104** transmits uplink communications **120** to the base station **114** through tower **110***c*, and user equipment **106** transmits uplink communications **122** to the base station **114** through tower **110***b*. For example, the UEs can be cellular phones, handheld devices, tablet computers or iPad® devices. It should be noted that the underlying concepts of the exemplary embodiments of the present invention would not change if one or more devices were added or removed from the communication network **100**.

(20) Each user equipment transmits its signal through an associated uplink channel. The transmitted uplink signal suffers from frequency offset due to Doppler shift and mismatch between oscillators in the transmitter of the UE and the receiver in the base station. Each user's frequency offset can be assumed to be independent from other users, since each user has its own oscillator and its motion and speed are independent from other users.

(21) To improve data reception for the uplink communications, the receiver **130** includes the frequency offset estimator **118**. The frequency offset estimator **118** operates to estimate the frequency offset associated with each of the users **104** and **106**. In an exemplary embodiment, the OE **118** estimates the frequency offset with a wide range (e.g., −1.7 kHz to 1.7 kHz), which enables accurate data reception on the uplink communications even when the users **104** and **106** are traveling at a high rate of speed. For example, a user may be riding on a high-speed train traveling at speeds approaching or exceeding 300 mph and the OE **118** will still be able to determine an accurate frequency offset. A more detailed description of the OE **118** is provided below.

(22) FIG. **2** shows an exemplary functional block diagram **200** of the communication network **100** shown in FIG. **1**. Each user equipment (**202**) transmits its signal through an uplink transmission to the receiver **130**. The transmitted signals suffer from associated frequency offset (**204**) due to Doppler shift and mismatches between oscillators in the user equipment (transmitters) and oscillators in the receiver **130** (base station). Each user's frequency offset can be assumed to be independent since each user has its own oscillator and is moving at a speed that is independent of the other users. In various exemplary embodiments, the frequency offset estimator **118** operates to estimate the frequency offset of each of the user with a wide range (e.g., −1.7 kHz to 1.7 kHz), which enables accurate data reception of the uplink transmission even when a user is traveling at a high rate of speed.

(23) FIG. **3** shows an exemplary diagram of data symbols **300** received at a receiver in uplink transmissions from a plurality of users. For example, the symbols **300** may be received by the receiver **130** shown in FIG. **2**. With respect to an LTE uplink transmission, each user's signal is configured as SC-FDMA (single carrier-frequency division multiple access), which is multiplexed in the frequency domain with other users. Each users' uplink transmission includes two DMRS (demodulation reference signal) symbols (**302**, **304**) per a sub-frame, where a sub-frame is the minimum transmission unit in LTE.

(24) The DMRS symbols work as pilot symbols, which enable channel estimation and frequency offset estimation. When they are used for frequency offset estimation, the phase difference between two channel responses estimated with them is measured. If the measured phase shift is ϕ, the frequency offset can be calculated as:

$f.\text{sub.offset}=(\phi/2\pi T)$

where T is time distance between the two DMRS, which is 0.5 ms in LTE systems. Thus, the estimation range is limited to $(-1 \text{ kHz}, 1 \text{ kHz})$, since it is difficult to distinguish the phase difference beyond the range of $(-\pi \text{ to } \pi)$.

(25) FIG. **4** shows an exemplary embodiment of a DMRS frequency offset estimator **408** for use in an exemplary embodiment of the frequency offset estimator **118** shown in FIGS. **1-2**. In an exemplary embodiment, the estimator **408** comprises a digital signal processor (DSP). A received signal is input to user separator **402**, which performs an (FFT) to separate out frequencies associated with a particular user. For example, since the LTE uplink uses SC-FDMA (single carrier-frequency domain multiple access) scheme to multiplex multi-user signals in frequency division manner, the receiver **130** operates to measure the frequency offset of each user by separating each user signal in the frequency domain. The output of the separator **402** is input to the DMRS frequency offset estimator **408**, which comprises a phase difference calculator **404** and a time interval divider **406**.

