

CHANNEL ESTIMATION WITH EFFECTIVE CO-CHANNEL INTERFERENCE SUPPRESSION

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of United States Provisional Patent Application No. 60/908,399, entitled A METHOD AND APPARATUS FOR CHANNEL ESTIMATION WITH EFFECTIVE CO-CHANNEL INTERFERENCE SUPPRESSION, and filed on March 27, 2007, the entirety of which is incorporated herein by reference.

BACKGROUND

I. Field

[0002] The following description relates generally to communications systems, and more particularly to performing channel estimations while effectively mitigating co-channel interference.

II. Background

[0003] Wireless communication systems are widely deployed to provide various types of communication content such as voice, data, and so forth. These systems may be multiple-access systems capable of supporting communication with multiple users by sharing the available system resources (e.g., bandwidth and transmit power). Examples of such multiple-access systems include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, 3GPP Long Term Evolution (LTE) systems, and orthogonal frequency division multiple access (OFDMA) systems.

[0004] Generally, a wireless multiple-access communication system can concurrently support communication for multiple wireless terminals that communicate with one or more base stations via transmissions on forward and reverse links. The forward link (or downlink) refers to the communication link from the base stations to the terminals, and the reverse link (or uplink) refers to the communication link from the terminals to the base stations. This communication link may be established via a single-in-single-out, multiple-in-single-out or a multiple-in-multiple-out (MIMO) system.

[0005] A MIMO system employs multiple (NT) transmit antennas and multiple (NR) receive antennas for data transmission. A MIMO channel formed by the NT transmit and NR receive antennas may be decomposed into NS independent channels, which are also referred to as spatial channels, where $N_S \leq \min\{N_T, N_R\}$. Generally, each of the NS independent channels corresponds to a dimension. The MIMO system can provide improved performance (e.g., higher throughput and/or greater reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

[0006] A MIMO system also supports time division duplex (TDD) and frequency division duplex (FDD) systems. In a TDD system, the forward and reverse link transmissions are on the same frequency region so that the reciprocity principle allows estimation of the forward link channel from the reverse link channel. This enables an access point to extract transmit beam-forming gain on the forward link when multiple antennas are available at the access point.

[0007] Wireless systems transmit pilot signals from base stations to receivers in order to facilitate communications. One important aspect that pilot signals are employed for is channel estimation at the respective receivers. In general, pilot signals can be generated from multiple base stations in a given area or from multiple sectors from a given base station. Such signal transmissions from these multiple transmission sources often interfere with each other. Thus, mechanisms have been devised to mitigate such interference. In one case, signals from different base stations or sectors can be encoded on different frequencies to mitigate interference between sources. Unfortunately, the number of frequencies for transmitting pilot signals is limited. Thus, other solutions have evolved. In another case, signals from different base stations or sectors are transmitted as an orthogonal sequence of three vectors, where each vector represents a different base station or sector. Utilizing this scheme, processing for a single sector requires processing all three vectors concurrently in order to cancel out the effects of cross channel interference. Concurrent vector processing unfortunately does not provide the desired detailed channel estimate information for any particular sector or base station since the computation is an amalgam derived from three sectors. Thus, it would be desirable to be able to mitigate interference between differing sectors and stations while being able to analyze a particular sector or station from other sources in order to effectively perform channel estimation.

SUMMARY

[0008] The following presents a simplified summary in order to provide a basic understanding of some aspects of the claimed subject matter. This summary is not an extensive overview, and is not intended to identify key/critical elements or to delineate the scope of the claimed subject matter. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

[0009] Systems and methods are provided to enhance the effectiveness of channel estimation by isolating signals associated with a single transmission source and mitigating or eliminating effects from interfering sources. Channel estimation is enhanced by transforming received time domain pilot and other time domain data from multiple sources into the frequency domain. When such signals are in the frequency domain, associated data from all sources is nulled in order to capture, isolate, and discriminate between the respective pilot signals. After isolating the signals, a frequency to time domain transform is performed on the isolated signals. In the time domain, pilot signals associated with the interfering sources is nulled in order to cancel their associated effects, where the remaining pilot signal is subsequently analyzed to perform time domain channel estimation. If desired, the remaining pilot signal can also be transformed back to the frequency domain, where frequency domain channel estimation can be performed. By nulling out extraneous data and interfering pilot channels, accurate channel estimations can be performed on the pilot signal of interest while mitigating the effects of co-channel interference.