(26) In an exemplary embodiment, the phase difference calculator **404** comprises at least one of a CPU, processor, state machine, logic, memory, discrete hardware and/or any combination thereof. The phase difference calculator **404** calculates a phase different between two DMRS symbols in a received sub-frame for a particular user. For example, as illustrated in FIG. **3**, the phase difference calculator **404** calculates the phase shift between DMRS symbols **302** and **304**.

(27) In an exemplary embodiment, the time interval divider **406** comprises at least one of a CPU, processor, state machine, logic, memory, discrete hardware and/or any combination thereof. The time interval divider **406** divides the calculated phase shift ϕ by the time interval (T) between the DMRS symbols (e.g., symbols **302** and **304**) to determine a DMRS frequency offset estimate. If the measured phase shift is ϕ, the DMRS frequency offset can be calculated as:

$f.\text{sub.offset}=(\phi/2\pi T)$

where T is time distance between the two DMRS, which, for example, is 0.5 milliseconds (ms) in LTE systems.

(28) FIG. **5** shows an exemplary embodiment of a user data stream **500** that includes data values having a cyclic prefix. In an exemplary embodiment, the DATA1 symbol has a cyclic prefix (CP1) that is a copy of the data **502** at the end of the DATA1 symbol. The data **502** is copied and then placed in front to prefix the symbol with a repetition of the data at the end of the symbol. The cyclic prefix serves two purposes. First, as a guard interval, it eliminates the inter-symbol interference from the previous symbol. Second, as a repetition of the end of the symbol, it allows a linear convolution of a frequency-selective multipath channel to be modelled as a circular convolution, which in turn may be transformed to the frequency domain using a discrete Fourier transform. This approach allows for simple frequency-domain processing, such as channel estimation and equalization. Typically, the length of the cyclic prefix must be at least equal to the length of the multipath channel.

(29) In an exemplary embodiment, to widen the frequency offset measurement range of the OE **118**

and to support the frequency offset estimation for multiple users in the LTE uplink, the cyclic prefix is exploited during the frequency offset estimation. For example, in an exemplary embodiment, the contribution of the cyclic prefix to the frequency offset estimation is separated in the frequency domain and selectively applied.

(30) FIG. **6** shows an exemplary embodiment of a frequency offset estimator **600** constructed in accordance with the present invention. For example, the frequency offset estimator **600** is suitable for use as the frequency offset estimator **118** shown in FIGS. **1-2**. The frequency offset estimator **600** comprises user separator **602**, DMRS frequency offset estimator **408**, offset combiner **606**, time offset adjuster **608**, user separator **610**, cyclic time shifter **612**, cross correlator **614** and frequency/time averager **616**.

(31) In an exemplary embodiment, the frequency offset estimator **600** estimates the frequency offset of each user by estimating a first frequency offset using two received DMRS (pilot) symbols and by estimating a second frequency offset using cyclic prefixes. The two frequency offsets are combined to form a final frequency offset estimation with much wider range than conventional offset detectors. A first processing path **632** is used to estimate the first frequency offset for a particular user using DMRS symbols for the frequency offset estimation. A second processing path **634** is used to estimate the second frequency offset for the particular user using cyclic prefixes. The offset combiner **606** operates to combine the first and second frequency offsets to produce a final frequency offset estimate **630** for the particular user with a wide range of up to (−15 kHz to 15 kHz).

(32) In an exemplary embodiment, the user separator **602** comprises at least one of a CPU, processor, state machine, logic, memory, discrete hardware and/or any combination thereof to perform user separation in LTE uplink. For example, since the uplink signals are frequency-domain multiplexed signals, each user's signal can be separated by its own transmitted frequency. In an exemplary embodiment, the separator **602** performs an FFT on the received signal **618** to separate frequency components associated with a particular user.

(33) In an exemplary embodiment, the DMRS frequency offset estimator **408** operates as described with reference to FIG. **4**. For example, the estimator **408** measures the phase difference between two DMRS symbols and estimates a fine frequency offset in the range of (−1 kHz to 1 kHz). The output of the estimator **408** is a first frequency offset estimate **622** that is input to the offset combiner **606**.