[0010] To the accomplishment of the foregoing and related ends, certain illustrative aspects are described herein in connection with the following description and the annexed drawings. These aspects are indicative, however, of but a few of the various ways in which the principles of the claimed subject matter may be employed and the claimed subject matter is intended to include all such aspects and their equivalents. Other advantages and novel features may become apparent from the following detailed description when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0011] FIG. 1 is a high level block diagram of a system that is provided to illustrate channel estimation in a communications environment.
- [0012] FIG. 2 is a high level flow diagram of a channel estimation methodology.
- [0013] FIG. 3 is an example diagram of processed pilot tones for three base stations or sectors.
- [0014] FIGS. 4-7 illustrate exemplary circuit diagrams to perform channel estimation.
- [0015] FIG. 8 illustrates an example logical module for channel estimation.
- [0016] FIG. 9 illustrates an example communications apparatus that employs channel estimation.
- [0017] FIGS. 10 and 11 illustrate example communications systems that can be employed with channel estimation components.

DETAILED DESCRIPTION

- [0018] Systems and methods are provided to facilitate channel estimation in the presence of interfering transmission sources. In an aspect, a method for a wireless communication system is provided. The method includes isolating a set of pilot signals, where the pilot signals are associated with multiple base stations or multiple sectors of a single base station. This includes nulling a subset of the pilot signals to mitigate co-channel interference and to perform channel estimation in accordance with at least one of the pilot signals.
- [0019] Furthermore, various aspects are described herein in connection with a terminal. A terminal can also be referred to as a system, a user device, a subscriber unit, subscriber station, mobile station, mobile device, remote station, remote terminal, access terminal, user terminal, user agent, or user equipment. A user device can be a cellular telephone, a cordless telephone, a Session Initiation Protocol (SIP) phone, a wireless local loop (WLL) station, a PDA, a handheld device having wireless connection capability, a module within a terminal, a card that can be attached to or integrated within a host device (*e.g.*, a PCMCIA card) or other processing device connected to a wireless modem.
- [0020] Moreover, aspects of the claimed subject matter may be implemented as a method, apparatus, or article of manufacture using standard programming and/or

engineering techniques to produce software, firmware, hardware, or any combination thereof to control a computer or computing components to implement various aspects of the claimed subject matter. The term "article of manufacture" as used herein is intended to encompass a computer program accessible from any computer-readable device, carrier, or media. For example, computer readable media can include but are not limited to magnetic storage devices (*e.g.*, hard disk, floppy disk, magnetic strips...), optical disks (*e.g.*, compact disk (CD), digital versatile disk (DVD)...), smart cards, and flash memory devices (*e.g.*, card, stick, key drive...). Additionally it should be appreciated that a carrier wave can be employed to carry computer-readable electronic data such as those used in transmitting and receiving voice mail or in accessing a network such as a cellular network. Of course, those skilled in the art will recognize many modifications may be made to this configuration without departing from the scope or spirit of what is described herein.

[0021] Referring now to **Fig. 1**, a system 100 illustrates channel estimation for a communications environment. The system 100 provides effective channel estimation for a multiple-in-signal-out or a multiple-in-multiple-out (MIMO) system (or other type systems described below). Various processing components removes, mitigates, or decreases components of channel interference while enabling focused channel estimations to be performed on a given station or sector. Wireless signals 110 (including symbols and other structures) are initially processed by input processing components 120 and are subsequently processed by a channel estimation processor 130.

[0022] The channel estimation processor 130 employs transform components 140 such as Fast Fourier Transforms (FFT) or Inverse Discrete Fourier Transforms (IDFT) to process various signals and stages of channel estimation. Nulling components 150 are provided to mitigate, cancel, or reduce effects of co-channel interference or other data that is not involved in channel estimation. It is noted that as used herein that nulling can include zeroing data, subtracting values, dividing values, or substantially any operation that reduces, minimizes, or mitigates the magnitude or other data value of an interfering source as will be described in more detail below. After extraneous data values or noise sources have been isolated and minimized, time and/or frequency domain channel estimates 160 are determined by the channel estimation processor.

[0023] In general, the system 100 enhances the effectiveness of channel estimation 160 by isolating signals associated with a single transmission source (e.g., base station or sector) and mitigating or eliminating effects from interfering sources. Channel estimation 160 is enhanced by transforming received time domain pilot and other time domain data at 140 from multiple sources into the frequency domain. When such signals are in the frequency domain, associated data from all sources is nulled at 150 in order to capture, isolate, and discriminate between the respective pilot signals. After isolating the signals, a frequency to time domain transform is performed on the isolated signals at 140. In the time domain, pilot signals associated with the interfering sources is nulled in order to cancel their associated interference effects, where the remaining pilot signal is subsequently analyzed to perform time domain channel estimation 160.

[0024] If desired, the remaining pilot signal can also be transformed back to the frequency domain at 140, where frequency domain channel estimation can be performed at 160. By nulling out extraneous data and interfering pilot channels, accurate channel estimations can be performed on the pilot signal of interest while mitigating the effects of co-channel interference. It is noted that the nulling and transforming acts described herein can be applied to other orthogonal sequences than pilot signals, where other types of signal processing can be performed in addition to the channel estimations previously described. The following provides more detailed discussion into the types of wireless signals 110 that are processed and the relationships between the respective signals.

[0025] The pilot signal of Long Term Evolution (LTE) systems have an inherent structure that enables co-channel pilot interference suppression from other sectors of the same cell. However, a careful channel estimation algorithm design is employed at receiver in order to capitalize this capability. This is particularly hard for a channel with long delay spread. The system 100 can suppress co-channel interference effectively and yet is also able to process long channel delay spread.

[0026] In one aspect, first convert a receiver pilot signal in frequency to time domain. This provides a simple a mechanism for suppression of co-channel interference, even with long delay spread. When co-channel interference is suppressed via a simple operation in time domain, the channel estimation is transformed back to frequency domain for further frequency domain processing (e.g., data demodulation, and so forth).

[0027] In an aspect, consider three pilots, occupying the same tones and time symbols. Consider a channel estimation in a single symbol. In the symbol carrying the pilot, every 6th tone is actually occupied by the pilot and again it is assumed that these will be the same tones for all three pilots. The pilots are spread in the frequency domain with one of the following sequences:

$$[1,1,1], [1,\alpha,\alpha^2], [1,\alpha^2,\alpha]$$

where α is a complex m^{th} unit root ($m=3$ in our case).

[0028] Considering that the pilot occupies every k^{th} tone ($k=6$ in this example), the above is equivalent to multiplying the pilot spectrum by

$$1, e^{2\pi j f / mk}, e^{-2\pi j f / mk}, \text{ respectively.}$$

[0029] Assume the system 100 processes the first pilot and ignores the presence of any other pilots (i.e., no despreading). In this case, one could carry out an FFT of the input signal resulting in N_{BW} tones in-band and then could extract every k^{th} tone, which are occupied by the pilot. Next, carry out an N_{BW}/k point DFT to get the time domain channel response estimate. With ideal time tracking, the time domain estimate would yield the c_i delay tap coefficients for $0 \leq i \leq L-1$ where $L = N_{BW}/k$.

[0030] One can observe that after this processing, the other two pilots would show up at channel tap points beginning at L/m and $2L/m$, respectively. With the long delay spread, the pilots would be cyclically wrapped around in addition creating an alias. But, if it is assumed that for each pilot the delay spread is less than L/m , then an ML pilot estimate can be generated for all three pilots very easily:

[0031] Generally, one can time window the channel taps so that the time domain estimates $\hat{c}_1, \hat{c}_2, \hat{c}_3$ for the three pilots, before going back to the frequency domain is as follows:

$$\hat{c}_{1,i} = \begin{cases} c_i & 0 \leq i \leq L/m \\ 0 & \text{otherwise} \end{cases}$$

$$\hat{c}_{2,i} = \begin{cases} c_{i+L/mk} & 0 \leq i \leq L/m \\ 0 & \text{otherwise} \end{cases}$$

$$\hat{c}_{3,i} = \begin{cases} c_{i+2L/mk} & 0 \leq i \leq L/m \\ 0 & otherwise \end{cases}$$