(34) In an exemplary embodiment, the time offset adjuster **608** comprises at least one of a CPU, processor, state machine, logic, memory, discrete hardware and/or any combination thereof and time adjustments the received symbols **618** to take the cyclic prefix portion of the transmitted symbols and to provide this cyclic prefix portion as an input to the user separator **610**. For example, in the transmitter (user equipment), the cyclic prefix is copied from the tail of each SC-FDMA symbol to the front of each symbol, so that the front and tail portion of the symbol are identical. Thus, in the receiver side (base station), both parts can be used for frequency offset estimation for each user. The cyclic prefix portion **636** is input to the user separator **610**.

(35) In an exemplary embodiment, the user separator **610** comprises at least one of a CPU, processor, state machine, logic, memory, discrete hardware and/or any combination thereof to perform user separation in LTE uplink communications. For example, since the uplink signals are frequency-domain multiplexed signals, each user's signal can be separated by its own transmitted frequency. In an exemplary embodiment, the separator **610** performs an FFT on the cyclic prefix input **636** to separate frequency components **638** of the cyclic prefix associated with the same user whose signal was separated out by the user separator **610**.

(36) In an exemplary embodiment, the cyclic time shifter **612** comprises at least one of a CPU, processor, state machine, logic, memory, discrete hardware and/or any combination thereof to perform cyclic time shifting of the FFT output (frequency components **638**) from the user separator **610**. To equalize the time alignment of time domain symbols for two offset detection paths, cyclic

time shifting is performed. This can be done in time (before FFT) or frequency (after FFT). In an exemplary embodiment, the cyclic time shifting is performed by applying complex sinusoid samples to the FFT output (components **638**), which results in cyclic time shifting of its time domain sequences (cyclic prefix input **636**). This block rotates the FFT output **624** to be aligned identically with FFT output **620** in the first processing path **632**.

(37) In an exemplary embodiment, the cross correlator **614** comprises at least one of a CPU, processor, state machine, logic, memory, discrete hardware and/or any combination thereof to cross correlate two inputs (the FFT output sequences **620** and **624**) from the first processing path **632** and the second processing path **634**, so that the correlated output **626** contains a complex number which can be accumulated over several symbol durations (which is configurable) and contains a phase difference in its phase angle. According to the frequency portion of each user, complex multiplication results of two FFT outputs are summed or averaged for the frequency offset estimation of multiple users.

(38) In an exemplary embodiment, the frequency/time average **616** comprises at least one of a CPU, processor, state machine, logic, memory, discrete hardware and/or any combination thereof to take an average of each of the frequency elements of the output **626** from the correlator **614** over some time duration, to lower the impact of the receiver noise on the phase difference which is measured through cross correlation.

(39) Therefore, by cross-correlating the two FFT outputs (noncyclic time shifted and cyclic time shifted) one by one, the phase difference of each element of the FFT output can be obtained, since there are two different tail parts when the frequency offset is not zero. During the cross-correlation, the normal data portion can be skipped, since the normal data portion is identical in both signal paths.

(40) In an exemplary embodiment, the frequency offset combiner **606** comprises at least one of a CPU, processor, state machine, logic, memory, discrete hardware and/or any combination thereof. The combiner **606** operates to receive the DMRS frequency offset estimate **622** from frequency offset estimator **408**, which represents a fine frequency offset (ϕfine), and the averaged cross-correlation result **628**, which represents a coarse frequency offset (ϕcoarse) determined by the cyclic prefix and its original part (tail of a normal symbol). The latter is for estimating the integer part of the phase difference, which is a "coarse frequency offset estimate." The combining results in a total phase difference ϕtotal that can be written as:

$\Phi_{total} = \Phi_{fine} + \Phi_{coarse} = \Phi_{fine} + 2n_{coarse}\pi$

where n_{coarse} is an integer from the coarse estimate of the frequency offset using the output from the second processing path **634** and can be obtained from:

$n_{coarse} = \text{round}[(\Phi_{coarse}/(2\pi T_{symb}/T_{dmrs}))]$

where T_{symb} a symbol duration (1/15 kHz), and T_{dmrs} is a time distance between two DMRS symbols (0.5 ms).