[0032] This approach is optimum if the delay spread is known to be less than $1/m$ times the delay spread corresponding to the original pilot spacing. If this is not the case, then an ML estimate can be given as follows:

$$\begin{aligned} \hat{c}_{1,i} &= \frac{c_i \cdot \sigma_{1,i}^2}{\sigma_{1,i}^2 + \sigma_{2,i-L/mk}^2 + \sigma_{3,i-2L/mk}^2 + \sigma_N^2} \\ \hat{c}_{2,i} &= \frac{c_{i+L/mk} \cdot \sigma_{2,i}^2}{\sigma_{1,i+L/mk}^2 + \sigma_{2,i}^2 + \sigma_{3,i-L/mk}^2 + \sigma_N^2} \\ \hat{c}_{3,i} &= \frac{c_{i+2L/mk} \cdot \sigma_{3,i}^2}{\sigma_{1,i+2L/mk}^2 + \sigma_{2,i+L/mk}^2 + \sigma_{3,i}^2 + \sigma_N^2} \end{aligned}$$

where $\sigma_{n,i}^2$ is the estimate channel tap power for pilot n at delay i .

$\sigma_{n,i}^2$ could be estimated, for example, as $\sigma_{n,i}^2 = PSD_{Pilot_n} \cdot e^{-\lambda_n i}$

where λ_n is the decay factor associated with an assumed exponential delay spread profile for sector (pilot) n . It is not efficient to estimate λ_n but some a priori stored estimate might suffice. There are alternate methods to estimate $\sigma_{n,i}^2$ as well.

[0033] The advantages of the time domain pilot separation method are the following: Simpler implementation, since the extra step of initial despreading is avoided; Potentially optimum performance if suitable estimates are used $\sigma_{n,i}^2$; Since despreading is performed further down the processing chain, more information can be used for optimum time windowing, and since all three pilots can be processed with common initial stages; the pilot separation is simply performed by the time windowing.

[0034] It is noted that pilot CDM multiplexing can also be carried out in the time domain, in other words, time domain spreading sequences can be used instead of frequency domain spreading sequences. The equivalent pilot separation method would imply a sync time domain interpolation, or equivalently, frequency domain windowing

or weighting. The condition for frequency domain windowing to be the optimum despreading method in this case is the following:

$$Doppler < \frac{1}{mT_p}$$

where m is again the number of pilots CDM's in the same resource blocks and T_p is the pilot symbol spacing in time. For example, with $T_p = 0.5\text{ms}$ and $m = 2$, the maximum supported UE velocity is 432km/h in the 2.5GHz band.

[0035] With more complex assumptions on the Doppler power spectrum in frequency, there can be better channel estimators developed but this is not a very practical scenario. In any case, if more than two signals need to be orthogonalized in the time domain, then it is generally better to use DFT unitary transforms rather than Walsh spreading. By using DFT, the ML methods are better facilitated.

[0036] A simplified pilot despreading approach was described, which is convenient to use in the case of frequency domain Code Division Multiplexing (CDM) processing. The proposed method carries out the despreading as part of the time domain windowing/thresholding portion of the channel estimation.

[0037] It is noted that the system 100 can be employed with an access terminal or mobile device, and can be, for instance, a module such as an SD card, a network card, a wireless network card, a computer (including laptops, desktops, personal digital assistants PDAs), mobile phones, smart phones, or any other suitable terminal that can be utilized to access a network. The terminal accesses the network by way of an access component (not shown). In one example, a connection between the terminal and the access components may be wireless in nature, in which access components may be the base station and the mobile device is a wireless terminal. For instance, the terminal and base stations may communicate by way of any suitable wireless protocol, including but not limited to Time Divisional Multiple Access (TDMA), Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA), Orthogonal Frequency Division Multiplexing (OFDM), FLASH OFDM, Orthogonal Frequency Division Multiple Access (OFDMA), or any other suitable protocol.

[0038] Access components can be an access node associated with a wired network or a wireless network. To that end, access components can be, for instance, a

router, a switch, or the like. The access component can include one or more interfaces, *e.g.*, communication modules, for communicating with other network nodes. Additionally, the access component can be a base station (or wireless access point) in a cellular type network, wherein base stations (or wireless access points) are utilized to provide wireless coverage areas to a plurality of subscribers. Such base stations (or wireless access points) can be arranged to provide contiguous areas of coverage to one or more cellular phones and/or other wireless terminals.

[0039] Referring now to **Fig. 2**, a channel estimation methodology 200 is illustrated. While, for purposes of simplicity of explanation, the methodology (and other methodologies described herein) is shown and described as a series of acts, it is to be understood and appreciated that the methodology is not limited by the order of acts, as some acts may, in accordance with one or more embodiments, occur in different orders and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology could alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be utilized to implement a methodology in accordance with the claimed subject matter.

[0040] Proceeding to 210 of process 200, wireless signals are received. The signals can be from multiple base stations or multiple sectors of the same base stations. At 220, the received signals are transformed from the time domain to the frequency domain. This will enable data to be isolated from pilot information which is employed to perform channel estimation. At 230, all data channels for signals received from all the respective base station is nulled or zeroed out. What remains are the multi-path remnants of the transmitted pilots for each base station. The time domain representation of the multi-path components is shown in **Fig. 3** at 300 where just the pilot signals and their respective multi-paths remain after zeroing and are shown for three base stations A, B, and C, respectively.

[0041] Proceeding back to **Fig. 2** and 240, the pilot signals of **Fig. 3** are transformed from the frequency domain into the time domain. At 250, the pilot signals for two of the base stations are nulled or zeroed. In the example shown in **Fig. 3**, pilot signals for base station B and C are nulled leaving pilot data base station A to perform channel estimation. At 260, time domain channel estimation is performed based on the remaining pilot data from 250. At 270, another time to frequency domain conversion

can occur on the remaining pilot signal. After the conversion, frequency domain channel estimation can be performed at 280.

[0042] Figs. 4-8 illustrate example circuits to perform channel estimation in accordance with the concepts described herein. It is to be appreciated that such circuits are not the only manner in which to perform channel estimation. Generally any components that performs pilot signal isolation via time and frequency domain transforms and employs subsequent data or other signal nulling is within the scope of the embodiments described herein.

[0043] Referring to **Fig. 4**, an example circuit 400 is illustrated to perform channel estimation. A received sample is processed via a tone extractor 410 that feeds output to a stagger component 414. The stagger component adds or otherwise combines pilot tones occupying different parts of the frequency spectrum in different OFDM symbols. Output from the stagger circuit 414 is combined with the pseudo-random pilot scrambling sequence used by the base station or other signals at 420, where an IDFT is performed at 424. Output from the IDFT 424 is truncated at 430 and combined with other phase information at 434. The other phase information may depend on the base station specific pilot tone offset in the frequency domain. Output from 434 is fed to a tap thresholding component 440 which drives a zero padding component 444. Output from the zero padding component 444 is fed to a DFT 450 which subsequently drives a channel estimate buffer 454 and a time domain interpolation filter 460 which generates a channel estimation.

[0044] Referring now to **Fig. 5**, an example circuit 500 is illustrated to perform channel estimation. Inputs samples are processed by a tone extractor 510 that combines output with the pseudo-random pilot scrambling sequence used by the base station or other signals at 514 which is then fed to an IDFT 520. Output from the IDFT 520 is truncated at 524 and combined with other phase information at 530. The other phase information may depend on the base station specific pilot tone offset in the frequency domain. Output from 530 is fed to a tap thresholding component at 540 which is fed to a zero padding component 544. Output from 544 is transformed via a DFT at 550 and fed to a channel estimate buffer which is processed by a time domain interpolation filter 560. Output from the filter 560 is fed to a tone extractor 570 where a channel estimation is then generated.

[0045] Turning to **Fig. 6**, an example circuit 600 is illustrated to perform channel estimation. For the purposes of brevity, the circuit 600 is not described as it is substantially the same as the circuit described in Fig. 4. It is noted however that phasor signals that are summed at point 610 are different from that shown at a similar point (434) in Fig. 4.

[0046] Turning now to **Fig. 7**, an example circuit 700 is illustrated to perform channel estimation. An input sample is extracted at 710 and combined with the pseudo-random pilot scrambling sequence used by the base station or other signals at 720. Output 720 is applied to a frequency domain filter 730 which feeds a channel estimate buffer 740. Output from the buffer 740 drives a time domain interpolation filter 750 that generates a channel estimate.

[0047] Turning now to **Fig. 8**, a system is provided that relates to channel estimation. The systems are represented as a series of interrelated functional blocks, which can represent functions implemented by a processor, software, hardware, firmware, or any suitable combination thereof.