(41) In an exemplary embodiment, the first processing path **632** is used for fine frequency offset in the range of (−1 kHz, 1 kHz), and the second processing path **634** is used for coarse frequency offset in the range of (−15 kHz, 15 kHz).

(42) Techniques to Determine Coarse Offset

(43) Determining the coarse offset with regards to the use of the normal data part of the symbol, two schemes are presented. In a first scheme, if the normal data part of the symbol is included in the cross-correlation performed by block **614**, the follow result is produced:

$X_{corr0} = A + B^{j\,\Phi^{coarse}}$

where A is a real constant obtained from the normal data part, and Φ_{coarse} is a phase difference between the cyclic prefix and tail part of each symbol. Thus, the coarse frequency offset can be estimated as follows:

$\Phi_{coarse} = \text{angle}(X_{corr0} - A)$

where A can be simply estimated by measuring the power of an SC-FDMA symbol.

(44) In a second scheme, to eliminate the impact of A, the normal data part can be skipped when cross-correlating at block **614**, which results in the following:

X.sub.corr1=B.sup.j Φ.sup.coarse

(45) The coarse phase difference then can be calculated simply as:

Φ.sub.coarse=angle(X.sub.corr1)

(46) It should be noted, however, in some cases in LTE uplink MIMO, some DMRS symbols are not orthogonal to other parts of the symbol, so in that case the first technique may yield better performance.

(47) FIG. **7** shows a method **700** for performing frequency offset estimation in a receiver in accordance with an exemplary embodiment of the present invention. For example, in an exemplary embodiment, the method **700** is suitable for use by the OE **600** shown in FIG. **6**.

(48) At block **702**, an uplink signal is received at a receiver from one or more users. For example, the uplink signal **618** comprises uplink transmissions from one or more users in an LTE communication network.

(49) At block **704**, at the start of the first processing path **632**, a particular user transmissions are separated from the received signal. In an exemplary embodiment, the user separator **602** performs this operation by performing an (FFT) to separate frequency components transmitted by the particular user and outputting these components.

(50) At block **706**, a DMRS frequency offset estimation is performed on the frequency components for the selected user. For example, the DMRS frequency offset estimator **408** operates to receive the user frequency components and perform frequency offset estimation using the DMRS symbols in the received transmissions. A more detailed description of the DMRS frequency offset estimator **408** is provided above with reference to FIG. **4**. In an exemplary embodiment, the time interval divider **406** divides the calculated phase shift ϕ by the time interval (T) between the DMRS symbols (e.g., symbols **302** and **304**) to determine a DMRS frequency offset estimate. If the measured phase shift is ϕ, the DMRS frequency offset can be calculated as:

f.sub.offset=($\phi/2\pi T$)

where T is time distance between the two DMRS, which, for example, is 0.5 milliseconds (ms) in LTE systems. The DMRS frequency offset estimate represents a fine frequency offset and is output to block **718**.

(51) At block **708**, at the start of a second processing path **634**, a time offset of the received signal is adjusted. In an exemplary embodiment, the time offset adjuster **608** adjusts a time offset of the received signal. The received signal with an adjusted time offset is then output.

(52) At block **710**, user transmissions are separated from the time adjusted received signal. In an exemplary embodiment, the user separator **610** performs this operation by performing an (FFT) to separate frequency components transmitted by the selected user (see block **704**) and outputting these components.

(53) At block **712**, a cyclic time shift is performed on the separated time adjusted user transmissions. Since two input signal samples for the two offset estimation paths are not time aligned, this time offset difference is compensated by cyclic time shifting. This can be done before or after the FFT process. In an exemplary embodiment, the cyclic time shifter **612** performs this operation.

(54) At block **714**, a cross-correlation is performed on the output of block **704** and the output of block **712**. For example, in an exemplary embodiment, the cross-correlator **614** performs a cross correlation on the user frequency components **620** derived from the received signal and the cyclic shifted frequency components **624**. For example, after an FFT converts the received signal samples (in time domain) to frequency domain samples in each offset estimation path, the resulting samples from the two paths are cross-correlated (1-to-1 complex multiplication) to compute the phase difference between them.