[0048] A system 800 is provided that facilitates wireless communications. The system 800 includes a logical module 802 means for converting a receiver pilot signal to time domain and a logical module 804 for suppressing co-channel interference. The system 800 also includes a logical module 806 for transforming channel estimate to frequency domain for further frequency domain processing.

[0049] **Fig. 9** illustrates a communications apparatus 900 that can be a wireless communications apparatus, for instance, such as a wireless terminal. Additionally or alternatively, communications apparatus 900 can be resident within a wired network. Communications apparatus 900 can include memory 902 that can retain instructions for determining a channel estimation in a wireless communications terminal. Additionally, communications apparatus 900 may include a processor 904 that can execute instructions within memory 902 and/or instructions received from another network device, wherein the instructions can relate to configuring or operating the communications apparatus 900 or a related communications apparatus.

[0050] Referring now to **Fig. 10**, a multiple access wireless communication system according to one aspect is illustrated. An access point 1000 (AP) includes multiple antenna groups, one including 1004 and 1006, another including 1008 and 1010, and an additional including 1012 and 1014. In Fig. 10, only two antennas are

shown for each antenna group, however, more or fewer antennas may be utilized for each antenna group. Access terminal 1016 (AT) is in communication with antennas 1012 and 1014, where antennas 1012 and 1014 transmit information to access terminal 1016 over forward link 1020 and receive information from access terminal 1016 over reverse link 1018. Access terminal 1022 is in communication with antennas 1006 and 1008, where antennas 1006 and 1008 transmit information to access terminal 1022 over forward link 1026 and receive information from access terminal 1022 over reverse link 1024. In a FDD system, communication links 1018, 1020, 1024 and 1026 may use different frequency for communication. For example, forward link 1020 may use a different frequency than that used by reverse link 1018.

[0051] Each group of antennas and/or the area in which they are designed to communicate is often referred to as a sector of the access point. Antenna groups each are designed to communicate to access terminals in a sector, of the areas covered by access point 1000. In communication over forward links 1020 and 1026, the transmitting antennas of access point 1000 may utilize beam-forming in order to improve the signal-to-noise ratio of forward links for the different access terminals 1016 and 1024. Also, an access point using beam-forming to transmit to access terminals scattered randomly through its coverage causes less interference to access terminals in neighboring cells than an access point transmitting through a single antenna to all its access terminals.

[0052] An access point may be a fixed station used for communicating with the terminals and may also be referred to as an access point, a base station, a Node B, or some other terminology. An access terminal may also be called an access terminal, user equipment (UE), a wireless communication device, terminal, access terminal, mobile station or some other terminology.

[0053] Referring to Fig. 11, a system 1100 illustrates a transmitter system 210 (also known as the access point) and a receiver system 1150 (also known as access terminal) in a MIMO system 1100. At the transmitter system 1110, traffic data for a number of data streams is provided from a data source 1112 to a transmit (TX) data processor 1114. Each data stream is transmitted over a respective transmit antenna. TX data processor 1114 formats, codes, and interleaves the traffic data for each data stream based on a particular coding scheme selected for that data stream to provide coded data.

[0054] The coded data for each data stream may be multiplexed with pilot data using OFDM techniques. The pilot data is typically a known data pattern that is processed in a known manner and may be used at the receiver system to estimate the channel response. The multiplexed pilot and coded data for each data stream is then modulated (i.e., symbol mapped) based on a particular modulation scheme (e.g., BPSK, QSPK, M-PSK, or M-QAM) selected for that data stream to provide modulation symbols. The data rate, coding, and modulation for each data stream may be determined by instructions performed by processor 1130.

[0055] The modulation symbols for all data streams are then provided to a TX MIMO processor 1120, which may further process the modulation symbols (e.g., for OFDM). TX MIMO processor 1120 then provides NT modulation symbol streams to NT transmitters (TMTR) 1122a through 1122t. In certain embodiments, TX MIMO processor 1120 applies beam-forming weights to the symbols of the data streams and to the antenna from which the symbol is being transmitted.

[0056] Each transmitter 1122 receives and processes a respective symbol stream to provide one or more analog signals, and further conditions (e.g., amplifies, filters, and up-converts) the analog signals to provide a modulated signal suitable for transmission over the MIMO channel. NT modulated signals from transmitters 1122a through 1122t are then transmitted from NT antennas 1124a through 1124t, respectively.

[0057] At receiver system 1150, the transmitted modulated signals are received by NR antennas 1152a through 1152r and the received signal from each antenna 1152 is provided to a respective receiver (RCVR) 1154a through 1154r. Each receiver 1154 conditions (e.g., filters, amplifies, and down-converts) a respective received signal, digitizes the conditioned signal to provide samples, and further processes the samples to provide a corresponding “received” symbol stream.

[0058] An RX data processor 1160 then receives and processes the NR received symbol streams from NR receivers 1154 based on a particular receiver processing technique to provide NT “detected” symbol streams. The RX data processor 1160 then demodulates, de-interleaves, and decodes each detected symbol stream to recover the traffic data for the data stream. The processing by RX data processor 1160 is complementary to that performed by TX MIMO processor 1120 and TX data processor 1114 at transmitter system 1110.

[0059] A processor 1170 periodically determines which pre-coding matrix to use (discussed below). Processor 1170 formulates a reverse link message comprising a matrix index portion and a rank value portion. The reverse link message may comprise various types of information regarding the communication link and/or the received data stream. The reverse link message is then processed by a TX data processor 1138, which also receives traffic data for a number of data streams from a data source 1136, modulated by a modulator 1180, conditioned by transmitters 1154a through 1154r, and transmitted back to transmitter system 1110.

[0060] At transmitter system 1110, the modulated signals from receiver system 1150 are received by antennas 1124, conditioned by receivers 1122, demodulated by a demodulator 1140, and processed by a RX data processor 1142 to extract the reserve link message transmitted by the receiver system 1150. Processor 1130 then determines which pre-coding matrix to use for determining the beam-forming weights then processes the extracted message.

[0061] In an aspect, logical channels are classified into Control Channels and Traffic Channels. Logical Control Channels comprises Broadcast Control Channel (BCCH) which is DL channel for broadcasting system control information. Paging Control Channel (PCCH) which is DL channel that transfers paging information. Multicast Control Channel (MCCH) which is Point-to-multipoint DL channel used for transmitting Multimedia Broadcast and Multicast Service (MBMS) scheduling and control information for one or several MTCHs. Generally, after establishing RRC connection this channel is only used by UEs that receive MBMS (Note: old MCCH+MSCH). Dedicated Control Channel (DCCH) is Point-to-point bi-directional channel that transmits dedicated control information and used by UEs having an RRC connection. Logical Traffic Channels comprise a Dedicated Traffic Channel (DTCH) which is Point-to-point bi-directional channel, dedicated to one UE, for the transfer of user information. Also, a Multicast Traffic Channel (MTCH) for Point-to-multipoint DL channel for transmitting traffic data.

[0062] Transport Channels are classified into DL and UL. DL Transport Channels comprises a Broadcast Channel (BCH), Downlink Shared Data Channel (DL-SDCH) and a Paging Channel (PCH), the PCH for support of UE power saving (DRX cycle is indicated by the network to the UE), broadcasted over entire cell and mapped to PHY resources which can be used for other control/traffic channels. The UL

Transport Channels comprises a Random Access Channel (RACH), a Request Channel (REQCH), an Uplink Shared Data Channel (UL-SDCH) and plurality of PHY channels. The PHY channels comprise a set of DL channels and UL channels.

[0063] The DL PHY channels comprises:

- Common Pilot Channel (CPICH)
- Synchronization Channel (SCH)
- Common Control Channel (CCCH)
- Shared DL Control Channel (SDCCH)
- Multicast Control Channel (MCCH)
- Shared UL Assignment Channel (SUACH)
- Acknowledgement Channel (ACKCH)
- DL Physical Shared Data Channel (DL-PSDCH)
- UL Power Control Channel (UPCCH)
- Paging Indicator Channel (PICH)
- Load Indicator Channel (LICH)

[0064] The UL PHY Channels comprises :

- Physical Random Access Channel (PRACH)
- Channel Quality Indicator Channel (CQICH)
- Acknowledgement Channel (ACKCH)
- Antenna Subset Indicator Channel (ASICH)
- Shared Request Channel (SREQCH)
- UL Physical Shared Data Channel (UL-PSDCH)
- Broadband Pilot Channel (BPICH)

[0065] In an aspect, a channel structure is provided that preserves low PAR (at any given time, the channel is contiguous or uniformly spaced in frequency) properties of a single carrier waveform.