(55) At block **716**, frequency/time averaging is performed. In an exemplary embodiment, the

frequency/time average **616** performs this operation by averaging together multiple correlation outputs over time. The averaged value is output as cyclic prefix (CP) frequency offset estimate **628**. For example, the cross-correlation results for the entire uplink frequency bands are summed or averaged selectively over the subcarrier range that has been scheduled for each uplink user. The uplink scheduling is being done in the receiver side, and this scheduling information is already known to the receiver. Those values are also accumulated or averaged over the selected symbols in each user's transmitting duration.

(56) At block **718**, an operation of combining is performed to combine the DMRS frequency offset estimate (fine offset) with the CP frequency offset estimate (coarse offset). In an exemplary embodiment, the offset combiner **606** performs this operation. The output of the combining operation is a final frequency offset estimate with 15 times wider range than frequency offset estimates using only the DMRS symbols.

(57) While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from this exemplary embodiment of the present invention and its broader aspects. Therefore, the appended claims are intended to encompass within their scope all such changes and modifications as are within the true spirit and scope of this exemplary embodiments of the present invention.

Claims

1. A method of estimating frequency offset range via signals received over a communication network, comprising: receiving a data stream containing data symbols via uplink communication channels from one or more user devices by a transceiver of a base station; separating the data symbols of associated user devices in accordance with frequency domain; finding a frequency offset in a range for each user device based on a fine frequency offset estimation in response to the data symbols, wherein the finding a frequency offset includes identifying a fine frequency offset estimate via the data symbols in response to at least measuring of phase difference between transmission channels for generating a fast Fourier transform (FFT) output for facilitating frequency alignment; generating a cyclic prefix (CP) frequency offset estimate via CP values situated in the data symbols, identifying a first CP situated at the beginning of a data symbol and a second CP situated at end of the data symbol; and generating a CP portion in accordance with the first and the second CPs for facilitating time adjustments for received symbols.

2. The method of claim 1, wherein the generating a CP frequency offset estimate further includes a coarse frequency offset estimate via cyclic prefix (CP) values situated at each end of the data symbols.

3. The method of claim 1, wherein the finding a frequency offset further includes generating a joint frequency offset estimation in accordance with values of demodulation reference signal (DMRS) symbols from a sub-frame of a data symbol.

4. The method of claim 1, wherein finding a frequency offset further includes generating a joint frequency offset estimation in response to values of cyclic prefix (CP) situated at each end of the data symbols.

5. The method of claim 1, wherein the receiving a data stream containing data symbols includes receiving signals organized in the data symbols via one or more uplink communications from one or more users.

6. The method of claim 1, wherein the finding a frequency offset includes separating at least two demodulation reference signal (DMRS) symbols from a sub-frame of the data stream.

7. The method of claim 1, wherein the finding a frequency offset includes measuring, by a phase difference calculator, a phase difference value between at least two demodulation reference signal (DMRS) symbols from a sub-frame of the data stream.

8. The method of claim 1, wherein the finding a frequency offset includes determining a time interval between at least two demodulation reference signal (DMRS) symbols in accordance with a sub-frame of the received signals.

9. The method of claim 8, wherein the finding a frequency offset includes dividing a phase difference value by the time interval to generate a DMRS offset estimate.

10. The method of claim 1, wherein the finding a frequency offset further includes adjusting a time offset of the received signals and separating a selected user's uplink transmission from the time adjusted received signals to generate a separated signal.

11. An apparatus capable of estimating frequency offset range via signals received over a communication network, the apparatus comprising: a plurality of portable devices configured to transmit one or more data streams containing data symbols via uplink communication channels over a communication network; a cell site containing multiple radio towers coupled to the plurality of portable devices for facilitating data transmissions via uplink communications; and an offset estimator of a transceiver coupled to the plurality of portable devices and capable of estimating a frequency offset within a range based on a joint frequency offset estimation by combining a fine frequency offset estimation and a coarse frequency offset estimation generated in response to the data symbols, wherein the offset estimator includes, a demodulation reference signal (DMRS) frequency offset estimator configured to provide a DMRS frequency offset estimate based on DMRS symbols by dividing a phase difference by a selected time interval between two DMRS symbols, a user separator for separating frequency components of a cyclic prefix (CP) associated with a user for facilitating user separation in one or more uplink communications, and a CP frequency offset estimator configured to generate a CP frequency offset estimate via CP values situated in data symbols, the CP frequency offset estimator configured to identify a first CP situated at beginning of a data symbol and a second CP situated at end of the data symbol and generating a CP portion in accordance with the first and the second CPs for facilitating time adjustments for received symbols.