[0066] What has been described above includes examples of one or more embodiments. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the aforementioned embodiments, but one of ordinary skill in the art may recognize that many further combinations and permutations of various embodiments are possible. Accordingly, the described embodiments are intended to embrace all such alterations, modifications and

variations that fall within the spirit and scope of the appended claims. Furthermore, to the extent that the term “includes” is used in either the detailed description or the claims, such term is intended to be inclusive in a manner similar to the term “comprising” as “comprising” is interpreted when employed as a transitional word in a claim.

CLAIMS

What is claimed is:

1. A method for a wireless communication system, comprising:
converting a set of pilot signals to the time domain;
suppressing co-channel interference on a subset of the pilot signals; and
performing a channel estimation in the frequency domain with at least one of the pilot signals.
2. The method of claim 1, the pilot signals are associated with multiple base stations or multiple sectors of a single base station.
3. The method of claim 2, further comprising transforming received signals from the base stations or sectors of a single base station to generate the pilot signals and associated data.
4. The method of claim 3, where transforming the received signals is a time domain to frequency domain transform.
5. The method of claim 3, further comprising nulling the associated data to isolate the pilot signals.
6. The method of claim 5, further comprising transforming the pilot signals from the frequency domain to the time domain.
7. The method of claim 6, further comprising analyzing pilot signal data from one base station or sector and nulling pilot signal data from all other base stations or sectors.
8. The method of claim 7, further comprising performing a time domain channel estimation with the analyzed pilot signal.

9. The method of claim 8, further comprising transforming the analyzed pilot signal from the time domain to the frequency domain.
10. The method of claim 9, further comprising performing a frequency domain channel estimation with the analyzed pilot signal.
11. The method of claim 1, the set of pilot signals is associated with three base stations.
12. The method of claim 1, the set of pilot signals is associated with three sectors of a single base station.
13. The method of claim 1, further comprising performing a tone extraction or an inverse discrete Fourier transform.
14. The method of claim 1, further comprising performing a discrete Fourier transform, a zero padding operation, or a time domain interpolation filter.
15. A communications apparatus, comprising:
 - a memory that retains instructions for performing a null operation on transformed data, the null operation zeros data associated with a set of base stations or sectors, the instructions perform a subsequent transform where interfering pilot tones are nulled; and
 - a processor that executes the instructions.
16. The communications apparatus of claim 15, further comprising performing a time domain channel estimate and a frequency domain channel estimate.
17. The communications apparatus of claim 15, further comprising a tone extraction circuit to facilitate channel estimation.

18. The communications apparatus of claim 15, further comprising a zero padding circuit to facilitate channel estimation.
19. The communications apparatus of claim 15, further comprising a time domain interpolation filter to facilitate channel estimation.
20. The communications apparatus of claim 15, further comprising a thresholding component to facilitate channel estimation.
21. A communications apparatus, comprising:
 - means for converting a receiver pilot signal to time domain;
 - means for suppressing co-channel interference; and
 - means for transforming a channel estimate to frequency domain for further frequency domain processing.
22. A computer-readable medium, comprising:
 - code for nulling data channels associated with orthogonal base stations or sectors;
 - code for nulling pilot tones associated with at least two base stations or sectors;
 - and
 - code for performing a channel estimation from pilot tones generated from at least one other base station.
23. The computer-readable medium of claim 22, further comprising performing a time domain channel estimate and a frequency domain channel estimate.
24. The computer-readable medium of claim 22, further comprising transforming incoming data to the frequency domain to perform a null operation for data associated with at least two base stations or sectors.
25. A processor that executes the following instructions:
 - nulling a set of data associated with at least two base stations or sectors from a set of three base stations or sectors; and

nulling a subset of pilot signals associated with the bases stations or sectors to mitigate co-channel interference and to perform channel estimation in accordance with at least one of the pilot signals.

26. The processor of claim 25, further comprising instructions for transforming received signals from the base stations or sectors of a single base station to generate the pilot signals and associated data.

27. The processor of claim 26, where transforming the received signals is a time domain to frequency domain transform.

28. The processor of claim 26, further comprising instructions for transforming the pilot signals from the frequency domain to the time domain.

29. The processor of claim 28, further comprising instructions for analyzing pilot signal data from one base station or sector and nulling pilot signal data from all other base stations or sectors.