12. The apparatus of claim 11, wherein the DMRS frequency offset estimate is provided based on a phase difference between the two DMRS symbols.

13. The apparatus of claim 11, wherein the offset estimator includes a combiner configured to combine the DMRS frequency offset estimate with the CP frequency offset estimate to generate a final frequency offset estimate.

14. The apparatus of claim 11, wherein the CP frequency offset estimator includes a time shifter capable of generating a fast Fourier transform (FFT) output for facilitating frequency alignment.

15. A method for facilitating an offset estimation via multiple channels of a communication network, the method comprising: receiving a data stream organized in data symbols via one or more uplink communications from one or more user devices; identifying a first cyclic prefix (CP) situated at beginning of a data symbol and a second CP situated at end of the data symbol; generating a fast Fourier transform (FFT) output by shifting frequency components of the first CP for facilitating frequency alignment; and generating a coarse frequency offset by averaging frequency elements in response to the FFT output.

16. The method of claim 15, further includes: generating a CP portion in accordance with the first and the second CPs for facilitating time adjustments for received symbols; and separating frequency components of the CP portion associated with a user for facilitating user separation in the one or more uplink communications.

17. The method of claim 15, further includes: identifying at least two pilot symbols from sub-frames of data symbols from the data stream from at least one user equipment; and determining a time interval between the at least two pilot symbols separated from one or more sub-frames of data symbols.

18. The method of claim 15, further includes generating a fine frequency offset by dividing a phase difference value by a time interval of a pilot symbol.

19. The method of claim 15, further comprising identifying at least two demodulation reference signal (DMRS) symbols from a sub-frame of signals for a user.

20. An apparatus of estimating frequency offset range via signals received over a communication network, comprising: means for receiving a data stream containing data symbols via uplink communication channels from one or more user devices by a transceiver of a base station; means for separating the data symbols of associated user devices in accordance with frequency domain; means for finding a frequency offset in a range for each user device based on a fine frequency offset estimation in response to the data symbols, wherein the means for finding a frequency offset includes means for identifying a fine frequency offset estimate via the data symbols in response to at least measuring of phase difference between transmission channels for generating a fast Fourier transform (FFT) output for facilitating frequency alignment; means for generating a cyclic prefix (CP) frequency offset estimate via CP values situated in the data symbols, means for identifying a first CP situated at the beginning of a data symbol and a second CP situated at end of the data symbol; and means for generating a CP portion in accordance with the first and the second CPs for facilitating time adjustments for received symbols.

21. The apparatus of claim 20, wherein the means for generating a CP frequency offset further includes means for determining a coarse frequency offset estimate via cyclic prefix (CP) values situated at each end of the data symbols.

22. The apparatus of claim 20, wherein the means for finding a frequency offset further includes means for generating a joint frequency offset estimation in accordance with values of demodulation reference signal (DMRS) symbols from a sub-frame of the data symbol.

23. The apparatus of claim 20, wherein the means for finding a frequency offset further includes means for generating a joint frequency offset estimation in response to values of cyclic prefix (CP) situated at each end of the data symbols.

24. The apparatus of claim 20, wherein the means for receiving a data stream containing data symbols includes means for receiving signals organized in the data symbols via one or more uplink communications from one or more users.

25. The apparatus of claim 20, wherein means for finding a frequency offset includes means for separating at least two demodulation reference signal (DMRS) symbols from a sub-frame of the data stream.

26. The apparatus of claim 20, wherein the means for finding a frequency offset includes means for measuring, by a phase difference calculator, a phase difference value between at least two demodulation reference signal (DMRS) symbols from a sub-frame of the data stream.